

Towards new research strategies: silent seismogenic areas or silent sources?

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Abstract

Some earthquakes, particularly the strongest ones, can re-occur within hundreds or thousands of years. Therefore, the areas whose «seismic history» seems to be totally lacking in information are indeed a problem. In the past, these «silences» were interpreted in the simplest way, as an indicator of a low degree of seismicity. More recently, the results of historical research, some geological observations and the limits imposed by the physics of the seismic cycle suggest that this interpretation is wrong and must be overcome by new multi-disciplinary strategies. These strategies will involve the use of both the general pattern offered by the knowledge on the historical seismicity, and the little, though valuable information gleaned from land geology. Similar to these «silent» or «missing» earthquakes are the cases of the «missed» earthquakes which occurred in such historical and territorial conditions that they went completely unnoticed. A third case regards «underrated» earthquakes, reported as events of moderate energy. «Missing», «missed» and «underrated» earthquakes call for some reflection on the problem of completeness in the catalogue, and require innovative research projects. In recent years the Istituto Nazionale di Geofisica and SGA have developed three of such projects. These concern: 1) Sicily in the period between the ninth and thirteenth centuries; 2) the Pollino area (Northern Calabria) before the nineteenth century; 3) the Velino-Sirente massif in the period between the eleventh and fourteenth centuries.

Key words *historical seismology – palaeoseismology – Apennines*

1. Introduction

It is said that the great earthquake of Avezzano in 1915 threw Mario Baratta into a deep depression, as if it had rendered useless his greatest work *I terremoti d'Italia* (The Earthquakes of Italy) (1901). Indeed, according to Baratta's data this region of the Abruzzo seemed to be one of the least seismic in the peninsula. So, was something wrong with the historical

method, or were the conclusions drawn just wrong? In some comments he published in the same year, Baratta (1915a,b) stated that there were some areas where it was necessary to do further historical research, or where the earthquakes had very long return periods. He suggested that there was still much work to be done and asked the governments to support long and difficult research programs.

Almost a century ahead, Baratta highlighted one of the fundamental problems of the modern procedures for seismic hazard analysis. This was that some earthquakes, particularly the larger ones, recur with the frequency of many centuries or even millennia. This means that historical research would have no relevance in all those regions where the data are very recent, or as the experience of Baratta shows, the results would be ambiguous where the data are complete and

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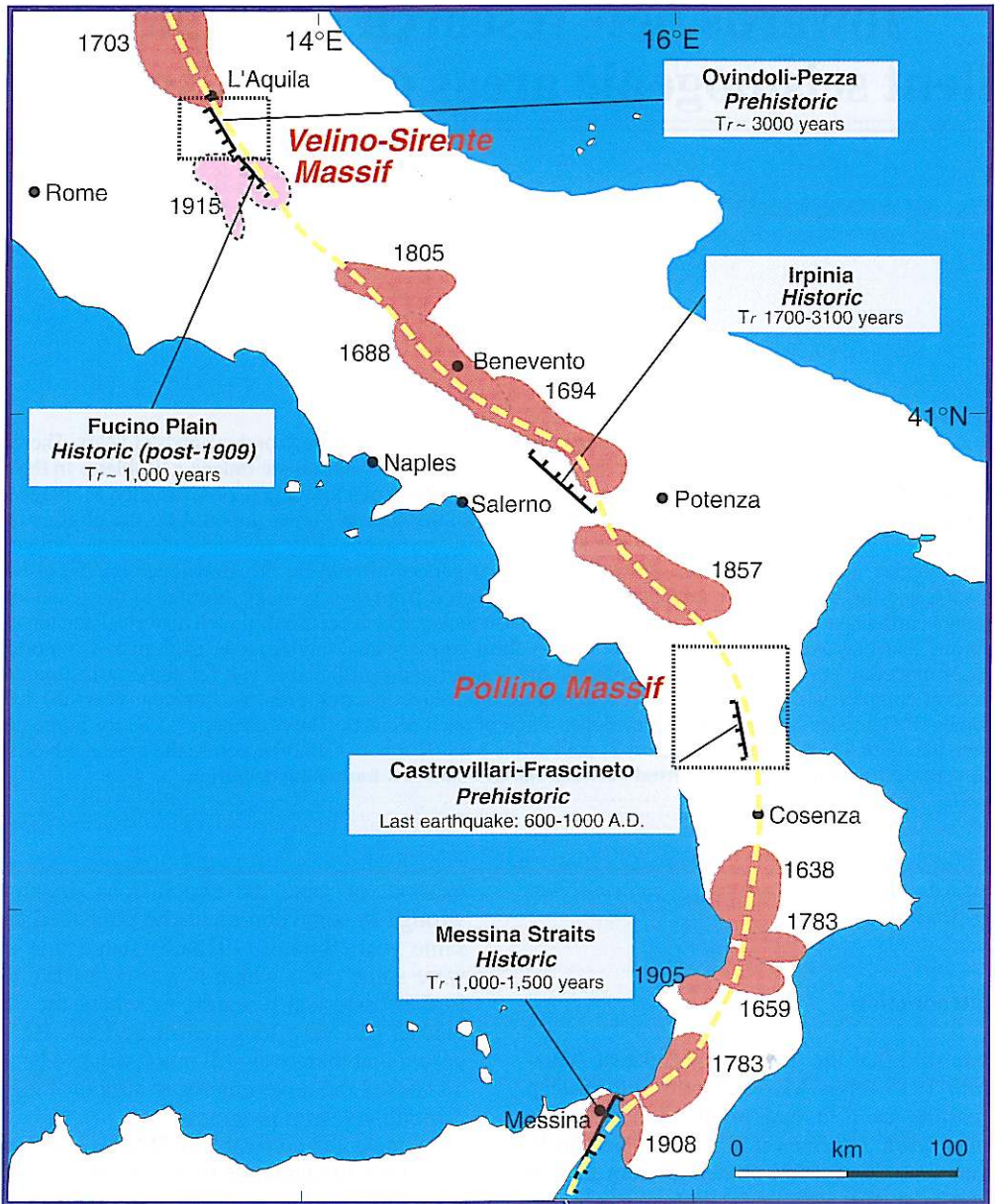


Fig. 1. Areas of largest damage (corresponding to the intensity X and XI isoseismals, Mercalli-Cancani-Sieberg scale) of large Apennine earthquakes between 1638 and 1908 (after Omori, 1909, redrawn and modified), and average recurrence intervals for selected large Italian faults. The figure shows a remarkable alignment along the crest of the Apennines and highlights two large gaps in historical seismicity (dotted areas), indicated by Omori himself as the seismically most dangerous places of Central and Southern Italy. Only a few years later about one third of the Abruzzi gap was filled by the occurrence of the 1915 Fucino plain earthquake (the shape of the associated intensity X isoseismal is indicated by a dotted line).

reliable for periods shorter than the millennium.

