# The 1511 Eastern Alps earthquakes: a critical update and comparison of existing macroseismic datasets — Source link

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**Institutions:** National Institute of Geophysics and Volcanology

**Published on:** 01 Apr 2011 - Journal of Seismology (Springer)

**Topics:** Seismic hazard and Quake (natural phenomenon)

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# The 1511 Eastern Alps earthquakes: a critical update and comparison of existing macroseismic datasets

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**Abstract** Three earthquakes condition the seismic hazard estimates of the eastern Alps: the 1348 “Villach”, the 1511 “Idrija”, and the 1976 Gemona events. Only the last one can be well documented, while doubts remain for location and size of the other two. New documents have been found about the 1511 quake that, together with a complete revision of the information already available, offer some new indications on the location and size of the event.

***Keywords*** *Historical earthquakes, 1511, Eastern Alps, Seismic hazard*

# 1 Introduction

In the past centuries the eastern Alps were hit by several destructive earthquakes, most of which clustered in the narrow strip of land running along the foothills which divide the Friuli plain from the Alpine chain proper (Fig. 1). Information on the earliest among these earthquakes is comparatively scarce; some strong 20th century earthquakes (Tolmezzo 1928; Cansiglio 1936; and, above all, Gemona 1976) have been thoroughly studied (Gortani 1928; Cavasino 1929; Andreotti 1937; Carulli and Slejko 2005).

The most seismically active sector of the eastern Alps is the area connecting them with the Dinarides (Tab. 1). This seismic source was modelled in various ways (Slejko et al. 2008) and seems to be the foremost contributor to the regional seismic hazard assessment (Rebez et al. 2001), though the seismicity of western Slovenia and Carinthia (southern Austria) also plays a part in shaping the seismic hazard of the eastern Alps. Among the few earthquakes that can be considered as key events for regional seismogenesis a fundamental role is played by the 1511 earthquake.

In addition to the specific studies on the 1511 earthquake based on archive investigations (the main locations obtained are shown as stars in Fig. 1), and widely documented in the following sections, Fitzko et al. (2005) modelled a possible epicentre and mechanism for the earthquake by using macroseismic data and recent studies on active tectonics. They obtained as best solution a 6.9 magnitude event rupturing 50 km of the Idrija right strike-slip fault (star labelled 7 in Fig. 1).

Aim of the present study is to document the new findings on the 1511 earthquake obtained by an intensive, although not exaustive, historical investigation and to highlight how the improved macroseismic data contribute to a seismotectonic comprehension of the earthquake.

## 2 Seismotectonic framework and implications for the regional seismic hazard

The area studied (Fig. 1) represents the north-eastern portion of the deformed margin of the Adria microplate, where a complex interaction between two orogenic chains occurs. The area comprises the hinge zone between the eastern sector of the Southern Alps and the north-western part of the External Dinarides. Both systems reflect in shape and in geodynamic evolution the effects of the collision between the Adria microplate and the European plate, and of the fragmentation of the microplate itself (Carulli et al. 1990).

The mountainous part of Friuli (excepted the Paleocarnic Chain of Paleozoic age) comprises the eastern portion of the Southern Alps, here gradually passing towards the east into the Dinaric orogenic belt. The southern parts of these mountain chains (Carnian and Julian Prealps) face southwards on the Friuli plain (i.e. the eastern end of the Po plain), which can be considered as their foreland basin. The structural units of the Dinaric orogenic belt have a SW vergence, while the Alpine ones have a S-SE vergence. The highest crustal shortening of the entire Southern Alps (up to 1/3 of the original terrain extension) can be seen in Friuli (Castellarin 1979; Castellarin and Vai 1981).

The Southern Alps orogenic belt is composed of closely-spaced, generally south-verging overthrusts (Fig. 1). The southernmost overthrusts, in the maximum shortening zone, developed in response to the more recent N-S oriented compressional stresses (Zanferrari et al., 2000). The recent activity of these tectonic lines is amply documented by geological data (Carulli et al.

1980; Zanferrari et al. 1982) and high-precision topographic measurements (Talamo et al. 1978).

The Dinaric system is characterized by overthrusts and by mostly dextral, sub-vertical faults with direction ranging between NW-SE and NNW-SSE, the most important of which is the Idrija line (g in Fig. 1) with its auxiliary faults, among which the Ravne line (f in Fig. 1) needs a mention. Seismic reflection data indicate buried overthrusts of Dinaric direction also in the northern Friuli plain (Carulli et al. 1990; Galadini et al. 2005). The displacement along the faults that cross the Southern Alps thrust front is smaller than that along the same faults in the External Dinarides. This suggests that the thrusting of the Southern Alps is younger than the faulting of the External Dinarides (Zupancic et al. 2001). In northern Slovenia, the main structures are E-W oriented and are the eastern continuation of the Gail line (a in Fig. 1), the Fella-Sava line (b in Fig. 1), and the Southern Alps thrusts (e.g., c and d in Fig. 1).

Thanks to the early settlement of this area (some towns, such as Belluno, Cividale, Ljubljana and Trieste did already exist in Roman times and flourished in the Middle Ages) the historical seismicity of the eastern Alps is comparatively well known (Bonito 1691; Baratta 1901). The eastern Alps and western Dinarides have a long history in instrumental data collection too, some seismographic stations (e.g.: Trieste, Ljubljana, Pula, Padova, Venezia, Treviso) having been operating since early 20th century. Thanks also to studies on regional seismicity (e.g.: Slejko et al. 1989), the latest Italian earthquake catalogues (Camassi and Stucchi 1996; Boschi et al. 1995, 1997; CPTI Working Group 1999, 2004) give a creditable overview of the seismically most active areas. Major seismicity occurs along the piedmont belt, from Cividale to Belluno, reaching its maximum in central Friuli. Other seismic areas are located in Southern

Austria, western Slovenia, and along the Croatian coast. On the whole, seismicity appears more uniform in Slovenia and in Croatia than it does in Veneto and Friuli (Del Ben et al. 1991).

Owing to the regional tectonic regime (mostly overthrusts), a direct association of earthquakes to faults is very difficult and, consequently, seismicity was more easily associated to fault systems. The association of some of the main earthquakes to individual faults was proposed by Galadini et al. (2005). In particular, four seismogenic sources are proposed east of the Tagliamento river: the Gemona-Kobarid (c in Fig. 1), the Susans-Tricesimo, the Trasaghis [both indicated by d in Fig. 1 because the Trasaghis fault is a blind fault beneath the Susans-Tricesimo one, according to Galadini et al. (2005)], and the Medea faults (e in Fig. 1). Again according to Galadini et al. (2005), the Gemona-Kobarid thrust is considered responsible of the 1348 earthquake while the two main events of the 1976 seismic sequence (May 6 and September 15) are associated with the Susans-Tricesimo and Trasaghis thrusts, respectively. The recent activity of the Medea thrust is inferred from surficial and deep structural data and no earthquake remains associated with it, although events with magnitude 6 and larger may be originated (Galadini et al. 2005).

For the above reasons, wide areas were generally proposed as seismogenic sources [see the most recent zonations in Slejko et al. (2008)] and used for seismic hazard assessment. With the exception of the zonation used for the most recent seismic hazard map of Italy (Gruppo di Lavoro 2004), where the seismogenic zones are very large, the location of the 1511 earthquake is crucial for all the other zonations because it could belong to different sources. Although its direct contribution to hazard is limited because of its long return period, the 1511 earthquake conditions largely the maximum possible magnitude for the seismogenic zone where it lays.

# 3 An overview of extant literature

The earliest studies of the 1511 earthquake date back to the late 19th century, when two distinct national schools of seismology first attempted to reconstruct its effects from historical evidence. The output of early Italian studies is summarized in Baratta (1901, Fig. 2), whose interpretation of the 1511 earthquake was based on an outstanding collection of original accounts (mostly contemporary, none later than the 17th century), assembled by the Bonito (1691) and Tommasi (1888) seismological compilations (Fig. 3) and by 18th-19th century historians. The output of Austrian-Slovenian studies is summarized in Ribaric (1982), whose interpretation is based partly on Valvasor (1689, a 15-volume encyclopedia of Carniolan lore) partly on early seismological studies (Hoefer 1880; Radics 1862, 1901, 1908). The occurrence of the 1976 Friuli earthquake rekindled the interest for the 1511 earthquake: forgotten earlier studies, such as Gruden (1919), were retrieved, new ones were made (Ambraseys 1976; Cremonesi 1977; Ribaric 1979; Gentile et al. 1984, 1985; Cergol & Slejko 1991a, 1991b; Degasperi et al. 1991; Boschi et al. 1995, 1997, 2000; Guidoboni et al. 2007).

None of these studies attempted a thorough investigation of the 1511 earthquake. However, each contributed to assaying the available source repositories and Ambraseys (1976) made an outstanding census of epigraphic sources. On the other hand, none of the recent studies seems to have taken into account the findings of recent local historiography, some of which are original and quite interesting.

Among recent studies, those who give the most comprehensive account of the state of the art on the 1511 earthquake are

Cergol & Slejko (1991a, 1991b) and Boschi et al. (1995). Boschi et al. (1997, 2000) and Guidoboni et al. (2007) though more recent than Boschi et al. (1995), do not greatly change its picture. Cergol & Slejko (1991a, 1991b) make a précis of information derived from the Italian/Slovenian tradition of seismological studies and a few unpublished contemporary sources. Boschi et al. (1995), based on a "critical revision of existing bibliography, and research of original sources for selected typologies of effects and localities", provides an intensity table based on macroseismic data derived from the main recent studies and from a sample of 17th-20th centuries historical and seismological compilations (Fig. 3). Its intensity estimates for the highest damage area (Is ≥ VII MCS) are mostly derived from non-contemporary works (Palladio degli Olivi 1660; Bonito 1691; Gallicciolli 1795; Marsich 1878; Tellini 1895; Baratta 1901; Zanon 1937; Ribaric 1979; Corbanese 1983-1987; Cergol & Slejko 1991a) and from two contemporary sources only (Belloni 16$^{th}$ cent; Sanudo 16$^{th}$ cent b).

## 4 The complex historical context of the 1511 earthquakes

None of the previous studies attempted to undertake either a methodical search for all original records of the 1511 earthquake or a thorough critical analysis of its vast seismological literature. In fairness to previous researchers, it must be stressed that such a task would have been extremely harduous. Piecing together a reliable picture of the macroseismic field of an historical earthquake requires, first of all, to assemble as many as possible of its contemporary (or nearly contemporary) written records. Such a task is never quite easy, and it can be very hard indeed in a case such as the 1511 earthquake's. Let's see exactly why.

### 4.1 A complex area

The 1511 earthquake occurred in the midst of a political, administrative and cultural tangle. The affected area was crisscrossed with international boundaries. Venice ruled over the south-western half, i.e. the region of plains and hills known as Friuli (chief town Udine); the Holy Roman Empire ruled over the north-eastern half, divided into the mountain duchies of Carinthia/Kärnten (chief towns Klagenfurt and Villach) and Carniola/Krain (chief town Laibach, now Ljubljana). Within and through these main partitions, lesser ones defined the territories ruled by local bishops (dioceses) and feudal lords (Fig. 4). Political boundaries were linguistic boundaries too. Friulan/Venetian and Tuscan were spoken on the southernmost side of the affected area; people on the northern and northeastern sides spoke either German or the Slav dialects; Latin was the *lingua franca* of cultured people throughout. The language issue was further complicated by later political upheavals. In 1797, the Venetian republic fell and Austria annexed its lands. In 1866, the newly-established Kingdom of Italy won back part of them. After World War I, at the division of the spoils of the former Austro-Hungarian Empire, Italy got back the rest of the ancient Venetian domains, while Yugoslavia got Carniola and Slovenia. After World War II, Yugoslavia took over part of the formerly Italian territories as well. With each change of rule, the extant placenames were translated into the official languages of the new rulers. Many of the localities mentioned by $16^{th}$-$17^{th}$ century sources are likely to have had their names changed several times over, which makes it rather hard to identify them now.

