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The L'Aquila trial

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Abstract: The first stage of the trial in L'Aquila (Italy) ended with a conviction of seven experts, convened by the head of Civil Protection on 31 March 2009, for multiple manslaughter and serious injuries. They were sentenced to six years in jail, perpetual interdiction from public office and a fine of several million euros to be paid to the victims of the earthquake of 6 April 2009 (moment magnitude 6.3) for having caused, by their negligent conduct, the death of 29 persons and the injury of several others. The verdict had a tremendous impact on the scientific community and on the way scientists deliver their expert opinions to decision makers and society. This paper analyses the scientific argumentations reported in the Verdict Motivations, where scientific data and results were largely debated and misused to demonstrate that they should have been considered as a tool to predict an impending large earthquake. Moreover, we show that the supposed message of reassurance was not generated at the experts' meeting or by the official Istituto Nazionale di Geofisica e Vulcanologia reports. The media had a key role in conveying information during the seismic swarm, contributing to the risk perception. We stress that prevention actions based on seismic hazard knowledge are the best defence against earthquakes.

The events that led to the accusation and conviction of seven expert seismologists and engineers who participated to the so-called meeting of the Commissione Grandi Rischi (High Risks Committee, HRC), six days before the earthquake of moment magnitude (M_w) of 6.3 on 6 April 2009 at L'Aquila in Italy, are very complex, preventing the analysis of individual issues outside the actual timeline and requiring a synoptic examination. The verdict motivations involve difficult juridical aspects and arguments connected to the role of scientists and risk communication, all issues exceeding the local (Italian) dimension and attracting broad interest worldwide.

The seven defendants (Franco Barberi, Enzo Boschi, Michele Calvi, Bernardo De Bernardinis, Mauro Dolce, Claudio Eva and Giulio Selvaggi) were convicted of the multiple manslaughter of 29 victims and multiple serious injuries, caused by 'negligence, imprudence and malpractice', having carried out, during the HRC meeting of 31 March 2009, an 'approximate evaluation of the risks connected to the actual seismic activity observed at and around the city of L'Aquila' (Verdict Motivations 2013). According to the judge, they provided the National and Regional Civil Protection Department (Dipartimento della Protezione Civile, DPC), the mayor of L'Aquila and the public with:

> 'incomplete, imprecise and contradictory information on nature, causes, hazard and future development of the seismic activity, neglecting thus their duties to evaluate the connected risks and the function of forecasting, prevention and delivery of clear, correct and complete information'.

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The reassuring message that, according to the judge, was conveyed by the HRC would have induced people not to leave their houses, as they were used to do by family tradition, after some shocks before the deadly M_w 6.3 earthquake (i.e. the behaviour of the defendants caused the death of the victims).

This article aims to analyse the scientific argumentations reported in the Verdict Motivations and their use in the trial held in the L'Aquila court. We do not interpret the trial as a prosecution to science, as claimed by some, but show how science entered the prosecution, the trial and the verdict. We then discuss the alleged 'act of tranquillization', that caused the death of 29 persons, together with the official reports to DPC from the Istituto Nazionale di Geofisica e Vulcanologia (INGV) (two defendants, Enzo Boschi and Giulio Selvaggi, were in 2009 the president of INGV and the director of the National Earthquake Centre of INGV, respectively) and the numerous declarations issued by various experts in the period before the main shock on 6 April 2009 and reported by the press and mass media. We conclude with a short analysis on the consequences of the L'Aquila trial for the scientific community and the impact on risk communication to the population in the case of natural disasters.

State of knowledge

Numerous studies performed in the decades preceding the 2009 L'Aquila earthquake yielded scientific results that fostered a clear understanding of the seismic hazard of the Abruzzo region. Geophysical and geological investigations (Galadini & Galli 2000; Boncio *et al.* 2004; DISS Working Group 2010 among many others) allowed the identification of the major active and seismogenic faults. Analysis of historical seismicity (Baratta 1901; Cavasino 1935; Boschi *et al.* 2000; Rovida *et al.* 2011) contributed to the comprehension of the seismogenic potential of active faults as well as to the earthquake recurrence in the region (Fig. 1).

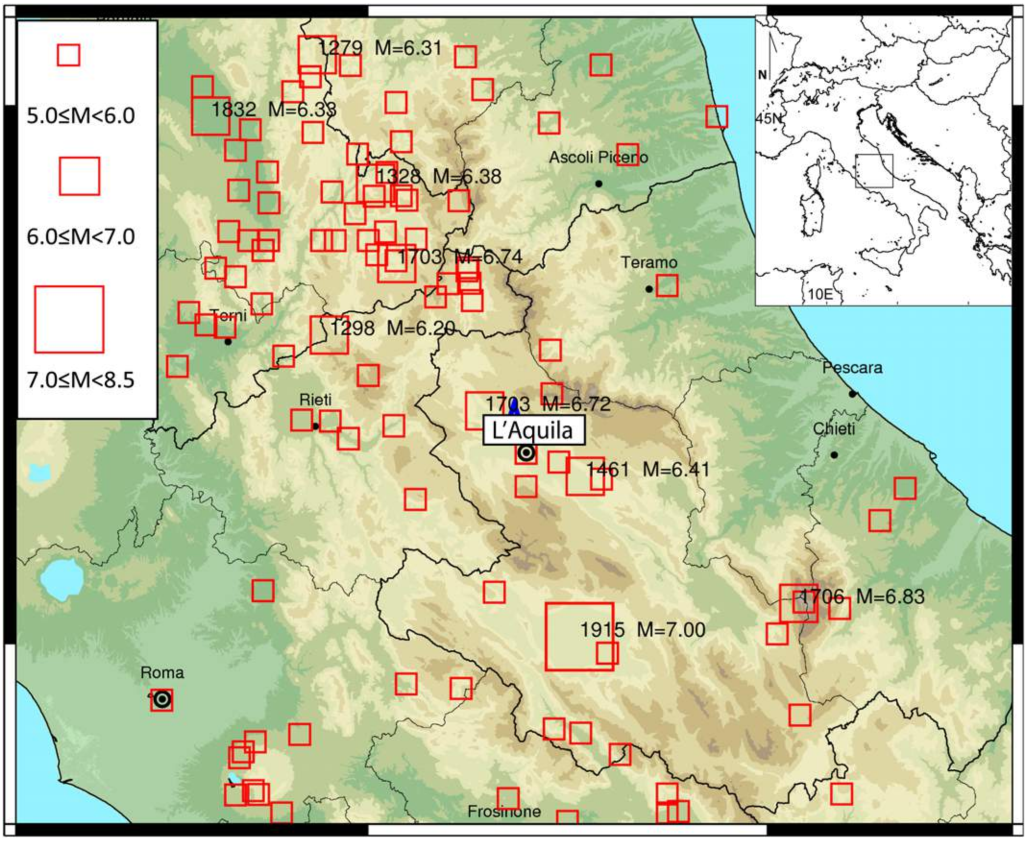

Fig. 1. Historical seismicity in central Italy for earthquakes with $M_W \geq 5$; red squares are the earthquakes, labels indicate events with $M_W \geq 6$ (Rovida *et al.* 2011).