In a certain sense the observations made by Baratta had been mentioned six years earlier in an article written by Omori after the great earthquake in Messina in 1908 (Omori, 1909). This well-known seismologist had been sent by the Emperor of Japan to study the effects of that seismic disaster. Alongside his comments on the damage to the city of Messina and the comparisons with the effects of similar catastrophic Japanese earthquakes, Omori traced on a map of the peninsula the envelope of the epicentral areas of the greatest earthquakes since the seventeenth century (fig. 1). What emerged was a long, thin «snake» stretching between L'Aquila and Syracuse, broken only in the area of Central Abruzzo, to the south of L'Aquila, and in the Pollino mountain range, on the border between Calabria and Lucania. Omori was used to the major earthquakes which with distinct spatial regularity and with a recurrence rate of almost a century marked the subduction of the Pacific plate beneath Japan. For him, those «silent» areas must automatically be interpreted as seismic gaps, thus something to cause serious worry. This has been proved right by the fact that one of the two gaps was soon filled by the catastrophe of Avezzano and Marsica in 1915.

Unfortunately, Omori's theories were not seen in a good light by the Italian scientific community in those years. What is more, after 1915 he neglected to point out that his intuition had been well-founded, and therefore both his comments and Baratta's just preoccupations remained a dead letter for many years.

Today, almost a century after the mentioned events, the Italian seismic catalogue has undergone huge improvements as regards both the data and the study methods. However, a systematic approach still needs to be found for the problem of the areas whose «seismic history», appears at the current state of knowledge to be totally lacking in data. In the meantime, the calculations of seismic hazard so far applied, as well as the consequent body of legislation, have interpreted these «silences» in the simplest possible way: assuming that the areas in question do indeed have a low seismicity degree. Today, a surprising consensus of results from historical research, geological observations and limits

imposed by the physics of the seismic cycle suggests that this interpretation is wrong and must be revised with the aid of new multi-disciplinary strategies.

2. A new image of risk

In the past few years there has been a rapid development and diversification in the research techniques used to estimate seismic risk, based exclusively on data of historical seismicity. This approach is unquestionably the most common not only in Italy but in all those nations with at least a few centuries of history behind them. It is based on a principle that we rarely take the trouble to check: that the historical record is sufficiently extended both in space and time to be considered representative of the seismicity of every given area. For a long time a slightly misguided view has conditioned work. On the one hand, it was considered sufficient to check the «completeness» of the historical catalogue. This meant, in seismological jargon, that a check was made that not only the strongest quakes but also the less violent and smaller ones were represented in a balanced way for each area. On the other hand, it was assumed that total seismic silence is not possible, and that in each area minor quakes occur in any case, distributed in such a way as to allow the magnitude of the expected seismic maximum to be evaluated by extrapolation. However the seismic history of this century alone already demonstrates the perils of these assumptions. It is enough to put ourselves in the position of Baratta, in the midst of his activity exactly one century ago, to realise that not only Central Abruzzo but also the area of the Straits of Messina and the westernmost part of Sicily had been up to that moment almost completely silent. The tremendous potential that they were soon to unleash could not therefore be anticipated on the basis of historical evidence, except by arbitrary extrapolation of the degree of seismicity of the adjacent areas.

The apparent dangers of history find a fairly simple explanation in the physics of the seismic cycle. Let us take a major earthquake such as that of Avezzano in 1915. This earthquake was

generated by a fault about 25 km long stretching along the eastern border of the river-bed of the former lake Fucino (Ward and Valensise, 1989). This fault dimension is fully compatible both with the magnitude of the earthquake, which ranges from 6.6 to 6.9 according to the system of evaluation used, and with the epicentral intensity and the overall severity of the effects. But the fact that such a large earthquake occurs also means that there is an area of the crust stretching just about 25 km which tends to behave in a unitary manner, storing up elastic energy by effect of the regional tectonic stress and releasing it all together in a great earthquake. As a consequence, the whole area will remain almost totally silent during the preparation cycle before a major earthquake. In practical terms, this will create a gap of 25 km in the seismic release and, consequently, in the historical records, if these exist. The ability to recognise the potential of that area through historical sources will therefore be strictly in accordance with the length of the window of historical observation in relation to the occurrence of the expected strong earthquake. For Baratta, for example, this window had a duration of presumably six to seven centuries, during which the Fucino area appeared to be totally without seismic activity. How could Baratta have known that 1901, the year of publication of his great catalogue, and the most recent extreme of this time window, fell only 14 years before the end of the seismic cycle for the fault responsible for the earthquake of Avezzano? And, if we think about it, had anyone noticed that the catastrophic earthquake in Lucania in 1857 had also occurred in an area which had been silent for many centuries? Was anything known about possible forerunners of the great earthquake in Liguria in 1887, or the 1873 earthquake in the Belluno area? An identical case is the largest known earthquake in Northern Italy, occurring in January 1117 in the area around Verona which since then has been almost completely quiescent.

To conclude, while experience of other areas such as the Romagna Apennines, Umbria, the Benevento area, Irpinia and Eastern Sicily seemed to suggest that major earthquakes take place with centennial frequency or at least such a frequency that history can record two or more

«twin» events, none of the most catastrophic earthquakes described in the work *I terremoti d'Italia* seemed to have a forerunner of equal magnitude. It should be noted that, at least in principle, the larger the source of a strong earthquake is, the larger the relative gap, the longer the preparation stage for the future earthquake, its return time, and the more serious its effects will be. In other words, relatively small and frequent though destructive earthquakes, like those of a magnitude between 5 and 6 occurring along the whole of the Apennines between Umbria and Liguria, are very likely to have left traces in history. What is more, the small size of the sources ensures that none of the villages along the Apennine backbone have escaped completely unscathed in the historical period. On the other hand, it is in the Central Southern Apennines that we find the larger structures and more infrequent activity, two characteristics that together may lead to gaps which are significantly extensive both in space and in time (e.g., Valensise and Pantosti, 2000).

All these considerations certainly seem obvious in the light of modern knowledge and especially of the *Fault Segmentation and Characteristic Earthquake Concept* (Schwartz and Coppersmith, 1984), a new frame of reference for the understanding of earthquake recurrence in space and time. Over the past few years this reference has been able to demonstrate on both a theoretical and experimental basis that earthquakes tend to be «characteristic»: in other words, they occur rather regularly in time but above all in space. Anyway, even Baratta and the scholars of his time must have reckoned with some form of the not total fortuitousness of earthquakes; why otherwise would they place such emphasis on identifying the «seismic sources»? What is more, it is maybe even less fortuitous that the first suspicions arose in Baratta in 1915 itself, perhaps in a pause of critical reflection at the end of such a fruitful career and in the aftermath of such a tragic and in particular «anomalous» earthquake, at least as regards the state of knowledge of the time.

To sum up, a re-reading of the catalogue of earthquakes in the light of the most recent knowledge and above all in consideration of the earthquakes of this century shows that, despite the

limited knowledge then available, Baratta had perfectly focussed on the problem. Indeed there is no need to invoke lengthy return periods to explain the occurrence of unexpected strong earthquakes. As we will see below, depending on the area, a few centuries or even less than that in particular territorial conditions may be sufficient.