### 4.2 A complex time

The first decade of 16$^{th}$ century was a very troubled time in the entire studied area. In 1499 Friuli had been laid waste by Turkish raids. As a modern historian said: "The results of these terrible eight days cannot be underestimated. Some of the peasant villages in the Turks' path never recovered" (Muir 1993). After the Turks, it was the turn of the German Emperor, who coveted Friuli because of its strategic mountain passes, leading from northern Europe to Italy. In 1504 the Emperor and the French King struck up a secret treaty to conquer and divide the mainland territories of Venice. In 1508 an imperial army invaded Friuli, and was beaten back. In 1509 the Cambrai League armies (formed by France, Spain, the Pope and other Italian rulers) invaded the Venetian mainland. The Venetian army was defeated in battle at Agnadello (on the Venetian-Milanese border) after which most mainland towns surrendered, and imperial troops went to harry Friuli again. In time Venice would resort to diplomacy, make a separate peace with the Pope and the Emperor, create a counter League (called the Holy League) against the French and win back its domains. By early 1511, however, this outcome was still far, pillage and devastation were rife over the whole country and epidemic outbursts were slaying soldiers and refugees alike. In Friuli, the general unrest exacerbated the internal strife between local clans. On Fat Thursday, February 27, 1511 a bloody riot broke out in Udine, whence it quickly escalated into "the most extensive and damaging popular revolt in Renaissance Italy" (Muir 1993). For weeks warring factions of mutineers pillaged and destroyed castles and country properties, increasing the vulnerability of many buildings that would soon be affected by the earthquake of March 26, 1511 (Fig. 5). It is therefore likely that the mutineers were at least partly responsible for the destructions traditionally credited to the earthquake. This series of unfortunate events was rounded off, in the summer of 1511, by a bona fide outbreak of plague all over the Venetian countryside.

### 4.3 A complex research

The 1511 earthquake affected an area placed at the cross-roads between several countries and cultures. It did not come alone, but was part of a sequence of dramatic events that affected the Eastern Alps area in the first decade of the $16^{th}$ century. Written accounts of its effects could have been couched in many different languages, stored in many different archives, some of them very far from the actually affected area (in Venice and Vienna for instance). The way in which contemporary witnesses perceived and described its effects could have been influenced or distorted by other stressful contemporary occurrences (war, riot, plague). The very placenames mentioned by their written records could have changed many times over in the following centuries and be very hard to identify by now. Against such a background, both to plan and successfully to carry out an exhaustive and thorough historical investigation is a task impossible to undertake without a sufficiency of time, means and, above all, without a concerted international effort by researchers from all the involved countries, that is from Austria, Italy and Slovenia, at the very least, and possibly more, original records of the 1511 earthquake effects being potentially available in archives and libraries all over Europe, on account, among other things, of the extreme width of this earthquake's far field area.

However, before it is possible even to start thinking of such a European venture, it is absolutely necessary to clear out the field of investigation from any errors, misunderstandings, duplications and suchlike, by which it could be cluttered, setting out as reliably and economically as possible the exact amount of knowledge that can be derived from the century-old tradition of

1511 earthquake studies.

# 5 A critical analysis of seismological literature

## 5.1. Working strategy

The objectives of this study of the 1511 earthquake are: 1) carrying out a critical analysis of the vast patrimony of knowledge collected in seismological literature; 2) reviewing the output of local Italian historiography over the last thirty years; 3) retrieving all primary sources identifiable through all the above. The reference lists given by previous studies have been carefully sifted in order to identify all their primary sources. A number of these (concerning Friuli and the transalpine countries) have been retrieved and critically examined, paying special attention to their descriptions of earthquake effects and the translation of these description into macroseismic intensity degrees. Though this work is still ongoing, its preliminary results are extremely rewarding, especially as the general picture of the distribution of earthquake effects does show rather significant changes.

## 5.2. Primary sources

Evidence of the long 1511 seismic sequence is available in a great many primary written sources (public and private administrative records, diplomatic reports, chronicles and diaries), scattered all over Friuli and northern Italy. As a general rule, the best ones should be those closest in time and space to the earthquake. However, reliable information can sometimes be derived even from very late works. Such a one is Valvasor (1689), who reports snippets from several contemporary sources, that were still extant in his times, but are not so anymore. The definition of primary source can be extended to archaeological and architectonic evidence, some of which came to light in recent years.

*5.2.1. Chronicles and private memoirs*

Most Friulan chronicles mention the 1511 earthquake within their tales of the early 16th century wars: among them Cergneu (16th cent), Mantica (16th cent), Monticoli (16th cent a, b), Mulioni (16th cent), Partenopeo (16th cent), Sini (16th cent) and the Udinese reporter of the "Cruel Fat Thursday Riot" Amaseo (16th cent a, b, c). However, the foremost contemporary source, both for reconstructing the macroseismic effects and cronology of the 1511 earthquake, and for setting it in its proper historical context, is not a Friulan but a Venetian one. The *Diarii* by Marino Sanudo give an unparalleled day-to-day report of European and Eastern occurrences from the privileged standpoint of the Venetian Seignory. This is a well-known source and previous studies of the 1511 earthquake have used it already. However, the structure of the *Diarii* is so complex that none of the previous studies did fully exploit its actual informative potential. Thus, by reading through the whole volume of the *Diarii* for the year 1511 (Sanudo, 16th b, c], this study retrieved some relevant pieces of information that no previous study had discovered until now.

Similar to chronicles in their wish to preserve the remembrance of an important event for future readers, are some memoirs of the 1511 earthquake, taken down by clerics in their prayerbooks or parish registers. Radics (1901) transcribes one such text, penned in a 1483 Bible owned by the National and University Library of Ljubljiana (Ljubljana Bible Note 16th cent). A prayerbook now in the Episcopal Library of Udine includes a description of the earthquake as felt in Cividale del Friuli (Breviario cividalese 16th cent). Similar accounts are to be found in the *Necrologia* (books of the dead) of the Concordia chapterhouse, the church of San Remiglio in Fanna and the Franciscan convent of Udine (Necrologio 16th cent a, b, c).

### 5.2.2. Notarial records

Notaries are public officers entitled to draw up contracts and certifying their correctness and conformity to law. Earthquakes can be mentioned in notarial records, either because they are connected in some way with the business in hand, or as an occasional memorandum. Important accounts of the 1511 earthquake are provided by contemporary notaries from Udine (Decio 16th cent; Roberto da Latisana 16th cent; Belloni 16th cent), Sacile (Brochetino 16th cent) and San Daniele (Locatello 16th cent).

### 5.2.3. Administrative records

A few outstanding administrative records of earthquake effects are to be found in past seismological and historical studies. Jörg von Egkh, the imperial representative in Carniola, described them at lenght in a letter to a senior officer of the imperial court (Egkh, 16th cent), a full transcription of which is given in Radics (1862). The minutes of the municipal councils of Gemona (Deliberazioni 16th cent) and Trieste (Codice Diplomatico Istriano 1500-1526) and the papers of the Luogotenente of Udine (Acta annalium 1505-1514) give detailed descriptions of damage and emergency repair work that are of outstanding importance for defining the extension of the near field area. A report of the Venetian border officers (Archivio di Stato of Venezia 16th cent), describes macroseismic and geological effects in Bovec, adding further details to a picture already sketched out by Sanudo (16th cent b).

*5.2.4. Epigraphic records*

Epigraphs recording the 1511 earthquake are mentioned by several studies, both in Italy - with special reference to the parish churches of Artegna (Tellini 1895) and Qualso (Ciceri 1976), the San Leonardo monastery of Gemona (Baldissera 1895) and the Mandracchio Tower of Trieste (Tomasin 1900) - and in Slovenia, with special reference made to Skofja Loka, Hasperk, Polhov Gradec, and Turjak by Ambraseys (1976).

*5.2.5. Historiography*

Indirect evidence of earthquake damage could be had from archaelogical and architectural studies. For instance, Tarcisio Venuti, who carried out a painstaking research on the votive chapels of the Natisone Valley, believes them to have been systematically restorated, rebuilt and (in some cases) even reconsecrated during the first half of 16$^{th}$ century. Recent studies on Slovenian castles (Jakic 1999; Cecic 2001) suggest that several of them could have been damaged by the 1511 earthquake, without providing any documentary evidence for this. In both cases, it would be worthwhile to look deeper into the matter, especially as corroborating evidence for these hypotheses could be derived either from Valvasor (1689) or from the epigraphic sources quoted by Ambraseys (1976).

**5.3. New data from old studies**

A cross-analysis of the available studies evidences many discrepancies through which new original information can be derived. Later studies sometimes "lose" part of the data gathered by previous ones. It is the case with Ambraseys (1976), whose list of earthquake-affected localities includes, in Italy, Buia, Frattins Gradisca, Magnano in Riviera, Moggio

Udinese, Montenars, Muggia, Villalta, Zucco; in Slovenia, Adelsberg (now Postojna); Floednig (now Smlednik), Gutenberg, Obers; none of which figure either in Ribaric (1979) or in the latest Italian seismological studies. Lack of interaction between historians and seismologists can also be responsible for loss of data: evidence of high damage in San Daniele del Friuli is provided by the former (Barbaro 1865; Lazzarini 1923; Miotti 1977-1979) but not received by the latter. Finally, if seismological studies actually "quote" primary historical sources, this should not be taken as evidence that these sources were thoroughly "consulted". On the contrary, a careful analysis of them can lead to the retrieval of overlooked information. Sometimes, the data thus retrieved concern localities already known to have been affected by the 1511 earthquake (it is the case with Ljubljana, for instance). Often, however, they give evidence for localities, such as Tricesimo (Mulioni $16^{th}$ cent), Villalta and Zucco (Monticoli $16^{th}$ cent), Maniago (Antonio di Maniago $16^{th}$ cent), Qualso (Ciceri 1976), whose involvement in the earthquake was previously either unknown or unreliably attested by late sources only.

The most underused of primary sources is the report on the 1511 earthquake by Sanudo ($16^{th}$ cent b), quoted by many seismological studies but never fully exploited by any of them. Sanudo lists 37 earthquake-affected localities, about half of which are ignored by previous seismological studies (Tab 2). Two of the "forgotten" localities, Bovec (Slovenia) and Villach (Austria), were heavily affected indeed. The authoritative witness records that Bovec, "(it is said) to be totally ruined and fallen down" *["sia totaliter cascato et ruinato"]*. Sanudo also adds that "two mountains that used to be close to each other, with only a road and a stream between them, fell against each other, shutting down the road to Germany. This is a good thing now that we are at war, but bad for trade once peace is restored". A contemporary document of the Venetian border authority (Venezia State Archive, 16$^{th}$ cent) confirms the occurrence of earthquake-induced landslides in the "porta Plecij" area (i.e. the "gate" or "defile" of Plech, the ancient name of Bovec): enormous boulders had detached themselves from the mountainside, obstructing the paths and demolishing a bridge. Sanudo's information on Villach is vaguer ("they say the earthquake was more fearsome in the mountains, towards Carinthia and Carniola, and Villach, with other German places, was ruined") and still unconfirmed by other contemporary evidence, but very interesting all the same.

