2012 EMILIA EARTHQUAKES

Looking for missing earthquake traces in the Ferrara-Modena plain: an update on historical seismicity

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Article history

Received July 17, 2012; accepted August 23, 2012.

Subject classification:

Historical seismology, Surveys, measurements, and monitoring, Seismic risk, Seismological data, General or miscellaneous.

1. Historical seismicity according to the catalog in current use

According to the latest issue of the Italian seismic catalogue [Rovida et al. 2011], the area most affected by the May-June 2012 Emilia sequence [for an overview, *vide* Galli et al. 2012; Tertulliani et al. 2012, this volume] has a centuries-old seismic history of comparatively low magnitude events. These have been on a par with those that have occurred in the nearby Reggiano-Parmense area (where M 4.5 to M 5.5 earthquakes were comparatively frequent in the last century), although less significant than those on record in the portion of the northern Apennines that forms the southern boundary of the Pia-nura Padana (Figure 1), and a lot lower than in the most seismically active zones of the Italian peninsula. Magnitude ca. 5.5 earthquakes are known to have occurred near Ferrara (in 1346, 1561) and in the areas of Finale Emilia-Bondeno (1574, 1908, 1986), Mantua (1901) and Cento (1922). However, this picture might be incomplete, as suggested by the recent discovery of a previously unknown earthquake that occurred in 1639, whose maximum intensity was assessed as 7-8 Mercalli-Cancani-Sieberg (MCS) in Finale Emilia by Camassi et al. [2011a].

To date, the most relevant historically known local event is the so-called Ferrara earthquake of 1570 (M_W 5.4), which was actually a complex seismic sequence that started on November 17, 1570 (when four strong shocks caused severe structural damage and partial collapses in Ferrara and its surroundings), went on with closely spaced aftershocks up to early 1572, and then gradually petered out over the following couple of years, until March 17, 1574, when a somewhat stronger shock caused further damage in Finale Emilia [Guidoboni et al. 2007]. Another few M ca. 5.5 earthquakes have been located on the outskirts of the area affected by the 2012 sequence area. To the southeast, there was the 1624 Argenta earthquake (M_W 5.4) that had a maximum intensity of 8-9 MCS in the Argenta locality [Guidoboni

et al. 2007], and two similarly-sized earthquakes that occurred in 1796 (M_W 5.6) and 1909 (M_W 5.5), the latter of which might have had a deep hypocentral location, judging from its wide far field [Meloni and Molin 1987]. To the southwest, in the Carpi-Reggio area, there have been several moderately sized earthquakes, the latest of which was located near Correggio in 1996 (M_W 5.4).

2. Assessing the quality of the information behind the current picture

The studies from which the earthquake parameters of Table 1 were taken by Locati et al. [2011] are of various provenance and of variable thoroughness, and in a few cases they are relatively out of date. Most derive from Guidoboni et al. [2007], a collection that includes both advanced and preliminary studies. The studies derived from Archivio Macrosismico GNDT [1995] and ING [1998] were extremely preliminary ones; the ENEL [1985] studies were at least 27 years old and might be improved by taking into account the latest findings of local historical research (as in the case described by Camassi et al. [2011b]). In a few cases (the earthquakes of 1425, 1508, 1901), the current catalog inherited the parameters assessed for them by an earlier catalog [Postpischl 1985]; two of these earthquakes have been recently studied by Molin et al. [2008].

Looking at the general picture of local seismicity from a historian's point of view, some peculiarities become obvious. Up to the mid-1800s, for instance, there was a marked tendency for the earthquakes to cluster around Ferrara and Modena, the main towns in the area. A comparison between the seismic histories of Ferrara and Modena and those of lesser towns located midway between them, such as Carpi, Mirandola and Finale Emilia (Figure 2), shows the former to be both longer and more detailed than the latter. This suggests that the original evidence from which these seismic histories were built might have been affected by what the founding fathers

Figure 1. Seismicity of the studied area, according to Rovida et al. [2011].

of modern historical seismology called 'the urban fixation' [Vogt 1986, Vogt and Ambraseys 1991, Vogt 1994]; i.e., an inclination to focus on what happened in towns, rather than in villages and rural areas. This was particularly the case in the centuries in which literacy tended to be more widespread among townspeople than in the countryside.