In the meantime, the problem of evaluating the return time of strong earthquakes generated by the same fault has been explored more objectively with the methods of Palaeoseismology. This involves using radiometric methods to date episodes of dislocation of the topographic surface along known faults, or comparing the amount of the deformation produced by a single major earthquake with cumulative deformation recorded by geological horizons of known age (see, for example, Pantosti and Yeats, 1993, for a summary of the characteristics of this discipline). In a compilation of results obtained by different authors, Valensise and Pantosti (2000) have shown that all the great Italian faults studied so far have generated violent earthquakes with a frequency of one thousand or even two thousand years. This is enough to extinguish any hope that history might have recorded more than one violent earthquake for each of the major seismogenic faults in Italy, and to make us fear that some of those faults have so far gone completely unnoticed. A number of research studies carried out in different parts of the country have in fact brought to light the existence of faults which have been active in history but to which no reference can be found in available historical sources. Examples are to be found in the area of Roccaraso, on the border between Abruzzo and Molise (D'Addezio *et al.*, 2000); around the Altopiano delle Rocche, in the L'Aquila area of Abruzzo (D'Addezio *et al.*, 1995); and in the Castrovillari area, at the foot of the Pollino Massif (Cinti *et al.*, 1997). Note that seismic activity with a recurrence rate of several hundreds or thousands of years is not only common to a huge number of regions of the world, but is also fully compatible with the current geodynamic knowledge about the Italian peninsula. If we combine observations on the violent earthquakes of this century with recent observations about the speed of tectonic processes, we obtain such «recharg-

ing» times of the structures that a shorter recurrence interval would be impossible. More frequent earthquakes would occur if one of the major faults able to generate great «characteristic» earthquakes, like that of the Straits of Messina, decided to change its behaviour and generate smaller but more frequent earthquakes. However, the faults whose behaviour is known with a certain amount of detail all tend to generate the strongest earthquake possible. The most striking example may be seen in the fault responsible for the catastrophic earthquake of 23 November 1980 in Irpinia, for which a direct geological record exists of at least five earthquakes occurring at intervals of about two thousand years (Pantosti *et al.*, 1993). If these earthquakes had not been «characteristic» we would expect to find in the historical catalogue a certain number of earthquakes of magnitude around 6 occurring at intervals of just a few centuries. Instead, the few strong historical earthquakes of the area seem to have been generated by independent structures and quakes of an intermediate magnitude are nearly absent.

Over the next few years, research on seismic risk in Italy will therefore be obliged to confront the perils represented by rare strong earthquakes and by prolonged seismic quiescence. The jigsaw of national seismogenic potential will have to be completed using the general outline provided by the knowledge of the historical seismicity as well as the rare but valuable pieces supplied by land geology, with the right balance and awareness of the physics of the seismic phenomenon. This process of completion may take place only if research in both disciplinary frameworks is able to challenge its own assumptions, identify innovative research strategies and transform into perfectly complementary actions certain conflicts which in the past have characterised this sector of such importance for Italy.

3. «Missing», «missed» and «underrated» earthquakes: new directions in historical seismological research

Having discussed aspects relative to the physics of the seismic phenomenon and to certain

fundamental characteristics of seismicity in Italy, let us now see how over the last few years research in historical seismology has been transformed and innovated in response to the evolution of the «seismological demand».

The most striking of the various cases we have outlined is that of violent earthquakes whose effects have been highlighted by geological research, but which are «missing» in the CFTI3 since their characteristic cycle has not yet been completed in the historical period. These earthquakes are today the greatest source of anxiety, since their sources may have had the whole historical period, in other words several centuries on average, to prepare for a new event, which could therefore be imminent.

A similar case is that of «missed» earthquakes. These are events which took place in such historical and territorial conditions that they passed in complete silence. Though apparently similar, the difference between this and the previous case is enormous. Indeed, given a certain seismogenic source identified directly in the field, in the first case history may give «negative evidence», confirming that the source has been quiescent for many centuries and thus triggering a situation of attention. In the second case, instead, historical research could unearth traces of an earthquake generated by that structure in an era sufficiently recent to drastically reduce the level of attention. The case we have described is simplifying since it is very difficult to evaluate the «seismogenic vocation» of a fault observed in the field, since a quiescence of several centuries may in any case be unimportant if the expected return time is in the order of millennia, as in the case of the earthquake of Irpinia in 1980, and since there is a fundamental ambiguity in attributing reports of damage by an ancient earthquake to a fault known geologically. Nevertheless, the «discovery» of new earthquakes, or new classes of effects for known events, is a fundamental and exciting step in the research of historical seismology.

Discoveries of this type are however not frequent and would merit a chapter to themselves within the research on historical seismicity. New destructive earthquakes can in fact be identified almost exclusively during systematic research. So far, however, the logic of revision of the

catalogue data has been developed essentially on already known chronological indicators, focusing on checks and examinations concerning known events. As we mentioned at the beginning, although there are valid reasons to use this approach, this line of investigation implies a «completeness of the catalogue», at least after the seventeenth century, which instead still remains to be demonstrated for the most part and which in any case does not solve the problems uncovered by the studies of historical seismicity.

But the perils of the history of seismicity, whether apparent or real, are not just found in «missing» or «missed» earthquakes. There is in fact a third case: «underrated», or strong earthquakes handed down in reports as moderately strong events. Indeed it has been found in a number of cases that events catalogued with an intensity lower than degree IX may actually have been much stronger. Thus these events are more significant both from the geodynamic point of view and especially as regards the residual potential of the region in which they occurred. There are two fundamental conditions that may lead to the underestimation of an earthquake of the past:

- Characteristics of settlements in the area, such that even a strong earthquake may not have damaged the buildings to the extent that might be expected (for further notes see the case of the 1315 earthquake in the L'Aquila area).

- The cultural dominance of large urban centres, which could have overshadowed areas with more destructive effects, leaving a minimal trace of damage (see for example in the CD-ROM the earthquakes located in Rome in ancient times). There also exist cases much closer in time: the earthquake of 1815, classified in the PFG catalogue (Postpischl, 1985) as a tremor of degree V in Rome, was actually a degree VII in Norcia. In this case, the 1985 catalogue had in fact only reported effects far from the epicentral area.

«Missing», «missed» and «underrated» earthquakes suggest that the completeness of the catalogue brings with it new problems and requires innovative action:

- Relating the known data to the information potential of the sources available.

- «Turning over» research on the earthquakes of the past to the history of the territory itself.

– Analysing the available sources from new points of view.

– Exploring the territorial contexts within specific time windows.

All this could be used to give specific responses not only to seismologists but also to researchers of other disciplines.

Over the past few years, ING and SGA have developed a number of research experiments, some still unpublished, which identify new solutions to the problem. In particular, three tests have been performed, each the product of specific motivations, which illustrate the concepts expressed here and the new slant given to research in historical seismology. In chronological order, the following research projects have been carried out:

1) Sicily: analysis of the apparent seismic quiescence in the period between the ninth and thirteenth centuries. This research was performed in 1992 and published in summary form in 1995.

2) The Pollino area (Northern Calabria): research of possible unknown destructive earthquakes and evaluation of the information potential of the area before the nineteenth century. This research was performed in 1993-1994.

3) The area of the Velino-Sirente massif (Central Abruzzo) between L'Aquila and Avezzano: research of unknown destructive earthquakes in the period between the eleventh and fourteenth centuries. This research was carried out in 1993-1994.