## 6 The assessment of macroseismic intensities

This study assembled a substantial set of data, varied both in its provenance from primary (chronicles, diaries, public records, private memoirs, epigraphs) and secondary sources (historiography), and in its informative content. Contemporary evidence of earthquake effects in Italy is available for a great many localities. In some cases (Gemona, Cividale, Udine), many sources provide detailed evidence of earthquake effects in the same site, and a reliable assessment of intensity is possible. In many more cases, all the evidence for one locality is provided by a single source, giving either a summary of effects or information on a single building; in these cases, it is harder to assess intensity in a reliable way. Finally, in some cases, only non-contemporary evidence of earthquake effects is available, from historiography unsubstantiated by original records, i.e. basically unreliable. In Slovenia, contemporary evidence of earthquake effects is available only for Ljubljana and Bovec. The latest seismological study (Ribaric 1979) lists several localities whose actual involvement in the 1511 is not borne out by earlier evidence at all.

A considerable amount of indirect evidence of earthquake damage was collected, mainly from the Venuti (1985, 1989, 1991) investigation of Friulan churches and chapels that were restored or re-consecrated in the years after 1511. Though direct documentary evidence is lacking, systematical restoration work on a regional basis could reasonably imply that at least some of the restored buildings had suffered from the earthquake; in a few cases this is borne out by epigraphic evidence.

To preserve the variable quality of the collected evidence, we decided to assess intensities in MCS scale degrees, only when detailed data were available. Whenever data were either generic, or related to single buildings or to monumental buildings (churches, castles) a single-letter-code was used: "F" (earthquake felt); "D" (damage); "HD" (high damage). For the sake of clarity, we also adopted, experimentally, the Musson (1998) proposal of a "reliability code" indicating a high level of uncertainty as to the consistency of the available information for purposes of (respectively), assessing macroseismic intensity, locating a macroseismic intensity data point, and evaluating the reliability of a direct or indirect testimony.

The results of this study are presented in Fig. 6 (Tab. 3). According to contemporary sources the worse damage occurred in Gemona and Cividale. The intensities assessed for both localities take into account their previous involvement in the February 1511 riot. Very high damage is recorded also in Venzone, Osoppo and Tolmino.

## 7 The seismic sequence

The main event of March 26, 1511, was part of a very complex seismic sequence, that no national catalogue seems to represent adequately, not least because of the possible interaction between distinct events occurred in contiguous areas. The current Italian parametric earthquake catalogue (CPTI Working Group 2004), which is a "declustered" one, lists 6 events located in North-Eastern Italy from 1511 to 1516, including 2 events located in Venice. The main event is identified with the one of March 26, 1511 (at 14.40 GMT), followed by an aftershock two days later. The Italian catalogue also lists an event in Venice on February 8, 1512, one in the Gemona area on July 12, 1514, and two in 1516, respectively located in Venice (March 9) and Gemona (December 20).

The parent-catalogue of CPTI Working Group (2004) is Postpischl (1985), whose depiction of the 1511 seismic sequence is rather more complex, resulting as it does from an assemblage between two separate regional catalogues (Iaccarino and Molin 1978; Bernardis et al. 1978, codenames 501 and 505), and a national catalogue compiled with data taken from Baratta (1901, codename 75). Besides all the previously mentioned events, Postpischl (1985) lists an event in 1510 (whose occurrence this study does not confirm), several events more in 1511, including an August 8, high intensity, one, and several minor events in the following years. The Slovenian catalogue (Ribaric, 1982) does further complicate the general picture by listing a sequence of 18 events located in the Idrija area between March and August, 1511. According to Ribaric (1982) the highest intensities were reached by the two main events of March 26 and 28, and by two more events occurred respectively on June 26 (Io= VIII MSK) and August 8 (Io= IX MSK).

A cross-check of information to be derived from Udinese and Venetian diaries and chronicles allows both to clarify and to enrich the general picture of a very complex seismic period. Tab. 4 gives a summary of all the data available for the 1511-1516 time-window. The most significant result of this revision is the cancellation of two previously listed events. One was an alleged foreshock, generically dated in 1510, which the investigation shows to have resulted from a string of dating errors made by historiographers (originating with Gallicciolli 1795). The other, much more significant, one is the August 8, 1511 (Io= IX MSK in Ribaric 1982) event described by Guidoboni et al. (2007) as destructive in Idrija and Cividale del Friuli. The Idrija information is quoted from Ribaric (1979); the Cividale del Friuli information one is a mistaken reading of a passage by Sanudo (16th cent b), according to whom in Cividale some 800 people died of the plague during the summer of 1511; no mention whatsoever of the alleged August 8 earthquake can be found either in Sanudo (16th cent b) or in any other contemporary chronicler.

## 8 How many main events?

The Italian interpretation of the 1511 earthquake mentions only one main shock, occurred at 14.40h. On the contrary, Ribaric (1979) asserts that on March 26, 1511 there were two main shocks, at 15h and at 20-20.30h CET respectively. The former should have been located in the neighbourhood of Idrija, where it purportedly caused severe damage. The latter should have been located some 50 kms north-westwards and caused severe damage to Friuli and Veneto. Unfortunately this assumption is not borne out by contemporary evidence.

Ribaric (1979) could have derived his intepretation from a comparison between the times quoted for the March 26 main event by several Friulan and Venetian contemporary sources (in Baratta, 1901) and one contemporary source from Laibach/Ljubljana (in Valvasor, 1689).

In fact, the Italian contemporary witnesses time the March 26 shock between 20.00h and 21.00h, while the Carniolan one records it at *"the third hour after midday"*. It seems likely that Ribaric did assume (mistakenly, as it happens) that all these hours were expressed according to the modern way of reckoning time, which sets the "0 hour" of the day at midnight. Unfortunately, however, the Italian sources did in fact reckon time according to an ancient system (the so-called “Italian timekeeping”) which set the “0 hour” of the day one hour after sunset. Thus, both the Italian and the Carniolan contemporary sources were actually speaking about one and the same event, occurred at about 15.00h-15.30h.

## 9 The tsunami story

In recent years, some alluringly controversial features of the 1511 earthquake gave food for debate to the scientific community and the popular media. The most discussed such episode is an earthquake-induced tsunami alleged to have devastated Trieste on March 27, 1511 (Fitzko et al. 2005). The several versions of CFTI assess intensity VIII/IX MCS for Trieste from a description of the “collapse of many houses, most of the city walls and two towers of the seaport” derived from a late 19th century historical compilation (Marsich 1878), but absolutely unsupported by actual contemporary evidence. On the effects of the 1511 earthquake in Trieste there is a plethora of late historiographical references (including Marsich 1878 and Tamaro 1924) all of which seem to do no more than echoing and amplifying a small nucleus of original data. The actual original evidence can be boiled down to two local contemporary sources: the minutes of the Trieste municipal council (Codice Diplomatico Istriano 16th cent), and the handwritten memoirs of the Chapter of the Trieste Cathedral (Memorie 16th cent). An accurate analysis of these contemporary sources shows the stories related by late historiographers to be highly exaggerated for what concerns the damage wrought by the 1511 earthquake in Trieste, and utterly false for what concerns the abnormal tidal wave that allegedly devastated the town. To clinch the matter, Sanudo’s *Diarii* for the year 1508 (16th cent a), describe in detail the siege and bombardment of Trieste by the Venetian army and fleet in May 1508. By May 5, 1508, according to reports sent to Venice by members of the expedition, at least two towers had been destroyed and a third was about to fall down. It is therefore likely that any earthquake damage suffered by Trieste in 1511 was enhanced by the aftereffects of the battering the town had undergone in the bombardment of two years before. Sanudo does not mention any tsunami either in Trieste or elsewhere, which makes it all the more likely that the related story, however popular with sensationally-minded newspapermen, is a tall tale and nothing more.

## 10 Indications on the source of the 1511 earthquake

The data collected for the 1511 earthquake allow us to face the problem about its source, already mentioned in the introduction. For this reason, we have used a simplified representation of some intensity maps and have mapped the highest 3 degrees with one colour and all values larger than, or equal to, III MCS with another colour. In this way we try to highlight the area with the largest damage from the area of perceptibility of the shock.

In addition to the 1511 earthquake, we have considered two main events which occurred recently in the study region: the Gemona 1976 main earthquake, whose source was located on the Susans-Tricesimo Alpine thrusts (Galadini et al. 2005) and the 1998 Bovec earthquake, whose source was associated to the Ravne Dinaric strike-slip fault (Bajc et al. 2001; Zupancic et al. 2001). For both these recent earthquakes an intensity map rich of information is available (Cecic personal communication). When comparing to them, the intensity map of the 1511 earthquake (Fig. 7a) seems poor also after the present investigation.

The comparison of the three maps does not offer an ultimate answer about the source of the 1511 event but suggests some clues. In fact, the 1511 quake shows a westward elongation (west of 13°) which is not evident in the case of the 1998 event.

But the same map shows also an elongation towards east and SE not in agreement with the 1976 intensity map. At this time, it seems that the source of the 1511 earthquake was different from that of the 1976 as well as that of the 1998 earthquakes, as if the intersection of the two Alpine and Dinaric systems had been interested by the phenomenon.

## 11 Conclusions

Generally speaking, improving/altering the macroseismic dataset of a single earthquake won't probably change seismic hazard very much, though it could have a great influence on the definition of damage scenarios. The 1511 earthquake could be the exception to this rule, because it is very important on both accounts. It was probably the worse natural disaster to have affected the whole Alpine arch during $16^{th}$ century (the 1564 Maritime Alps earthquake could be a close second, but it certainly affected a smaller area), and it "drives" the space geometry and the seismic characterization of some seismogenic zones of the eastern Alps.

The available historical dataset for this event – a key one for the study of Alpine natural phenomena – has now been put in order by this study. Its results point out that historical investigation can still contribute much to the knowledge of past seismic events, and that there is still much to be gained from the in-depth study of a single strong earthquake, as far as our understanding of the Alpine geodynamics is concerned.

Acknowledgements Many thanks are due to G.B. Carulli, University of Trieste, for checking the geological part of this paper. The majority of the figures have been produced by the GMT software (Wessel and Smith, 2006). The authors are greatly indebted to the pioneering and unparalleled research carried out after the 1976 earthquake by N. Ambraseys. Many thaks are due also to I. Cecic, M. Cergol, D. Molin and T. Venuti for sharing sources, ideas and suggestions.

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## Figure captions

Fig. 1 – Seismotectonic map of the eastern Alps region. Red lines represent faults (from Carulli, 2006), blue hexagons and circles indicate the epicenters of the earthquakes with $M_W \geq 4.0$ respectively before and after 1900 (data from CPTI Working Group, 2004), black stars show the epicenters of the 1511 earthquake according to (1) Ambraseys (1976), (2) and (3) Ribaric (1979), (4) Postpischl (1985), (5) Boschi et al. (2000), (6) CPTI Working Group (2004), and (7) Fitzko et al. (2005), the beach balls represent the focal mechanisms of the 1976 (Slejko et al., 1999) and 1998 (Zupancic et al., 2001) earthquakes.