It is also noticeable that earthquakes appear to have been comparatively scarcer in the 1600s to 1700s time window than in earlier centuries. This might reflect a real trend in the seismicity, although it might also be, partly at least, the result of choices made in the selection of historical earthquake data collected by the pre-instrumental tradition of Italian descriptive earthquake studies. This culminated in the great compilation by Baratta [1901], which is responsible, to this day, for the identification of most earthquakes that are included in the current catalog [vide Camassi et al. 2011a]. For a couple of examples, the great 18th century standard collection of medieval chronicles known as *Rerum Italicarum Scriptores* was undoubtedly instrumental in providing information on many earthquakes observed in Modena and Ferrara before the 1500s. Conversely, the paucity of data available in the 1600s to 1700s time window might be at least partly due to the chance selection of the Bologna gazette as a privileged source of earthquake information by Baratta [1901]. This gazette was one of the oldest Italian periodicals (1678-1796), and it usually published news from Rome and from a few Italian (Venice, Milan, Genoa) and European towns, but not from those at the eastern end of the Pianura Padana, such as Ferrara and Mantua [Camassi and Caracciolo 1994].

3. A few missing local earthquakes rediscovered

The incompleteness of the current picture of local seismicity is shown by the number of previously unknown, moderately damaging, local earthquakes, for which the information was retrieved by recent studies (Table 2). Three of the more interesting cases are described below.

1) April 6, 1639 (Finale Emilia, Carpi?)

A recent history of the Jewish community of Finale Emilia [Balboni 2005] quotes an authoritative local history [Frassoni 1778] as having reported an earthquake that occurred on April 6, 1639. This earthquake caused houses and chimneys to collapse in Finale, where a woman was killed. Reliable contemporary confirmation of this scenario can be found in the records of an inspection that was made by the bishop of Modena to the Finale churches in October 1639, which describes the tumbledown conditions of the Chapel of the Most Holy Annunciation "owing to the earthquake" [AAMoN 1639]. A document in the Carpi municipal archives dated as July 3, 1638, and transcribed by D'Orazi [2012] records the damage to the municipal tower of Carpi caused by "the past earthquake". Further research will be devoted to check the date of the Carpi document, and to look out for connections before it and the 1639 Finale Emilia earthquake.

2) December 15, 1761 (Mirandola, Carpi, Modena)

A collection of lives of eminent Mirandola citizens [Ceretti 1905] affirms that in 1762 one of them wrote a dissertation on earthquakes, taking his cue from "the one that occurred in Mirandola on December 15, 1761". In the after-

Table 1. Local seismicity, according to Locati et al. [2011]. Np, number of macroseismic intensity data points; Imx, maximum intensity; Io, Epicentral intensity; Latit, latitude; Long, longitude; Mw, moment magnitude; Dmw, magnitude standard deviation.