4. Medieval Sicily: six «missed» seismic events on the eastern coast

Sicily's particular geographical and historical situation was a determining factor in the *destiny* of some earthquakes, but at the same time many other historical and cultural reasons have erased events from memory. Indeed, sources have mainly concentrated on the military events that often tend to overshadow the natural events, sometimes even obscuring them completely. It was above all the political equilibrium of the Mediterranean which caused, *de facto*, grey areas in the documentation. For the earliest age, the marginal importance of Sicily with respect to the Roman, and later Byzantine, sphere of

influence was a determining feature. Moreover, urban constructions were rarely found, except in a very few cases, the effect of which was that Sicily tended to be rather isolated from the political trends which already prevailed in areas with both geographical and historical affinities, such as North Africa.

Even during the period of the Arab domination (ninth-eleventh centuries), despite renewed interest in geographical and natural sciences, little attention was paid to the seismic activity in Sicily, even in its most violent forms (Johns, 1989). Arab geographers restricted themselves to considering the activity of Etna. Though located at the centre of the Mediterranean, in the perspective of the scholars of Baghdad or the historians themselves, Sicily was still considered part of the «Maghreb», the Muslim West. Some more important information emerged during the following period. Whereas Latin chronicles have enabled earthquakes such as that of 1169 to be studied (see in the CD-ROM), on the Greek side there was a certain lack of interest in the more «western» regions of the Byzantine area of influence. So in this case too Sicily remained a marginal territory and Sicilian scholars have attempted in vain to find references to Sicily, or at least to Southern Italy, made by Byzantine historians and chronographers.

Despite the efforts of Sicilian erudites of the sixteenth, seventeenth and eighteenth centuries, thwarted by their lack of experience in ancient and Byzantine chronologies, research on medieval earthquakes in Sicily has not had a modern tradition of studies of its own. A certain degree of «localism» of the Sicilian historiographic tradition, overcome only in the last few decades, has also long been an impediment to an overall evaluation of data on the effects of earthquakes. Therefore the available documentation is still far from satisfactory from a critical and quantitative point of view. As a whole, medieval Sicilian documents are still much less known or less widely published than, for example, those of Northern or Central Italy or even Neapolitan documents. However, it is not exclusively a question of documentation limits; as is shown by the completed research project, part of the results is based on published sources. The problem is thus not just the scarcity of published

documentation, but also the way it is interpreted. The extreme level of various specialisations often prevents the data being known and evaluated from other points of view. Indeed, the possibility of evaluating the historical traces of the earthquakes in a Mediterranean perspective has proved to be of fundamental importance for a better understanding of these events in the sources of the time. A territory at the edge of different civilisations, as Sicily was for many centuries, can be studied with profit by historical seismology only in the light of a more extensive documentation, both geographically and linguistically, and taking into account the problems that so much material involves.

It is thus due to a more attentive perspective towards Sicily, as a territory within a precise historical and geographical context, that it has been possible to integrate and correct the previous state of knowledge (Guidoboni and Traina, 1997). The presence of different peoples and dominations, and therefore of different languages and cultures, has often complicated the framework of reference of medieval Sicilian sources. The limits of local sources and erudite historiography have been overcome, events have been analysed on the basis of a wider context, and new types of sources have been used (including the liturgical codexes of the Greek church of Messina). In this way it has been possible to identify six seismic events so far unknown to the national catalogue (fig. 2):

- 853, 31 August, Messina;
- 1125, 7 June, Syracuse;
- 1171/1173, 6 September, Messina;
- 1255/1256, Messina;
- 1295/1296, probably on the eastern coast;
- 1203/1204, probably on the eastern coast.

These are valuable data, often lost or simply forgotten by the myriad specialist sectors of historical, philological and codicological research, which in this case has shown the limits of the previous state of knowledge. Along these chronological guidelines we have set up some documentary research in an attempt to increase the level of information (Vallerani, 1995). These research projects certainly improve the state of knowledge and help to illustrate the distribution

and activity of the main seismogenic sources of one of the most active zones in the Mediterranean. However, they do not completely solve the problem of the completeness of the catalogue for the centuries considered here: for these there is still an undeniable lack of information.

Five of the six new events identified are recorded explicitly by authoritative sources consulted in recent critical editions. The 1125 event in Syracuse instead was «lost» with a large number of different dates within the erudite tradition of the seventeenth century. Not rarely historians dealing with the revision of earthquake catalogues, particularly for the medieval period, are seized by a sort of «impatience». Indeed, they sometimes prefer to eliminate a seismic event if it is not backed by contemporary sources, rather than use it to start a new research path. This elimination criterion, based on the philological principle of «contemporaneity» alone, seems to be rather limited in the light of the present research. It is true that by retaining only the events testified by contemporary sources and rejecting the others a sort of impeccable guarantee is offered, but in actual fact not a few research problems are eliminated and with them sometimes also the concrete leads for identifying new earthquakes. The 1125 earthquake was thus an event «at risk of elimination» because it could not directly be supported by sources and appeared to be preserved only in the erudite tradition of more than four hundred years later, which was often revealed to be fallacious or highly inaccurate.

The conflicting data about the chronology of this earthquake required a «backward» analysis through local erudite tradition, right up to the identification among the numerous European medieval sources of what could have been the text of the first basic information. This way of working is not unusual in the studies of historical seismology. In this field, linguistic analysis and attention to the circulation of information given in texts which were read, copied and rarely quoted sometimes provide an occasion for proceeding to identify more reliable data.

The Latin source at the basis of the first written reference to the 1125 event is the chronicle of Richard of Poitou (a twelfth-century Cluniac monk). The text also contains indirect