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In 2004, all relevant studies to assess seismic hazard were used by scientists to release a new seismic hazard map of Italy. This scientific achievement (the new Italian Seismic Hazard map (Stucchi *et al*. 2011)), which represents the findings of the collaborative work of a team of experts officially engaged to this task by INGV, became a national law through a legal ordinance published in 2006 (PCM 3519/2006; http://zonesismiche.mi.ingv.it). It is still the reference for the Italian building code (Decree of the Ministry of Infrastructure in Gazette n. 29 of 4 February 2008) and the seismic classification. Today, as well as before 31 March 2009, the Italian Seismic Hazard Map (Fig. 2) represents a fundamental instrument for the prevention and mitigation of seismic risk. It is one of the ways in which scientists had conveyed their research products to decision and policy makers, including national and regional civil defence agencies and local authorities.

The seismic hazard map clearly shows that L'Aquila is one of the most hazardous areas in Italy. This information was accessible to the public through institutional websites and was delivered

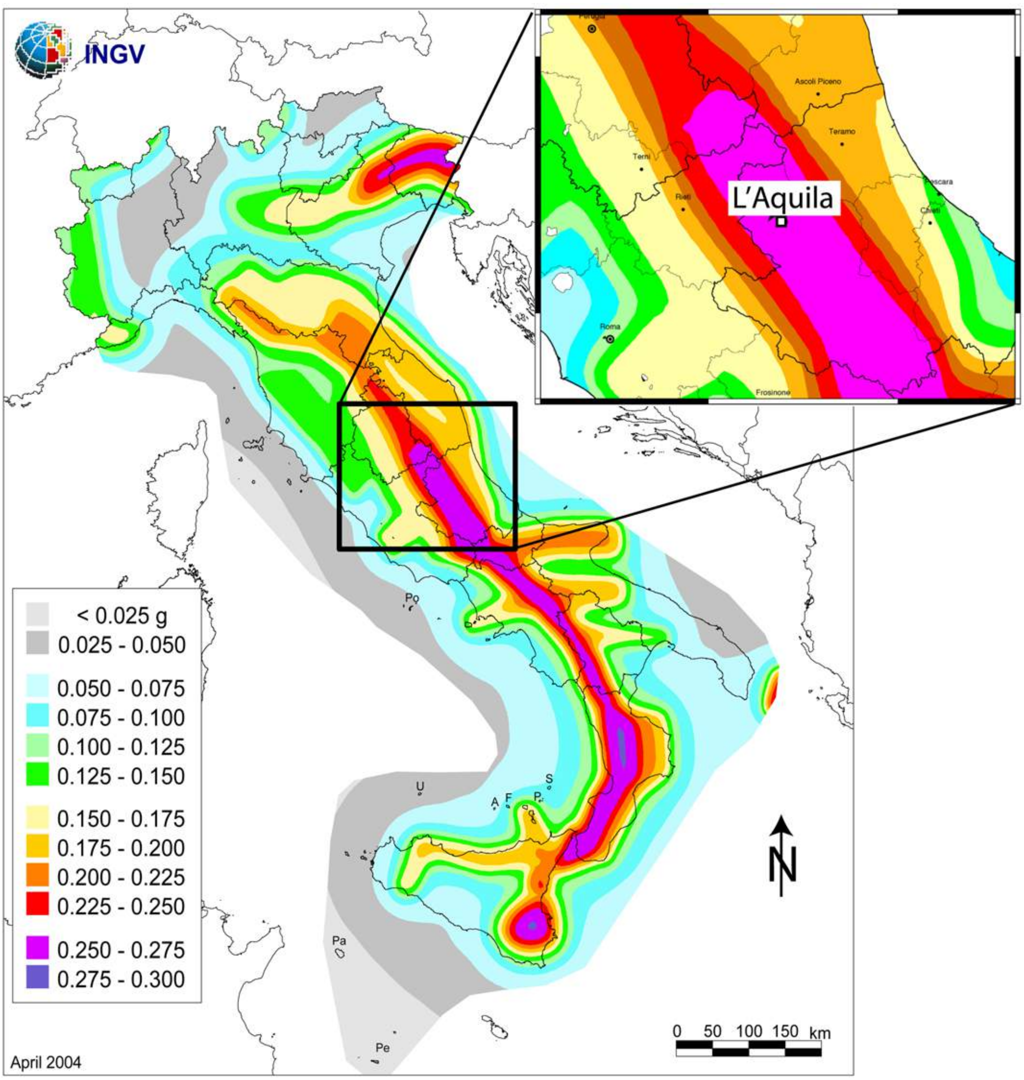

Fig. 2. Italian Seismic Hazard Map (Italian Seismic Hazard map, PCM 3519/2006; http://zonesismiche.mi.ingv.it) of maximum acceleration value having 10% of exceedance in 50 years (in g). The inset is a zoom of this map for the region surrounding L'Aquila.

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to decision makers and involved stakeholders through a national law and a legal ordinance. Information concerning the high seismic hazard of the region was also conveyed to the public through specific dissemination activities (La Longa *et al.* 2012), although this was certainly insufficient to create the necessary preparedness and awareness about seismic risk. The vulnerability assessment of public and strategic buildings in the town of L'Aquila was also known by the local authorities, since it was the object of a specific study published by the DPC in 1999 (the so-called 'Barberi Report'; Dipartimento della Protezione Civile 1999). The Abruzzo region was one of those described in the Barberi Report, which was sent to all involved Italian municipalities soon after its publication including those local authorities invited to attend the HRC meeting on 31 March 2009. All this information was shared within the scientific community and, more importantly, it was delivered to decision makers (Civil Protection officers, mayors, etc.), who had all the necessary knowledge and time to start preventive actions in the (ten) years preceding the 2009 L'Aquila earthquake.

Another missing piece to complete this overview concerns the temporal evolution of the seismic sequences. Several studies have described that most historical strong earthquakes were not preceded by seismic sequences. A few reports on foreshock activity have been found for the 1461 earthquake (M_W 6.4; Baratta 1901), whereas there was probably not foreshock activity before the M_W 6.7, 1703 event (Rovida *et al.* 2011), apart from the intense seismicity in the area near Norcia (located about 50 km north of L'Aquila). Even the devastating earthquake of 1915 in the Fucino area south of L'Aquila was not preceded by foreshocks (Cavasino 1935). In addition, it is well-known that several seismic sequences, some of which had similar characteristics to the one preceding the 2009 earthquake, had occurred in the Abruzzo region in the past without generating a strong earthquake (see Amato & Ciaccio 2012, for a review; similar results have been reported for the nineteenth century in Galadini 2013). This information was already known within the scientific community and G. Selvaggi, one of the convicted seismologists, showed at the HRC meeting the map of previous seismicity, including the one produced in 1985.

This behaviour is common to many regions in Italy. The number and features of the numerous seismic sequences occurring every year are very high and heterogeneous. Arcoraci and colleagues determined that 70% of the earthquakes occurring in Italy cluster in sequences or swarms (the remaining 30% pertain to the so-called 'background seismicity') and reported at least 127 sequences occurred in Italy in the period 2008 to 2010 (Arcoraci *et al.* 2011) (Fig. 3). If we look at the time distribution of these sequences, we see clearly that they last from few days to several months and their magnitude distribution in time is highly variable. We can therefore conclude that the past and present state of knowledge would have not allowed us to identify a 'peculiar character' for the 2009 seismic sequence up to 31 March, in contrast with the Verdict Motivations.