Fig. 2 – Intensity map according to the data reported by Baratta (1901).

Fig. 3 – Family-tree of studies and sources collected and re-evaluated in this study for the 1511 earthquake. The two main group of studies are evidenced in green and red. Note that almost all the previous works were based mainly upon two seismological compilations (Tommasi, 1888; Baratta, 1901) and a chronicle (Sanudo, XVI).

Fig. 4 – Historical map of the area affected by the earthquake (from Muir, 1993, modified).

Fig. 5 – Effects of the "Cruel Fat Thursday Riot", according to Bianco (1995): 1 = Possible damage not clearly defined; 2 = Generic damage to the locality; 3 = damage to single buildings (Castles); 4 = Hard damage; 5 = Extensive damage; X = Additional informations of damage from Muir (1993).

Fig. 6 – Macroseismic data obtained by the present study: a) intensity map; b) quality of the data: A = coeval detailed information; B = coeval generic information; C = indirect

information; D = indirect generic information; E = uncertain information.

Fig. 7abc – Simplified intensity maps, the points with a large intensity (equal to the highest 3 MCS degrees) are mapped in black, those with an intensity larger than, or equal to, III are mapped in grey: a) 1511 earthquake, b) 1976 Gemona earthquake, c) 1998 Bovec earthquake.

**table**

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| Year Mo Da | Ho Mi | Epic. Area | Ref. | Os | Io | Lat | Lon | Maw |
|---|---|---|---|---|---|---|---|---|
| 778 | | Treviso | CFTI | 1 | 8/9 | 45.670 | 12.250 | 5.84 |
| 1268 11 04 | | Trevigiano | CFTI | 4 | 7/8 | 45.730 | 12.080 | 5.37 |
| 1279 04 23 | 19 | Friuli | CFTI | 3 | 7/8 | 45.930 | 13.400 | 5.37 |
| 1348 01 25 | | CARNIA | DOM | 46 | 9/10 | 46.254 | 12.883 | 6.66 |
| 1389 08 20 | 13 | Moggio Udinese | CFTI | 3 | 7/8 | 46.400 | 13.200 | 5.28 |
| 1511 03 26 | 14 40 | Slovenia | CFTI | 66 | 9 | 46.200 | 13.430 | 6.51 |
| 1574 08 14 | | CICARIJA | CVI86 | | 8 | 45.400 | 14.100 | 5.57 |
| 1690 12 04 | 15 45 | KAERNTEN | DOM | 17 | 8/9 | 46.633 | 13.872 | 5.97 |
| 1691 02 19 | | Slovenia | CFTI | 6 | 7/8 | 46.100 | 14.450 | 5.46 |
| 1700 07 28 | | RAVEO | DOM | 28 | 8/9 | 46.433 | 12.868 | 5.77 |
| 1721 01 12 | | RIJEKA | CVI86 | | 9 | 45.300 | 14.400 | 6.00 |
| 1750 12 17 | | RIJEKA | DOM | 6 | 7/8 | 45.391 | 14.411 | 5.37 |
| 1776 07 10 | | TRAMONTI | DOM | 19 | 8/9 | 46.233 | 12.706 | 5.82 |
| 1788 10 20 | | TOLMEZZO | DOM | 7 | 8/9 | 46.398 | 13.019 | 5.71 |
| 1794 06 07 | | TRAMONTI | DOM | 18 | 7/8 | 46.297 | 12.795 | 5.55 |
| 1802 01 03 | 06 30 | RIJEKA | CVI86 | | 8 | 45.400 | 14.300 | 5.57 |
| 1812 10 25 | 07 | SEQUALS | DOM | 34 | 7/8 | 46.027 | 12.589 | 5.70 |
| 1870 03 01 | 19 57 | GORSKI KOTAR | CVI86 | | 8 | 45.400 | 14.400 | 5.57 |
| 1873 06 29 | 03 58 | Bellunese | CFTI | 200 | 9/10 | 46.150 | 12.380 | 6.33 |
| 1897 05 15 | 05 57 | LJUBLJANA | CVI86 | | 8 | 46 000 | 14.500 | 5.57 |
| 1900 03 04 | 16 55 | VALDOBBIADENE | DOM | 99 | 6 | 45.850 | 12.067 | 5.22 |
| 1904 03 10 | 04 26 | IUGOSLAVIA | POS85 | | 6 | 46.500 | 13.800 | 5.32 |
| 1908 07 10 | 02 13 | Carnia | CFTI | 121 | 7/8 | 46.470 | 13.180 | 5.34 |
| 1920 05 05 | 14 41 | CARNIA | DOM | 35 | 6/7 | 46.384 | 13.144 | 5.48 |
| 1924 12 12 | 03 29 | CARNIA | DOM | 78 | 7 | 46.462 | 12.981 | 5.53 |
| 1926 01 01 | 18 04 | Slovenia | CFTI | 63 | 7/8 | 45.770 | 14.280 | 5.71 |
| 1928 03 27 | 08 32 | CARNIA | DOM | 359 | 8/9 | 46.372 | 12.975 | 5.75 |
| 1931 12 25 | 11 41 | TARCENTO | DOM | 45 | 7 | 46.259 | 13.104 | 5.36 |
| 1936 10 18 | 03 10 | BOSCO CANSIGLIO | DOM | 267 | 9 | 46.088 | 12.380 | 5.90 |
| 1959 04 26 | 14 45 | CARNIA | DOM | 122 | 7/8 | 46.484 | 13.021 | 5.23 |
| 1976 05 06 | 20 | FRIULI | DOM | 772 | 9/10 | 46.241 | 13.119 | 6.43 |
| 1976 09 15 | 09 21 | Friuli | CFTI | 54 | 8/9 | 46.250 | 13.120 | 5.92 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1977 09 16 | 23 48 | TRASAGHIS | POS85 | | 7/8 | 46.300 | 12.983 | 5.54 |
| 1998 04 12 | 10 55 | SLOVENIA-FRIULI | BMING | 227 | 6 | 46.068 | 13.348 | 5.70 |

Tab. 1 – Historical earthquakes of the area (Maw ≥ 5.2, CPTI Working Group 2004).

| Locality | Lat | Lon | Boschi et al. | Sanudo |
|---|---|---|---|---|
| Bovec | 46.344 | 13.557 | | HD |
| Gemona del Friuli | 46.278 | 13.135 | 9 | HD |
| Osoppo | 46.256 | 13.081 | 9 | HD |
| Venzone | 46.333 | 13.139 | 9 | HD |
| Cividale del Friuli | 46.093 | 13.431 | 8/9 | HD |
| Tolmin | 46.187 | 13.731 | 8/9 | HD |
| Villach | 46.610 | 13.849 | | HD |
| Bergamo | 45.694 | 9.670 | | D |
| Chioggia | 45.219 | 12.279 | 6/7 | D |
| Cormons | 45.959 | 13.468 | | D |
| Ferrara | 44.836 | 11.618 | 6 | D |
| Gorizia | 45.943 | 13.620 | | D |
| Gradisca | 45.890 | 13.498 | | D |
| Muggia | 45.599 | 13.768 | | D |
| Novigrad | 45.317 | 13.562 | | D |
| Padova | 45.406 | 11.876 | 6/7 | D |
| Spilimbergo | 46.110 | 12.899 | 7 | D |
| Tolmezzo | 46.398 | 13.019 | 8 | D |
| Treviso | 45.669 | 12.244 | 7 | D |
| Trieste | 45.656 | 13.784 | 8/9 | D |
| Udine | 46.063 | 13.236 | 8 | D |
| Vicenza | 45.549 | 11.549 | 6 | D |
| Venezia | 45.438 | 12.335 | 7 | D |
| Cervia | 44.263 | 12.353 | | HF |
| Fanna - Cavasso Nuovo | 46.186 | 12.752 | | HF |
| Bondeno | 44.944 | 10.857 | 5/6 | SD |
| Bologna | 44.498 | 11.340 | 4 | SD |
| Castelfranco Veneto | 45.671 | 11.926 | 6/7 | SD |
| Mazzorbo | 45.486 | 12.408 | 6/7 | SD |
| Mestre | 45.493 | 12.241 | 6/7 | SD |
| Torcello | 45.497 | 12.418 | 6/7 | SD |
| Finale Emilia | 44.833 | 11.294 | | HF |
| Monfalcone | 45.805 | 13.529 | | HF |
| Ravenna | 44.417 | 12.198 | F | HF |
| Rimini | 44.059 | 12.567 | | F |
| Urbino | 43.726 | 12.636 | F | F |
| Milano | 45.464 | 9.190 | | NF |

Tab. 2 – Localities quoted by Sanudo ($16^{th}$ cent) compared with the intensity estimation proposed by Boschi et al. (2000): (HD: heavy damage; D: damage; SD: slight damage; HF: heavily felt; F: felt; NF: not felt).

| Locality | Lat | Lon | SC | Int | Qc |
|---|---|---|---|---|---|
| Cividale del Friuli | 46.093 | 13.431 | | 9 | 000 |
| Gemona del Friuli | 46.279 | 13.135 | | 9 | 000 |
| Osoppo | 46.256 | 13.081 | | 9 | 000 |
| Bovec | 46.338 | 13.553 | | 8/9 | 000 |
| Faedis | 46.151 | 13.347 | | 8/9 | 000 |
| Fontanabona | 46.142 | 13.185 | | 8/9 | 000 |
| Skofja Loka | 46.167 | 14.309 | | 8/9 | 000 |
| Tolmin | 46.187 | 13.731 | | 8/9 | 000 |
| Tricesimo | 46.160 | 13.215 | | 8/9 | 100 |