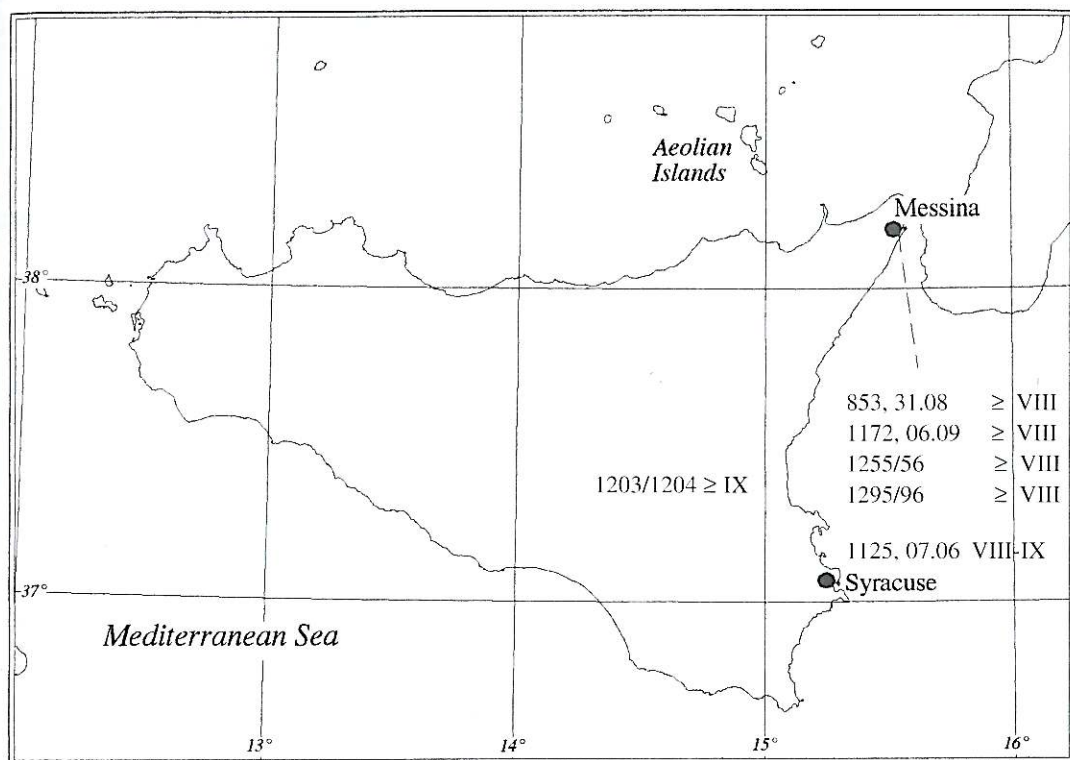


Fig. 2. Previously unknown earthquakes of medieval Sicily found during the research carried out in 1992-1993. The Syracuse earthquake of 1125 has been included in this version of the CFTI (see the CD-ROM). The remaining earthquakes shown on the map are still being studied and will be inserted in the future version of the CFTI (version 4, in preparation), which is devoted entirely to «new» earthquakes, *i.e.* earthquakes unknown to current Italian catalogues.

chronological clues which have led to a realistic definition of the day, month and year of the event (through calculation of the cycles of indiction and liturgical feasts). The text of the Sicilian erudite Scobar (1520) confirms and complements the Latin source. Its analysis has shown that Sicilian antiquarian historiography depended on a Greek tradition of the information, belonging to no longer existing sources (see Guidoboni, 1996, in particular pp. 180-184).

Altogether, the research has shown that there are considerable difficulties in co-ordinating ambiguous and sometimes inaccurate historical data and checking them. However it is possible to correct traditionally accepted earthquake data

(or sometimes traditionally rejected data) with a reading of the sources which is philologically and historically aware of the historical and cultural context of the events and their tradition.

5. The shadows in a thinly documented history: the «missing» earthquakes in the area of the Pollino massif

The area of the Pollino massif (see fig. 1), as we have seen, represents a glaring interruption in the continuity of earthquakes in the Apennines, but also bears clear geological traces of recent seismic activity. The seismological ques-

tion on the matter was this: have there been strong earthquakes in this area? And should one of these earthquakes have occurred, would we have known about it? These questions have been turned onto the area itself, and so formed another question: is there evidence in the inhabited context of serious seismic destruction, such as may be found either in written documentation or in the history of the settlement itself?

In order to answer this question it was necessary to look back in detail to the whole history of the Pollino region, particularly to the period preceding the seventeenth century, commonly considered the most «incomplete» of the catalogue. To give an idea of this approach (whose results are given in detail in SGA, 1994a, with complete bibliography), we give an outline here of the followed process.

The area in question extends for about 2000 km² between Basilicata and Calabria and includes 59 villages and hamlets of Basilicata, the lower Valle del Crati, the Piana di Sibari and the «Upper Ionian» region. We first divided the area into periods from the early Middle Ages on, then considered some specific themes regarding the settlement types.

Thus we examined the area in the long term from the viewpoint of the complex historical evolution of human presence. The accumulation of memory and its transmission are in fact closely connected with the process of population, and in the particular natural environment of the Pollino the dynamics of these processes are far from being constant or consolidated. In this way the results and limits of historiographical research (the «state of the art») were gathered, while the area was divided into historical periods so that new research could be performed on unpublished sources.

This analysis of the historical events of the Pollino region has helped to identify certain periods featuring major information gaps, which are very unlikely to be filled even in the future. In fact, a number of historical and political events have affected the preservation of local memory, as whole villages were destroyed together with most of their documentation.

From the first centuries of the early Middle Ages and for a long time after that, the Pollino area was being identified as the area of border

and conflict between the Lombard and the Byzantine world. The political turbulence, the succession of wars and the orographic characteristics of the territory did not favour the population process. Between the eighth and ninth centuries, the entire region became an object of contention between the Lombards, Franks and Byzantines. Throughout the period between the eighth and tenth centuries, the situation was aggravated by continuous devastating Saracen raids, which turned out indeed to be disastrous for that documentary heritage which could have been used to reconstruct the events of those centuries. This situation led the inhabitants of coastal towns to seek refuge inland, on sites which were easy to defend and difficult to reach from the coast. It was in this period that new settlements were founded on the Ionian spurs of the Pollino and along the middle valley of the River Sinni. These were settlements of modest dimensions, small villages whose inhabitants were unable, given the general conditions of the region, to promote a stable process of colonisation and population. There are fragmentary testimonies of the presence and diffusion of hamlets and settlements along the ancient Via Popilia and close to pre-existing villages. These were rapidly abandoned, destroyed by Saracen raids or wars. Some of these settlements were later repopulated once the general conditions had changed.

Another important factor in the history of the settlements in the Pollino area between the seventh and eleventh centuries was the presence of Greek anchoritic monasticism. Pushed by the Arab advance in the seventh/eighth centuries to take refuge in Southern Calabria, their ascetic ideals drove the Greek monks to settle in the thinly populated mountainous areas of Northern Calabria, even on the steep spurs of the Orsomarso and the Pollino, the monastic eparchy of the *Mercurion*. The spread of monastic centres had a great impact on the social and cultural situation of the region. The flowering of the culture of Greek monasticism had its roots in the practice of the transmission of written memoirs, an exercise in which the Greek monks attained very high levels of quality and quantity. Surviving testimonies give an idea of a flourishing activity of writing, transcription and miniature

as well as the existence of well-stocked libraries in the hermitages. Unfortunately very little was to be spared by the incessant Saracen raids.

In 1061, with the fall of Reggio Calabria, the last major Byzantine stronghold in Calabria, the Normans completed their conquest of Southern Italy, setting off the process of Latinisation of the structures of civil power and religious life. Following the Norman-Swabian conquest, the area of the Pollino, now part of a wider and more centralised state context, experienced the vast diffusion of the feudal system. The region thus followed the historical, social and economic events of the Southern Italy, though preserving some features of its own. Of 36 towns whose history has been reconstructed on the basis of available historiography, 15 proved to have foundations of before the year 1000, whilst the remainder were shown to have been founded between the eleventh and fifteenth centuries. This indication alone shows that it is practically impossible that there exists a potential of territorial information of before this period.

The spread of the feudal system, as the supporting structure of monarchic power on state territory, and the Latinisation of the monastic orders brought about a change in the methods of transmission of historical memory and the places where the new documentation was preserved. Feudalism saw the appearance of a class of barons and seigniors, also belonging to the clergy. From these emerged some very powerful families who have dominated the lives of Calabrian communities right up to contemporary times and often in open contrast with the central powers. An initial reconstruction at the State Archives of Naples of the feudal and administrative events of the most important localities of the Pollino region has uncovered a series of documentary collections belonging to families who wielded power in the area for many centuries (the Sanserverino, Carafa, Pignatelli d'Aragona, Pignone del Carretto, Bisignano, Chiaromonte, etc.). Some of these archives contain written testimonies and cartographic documentation of great interest for our research purposes. Of considerable importance were also the archives of the monastic orders located in the Pollino region with major settlements on both the Calabrian and Lucanian sides.