The meeting of the national High Risks Committee

A seismic sequence had been occurring since January 2009, with many small earthquakes of maximum magnitude of 2.9 on 11 March (Fig. 4). At that time, two seismic sequences were simultaneously striking the surroundings of L'Aquila and Sulmona towns (Abruzzo region), creating panic since earthquakes were often felt. According to standard algorithms (Reasenberg 1985), the space–time evolution of the seismicity in 2008 and 2009 shows an abrupt change in the number of seismic events after mid-January 2009, with a maximum magnitude of 2.9 within 30 km from L'Aquila (Fig. 5). The seismic activity in the previous 12 months is well described as 'background seismicity', which is peculiar of active tectonic regions and may include sporadically felt earthquakes. Background seismicity is identified by a constant slope of the curve of cumulative number of earthquakes (Fig. 5) and small statistical variations (in both number and magnitude) are common features of all the active seismogenic areas.

The reaction of the population was influenced by the amateur predictor, Giampaolo Giuliani, a technician of the former IFSI-Torino (National Institute for Astrophysics, Italy), who claimed to be able to predict earthquakes in the area on the basis of his homemade instruments. During the seismic activity, he made contradictory forecasts for either an imminent large earthquake or the end of the seismic activity, raising public order problems. These warnings were never precise enough to constitute an accurate prediction and were subsequently shown to be unsound; at the time, however, they caused public alarm. The reaction of the population, and the lack of preparedness and awareness of seismic hazard, demonstrate that there had not been adequate prevention and mitigation initiatives in the previous years by the local authorities to increase the resilience of society to seismic hazard.

G. Giuliani used his homemade instruments to detect radon variations and interpreted his observation as the evidence for impending earthquakes; this activity was not institutional and he still carries it out within his private foundation. On 29 March, after a shock of a Richter magnitude

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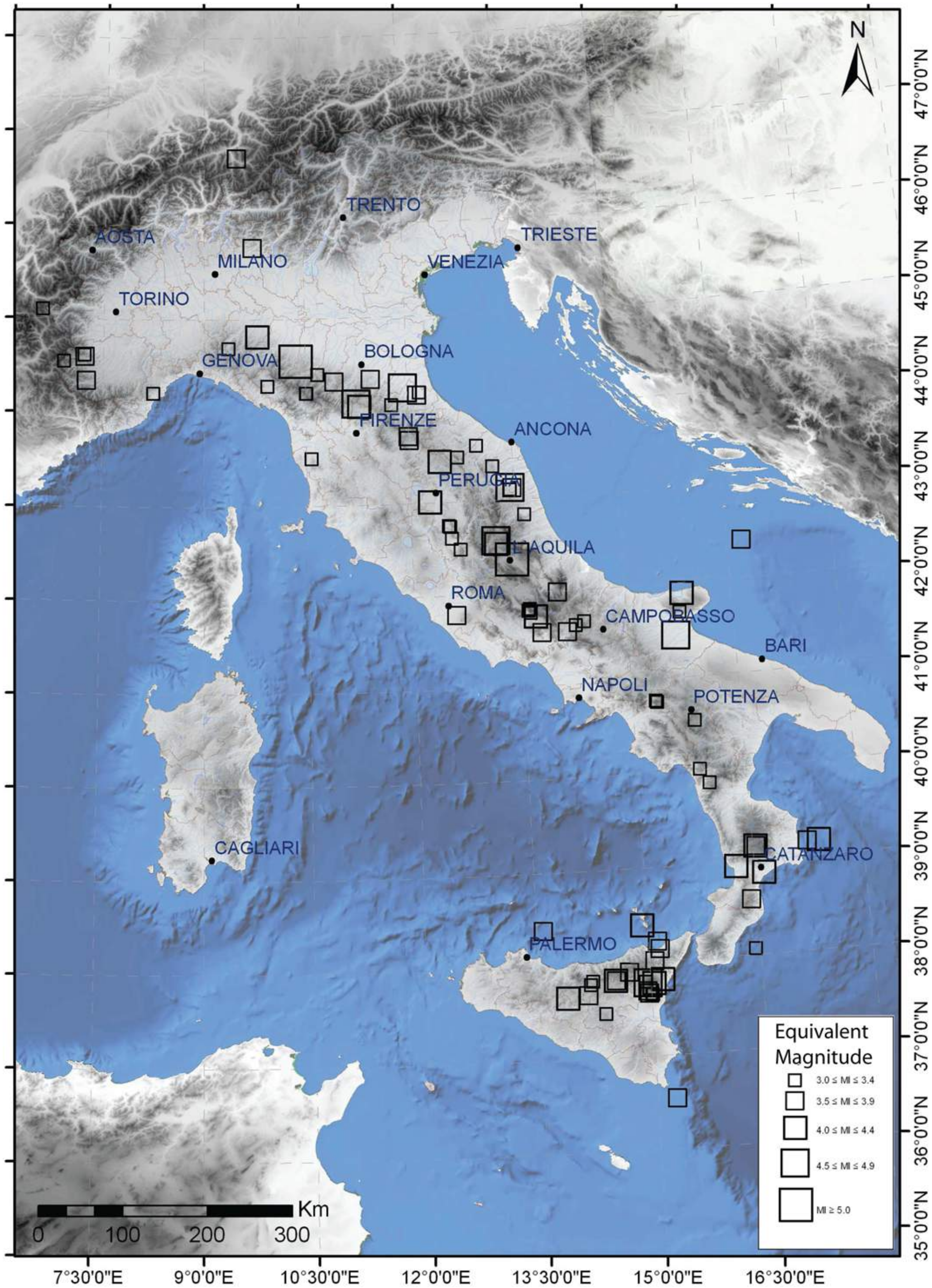

Fig. 3. Main seismic sequences that occurred in Italy in 2008–2010 (modified from Arcoraci *et al.* 2011). Almost all sequences (black squares) occur along the Apennine chain where most of the tectonic deformation was released.

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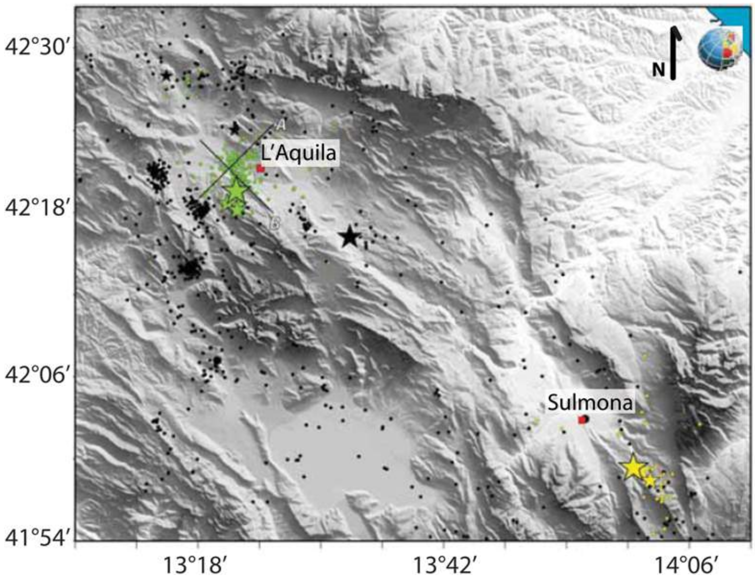

Fig. 4. Seismicity localized in the Abruzzo region up to 31 March 2009. Yellow and green stars are the 2009 seismic sequences; black dots and stars are older earthquakes. The figure is taken from the Istituto Nazionale di Geofisica e Vulcanologia (INGV) report discussed at the High Risks Committee meeting.