| | | | | | |
|---|---|---|---|---|---|
| Venzone | 46.333 | 13.139 | | 8/9 | 000 |
| Buia | 46.205 | 13.124 | MS | 8 | 001 |
| Colloredo di Monte Albano | 46.162 | 13.136 | | 8 | 100 |
| Fagagna | 46.103 | 13.094 | | 8 | 100 |
| Maniago | 46.167 | 12.708 | | 8 | 000 |
| Mels | 46.177 | 13.108 | | 8 | 100 |
| Moruzzo | 46.119 | 13.123 | | 8 | 100 |
| Pers | 46.176 | 13.093 | | 8 | 100 |
| Pinzano al Tagliamento | 46.182 | 12.945 | | 8 | 100 |
| Tarcento | 46.214 | 13.215 | | 8 | 100 |
| Villalta | 46.104 | 13.114 | | 8 | 100 |
| Zucco | 46.255 | 13.160 | | 8 | 100 |
| Artegna | 46.238 | 13.156 | | 7/8 | 101 |
| Bled | 46.369 | 14.113 | | 7/8 | 101 |
| Campeglio | 46.129 | 13.363 | | 7/8 | 001 |
| Fanna | 46.186 | 12.752 | | 7/8 | 000 |
| Flaibano | 46.058 | 12.984 | | 7/8 | 001 |
| Hasperk | 45.816 | 14.267 | SB | 7/8 | 101 |
| Ljubljana | 46.058 | 14.503 | | 7/8 | 000 |
| Moggio di Sopra | 46.405 | 13.189 | | 7/8 | 001 |
| Polhov Gradec | 46.065 | 14.312 | | 7/8 | 101 |
| Postojna | 45.778 | 14.219 | | 7/8 | 101 |
| Qualso | 46.175 | 13.244 | | 7/8 | 101 |
| San Daniele del Friuli | 46.157 | 13.010 | | 7/8 | 101 |
| Tolmezzo | 46.398 | 13.019 | | 7/8 | 001 |
| Turjak | 45.878 | 14.615 | SB | 7/8 | 100 |
| Udine | 46.063 | 13.236 | | 7/8 | 000 |
| Villach | 46.616 | 13.849 | | 7/8 | 100 |
| Belluno | 46.146 | 12.222 | | 7 | 001 |
| Sacile | 45.953 | 12.499 | | 7 | 000 |
| Spilimbergo | 46.110 | 12.899 | | 7 | 100 |
| Trieste | 45.656 | 13.784 | | 7 | 000 |
| Venezia | 45.438 | 12.335 | | 7 | 000 |
| Cormons | 45.959 | 13.468 | | 6/7 | 000 |
| Gorizia | 45.943 | 13.620 | | 6/7 | 000 |
| Gradisca d'Isonzo | 45.890 | 13.498 | | 6/7 | 100 |
| Muggia | 45.599 | 13.768 | | 6/7 | 101 |
| Padova | 45.407 | 11.876 | | 6/7 | 000 |
| Pordenone | 45.964 | 12.660 | | 6/7 | 000 |
| Treviso | 45.669 | 12.244 | | 6/7 | 000 |
| Vicenza | 45.549 | 11.549 | | 6/7 | 100 |
| Ferrara | 44.836 | 11.618 | | 6 | 000 |
| Mantova | 45.152 | 10.775 | | 6 | 000 |
| Verona | 45.438 | 10.994 | | 6 | 000 |
| Bergamo | 45.694 | 9.670 | | 5/6 | 101 |
| Bologna | 44.498 | 11.340 | | 5/6 | 001 |
| Bondeno | 44.889 | 11.417 | | 5/6 | 100 |
| Castelfranco Veneto | 45.671 | 11.926 | | 5/6 | 001 |
| Mestre | 45.493 | 12.242 | | 5/6 | 001 |
| Wien | 48.208 | 16.373 | | 5/6 | 101 |
| Cervia Vecchia | 44.249 | 12.332 | | 5 | 101 |
| Ceské Budejovice | 48.976 | 14.478 | | 5 | 101 |
| Como | 45.810 | 9.084 | | 5 | 000 |
| Finale Emilia | 44.833 | 11.294 | | 5 | 000 |
| Litomerice | 50.534 | 14.127 | | 5 | 101 |
| Lodi | 45.314 | 9.501 | | 5 | 000 |
| Monfalcone | 45.805 | 13.529 | | 5 | 100 |
| Piacenza | 45.052 | 9.693 | | 5 | 101 |
| Ravenna | 44.417 | 12.198 | | 5 | 000 |
| Slanj | 50.228 | 14.081 | | 5 | 101 |
| Chioggia | 45.219 | 12.279 | | 4/5 | 001 |
| Mazzorbo | 45.486 | 12.408 | | 4/5 | 001 |
| Modena | 44.647 | 10.925 | | 4/5 | 000 |
| Parma | 44.801 | 10.329 | | 4/5 | 000 |

| | | | | | |
|---|---|---|---|---|---|
| Torcello | 45.497 | 12.418 | | 4/5 | 001 |
| Gutenberg | | | SB | D | 101 |
| Idrija | 46.002 | 14.030 | | D | 101 |
| Kamnik | 46.220 | 14.612 | | D | 101 |
| Magnano in Riviera | 46.231 | 13.178 | | D | 001 |
| Oberstein | 46.224 | 14.618 | SB | D | 101 |
| Planina | 45.834 | 14.256 | | D | 101 |
| Prezek | | | | D | 111 |
| Smlednik | 46.165 | 14.426 | | D | 101 |
| Susans | 46.194 | 13.048 | | D | 100 |
| Trzic | 46.363 | 14.312 | | D | 101 |
| Albana | 46.051 | 13.492 | | (d) | 101 |
| Altana | 46.111 | 13.548 | SS | (d) | 101 |
| Antro | 46.152 | 13.478 | | (d) | 101 |
| Attimis | 46.188 | 13.307 | | (d) | 101 |
| Biacis | 46.148 | 13.483 | | (d) | 101 |
| Castelmonte | 46.094 | 13.520 | SS | (d) | 101 |
| Cergneu Superiore | 46.215 | 13.318 | | (d) | 101 |
| Cialla | 46.079 | 13.481 | SS | (d) | 101 |
| Ciubiz | 46.104 | 13.588 | SB | (d) | 101 |
| Codromaz | 46.097 | 13.572 | SS | (d) | 101 |
| Costne | 46.153 | 13.608 | SS | (d) | 101 |
| Craoretto | 46.025 | 13.469 | SS | (d) | 101 |
| Cravero | 46.133 | 13.558 | | (d) | 101 |
| Iainich | 46.103 | 13.548 | SS | (d) | 101 |
| Kamen | 46.382 | 14.217 | | (d) | 011 |
| Kocevska Reka | 45.574 | 14.801 | | (d) | 101 |
| Lasiz | 46.164 | 13.482 | | (d) | 101 |
| Mereto di Tomba | 46.051 | 13.041 | | (d) | 101 |
| Mozelj | 45.586 | 14.933 | | (d) | 101 |
| Novigrad | 45.316 | 13.562 | | (d) | 100 |
| Pechinie | 46.182 | 13.528 | | (d) | 101 |
| Pulfero | 46.173 | 13.485 | | (d) | 101 |
| S. Leonardo del Friuli | 46.118 | 13.532 | | (d) | 101 |
| San Pietro al Natisone | 46.126 | 13.485 | | (d) | 101 |
| Spignon | 46.147 | 13.465 | SS | (d) | 101 |
| Stregna | 46.126 | 13.578 | | (d) | 101 |
| Vernassino | 46.160 | 13.519 | SS | (d) | 101 |
| Vernasso | 46.121 | 13.475 | | (d) | 101 |
| Frattins | 46.267 | 13.211 | | EE | 011 |
| Montenars | 46.256 | 13.181 | | EE | 010 |
| Alessandria | 44.913 | 8.615 | | F | 001 |
| Bamberg | 49.892 | 10.896 | | F | 101 |
| Bayreuth | 49.936 | 11.590 | | F | 101 |
| Hof | 50.332 | 11.923 | | F | 101 |
| Portobuffolè | 45.853 | 12.538 | | F | 101 |
| Rimini | 44.059 | 12.567 | | F | 100 |
| Urbino | 43.726 | 12.636 | | F | 101 |
| Milano | 45.464 | 9.190 | | NF | 000 |

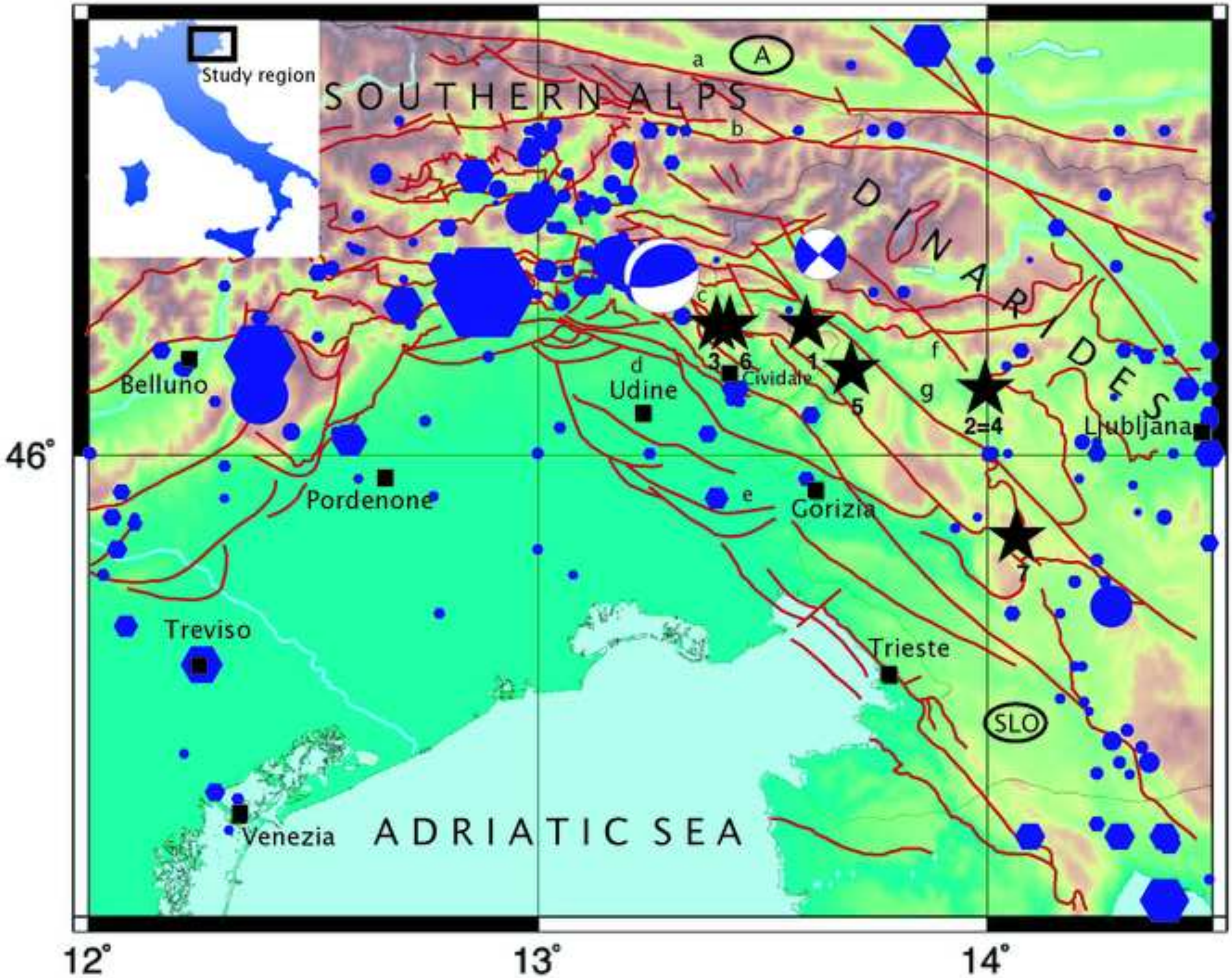
Tab. 3 – Table of intensities according the present study (SC= Special Case. MS: Multiple Seattlement; SB: Solitary Building; SS: Small Seattlement). Quality Code (Qc) according Musson (1998). Intensity codes: (d): information of damage to a single monumental building; EE: environmental effects; F: felt; NF: not felt)

| Date | Time | Area | Eff. | Main References |
|---|---|---|---|---|
| *1510* | - | | *FAKE* | |
| 1511.03.26 | 15.30 | Friuli Main shock | HD | |
| 1511.03.26 | 19.30 | Venezia, Udine | F | Sanudo (16th cent), Roberto da Latisana (16th cent) |
| 1511.03.27 | 5 | Venezia, Udine | F | Sanudo (16th cent), R.da Latisana (16th cent) |