The establishment of the Angevin domination throughout the kingdom of Naples (thirteenth century) led to a considerable worsening in general economic conditions, an increase in fiscal pressure from the central power, pressure from the new French feudal lords and a marked decline in population. These phenomena had far-reaching effects throughout Calabria and especially in the northern areas. To escape from fiscal pressure, the populations of many towns, including Castrovillari, temporarily abandoned their homes and land.

The war of the Vespers (1282-1302) did not improve the situation, and the settlements of the Pollino region were repeatedly looted by the various soldier mobs, recalling the scenes of desolation familiar during the Saracen invasions. The inhabitants of some villages deserted their homes and in some cases migrated towards impervious and inaccessible areas. Much of the historical documentation, particularly that preserved in the archives of the ecclesiastic authorities, was destroyed. The events of the centuries to follow accentuated the picture of poverty, isolation and desertion inherited from the beginnings of the Aragonese domination. Confirmation of this may be seen in the great staidity of the towns and economic life, sorely tried by the plague of 1348 and the rebellions following the Western Schism (1378-1409).

There was a change in the area's population in the fifteenth century with the foundation of Albanian hamlets on the Ionian side of the Pollino massif. After 1435, the year of the Turkish conquest of Albania, a flow of refugees began to move from there towards Southern Italy and particularly in the direction of Calabria. Immigration continued in a constant flow for the whole of the fifteenth century and in the first forty years of the sixteenth, leading to the foundation of new hamlets or to the repopulation of previously abandoned towns, mainly close to the Ionian coast.

At the beginning of the sixteenth century the panorama of the Pollino region featured few towns of demographic or economic importance (Castrovillari and Cassano) and a number of small villages surrounded by groups of houses and hamlets of precarious destiny. Of these latter few traces remain and historiography has

taken little interest in them. The main town remained Castrovillari, due to the presence of a merchant class and various monastic orders. In 1545 it housed about 8000 inhabitants.

A series of local events and the general economic crisis exacerbated by the pressures of the local potentates and the central government led to a drastic decline in the population in the seventeenth century. The desertion affected all the towns in the Pollino region, on both the Calabrian and Lucanian sides. The situation of demographic crisis and economic isolation continued until the end of the eighteenth century.

As we can see, on the one hand there were no stable centres of culture and power able to produce continuing documentary traces; on the other hand the historical and social «fractures», usually responsible for the destruction of the sources are numerous. Further, the marginal nature of the area with respect to the «gravitational» centre of Naples also demotivated possible cultural or naturalist interests in this area. Anyway, the numerous sources identified have unearthed a number of specific traces of seismic activity of low intensity (from MCS-degrees V to VII-VIII) which occurred between the sixteenth and twentieth centuries affecting the larger towns. In some cases these were small local tremors, while for the remainder these were the effects of violent earthquakes located elsewhere (see table I in Mariotti *et al.*, 2000, this volume).

Finally we explored the ethnological and folklore tradition, so as not to exclude any of the possible «points of view» from which we might uncover a trace of a possible major seismic event. Amongst the papers of the ethnologist and scholar Padula, it emerged that until the nineteenth century local peasants referred to a split in a rocky area along the River Lao, near Viggianello (Potenza), as the trace of a violent earthquake, which had occurred «in the time of Christ». The chronological indication is obviously only a *topos* to refer to an indeterminate and distant time, and the religious reference blurs the outlines and increases the inherent problems. From an ethnographic point of view, the indication «birth of Christ» is no direct reference to the actual span of time passing since that event, in other words about two thousand

years. However, the indication might refer to a much more recent event, occurring in a period of established Christianisation of the countryside, while still being remote enough for other significant references not to be found, a period perhaps not exceeding the millennium.

In a certain sense, the information limit of the historical documentation has thus been reached, with the demonstration of the existence of extensive documentary gaps but also the absence of traces of violent local earthquakes in recent times. The problem of searching for an ancient earthquake that occurred «in the time of Christ» has been passed on to the geologists with the following questions: why did the memory of a remote earthquake establish a trace near a specific place? Is there something at Viggianello that we still do not know?

6. Major «underrated» earthquakes: the case of the 1315 earthquake in Central Abruzzo (the Velino-Sirente massif)

This line of research concerned a third situation which may be concealed within the chronological series of the Italian seismic catalogue: the possibility that violent earthquakes were classified as minor or not very destructive only because the structure of the population and the local residential features made it impossible to leave evidence of widespread damage. The research was propitiated by recent palaeoseismological studies conducted around Ovindoli (L'Aquila). At this site traces have been uncovered of a violent earthquake caused by a seismogenic structure (the Ovindoli-Pezza fault) representing the NW prolongation of the fault which generated the earthquake of Avezzano in 1915 (Pantosti *et al.*, 1996). Geological data suggest that this event must have occurred during the first four centuries of this millennium and must have had dimensions comparable with, if not superior to, those of the earthquake of 1915. However, seismic catalogues do not report strong earthquakes centred in this area, although there is no lack of cases such as that of the known earthquakes in Abruzzo in September 1349, where there are still problems in attributing the tremors to specific seismogenic structures.

Historical research started with the hypothesis that the earthquake identified by palaeoseismologists might have passed unnoticed to some extent because of the area's geography and housing characteristics, this being a mountainous area which even today has a very low population density (D'Addezio *et al.*, 1995). Research was thus directed towards identifying possible unknown violent earthquakes that occurred between the eleventh and fourteenth centuries (SGA, 1994b).

The problem of the relation between the entity of the tremor and the associated damage has already been analysed as part of the research on the antique and early medieval world (see Fumagalli and Guidoboni, 1989). The habitational characteristics of vast areas of Italy could greatly attenuate the effects of the tremor, both because of the choice of the building materials (use of wood and lightweight plant materials) and the low population density even within the towns. Therefore the traces left by an earthquake of considerable intensity might just have been only great fear. It has been hypothesised in quite reasonable terms that the numerous anthropic elements that have characterised the habitational history of Italy have, in certain periods, been able to «deconstruct» potential seismic disasters understood in the modern sense (Guidoboni, 1990). In this way, earthquakes whose released energy classifies them as violent may not actually appear such in certain inhabited environments, or may be totally absent from the historical record since no significant trace has been left on the inhabited environment. Nor is this element necessarily linked to their remoteness in time. It is important therefore to split the equation *violent earthquakes equal seismic disasters* that has so far dominated historical seismology. Indeed if we take a violent earthquake to mean exclusively that identified through signs of great destruction, we run the risk of gaining a false picture of the seismicity in progress. But is there a way out of this blind alley? How do we split the self-referential system formed by the link between human context and seismic disaster?

Research for identifying strong unknown earthquakes in Abruzzo has provided an excellent starting point for responding to this ques-

tion. First of all we have drawn up an outline of the history of the population of the area starting from the early Middle Ages. Our research study uncovered special characteristics of this area on the border between two different kingdoms (the Church State and the kingdom of Sicily). The most important phenomenon as regards the territorial layout in this area was that of fortification. Recent studies have shown that it was the product of three distinct historical processes:

1) Fortification of pre-existing settlements, or construction of fortified structures in the vicinity.