Year	Mo	Da	Ho	Mi	Se	Epicentral area	Macroseismic study	Np	Imx	Io	Latit	Long	Mw	Dmw
1234	03	20				Ferrara	ENEL 1985	5	7	7	44.836	11.618	5.1	0.34
1249	09					Modena	Guidoboni et al. 2007	4	7-8	6-7	44.647	10.925	4.9	0.34
1285	12	13				Ferrara	ENEL 1985	2	7	7	44.836	11.618	5.1	0.34
1339	11	16	14	10		Ferrara	Guidoboni et al. 2007	1	6	6	44.836	11.618	4.7	0.34
1346	02	22	11			Ferrara	Guidoboni et al. 2007	5	7-8	6-7	44.836	11.618	4.9	0.34
1409	08	17	00	35		Ferrara	Guidoboni et al. 2007	1	6	6	44.836	11.618	4.7	0.34
1410	05	09	22	30		Ferrara	ENEL 1985	3	6-7	6-7	44.836	11.618	4.9	0.34
1411	01	09	02			Ferrara	Guidoboni et al. 2007	1	7	7	44.836	11.618	5.1	0.34
1425	08	10	19			Ferrara Sud	Postpischl 1985, Molin et al. 2008		7	6	44.833	11.667	4.7	0.34
1474	03	11	20	30		Modena	ENEL 1985	12	6	5	44.647	10.925	4.3	0.34
1483	03	03	22			Ferrara	ENEL 1985	1	5-6	5-6	44.836	11.618	4.5	0.34
1508	10	18	15			Ferrara Sud	Postpischl 1985, Molin et al. 2008		5	6	44.833	11.667	4.7	0.34
1561	11	24	01	25		Ferrara	Guidoboni et al. 2007	5	6-7	5-6	44.781	11.454	4.5	0.34
1570	11	17	19	10		Ferrara	Guidoboni et al. 2007	60	8	7-8	44.824	11.632	5.4	0.25
1574	03	17	03	40		Finale Emilia	ENEL 1985	4	7	6	44.833	11.294	4.7	0.34
1661	03	21	23			Modenese	Guidoboni et al. 2007	4	6-7	6-7	44.734	10.863	4.9	0.34
1666	04	14	18	58		Bolognese	Guidoboni et al. 2007	3	6	5	44.641	11.113	4.3	0.34
1671	06	20	10			Modena-Reggio Emilia	Guidoboni et al. 2007	8	7	7	44.674	10.866	5.2	0.72
1695	02	28				Ferrara	Archivio Macrosismico GNDT 1995	1	5-6	5-6	44.836	11.618	4.5	0.34
1743	05	29				Ferrara	Archivio Macrosismico GNDT 1995	1	6-7	6-7	44.836	11.618	4.9	0.34
1787	07	16	10			Ferrara	Guidoboni et al. 2007	3	6-7	5-6	44.836	11.618	4.5	0.34
1796	10	22	04			Emilia orientale	Guidoboni et al. 2007	27	7	7	44.615	11.670	5.6	0.36
1799	02	22	05	45		Correggio	Guidoboni et al. 2007	2	6	5	44.771	10.779	4.3	0.34
1810	12	25	00	45		Novellara	ENEL 1985	33	7	6	44.898	10.712	5.2	0.22
1832	03	11	06	45		Carpi	Guidoboni et al. 2007	14	6	5	44.778	10.832	4.8	0.37
1841	10	15	22			Sanguinetto	ENEL 1985	19	6	5	45.167	11.110	4.1	0.44
1873	05	16	19	35		Reggiano	ENEL 1985	15	6-7	6-7	44.612	10.701	5.0	0.59
1901	01	20	06	30		Poggio Rusco	Postpischl 1985			6	45.000	11.100	4.7	0.34
1908	06	28	03	19	58.00	Finale Emilia	Guidoboni et al. 2007	15	6	5	44.835	11.329	4.2	0.53
1910	03	22	23	29		Bassa modenese	Guidoboni et al. 2007	15	5-6	5	44.821	11.162	4.3	0.34
1922	05	24	21	17	25.00	Ferrarese	Guidoboni et al. 2007	7	4-5	4	44.821	11.408	4.3	0.25
1928	06	13	08			Carpi	ENEL 1985	35	7	6	44.797	10.872	4.7	0.23
1953	08	22	05	26		Reggiano	Guidoboni et al. 2007	6	6	6	44.787	10.795	4.7	1.00
1963	04	05	13	49	42.00	Finale Emilia	Guidoboni et al. 2007	6	5-6	4-5	44.826	11.265	4.0	0.34
1970	11	02	08	42	12.00	Bassa modenese	Guidoboni et al. 2007	3	5-6	4-5	44.853	11.167	4.0	0.34
1971	09	11	23	18	12.00	Correggio	Guidoboni et al. 2007	15	5-6	5	44.764	10.862	4.2	0.31
1978	12	25	22	53	42.00	Bassa mantovana	Guidoboni et al. 2007	28	5-6	5	44.845	10.990	4.2	0.22
1986	12	06	17	07	20.00	Bondeno	Archivio Macrosismico GNDT 1995	604	6	6	44.879	11.334	4.6	0.10
1987	05	08	11	10	27.00	Bassa modenese	Archivio Macrosismico GNDT 1995	17	6	6	44.861	11.157	4.5	0.23
1998	02	21	02	21	13.00	Reggiano	ING 1998	104	5-6	5	44.777	10.723	4.3	0.17

Figure 2. Comparison between seismic histories [from Locati et al. 2011].