(M_L) of 3.9, he predicted a large earthquake in the town of Sulmona (Fig. 4); different from what was predicted, the following day a M_L 4.0 shock occurred in L'Aquila, more than 50 km north-west of Sulmona (Fig. 4), increasing the panic in the population.

The head of the national DPC, Guido Bertolaso, then decided to convene in L'Aquila a meeting of the HRC experts on the following day, 31 March. The HRC is an advisory body of the National Civil Protection Department which has the duty of evaluating the risk associated with situations such as earthquakes, volcanic eruptions and nuclear accidents, providing expert opinions to DPC, HRC evaluations are based on scientific data provided by experts and research institutes like INGV (the DPC 'competence centre' for earthquakes).

The experts were charged, then, with providing an 'accurate analysis of the scientific and civil protection aspects of the recent seismic sequence occurring in the Abruzzo area' (Convocational Letter 2009). As the judge claimed in the Verdict Motivations, 'a well-founded evaluation of risk prediction' was not explicitly requested. In addition, the volcanologist F. Barberi, the vice-president of the HRC, stated at the beginning of the meeting that the committee should have performed an objective evaluation of the ongoing seismicity also in terms of what could be forecasted, and that it should have discussed and provided indications on the

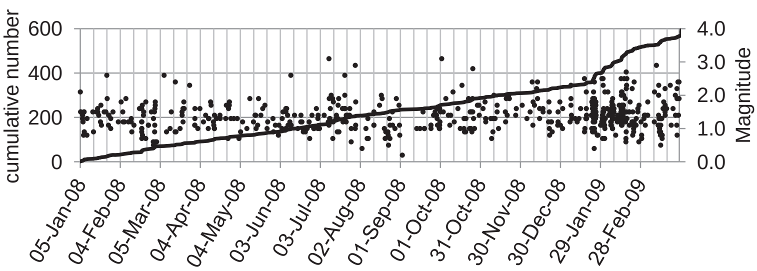

Fig. 5. Cumulative number and magnitude of earthquakes in the region of L'Aquila from 1 January 2008 to 29 March 2009; selection includes epicentres within 30 km of the town. For clarification, the Verdict motivations claim that the sequence began in June 2008, whereas it started in January 2009 (courtesy of F. Mele).

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alarms that people were suffering (Meeting draft report 2009).

Several authorities attended the meeting, each of them having different roles and duties: government officials (national and regional DPC, the Mayor of L'Aquila, etc.) and scientists appointed as members of the HRC or invited without voting rights. In particular, the INGV seismologist and director of the INGV National Earthquake Centre (Giulio Selvaggi) was appointed by INGV to accompany his president, Enzo Boschi (an HRC member), to report on the seismicity recorded and localized by the INGV seismic network.

The minutes of the meeting show that the experts were neither alarmist nor reassuring, presenting the hazard map of the area and debating on what the scientific community knew at that time (Minutes report 2009). The report explains that seismic sequences frequently occur without leading to a damaging shock and that the earthquakes are not predictable deterministically. However, the occurrence of a damaging earthquake in the L'Aquila region, such as the one of 1703, was considered unlikely in the short term but not 'excluded in absolute terms', as suggested by the seismic history of the region and by the presence of many active faults capable of causing damaging earthquakes.

As part of their suggestion for DPC actions, the experts underlined that, nowadays, it is impossible to predict earthquakes 'but their effects can be mitigated and so it should be appropriate to make prevention (resistant buildings)' (E. Boschi, Meeting draft report 2009) and that:

> 'the only way to be protected against earthquakes is to strengthen and improve the constructions and their ability to withstand the earthquake. Another important aspect to be treated for the purposes of civil protection is to improve the level of preparedness to handle an emergency earthquake' (F. Barberi, Minutes report 2009).

No minutes of the meeting were available before 6 April and therefore no-one could have read them before the night of the earthquake.

The press conference, at the end of the HRC meeting, was convened by the vice-head of the national DPC, Bernardo De Bernardinis, and the regional DPC head officer, Daniela Stati. Its contents were not agreed during the HRC meeting. Several participants attended the press conference in which the seismologists were not invited to participate. Nobody knows exactly what was said because there is no audio recording or a press release.

In the interviews that followed (e.g., the one of F. Barberi to the Abruzzo24ore.tv channel), the concept of the impossibility to predict earthquakes was repeated and no reassuring message was expressed. However, local media (Abruzzo24ore.tv channel) reported that the presence of the ongoing seismic swarm was positive due to the discharge of energy. Some went on broadcasting the interview of the vice-head of national DPC (B. De Bernardinis), given before the HRC meeting, where he declared that the situation was positive: 'the scientific community keeps on telling me that the situation is favourable and that there is a discharge of energy' due to the continuous microseismic activity observed in the weeks before 6 April. According to this (scientifically wrong) idea, the occurrence of many small seismic events would reduce the accumulated energy on the fault, thus preventing the occurrence of a strong earthquake. He claimed he learned the story of the 'discharge of energy' from newspaper articles or press releases of researchers' interviews, without either considering the official INGV reports released in February and March (INGV official reports 2009), which had completely different contents, or consulting the scientific community directly. The release of energy in an earthquake of magnitude 6 is about a thousand times the energy released by a magnitude 4 and a million times the energy released by a magnitude 2, so clearly the occurrence of a small-magnitude seismic sequence does not release the energy of a potential large earthquake and thus preventing it. Neither can it be stated that the low-magnitude seismicity recorded until 31 March could have been considered as an unequivocal precursor of an imminent large-magnitude event.

Five days after the HRC meeting, two earthquakes of magnitude >3 occurred in the night between 5 and 6 April, and few hours later the destructive main shock struck the town of L'Aquila at 3:32 local time.

Scientific arguments used in the trial

According to the Verdict Motivations (2013), the defendants have performed an incomplete and approximate risk analysis because the event was in their 'sphere of predictability' based on scientific data and current knowledge.

Many scientific arguments were discussed in the trial. Here we briefly review those that, according to the Verdict Motivations, could have been related by the defendants to the occurrence of an impending strong shock. These are: (a) 'the seismic history of L'Aquila, in particular the recurrence of large earthquakes preceded by swarms'; (b) the 'peculiar time evolution of the sequence, with increasing number and magnitude of the earthquakes focused at the same hypocentre and depth'; (c) the high seismic hazard of the L'Aquila area; (d) 'the probabilistic study by Enzo Boschi and Giulo Selvaggi, indicating the region of L'Aquila

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as one with the highest probability of occurrence of an earthquake of magnitude greater than 5.5 or 5.9, as with values among the highest in the national territory; even with a certainty judgement, probability (*P*) equal to 1, in the period 1995 to 2015' (the authors of the paper are indeed Boschi, Gasperini and Mulargia (Boschi *et al.* 1995), not Selvaggi as erroneously indicated in the verdict motivations). Moreover, (e) the verdict motivations state that, based on the elements above, the main shock on 6 April was in 'the sphere of control and knowledge of the defendants', or in other words, 'it was part of their sphere of predictability' (Verdict Motivations 2013).