2) Creation of territories, formation of a *districus*, establishment of the seigniorship *di banno*.

3) Abandonment of scattered dwellings and concentration of the settlement in fortified structures founded by the seigniorship.

Given these situations three types of settlement emerge:

a) Towns formed in the Middle Ages and inhabited in continuation up to today. In these the medieval configuration is significantly modified and it is difficult to identify permanent topographical and architectural features.

b) Clusters of settlements abandoned in the late Middle Ages. Of these, large complexes of ruins often remain, especially when they were located in sites difficult to reach, unsuitable for crop farming, and therefore abandoned permanently by human settlements and used only as shelters for shepherds or fringe-population.

c) Scattered rural settlements. These are essentially churches built close to the Roman rural settlement, often making use of former structures. When located in areas with a strong farming tradition, these settlements disappeared, though leaving toponomastic traces which are tenaciously preserved. There are many such buildings still surviving, though they are of difficult archaeological interpretation.

The religious communities of San Clemente a Casauria and of San Salvatore alla Maiella formed the two focal points of the political and economical organisation of the Abruzzo between the ninth and thirteenth centuries. It was only with the arrival of the Normans that the fortification lost those features of «incompleteness» that it had retained until then. In fact, between

the ninth and the eleventh centuries there does not seem to have been a dominant settlement system. The co-existence of *casalia* and *castra* seems to indicate the absence of a true unitary plan of political control of the territory, and the incapacity of the local powers in the valleys of the Abruzzo to gain control over the others.

The territory gradually became known as a safe passage for the imperial armies, and it was this strategic position on the frontier which made it important to gain control of the region of Marsica. Even during the brief reign of Otto IV (1209-1218) the area remained important as a point of friction between the state of the Church and the kingdom of Sicily. The coronation of Federico II (1220) instead marked the start of a rapid decline in the count's fortunes, which was concluded two years later with the destruction of the castle of Celano. This destruction led to a new urban dislocation of a rural nature with respect to the fortification of the mountain. The Swabian period of the history of Abruzzo and Molise is therefore characterised by the struggle against the great feudal system, the problem of communication, and that of communal freedom. All these elements merged to form what is considered to be the main episode in thirteenth-century Abruzzo: the foundation of the town of L'Aquila in 1254. Thus L'Aquila was at the beginning of the fourteenth century a new town, with «symbolic» building structures: churches, monasteries, a few noble palaces and wooden city walls. 70 sites including castles and *villae* spread over a very vast area were part of the «land» of L'Aquila.

When in 1315 the chronicler Buccio di Ranallo was an eyewitness in L'Aquila of an earthquake which hit the area, he only described the effects in the city, the sole point of observation possible for an intellectual of the time. The collapse of some churches and the damage to a few monasteries were later to delineate the features of an event considered of moderate destructiveness in the nineteenth-century seismological tradition (Baratta, 1901). The event was subsequently classified as MCS-degree VIII in the two recent national catalogues (Carrozzo *et al.*, 1973; Postpischl, 1985).

Systematic historical research and analysis of the particular context of habitation in the area

have revealed new elements concerning this earthquake:

1) King Robert d'Anjou considered the earthquake as an important reason for making peace between the city's rival factions, which he himself approved. The document (State Archives of Naples, Department of Angevin Reconstruction) was not known to Baratta (1901).

2) The royal diploma of confirmation explicitly mentions that peace had been made because of the «awesome earthquake which had shook the land so tremendously» (*quia terremoto pavido... terram ipsam terribiliter quatiente homine ipsi valido tremore concussi...*). These terms used by a royal chancellery are important indicators of an event which must have generated a lot of talk and whose notoriety probably took on an aura which aroused strong emotions among the people of the time.

3) The reference to the «land» of L'Aquila alludes to a territorial context much vaster than the town itself, the identification of which refers to the formation of the Aquila district in the thirteenth and fourteenth centuries.

4) The most violent aftershocks continued for at least a month, a fact that in itself suggests that the mainshock had been rather strong.

An allusion to this seismic event can be found in a document of 3 June 1318, a notarial deed drawn up at Trivento by the notary Giovanni di Cieco de Riccardone d'Agnone. It concerns an extract of the deed of the judge Andrea di Trivento containing the privileges and benefits granted to the inhabitants of the hamlet of Santa Maria della Noce and to those who wished to settle there after the reconstruction supported by the abbot of the monastery (SGA, 1994b). The monastery of Santa Maria della Noce or dell'Abate is located towards the far limits of the feud of Monte Rocca l'Abate, opposite Belmonte del Sannio, to which belongs the territory named after the ancient abbey, in the diocese of Trivento in Upper Molise. Linked to the territory to which this document refers is the locality of Barrea, referred to in a document of 25 April 1343, which may be connected to the earthquake of 1315. Indeed, from Avignon as many as thirteen bishops each granted forty days of indulgence in favour of the chapel of Santa Maria, rebuilt in the church

of San Tommaso in Barrea, part of the Cassinese diocese, under the nobleman Oddone da Barrea and his wife Ianucia. We have scrutinized other important archives of the Abruzzo area, but the search for positive documentary elements directly referring to the earthquake of 1315 has proved fruitless. Our research continued up to the year 1349, with the beginning of the documentation relative to the better known and well-documented earthquake of September 1349.

In order to evaluate possible effects in Rome of the 1315 earthquake in L'Aquila, we carried out research on the basis of a selection of published sources. Results have shown that there are no published narrative sources produced in the Roman context in the fourteenth century containing information about the year 1315. Indeed, the work of the Anonymous Roman, though lacking the first chapter, begins its narration with 1317 and makes no reference to seismic events, while the *Fragmenta historiae Romanae*, with which the Chronicle of the Anonymous Roman is closely connected, began to describe events occurring in 1327. The unpublished *Cronichetta* of the monastery of «S. Andrea ad Clivium Scauri» is a source produced in a monastic context, containing information about the history of Rome, but does not concern the year 1315. In other words, no Roman chronicle recalls this year.

Besides this objective and irreparable lack of narrative sources, research has highlighted a gap in the administrative sources due to the institutional instability of Rome in that period. All the documentation and the chronicles of pontifical production are of limited utility for 1315 since by that time the pontiffs had already resided in Avignon for six years. What is more, this source was particularly lacking in information as regards the year 1315 since the papal seat had been vacant from 1314 to 1316. However, despite their distance from Rome, the Avignon pontiffs retained control over the Roman churches, which continued to stand out as institutions producing documentation of great importance for the city. In the light of these considerations, we consulted published pontifical, documentary and administrative documentation relative to the years following 1315. Nothing was

found in the letters of John XXII addressed to the churches and the political authorities of the city of Rome in the period 1316-1320, nothing in the *Liber Pontificalis*, nothing in the diplomatic Codex of the Roman Senate. There is therefore an objective lack of information to prove the theory that the 1315 earthquake in L'Aquila was felt in Rome. Secondary damage may not however be totally excluded *ex silentio*.