math of the late eighteenth century Italian earthquakes, many such works were produced by supporters and opponents of the then fashionable theory of electricity as the cause of earthquakes [Castelli 2010]. Although this earthquake has been ignored by Italian seismological compila-

tions and catalogs alike, it was strongly felt in Carpi [D'Orazi 2012] and more faintly in Modena [Gazzetta di Mantova 1761, Gazette de Leyde 1762]. The stir that this earthquake caused in Mirandola is attested by the large altarpiece that a prominent local family gave to the church of St Francis as a votive offering, by way of thanks for having been preserved from the earthquake [Ceretti 1890]. The painting, which is now in the Museo Civico of Mirandola and is viewable via the Emilia Romagna Heritage online catalog [IBC 2010], shows the Virgin and Child with two saints (one of which is Francis Solano, who was venerated as a special protector against earthquakes [Castelli and Camassi 2006]), and the tottering buildings of Mirandola in the background. Further research will be devoted to looking for *in-situ* evidence of damage (if there is any).

3) May 11, 1778 (*Rovereto sulla Secchia, Concordia sulla Secchia, Carpi*)

This appears to have been a seismic sequence of some duration that started with a "fearful" shock that was felt in Carpi on May 1, 1778, and continued on to August 25 of the same year [D'Orazi 2012]. The main shock on May 11, 1778, caused irreparable damage to the "most ancient and strong" tower of the Sacchella, located in the nearby hamlet of Rovereto sulla Secchia, which consequently had to be completely demolished. Fearing further collapses, the people of Rovereto and those of nearby Concordia sulla Secchia left their houses and camped in the fields until the end of the shocks. This sequence has also remained so far unknown to any Italian seismological compilation or catalog.

4. Conclusions

The information available on the historical seismicity of a region subjected to investigation needs to be submitted to critical scrutiny, especially in the aftermath of a strong earthquake, to test our understanding of it, and if necessary, to improve upon it. In this case, the May 2012 sequences can bid fair as the largest known to date for these areas, as the 1570 Ferrara sequence apparently occurred in a more eastward sector of the same seismogenic structure [vide Galli et al. 2012]. Our present knowledge of historical seismicity in the territory that extends from Ferrara to Finale Emilia, and from there to Mirandola and Novi di Modena, appears to be both defective and vague. However, we appear to be well on the way towards an improvement to this situation. Recent studies have retrieved the traces of several damaging earthquakes (Table 2) that occurred between the 1600s and 1700s that have so far been overlooked by the seismological literature and the parametric catalogs. The likeliest reasons for their fall into oblivion would appear to be that they failed to attract the attention of most outside contemporary witnesses because their highest macroseismic effects occurred in circumscribed, mostly rural, areas, while their attenuation

Figure 3. Locations where evidence of some missing earthquakes has been found.

Date	Quoted localities	Source / Study	Notes
1600 10 28	Reggio Emilia	Camassi et al. 2011a	Strong damage in Reggio Emilia
1608 01 01	Carpi, Modena, Reggio Emilia	<i>Ongoing investigation</i>	Probably underestimated by previous studies
1639 04 06	Finale Emilia	Camassi et al. 2011a	Strong damage, one victim in Finale Emilia
1646 05 30	Mantova, Cremona	Camassi et al. 2011a	Strong shaking in Mantova; felt in Cremona
1653 04 19	Reggio Emilia, Colorno, Cremona, Milano	Camassi et al. 2011a	Damage in Reggio Emilia and Colorno
1761 12 15	Mirandola, Carpi, Modena	<i>Ongoing investigation</i>	Strong shaking in Mirandola (damage?); felt in Carpi and Modena
1778 05 11	Rovereto sulla Secchia, Concordia sulla Secchia, Carpi	<i>Ongoing investigation</i>	Heavily damaged tower in Rovereto

Table 2. Traces of missing local earthquakes retrieved by recent studies.

was so strong that they were not felt in any major nearby town (e.g., Bologna, Ferrara, Modena or Mantua). Through the clues retrieved so far, the authors of this paper are about to start an *ad-hoc* quest for earthquake information in local archives and libraries.

Acknowledgements. We thank Paolo Galli and an anonymous reviewer for their thoughtful suggestions.

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