According to the judge, this would suggest that the five arguments described above are indicators of an impending strong earthquake and that these elements are closely related in a sort of conceptual model. Are these elements really linked in a clear and unique way, so that any expert could have drawn the same conclusion from their analysis, at the time of the meeting on 31 March? The answer is no: the scientific community worldwide has been working on these issues for many decades, without providing a unique answer to be used for civil protection purposes.

The first element concerns the (few) strong historical earthquakes in the region and their relationship with the (frequent) seismic sequences affecting the same area. The historical earthquakes (M_w 6.6 in 1349, M_w 6.4 in 1461, M_w 6.7 in 1703 and M_w 6.0 in 1762; Fig. 1) had been used to determine the high seismic risk of the L'Aquila area, as discussed during the HRC meeting. However, the evidence of seismic sequences preceding historical large earthquakes is rather weak and cannot be considered as a prognostic indicator of an impending shock. Indeed, during the twentieth century, there were at least 23 seismic sequences in the Abruzzo region with only one followed by a strong earthquake: the main shock on 6 April 2009 (Amato & Ciaccio 2012). A statistical analysis of the catalogue of Italian earthquakes between 1950 and 2010 revealed that about 0.8% of the seismic sequences, having at least an M_L 4 shock, was followed by a strong earthquake within a radius of 10 km and within three days (Marzocchi & Zhuang 2011). We can therefore conclude that a clear causal link between swarms (or seismic sequences) and strong earthquakes cannot be demonstrated.

The second element is the 'peculiar time evolution of the sequence, with increasing number and magnitude of the earthquakes focused at the same hypocentre and depth' (Verdict Motivations 2013). First of all, any ongoing seismic sequence is associated with an increase in the number of earthquakes with magnitudes larger than those characterizing the background seismicity (Fig. 5). Therefore, the analysis of the temporal evolution of seismicity does not permit the recognition of unambiguous peculiar features to be used to forecast a large earthquake. Recent studies tackle this problem by computing the probability of occurrence of a large earthquake from the spatio-temporal changes in the rate of earthquake production. Although it is well documented that the increase in probability caused by a large magnitude shock induces aftershocks, the opposite case (small earthquakes inducing strong events) is still a matter of debate in the scientific community (Marzocchi & Zhuang 2011). Indeed, there are models claiming that important seismic events are preceded by seismic quiescence (Habermann 1988; Murru *et al.* 1999; Katsumata 2011).

The statistical models used in the operational earthquake forecast (Jordan *et al.* 2011), a type of seismicity-based probabilistic forecast in the short term (days, week), show that the short-term probabilities of a damaging event generally remain below 1% per day (Jordan *et al.* 2011) and are generally too low to be used for civil protection actions. It is therefore not demonstrated that there is a 'peculiar' type of seismic sequence that can be used as a predictive tool. Finally, it is important to emphasize that the discussion concerning the operational earthquake forecasting is quite recent and started after the 2009 L'Aquila earthquake.

The third element considered as a risk indicator is the long-term hazard of the region. The Italian Seismic Hazard Map indicates that the area has the highest hazard in Italy. The map was shown and discussed at the meeting on 31 March and this fact alone rules out any reassuring message from the scientific community. We stress again that the occurrence of a seismic sequence in a high hazard region worldwide is a frequent circumstance and does not provide any unambiguous indication for the short-term forecast of a strong earthquake.

The fourth element refers to a paper published by Boschi *et al.* (1995) in the *Bulletin of the Seismological Society of America* which reported a probability equal to 1 that a $M > 5.5$ earthquake would have occurred near L'Aquila in the 5, 20 and 100 years after the year of publication (1995). As for all scientific research, this article was written to contribute to the scientific issues on earthquake occurrence and seismic hazard, and certainly not for discussion and interpretation during a legal prosecution, and the discussion on the validity of those results pertains to the scientific debate. Moreover, the article's conclusions do not contradict the INGV official statements and Enzo Boschi's declarations before, during and after the HRC meeting, since the target area had a high probability of occurrence and high seismic hazard. In their paper, Boschi and colleagues adopted a probabilistic model using a Gaussian distribution in a small region

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surrounding L'Aquila where three earthquakes had occurred in 1646 (M_w 4.5), 1703 (M_w 6.7) and 1762 (M_w 6.0), with an interval of about 60 years between earthquakes. The resulting probability values computed in the paper for three time intervals (5, 20 and 100 years) were always 1; that means certainty in the period range 1995–2000 as well as 1995–2095. However, the available data were relatively scarce and the statistical validity of the authors' conclusions was rather poor. Indeed, they warned the reader about this anomalous result, admitting that the statistical sample was not significant (only three cases in many centuries) and suggesting it could be due to earthquake clustering. The very different magnitudes of the three earthquakes (Rovida *et al.* 2011), ranging from 4.5 to 6.7 (i.e. a factor 2000 in energy), make the statistical analysis not significant.

The 'elements of risk evaluation', which according to the Verdict Motivations would have been prognostic to recognize the imminent risk of a strong earthquake in L'Aquila, are common to many seismically active regions in Italy and worldwide. The statement that the effects of the devastating earthquake were in 'the sphere of predictability' of the experts means that they should have emphasized the need for prevention actions, which they actually did. Thus, it is difficult to understand why this responsibility is not extended to those policymakers who did not promote any prevention initiative to mitigate earthquake risk in the decades preceding the L'Aquila shock.

The relationship among the so-called 'risk indicators' is difficult to assess from a scientific point of view. It is appropriate for scientific discussions, papers and conferences, but is very critical when brought into a courtroom to individuate *a posteriori* possible legal responsibilities.

The mass media and the presumed act of tranquillization

The prosecution's main accusation against the seven defendants concerns their responsibility in delivering 'incomplete, imprecise and contradictory' information in communicating risk to the population as well as in the reassurance message that could have led people to remain in their houses during the night between 5 and 6 April 2009. During the seismic emergency, the population received information from local authorities and the regional DPC head officer as well as from scientists and decision makers, which were filtered and in some cases biased by the media. Without any doubt, unclear, ambiguous and inconsistent messages disseminated by the mass media in the two months preceding the main shock certainly did not help the citizens to get a clear idea about what was going on (Fig. 6). In one single day, on 3 April 2009, one could


LA TERRA CONTINUA A TREMARE
Terremoto, chiesto lo stato di emergenza
Oggi scuole aperte. La polizia dà la caccia a chi lancia falsi allarmi scossa

The Earth is still shaking – **Earthquake, requested state of emergency** –*Today schools are open. The police are looking for predictors of false allerts* (Il Centro, April 2)


Nelle scuole esercitazioni di sgombero
In alcuni istituti distribuiti volantini con i consigli antipanico

Evacuation exercises in schools – *flyers with advice are distributed in some schools* (Il Centro, April 4)


Cialente conferma l'esistenza di un piano di emergenza assolutamente tranquillizzante. Interrogazione di Saia
Terremoto, ritorno alla normalità
Il 15 aprile gli alunni della De Amicis dovrebbero rientrare in sede

Cialente confirms an emergency plan absolutely reassuring – **Earthquake, back to normality** –*The 15th of April scholars of De Amicisshould go back to their schools* (Il Messaggero, April 3)

Fig. 6. Titles of articles that appeared in newspapers in the first days of April 2009 in the period between the High Risks Committee meeting on 31 March and the occurrence of the destructive earthquake on 6 April. Unclear, ambiguous and inconsistent messages disseminated by the mass media did not help the population to form a clear idea about what was going on.