| | | | | |
|---|---|---|---|---|
| 1511.03.28 | 14.30 | Ljubljana, Udine, Venezia, Vicenza, Ferrara, Ravenna, Padova | HD | R.da Latisana (16th cent) Rodi 16th cent), Sanudo (16th cent), Terremoti (168h cent) |
| 1511.04.01 | 17/21 | Gemona, Udine, Venezia, Ferrara, Padova | D | Mulioni (16th cent), Decio (16th cent), R. da Latisana (16th cent), Terremoti (18th cent); Sanudo (16th cent), Sanvito (16th cent) |
| 1511.04.03 | 22/23 | Venezia | F | Terremoti (18th cent); |
| 1511.04.04 | 22/23 | Venezia | F | Terremoti (18th cent); Sanudo (16th cent) |
| 1511.04.06 | 23 | Venezia | F | Terremoti (18th cent); |
| 1511.04.07 | midnight | Venezia | F | Terremoti (18th cent); |
| 1511.04.11 | 21 | Venezia | SF | Sanudo (16th cent) |
| 1511.04.20 | 7 | Ljubljana | HF | Radics (1901): |
| 1511.06.06 | 13 | Ljubljana | HF | Radics (1901): |
| 1511.06.25 | before 1 | Ljubljana, Venezia, Udine | HF | Sanudo (16th cent), Radics (1901); R. da Latisana (16th cent) Joppi (18th cent) |
| 1511.06.26 | 23 | Udine | D | R. da Latisana (16th cent) |
| 1511.07.14 | - | Ljubljana | F | Radics (1901) |
| *1511.08.08* | - | | *FAKE* | |
| 1511.08.16 | 3.30 | Venezia, Sacile | HF | Terremoti (18th cent); Joppi (18th cent); Sanudo (16th cent) |
| 1511.08.26 | 9 | Venezia | HF | Terremoti (18th cent); Joppi (18th cent); Sanudo (16th cent |
| 1511.09.31 | | Ljubljana | F | Radics (1901) |
| 1511.10.03 | | Ljubljana | F | Radics (1901) |
| 1512.02.08 | 10.30 | Venezia | HF | Sanudo (16th cent) |
| 1512.02.15 | | Udine | F | Amaseo (16th cent) |
| 1513.02.25 | 9.30/10.30 | Gemona | HF | Mulioni (16th cent) |
| 1513.05.20 | 15.30/16.30 | Gemona | SF | Mulioni (16th cent) |
| 1513.05.28 | 21.30 | Gemona | F | Mulioni (16th cent) |
| 1513.12.16 | 5 | Gemona | F | Mulioni (16th cent) |
| 1514.01.01 | | Gemona | HF | Mulioni (16th cent) |
| 1514.01.15 | 5.20 | Gemona | HF | Mulioni (16th cent) |
| 1514.01.30 | 15 | Gemona | F | Mulioni (16th cent) |
| 1514.04.12 | | Gemona | F | Mulioni (16th cent) |
| 1514.06.17 | | Gemona | F | Mulioni (16th cent) |
| 1514.07.04 | | Gemona | SF | Mulioni (16th cent) |
| 1514.07.07 | 22 | Venezia | HF | Sanudo (16th cent) |
| 1514.07.12 | 8/9; 18 | Gemona, Venezia | HF | Mulioni (16th cent); Sanudo (16th cent) |
| 1514.09.30 | 3 and 5 | Gemona | F | Mulioni (16th cent) |
| 1515.07.31 | 1 | Gemona | F | Mulioni (16th cent) |
| 1515.10.25 | 15 | Venezia | HF | Sanudo (16th cent) |
| 1516.03.02 | 5. | Gemona | F | Mulioni (16th cent) |
| 1516.12.19 | 23 | Gemona | HF | Mulioni (16th cent) |

Tab. 4 – Informations available on the seismic sequence.

**colour figure**

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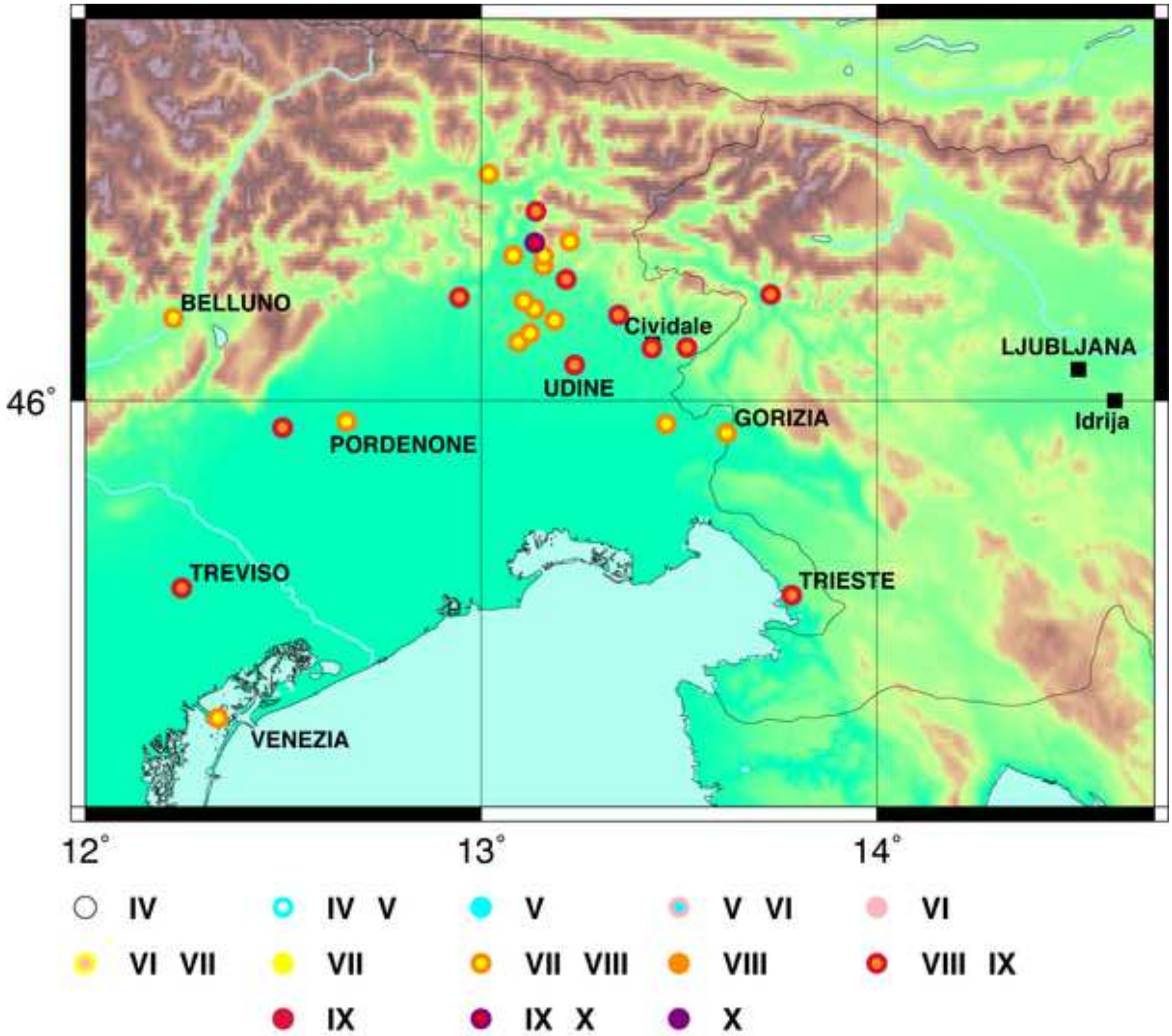

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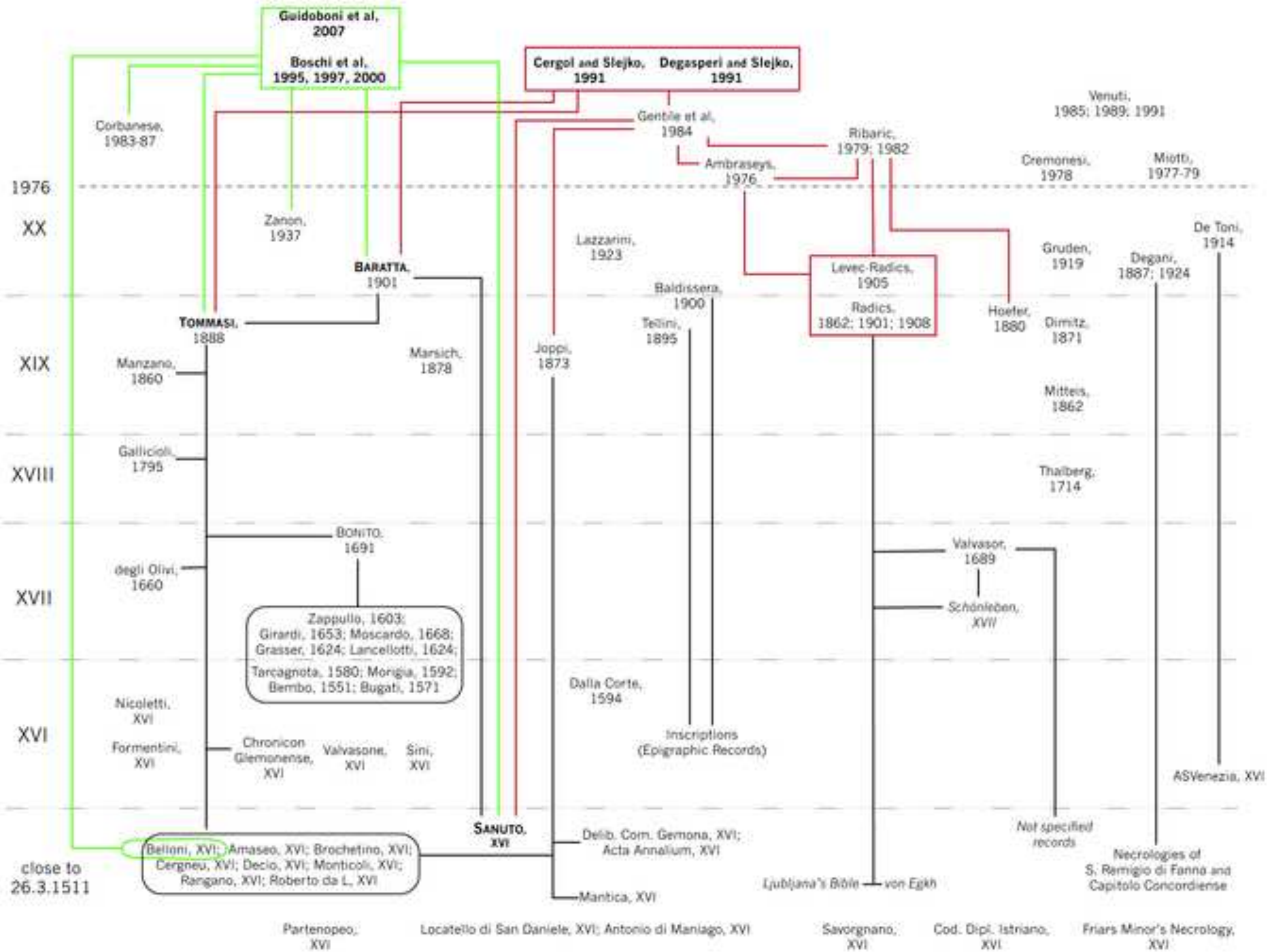