The research, to which this rapid summary perhaps does not do justice, was long and complex and concluded with the hypothesis that the 1315 earthquake might have been generated by the Ovindoli-Pezza fault, as suggested by the palaeoseismologists. The distance of about 25 km between Ovindoli, the site at which direct traces of the earthquake have been observed, and L'Aquila, and the particular conditions of habitation in the area between these two towns would be enough to explain why an earthquake of magnitude in the range 6.5 to 7.0, left traces which make it appear an event of limited impact on the structure of settlements of the time.

This experience has urged the need for a detailed critical re-reading of also other non-destructive earthquakes, whose evaluation in degrees of intensity is at present given by the catalogue through a single point, located on or around an urban centre. We believe that the revision should be done with specific reference to the historical contexts and the local population in order to prevent violent earthquakes being drastically, however involuntarily, «underrated».

7. Conclusions

The cases we have outlined comprise perhaps the best possible examples of a new form of interaction between research in historical seismology on the one hand, active faulting and palaeoseismology on the other hand. It has been a decade since the seismological community has come to realize that on average the recurrence interval of the main Italian earthquakes is two or three times longer than the available historical record, and that the record itself is a lot more sparse than previously believed. There are significant chances that major earthquakes are «missing» from the record because they occurred

too early in history, that they have been «missed» because they occurred in times and places for which the sources are less complete than we expected, or that they have been «underrated» because their epicentral area was scantily inhabited when they took place. Enforcing geological and physical constraints is the way by which the resolving power of historical analysis can really be stretched to the limits. We expect the new strategies described in this article to contribute greatly to the understanding of Italy's active faulting and earthquake patterns.

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REFERENCES

- BARATTA, M. (1901): *I terremoti d'Italia. Saggio di storia geografica e bibliografia sismica italiana*, Turin (anastatic reprint, Sala Bolognese, 1979).
- BARATTA, M. (1915a): Difendiamoci dai terremoti. A proposito del recente disastro sismico Marsica, *Nuova Antologia di Lettere, Scienze ed Arti*, s. V, **177**, 142-150.
- BARATTA, M. (1915b): Le condizioni sismiche della regione marsicana, *La Geografia*, **3**, 106-111.
- CARROZZO, M.T., G. DE VISINTINI, F. GIORGETTI and E. IACCARINO (1973): *General Catalogue of Italian Earthquakes*, CNEN, RT/PROT (73)12, Roma.
- CINTI, F., L. CUCCI, D. PANTOSTI, G. D'ADDEZIO and M. MEGHRAOUI (1997): A major seismogenic fault in a «silent area»: the Castrovillari fault (Southern Apennines, Italy), *Geophys. J. Int.*, **130**, 322-332.
- D'ADDEZIO, G., F.R. CINTI and D. PANTOSTI (1995): A large unknown historical earthquake in the Abruzzi region (Central Italy): combination of geological and historical data, *Ann. Geofis.*, **38** (5-6), 491-501.
- D'ADDEZIO, G., E. MASANA and D. PANTOSTI (2000): The Holocene paleoseismicity of the Aremogna-Cinque Miglia Fault (Central Italy), *J. Seismol.*, **4** (in press).
- FUMAGALLI, V. and E. GUIDOBONI (1989): I terremoti nel paesaggio urbano e rurale dei secoli VI-X, in *I terremoti prima del Mille in Italia e nell'area mediterranea. Storia archeologia sismologia*, edited by E. GUIDOBONI, ING-SGA, Bologna, 264-279.
- GUIDOBONI, E. (1990): Paesaggi seminascosti: sismicità e disastri sismici in Italia, in *Il declino degli elementi: ambiente naturale e rigenerazione delle risorse nell'Europa moderna*, edited by A. CARACCIOLLO and G. BONACCHI, Bologna, 205-237.
- GUIDOBONI, E. (1996): I grandi terremoti della Sicilia orientale, in *La Sicilia dei terremoti. Lunga Durata e Dinamiche Sociali*, edited by G. GIARRIZZO, Catania, 177-195.
- GUIDOBONI, E. and G. TRAINA (1997): Earthquakes in medieval Sicily. A historical revision (7th-13th century), *Ann. Geofis.*, **39** (6), 1201-1225.
- JOHNS, J. (1989): Il silenzio delle fonti arabe sulla sismicità della Sicilia, in *I terremoti prima del Mille in Italia e nell'area mediterranea. Storia archeologia sismologia*, edited by E. GUIDOBONI, ING-SGA, Bologna, 306-319.
- MARIOTTI, D., A. COMASTRI and E. GUIDOBONI (2000): «Unknown» earthquakes: a growing contribution to the Catalogue of Strong Italian Earthquakes, *Ann. Geofis.*, **43** (4), 787-795 (this volume).
- OMORI, F. (1909): Preliminary report on the Messina-Reggio earthquake of December 28, 1908, *Bulletin of the Imperial Earthquake Investigation Committee*, **3-2**, 37-46.
- PANTOSTI, D. and R.S. YEATS (1993): Paleoseismology of great earthquakes of the late Holocene, *Ann. Geofis.*, **36** (3-4), 237-257.
- PANTOSTI, D., D.P. SCHWARTZ and G. VALENSISE (1993): Paleoseismology along the 1980 Irpinia earthquake fault and implications for earthquake recurrence in the Southern Apennines, *J. Geophys. Res.*, **98**, 6561-6577.
- PANTOSTI, D., G. D'ADDEZIO and F.R. CINTI (1996): Paleoseismicity of the Ovindoli-Pezza fault (Central Apennines, Italy): geological evidence for a large unknown Middle Ages earthquake, *J. Geophys. Res.*, **101**, 5937-5939.
- POSTPISCHL, D. (Editor) (1985): Catalogo dei terremoti italiani dall'anno 1000 al 1980, *Quad. Ric. Sci., CNR-PFG*, **114** (2B), Roma.
- SCHWARTZ, D.P. and K.J. COPPERSMITH (1984): Fault behavior and characteristic earthquakes: examples from the Wasatch and San Andreas fault zones, *J. Geophys. Res.*, **89**, 5681-5698.
- SCOBAR, L.C.H. (1520): *Episcoporum siracusanorum numerus in de rebus praeclaris syracusanis*, Venezia.
- SGA (1994a): *Rapporto Tecnico no. 115*, at Istituto Nazionale di Geofisica, Roma.
- SGA (1994b): *Rapporto Tecnico no. 121*, at Istituto Nazionale di Geofisica, Roma.
- VALENSISE, G. and D. PANTOSTI (2000): Seismogenic faulting, moment release patterns and seismic hazard along the Central and Southern Apennines and the Calabrian arc, in *Anatomy of an Orogen: the Apennines and Adjacent Mediterranean Basins*, edited by G.B. VAI and I.P. MARTINI (Kluwer, Dordrecht) (in press).
- VALLERANI, M. (1995): Urban decay and abandonment in western medieval Sicily: a problem for the study of destructive earthquakes, *Ann. Geofis.*, **38** (5-6), 691-703.
- WARD, S.N. and G. VALENSISE (1989): Fault parameters and slip distribution of the 1915 Avezzano, Italy, earthquake derived from geodetic observations, *Bull. Seismol. Soc. Am.*, **79**, 690-710.