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find on the news that 'the earthquake doesn't scare any more' (*Il Messaggero* newspaper) and 'it does not tranquillize the souls' (*Il Tempo* newspaper). Without going into further details, a complete overview of newspaper articles can be found at http://processoaquila.wordpress.com/media/rassegna-stampa-2009-2009-press-review and in the paper by Amato & Galadini (2014).

The mass media played a crucial role in communicating risk to society and in particular in delivering alarming or reassuring messages to the general public during the days before and after the HRC meeting. One of the journalists' important sources of information on the ongoing seismic activity was the DPC. Because the communication of risk is one of the institutional duties of the DPC, their expertise is beyond question. It is therefore difficult to understand why the head of DPC and his deputy were convinced of the correctness of the formerly mentioned wrong concept of the discharge of energy as an inhibitor of strong earthquakes, since this statement was never included in the official INGV reports, which were delivered directly to DPC without any filter by the media. This concept was directly mentioned by the vice-head of DPC (Bernardo De Bernardinis) in the aforementioned TV interview on 31 March 2009 before the HRC meeting, when the journalist suggested to him that he should 'clink glasses full of local wine' and stay calm. Reassuring messages were also delivered by the regional DPC head officer, Daniela Stati, who claimed on 21 March that 'she would have already moved her family into a tent in the garden, if there was imminent danger' (TV interview, https://www.youtube.com/watch?v=PkOO8xU332o) and on 30 March stated in a press release issued by Agenzia Nazionale Stampa Associata (ANSA) 'no further earthquakes of any magnitude are expected [...] Anything else is false' (Verdict Motivations 2013). After the conclusion of the HRC meeting on 31 March, contradictory decisions were taken by the mayor of L'Aquila and the dean of the university of L'Aquila. The former decided to keep the schools closed for safety verifications on the following day, while the latter ordered the university to remain open.

The INGV official reports (INGV official reports 2009) did not minimize the seismic risk in the Abruzzo region, but underlined the presence of active faults and the presence of strong historical earthquakes. They also stated that:

> 'According to the present knowledge we can say that the seismic sequence of the past months has not changed, that is, increased or decreased, the probability of occurrence of strong earthquakes in the area'.

INGV official reports and comments released during interviews simply report the formerly explained concepts: (a) seismic sequences are often observed in Italy without generating damaging earthquakes; (b) this does not significantly change the probability of occurrence of a large magnitude earthquake; and (c) the region of L'Aquila has experienced in the past many strong earthquakes and active faults are well known in the area indicating that prevention actions are certainly needed. Since such declarations have a neutral character regarding the future occurrence and impact of a main shock, they can be misused in a binary black–white scheme in the sense of 'if there is no alert, we can feel either reassured or scared'.

Discussion

The evidence discussed in previous sections demonstrates that science was part of the trial. The use of scientific results, characterized by use of a technical language and uncertainties, can be extremely misleading when brought in a courtroom. In that context, the search for an absolute truth (beyond any reasonable doubt) can force the interpretation of uncertain scientific knowledge in one direction or in another. For instance, the interpretation of the premonitory role of a seismic sequence in the trial and in the Verdict Motivations can be affected by the human tendency to interpret facts *a posteriori* by reconsidering them with the help of updated knowledge after their occurrence (one is always more clever afterwards). The basic principle of scientific research, guided by doubts, experimentation, mistakes, continuous revisions and updates, and new discoveries, is incompatible with the practice of *a posteriori* assessment of an intrinsically unlikely event, such as an earthquake, that occurs irregularly and with a multisecular recurrence.

We have discussed in detail how the verdict motivated the accusation for imprecise and ambiguous communication of the imminent risk. Nowadays scientists are forced to learn and adopt new approaches to communicate risk and the associated uncertainties. This requires a multidisciplinary approach involving complementary expertise and long-term plans to create awareness and preparedness in populations living in earthquake-prone regions. Different actors with different roles are needed to apply these plans, in which scientists are only one of the key players. The lack of this approach amplified the difficulties in managing the emergency before and after the L'Aquila main shock. If it is hard for people to understand and accept the uncertainty typical of science during quiet periods, it becomes impossible during a crisis, when irrational behaviour tends to prevail. In these moments, the intermediation role of mass media is crucial, easily bringing about opposite

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extremes. This means that, in case of an evolving seismic crisis affecting a poorly resilient society, either alarming or reassuring messages are conveyed to the population, often fluctuating from one extreme to the other.

During the weeks preceding the earthquake on 6 April 2009, journalists often badly interpreted and translated what was really affirmed by seismologists. This probably contributed to the tranquillization of the general public and certainly generated confusion and insecurity. This was analysed in detail by Mario Morcellini (Professor of Sociology of Cultural and Communicative Processes, and Director of the Department of Communication and Social Research, 'La Sapienza' University of Rome) for this particular case (personal communication). He reviewed over 50 years of empirical literature on communication models and media organizations to claim that journalistic interpretations can be considered as a deforming lens, capable of altering the correct perception by the citizens, especially in situation of major risks. Even in the context of risk communication, the question of 'journalistic bias' able to construct their own portrayals of reality as well as influence perception of citizens exposed to a perceived risk, has been the subject of many theoretical studies and much empirical research, the implications of which are discussed in Slovic (1986), Lichtenberg & MacLean (1991), Leiss (1996), Kitzinger (1999), Wahlberg & Sjoberg (2000) and Murdock *et al.* (2003).

Antonello Ciccozzi, a consultant whose anthropological analysis was used by the judge to assess the effect of the reassuring messages as the real (contributory) cause of the deaths, affirms instead that 'it is demonstrable that the media did not distort anything concerning the obtained information: the tranquillization came from the scientific institutions' (Ciccozzi 2013). We disagree with his conclusions and believe that the evidence discussed above confirms that the media play an important role in determining an ambiguous risk perception. Evidence from over 30 years of research on risk communication demonstrates that, in impending risk situations, the public's trust in public institutions, decision makers and scientists should never be taken for granted. Moreover, the risk communication guidelines issued by major risk agencies such as the US Environmental Protection Agency (US EPA 1988), the US Nuclear Regulatory Commission (NRC, 2004) and UK Resilience (UK Resilience 2006) clearly indicate that building, maintaining or restoring trust and credibility between the general public, scientists and decision makers must be assumed as one of the main goals of any effective risk communication strategy.