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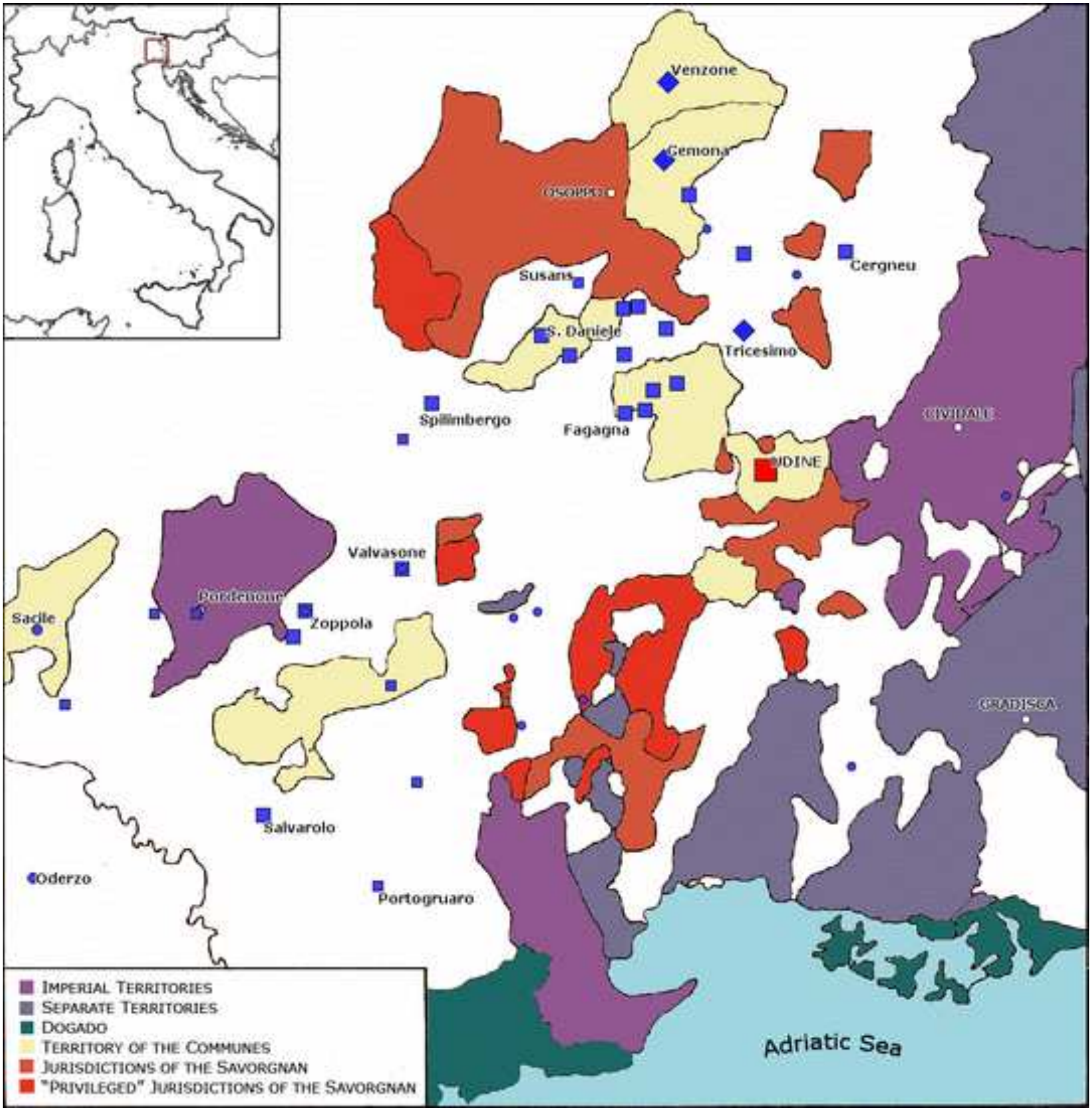

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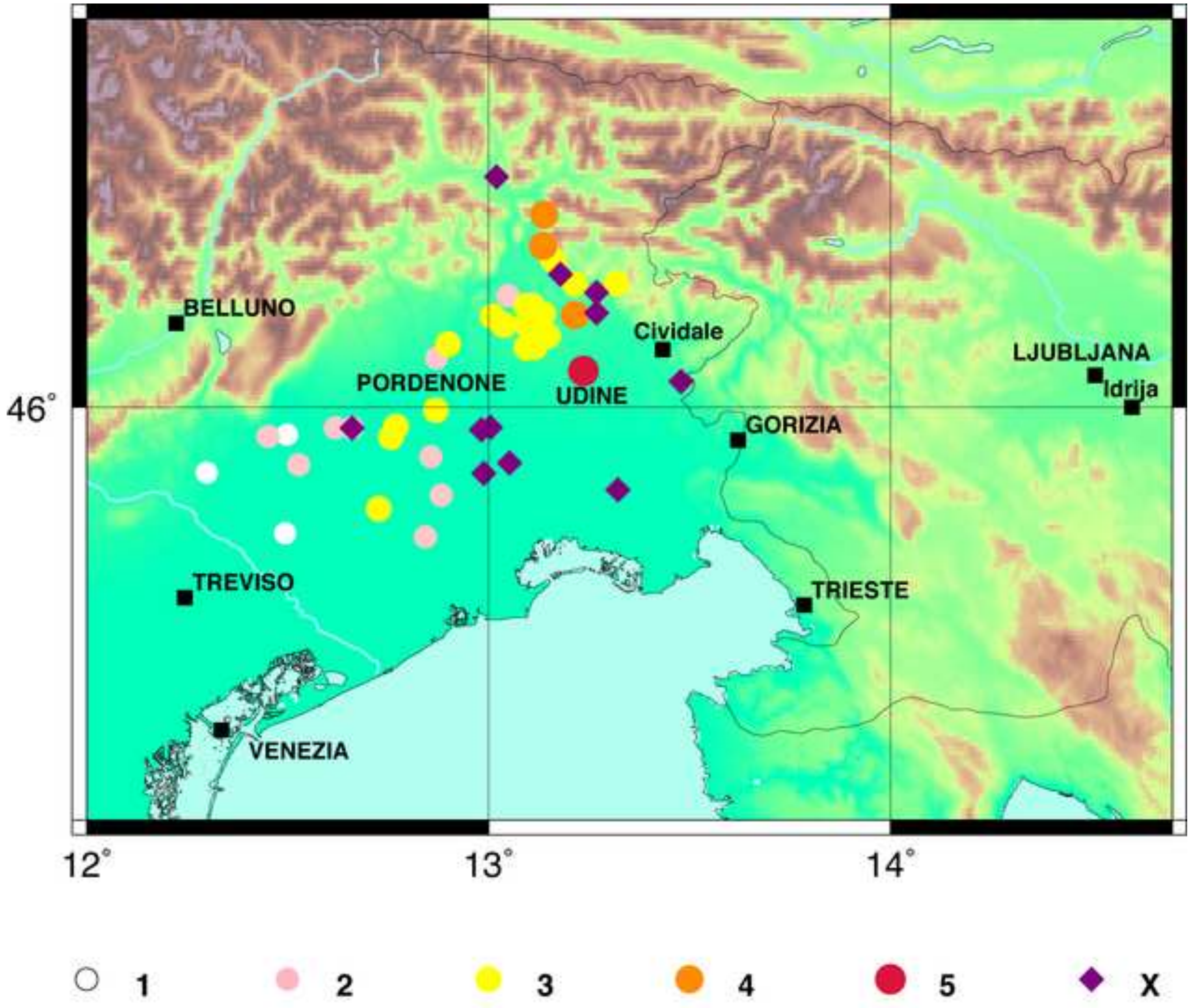

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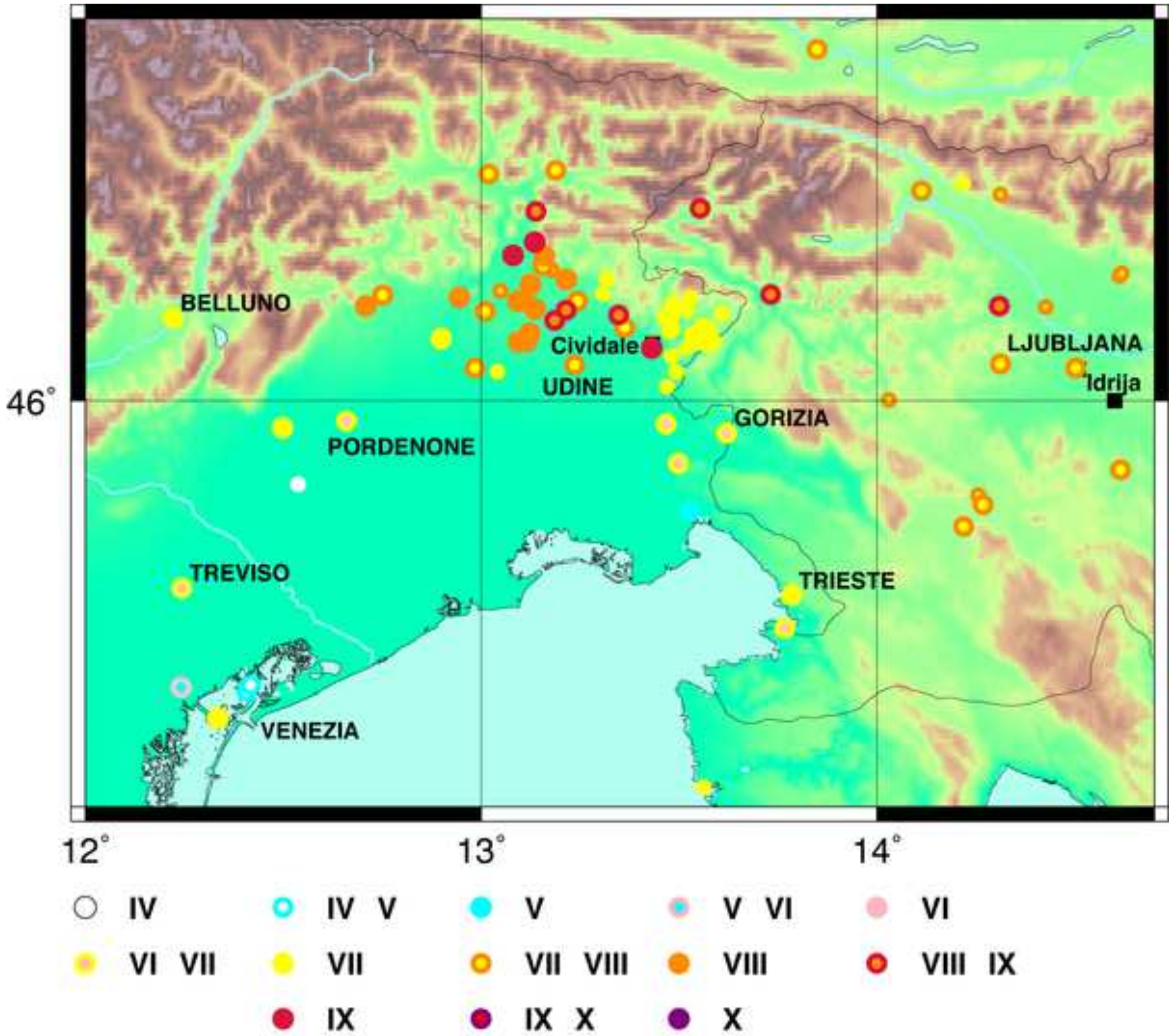