Unfortunately, there are no clear answers to the questions that seismologists are frequently asked: 'Is a stronger earthquake expected?', 'How will the seismic sequence evolve?', 'Will the seismic activity cease soon?', 'Should we keep calm?' and 'Can you reassure the citizens?'. A risk-prepared society should raise different questions such as: 'Do I live in a resistant building, capable of protecting me from a damaging earthquake?' and 'Are there evacuation plans in place that will allow me to leave my house safely after a major shock?'. In general, from the media point of view, the lack of spectacular news ('The dog that doesn't bite is not news', Hough 2009) represents a negative factor. A prudent, sound and realistic information based on (uncertain) scientific data is not suited to them, especially in the case of a seismic crisis when people are scared and want absolute certainty and reassurance. The tendency of unconsciously distorting technical and scientific knowledge provokes the propagation of mostly incomprehensible, but sometimes even tranquillizing information. The linguistic complexity of science and the cultural distance from the civil society constitute elements of weakness, favouring the blaming of the scientific community.

The L'Aquila case represents a clear example in which the results of decades of scientific research were applied to characterize the seismic hazard and the vulnerability of the territory. The scientific results were also transferred to decision makers, since the new seismic hazard map of Italian territory became a law of the Italian Republic. Furthermore, these results were transferred to local authorities in the years preceding the 2009 earthquake. This demonstrates that all the conditions were in place to define and apply prevention actions and preparedness initiatives involving the population. This strategy is still recognized as the most effective approach to mitigate seismic risk in any place of the world. For this reason, the statement of the Verdict Motivations (2013) that 'the only defence from earthquakes that consist in reinforcing buildings and increase in that way their capacity to resist shaking seems as obvious as useless' is wrong and dangerous.

We agree with all those who believe that the L'Aquila trial and its verdict, by invoking last minute risk communication and convicting the seismologists and engineers, diverts attention from the responsibilities of those who, for decades, refused to control and reduce building vulnerability. Vittorini (2011), a medical scientist and local councillor of L'Aquila, noted that the information on the seismic hazard in the Abruzzo region was available but it was left in the desk drawers of the politicians and administrators. He seems to assign the responsibility of the lack of awareness of L'Aquila citizens to the past administrations for having ignored and not even partially used the available information for

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implementing the necessary measures for land-use planning.

The L'Aquila earthquake caused much controversy and certainly did not help to strengthen the central role of prevention and of reducing the vulnerability of buildings. A modern defence strategy from seismic disasters requires citizens to have a realistic perception of the potential damages of a seismic event in their region and of the security level of their homes and working places. Unfortunately, a reduced perception of seismic risk is common to many regions in Italy even today, particularly in high hazard areas (Crescimbene *et al.* 2013).

Last but not least, another consequence regards the exposure of the scientist involved in technical committee, as well summarized by the journalist Anna Meldolesi in an interview to the newspaper *Il Centro* on 23 October 2012:

> 'The next time a scientist is asked to evaluate the risk of flooding or earthquakes, he will first evaluate the proper risk of his statements before communicating. We run the risk that a phenomenon will arise, like in defensive medicine, where doctors choose for the patient the therapy which implies the lower risk for themselves from a legal point of view, instead of the best one for the patient'.

In the same line, Marzocchi (2012) wrote:

> 'When the next earthquake crisis occurs, seismologists will be afraid to say or to do anything. I expect this verdict may affect also many other scientific fields where important decisions have to be made under large scientific uncertainty'.

Opting for the worst possibility does not provide a useful service to citizens, resulting in continuous and useless one night evacuations, as it happened after the M_w 4.8 earthquake in the Garfagnana area (Tuscany, Italy) in January 2013. In the past few years in Italy, there have been several one day school evacuations after very small (even M_L 2) earthquakes due to scared teachers and local authorities. Most of the time, these evacuations were not followed by any subsequent action for effective risk reduction (building performance evaluation and retrofitting), but only by a removal of the imminent risk: no more swarm, no more risk – a dangerous practice.

We believe that progress in the mitigation of natural risk should be based on knowledge of the hazard of the territory, on the reduction of vulnerability and awareness of risk exposure. This can only be achieved through the joint action of scientists, institutions, local authorities, the media and society. In any seismic country in the world, the best defence against earthquakes is safe buildings and citizens' preparedness to face the occurrence of an earthquake.

On 10 November 2014, while this paper was about to be published, the Appeal Court acquitted the experts Giulio Selvaggi, Enzo Boschi, Franco Barberi, Michele Calvi, Mauro Dolce and Claudio Eva on all counts because no crime had been committed; the court upheld a guilty verdict against Bernardo De Bernardinis and issued a suspended two-year sentence. The verdict's reasoning is expected in 90 days. This verdict closely reflects our position about the innocence of scientists and we think that the arguments analysed in this paper are still worth discussing in the light of public and media reaction to the Appeal Court's decision.

The authors would like to thank their colleague G. Selvaggi for long discussions about the trial, an event that had and still has a major impact on the interaction between the scientific community and civil society both in Italy and abroad. The authors participate in the INGV working group for the information management on the L'Aquila trial (http://processoaquila.wordpress.com/), where many documents on the issues raised in this paper have been collected. Our thoughts go once again to the earthquake victims and their relatives: we know that no sentence could ever compensate for the loved ones lost in this disaster.

References

AMATO, A. & CIACCIO, M. G. 2012. Earthquake sequences of the last Millennium in L'Aquila and surrounding regions (central Italy). *Terra Nova*, **24**, 52–61, http://dx.doi.org/10.1111/j.1365-3121.2011.01037.x

AMATO, A. & GALADINI, F. 2014. Gli argomenti della scienza nel processo dell'Aquila alla 'commissione grandi rischi. ANALYSIS, Rivista di cultura e politica scientifica 3/2013 (in Italian with English abstract).

ARCORACI, L., BATTELLI, P., CASTELLANO, C., MARCHETTI, A., MELE, F., NARDI, A. & ROSSI, A. 2011. Bollettino Sismico Italiano 2008–2010. Poster presented at 30th National Congress, Gruppo Nazionale di Geofisica della Terra Solida, November 2011, Trieste, Italy.

BARATTA, M. 1901. *I Terremoti d'Italia*. Arnaldo Forni Editore, Turin.

BONCIO, P., LAVECCHIA, G. & PACE, B. 2004. Defining a model of 3D seismogenic sources for Seismic Hazard Assessment applications: the case of central Apennines (Italy). *Journal of Seismology*, **8**, 407–425.

BOSCHI, E., GASPERINI, P. & MULARGIA, F. 1995. Forecasting where larger crustal earthquakes are likely to occur in Italy in the near future. *Bulletin of the Seismological Society of America,* **85**, 1475–1482.

BOSCHI, E., GUIDOBONI, E., FERRARI, G., MARIOTTI, D., VALENSISE, G. & GASPERINI, P. (eds) 2000. Catalogue of strong Italian earthquakes from 461 B.C. to 1997. *Annals of Geophysics*, **43**, 609–868, with database on CD-ROM.

CAVASINO, A. 1935. I Terremoti d'Italia nel Trentacinquennio 1899–1933. Appendix to Volume IV, Ser. III Delle Memorie del R. Ufficio Centrale di Meteorologia e Geofisica. Instituto Poligrafico dello Stato, Rome.

Downloaded from http://sp.lyellcollection.org/ by guest on February 15, 2015

CICCOZZI, A. 2013. Parola di scienza. Il terremoto dell'Aquila e la Commissione Grandi Rischi. Un'analisi antropologica. DeriveApprodi, Rome.

CONVOCATIONAL LETTER 2009. http://processoaquila.files.wordpress.com/2012/10/2-cgr-convoc-310309.pdf (oin Italian) (accessed 27 November 2014).

CRESCIMBENE, M., LA LONGA, F., CAMASSI, R. & PINO, N. A. 2013. D2.6 Report on risk perception. DPC-INGV-S2 project. Istituto Nazionale di Geofisica e Vulcanologia, https://sites.google.com/site/ingvdpc2012progettos2/deliverables/d2_6 (accessed 27 November 2014).

DIPARTIMENTO DELLA PROTEZIONE CIVILE 1999. Censimento di vulnerabilità degli edifici pubblici, strategici e speciali nelle regioni Abruzzo, Basilicata, Calabria, Campania, Molise, Puglia e Sicilia, 3 volumes. Dipartimento della Protezione Civile, Rome.

DISS WORKING GROUP 2010. Database of Individual Seismogenic Sources (DISS), Version 3.1.1: A compilation of potential sources for earthquakes larger than M5.5 in Italy and surrounding areas. Istituto Nazionale di Geofisica e Vulcanologia, http://diss.rm.ingv.it/diss/ (accessed 27 November 2014).

GALADINI, F. 2013. I terremoti in Abruzzo e la cultura sismologica tra la fine dell'Ottocento e i primi del Novecento. *In*: '… pareva quel giorno dell'Universal Giuditio. Il terremoto aquilano del 1703 tra indagine storica e sviluppo della sismologia moderna'. Kirke, Cerchio, XVII–CIV.

GALADINI, F. & GALLI, P. 2000. Active tectonics in the central Apennines (Italy) – input data for seismic hazard assessment. *Natural Hazards*, **22**, 202–223.

HABERMANN, R. E. 1988. Precursory seismic sequence: past, present and future. *Pageoph*, **126**, 2–4.

HOUGH, S. 2009. *Predicting the Unpredictable: The Tumultuous Science of Earthquake Prediction*. Princeton University Press, Princeton, New Jersey.

INGV OFFICIAL REPORTS 2009. INGV reports to DPC (February 17 and March 12, 2009), http://processoaquila.wordpress.com/prima-del-processo/ (accessed 27 November 2014).

JORDAN, T. H., CHEN, Y.-T. *ET AL.* 2011. Operational earthquake forecasting: state of knowledge and guidelines for utilization. *Annals of Geophysics*, **54**, 315–391, http://dx.doi.org/10.4401/ag-5350

KATSUMATA, K. 2011. A long-term seismic quiescence started 23 years before the 2011 off the Pacific coast of Tohoku Earthquake (M = 9.0). *Earth Planets Space*, **63**, 709–712.

KITZINGER, J. 1999. Researching risk and the media. *Health, Risk & Society*, **1**, 55–69.

LA LONGA, F., CAMASSI, R. & CRESCIMBENE, M. 2012. Educational strategies to reduce risk: a choice of social responsibility. *Annals of Geophysics*, **55**, 445–451, http://dx.doi.org/10.4401/ag-6110

LEISS, W. 1996. Three phases in the evolution of risk communication practice. *The Annals of the American Academy of Political and Social Science*, **545**, 85–94.

LICHTENBERG, J. & MACLEAN, D. 1991. The role of the media in risk communication. *In*: KASPERSON, R. E. & STALLEN, P. J. M. (eds) *Communicating Risks to the Public: International Perspectives*. Springer, Dordrecht, **4**, 157–173.

MARZOCCHI, W. 2012. Putting science on trial. *Physics World*, **25**, 17–18.

MARZOCCHI, W. & ZHUANG, J. 2011. Statistics between mainshocks and foreshocks in Italy and Southern California. *Geophysical Research Letters,* **38**, L09310.

MEETING DRAFT REPORT 2009. Draft of the minutes report of the 31 March 2009 HRC meeting, http://processoaquila.files.wordpress.com/2012/11/3b-bozza-cgr-310309eng.pdf (accessed 27 November 2014).

MINUTES REPORT 2009. Riunione Commissione Grandi Rischi, L'Aquila, 31 marzo 2009, http://processoaquila.files.wordpress.com/2012/10/4-cgr-310309.pdf (accessed 27 November 2014).

MURDOCK, G., PETTS, J. & HORLICK-JONES, T. 2003. After amplification: rethinking the role of the media in risk communication. *In*: PIDGEON, N., KASPERSON, R. E. & SLOVIC, P. (eds) *The Social Amplification of Risk*. Cambridge University Press, Cambridge, 156–178.

MURRU, M., CONSOLE, R. & MONTUORI, C. 1999. Seismic quiescence precursor prior to the 1983 Nihonkai-Chubu (M7.7) earthquake, Japan. *Annali di Geofisica*, **42**, 871–882.

NRC 2004. Effective Risk Communication. The Nuclear Regulatory Commission's Guidelines for external Risk Communication, NUREG/BR-0308. Nuclear Regulatory Commission, Washington DC.

REASENBERG, P. 1985. Second-order moment of central California seismicity, 1969–1982. *Journal of Geophysical Research*, **90**, 5479–5495.

ROVIDA, A., CAMASSI, R., GASPERINI, P. & STUCCHI, M. (eds) 2011. Catalogo Parametrico dei Terremoti Italiani, version CPTI11, December 2011. Istituto Nazionale di Geofisica e Vulcanologia, Milano, Bologna, http://emidius.mi.ingv.it/CPTI, http://dx.doi.org/10.6092/INGV.IT-CPTI11 (accessed 27 November 2014)

SLOVIC, P. 1986. Informing and educating the public about risk. *Risk Analysis*, **6**, 403–415.

STUCCHI, M., MELETTI, C., MONTALDO, V., CROWLEY, H., CALVI, G. M. & BOSCHI, E. 2011. Seismic Hazard Assessment (2003–2009) for the Italian Building Code. *Bulletin of the Seismological Society of America*, **101**, 1885–1911, http://dx.doi.org/10.1785/0120100130

UK RESILIENCE 2006. *Communicating Risk Guidance*. HMSO, London.

VERDICT MOTIVATIONS 2013. Tribunale di L'Aquila, Sezione Penale, Dott. M. Billi. Sentenza n. 380/2012. http://processoaquila.files.wordpress.com/2013/01/sentenza-grandi-rischi-completa-1.pdf (accessed 27 November 2014).

VITTORINI, V. 2011. *In*: Protezione Civile e responsabilità nella società del rischio: chi valuta, chi decide, chi giudica. Edited by the Department of Civil Protection of the Presidency of the Council of Ministers and CIMA Research Foundation. Edizioni ETS, Pisa, 136–140.

US EPA 1988. Seven Cardinal Rules of Risk Communication, OPA-87-020. US Environmental Protection Agency, Washington DC.

WAHLBERG, A. A. & SJOBERG, L. 2000. Risk perception and the media. *Journal of Risk Research*, **3**, 31–50.