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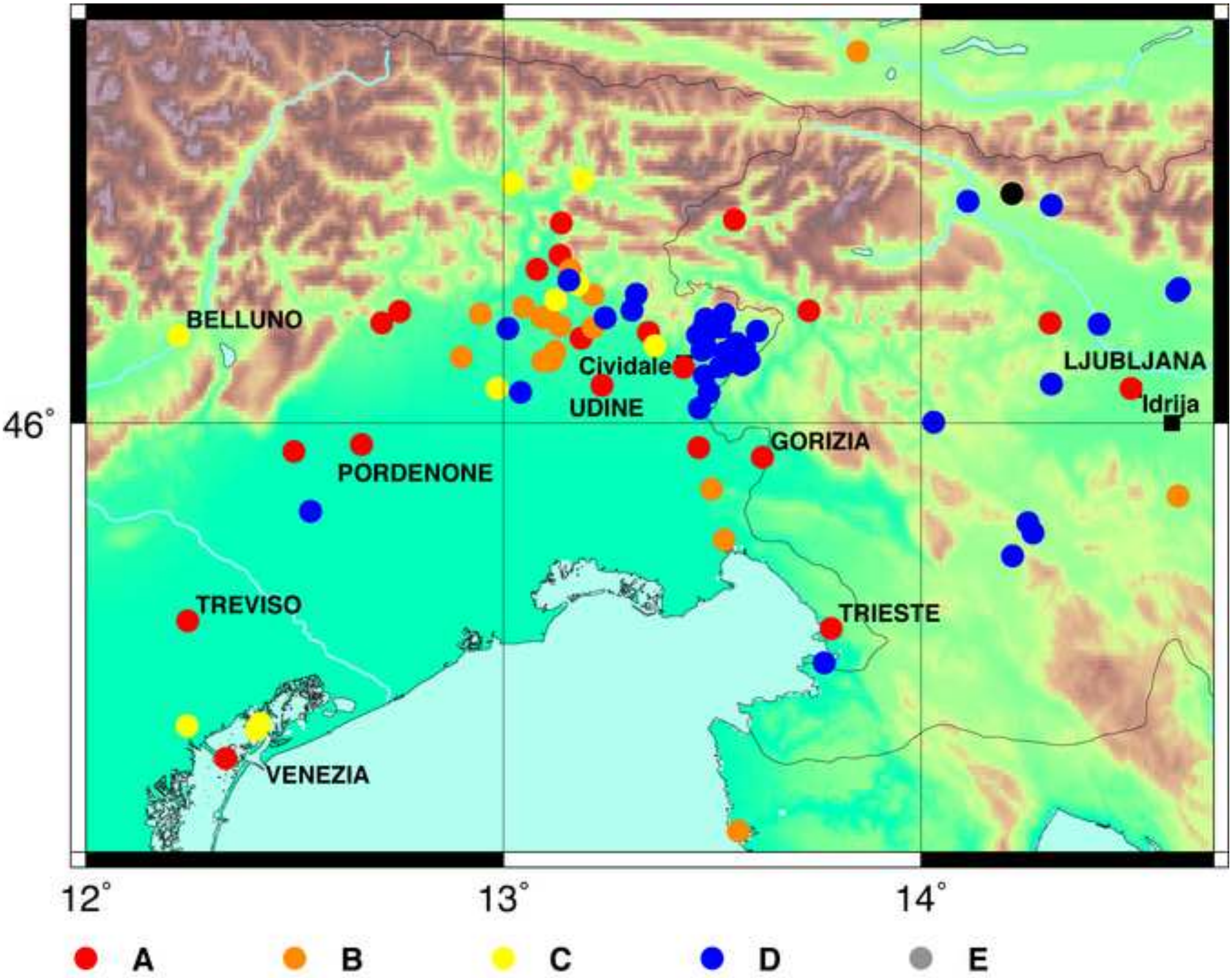

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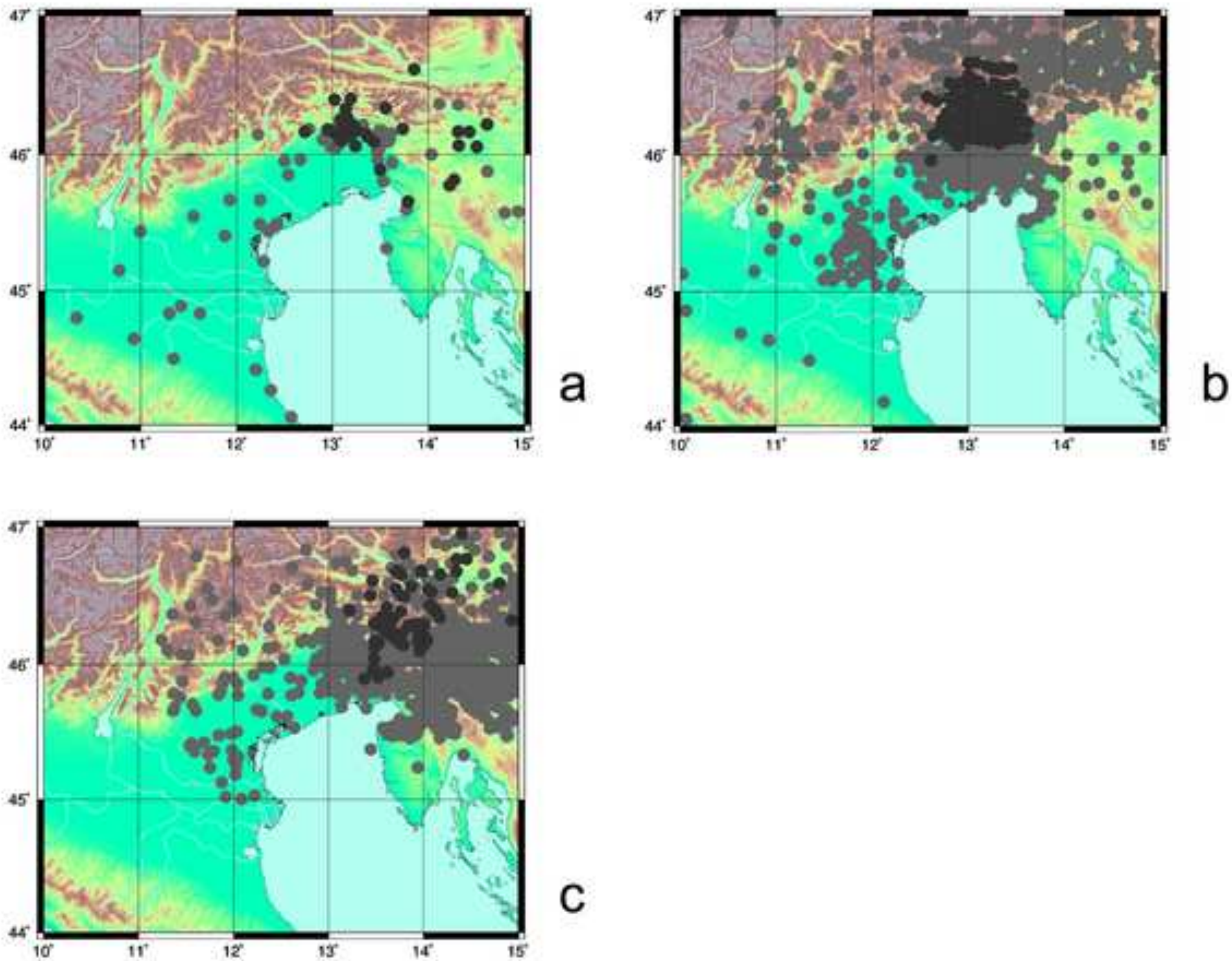

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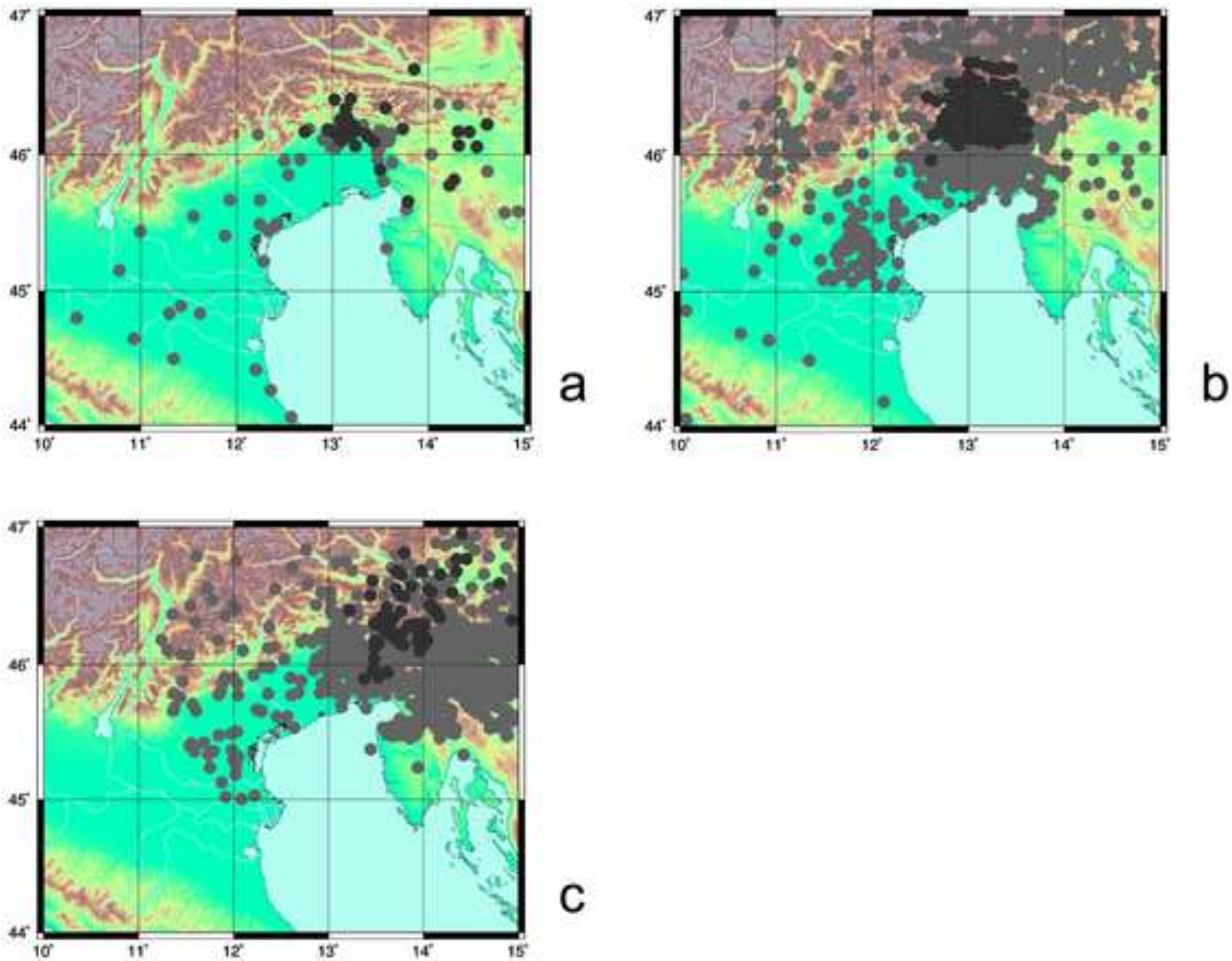

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