

The archaeology of earthquakes: the application of adaptive cycles to seismically-affected communities in late medieval Europe

The study of archaeoseismology (or 'earthquake archaeology') focuses mainly on the analysis of earthquakes at an archaeological scale, either in order to reconstruct the parameters of past seismic events (ie. their intensity, chronology, magnitude, epicentre, etc) or else to measure their impact on archaeological sites (Galadini et al. 2006; Ambraseys 2006; Rodríguez-Pascua et al. 2011). This approach has its critics because archaeological methodologies such as excavation, field survey and remote sensing, or standard archaeological approaches to context recording, material culture and the integration of other sources of information such as history or ethnography are often laid aside (Jusseret 2014). In short, archaeoseismology reflects far better the interests of palaeoseismologists than archaeologists (Caputo and Helly 2008; Silva et al. 2011; Sintubin 2011) and can be perceived as an ancillary discipline relegated to the gathering of historical seismic catalogues (Caputo and Helly 2008; Guidoboni and Ebel 2009).

Among the topics less well studied are those tactics elaborated by past societies to cope with the damage caused by earthquakes and to increase their preparedness for future seismic events. In this paper we apply resilience theory (Holling and Gunderson 2002; Redman and Kinzig 2003; Redman 2005) which emphasises the *chaîne opératoire* ('chain of actions') put in place by medieval communities and we use a modern risk assessment workflow to assess the range of the strategies adopted (Smith and Petley 2009). In particular, the importance of a multi-disciplinary perspective is underlined, one which integrates diverse sources of information ranging from archaeological to geological, historical, architectural, iconographical and ethnographical data. A unifying approach which combines evidence from the humanities and natural sciences in a common framework is fundamental in order to evaluate fully the diversity of responses adopted. Illustrative case studies are drawn from well-documented events for which fresh evidence has been gathered for the Armedea project (Archaeology of medieval earthquakes in Europe, 1000-1550 AD; Forlin et al. 2015).

2. Adopting adaptive cycles

Resilience theory highlights transformations, such as those induced by seismic disasters, and helps to characterise their associated dynamics, conditions, and any opportunities they present. Here we adopt the definition of the adaptive cycle described by Holling and Gunderson (2002:34) as a 'figure of eight' (**Fig. 1**).

Within a panarchical framework, a destructive earthquake can be taken as the cause for an abrupt disturbance within a given stable system. If a social and ecological system

settled in a k phase corresponds to the conservation of an apparent equilibrium, the Ω phase (release) would be represented by a sudden earthquake occurrence. The α phase (recovery) would correspond with the successive aftermath and the r phase (exploitation) with the period during which the new possibilities of development offered by a 'recently disturbed area' are exploited (Holling and Gunderson 2002: 33). The recurrence of the 'seismic' adaptive cycle is then represented by a second stable k phase, interrupted by another earthquake (Ω), recovery (α) and exploitation (r) and so on through multiple completed cycles. The duration of each phase and the precise circumstances will vary between periods and regions but the framework does encourage the investigation of each of the adaptive cycles in a standardised way and this is helpful for comparative purposes. No attempt has yet been made to apply adaptive cycles to seismically-prone areas on a large scale through a study of 'vertical stratigraphy', in other words the analysis of multiple events over a long time period in a single region. As a first step towards this goal, this paper collates 'horizontally' diverse information from different case studies, focusing on the complex strategies employed by late medieval European societies during the α , r and k phases.

There have been several different attempts in the past to model disaster responses. Pfister, for instance, has proposed a functionalist model which summarises adaptive responses to disasters in three simple phases: emergency, damage compensation and reconstruction (Pfister 2009). The transition from each phase to the next is represented by what is referred to as a 'potential adaptive and mitigative learning step'. Pfister's model focuses on pragmatic and rational reactions, but largely ignores the viewpoint of the individual and community as well as other socio-cultural factors (Schenk 2015:73-4). By contrast, mentality, belief and religion are at the core of the disaster interpretations proposed by Juneja and Mauelshagen (2007) for pre-industrial societies. Stressing that the moral interpretation of natural disasters is pervasive among past societies, they define this as a 'peccatogenic' perspective (that is, triggered by sins). According to this view, adaptation to disaster in medieval Christianity was driven by religious responses such as collective processions, extraordinary Masses, laws against sinners, etc., all of which were aimed at mitigating the wrath of God and preventing repeat disasters (Hanska 2002).

These two models can be integrated into a single flowchart which expresses technological, scientific, philosophical and religious responses as well as the values and beliefs of late medieval communities. This is the 'risk management flowchart' as developed by Smith and Petley (2009:65) which illustrates how modern governments (should) evaluate risk and (should) respond to natural hazard. The flowchart has two macro-steps: the post-disaster recovery (PDR) and the pre-disaster protection (PDP).

Both the PDR and PDP each have four stages: relief, rehabilitation, reconstruction and learning review constitute the PDR phase, whereas risk assessment, mitigation, preparedness, emergency plans characterise PDP. This flowchart can be integrated into the seismic adaptive cycle (**fig. 2**), assuming that PDR relief and rehabilitation are included in the α phase (recovery), PDR reconstruction and learning review in the r phase (exploitation), and PDP as a whole is incorporated into the k phase (equilibrium). The k phase, according to this perspective, would be a typical unstable equilibrium which anticipates a further seismic disaster and activates a new cycle.

3. Post-Disaster Recovery and Pre-Disaster Protection in seismic adaptive cycles

3.1 Relief

Relief is the first stage of the Post-Disaster phase and corresponds to the most acute period of an emergency immediately after a disaster (Smith and Petley 2009:73-4). Then as now, the first action undertaken by survivors in the 'golden hours' after a seismic event was often the rescue of those trapped beneath the rubble. When a destructive earthquake hit Heraklion in May 1508, some 400 victims, including the Venetian chancellor, were recovered by the survivors digging through the debris (Ambraseys 2009:419). The identification of human skeletal remains from beneath earthquake rubble is very uncommon in medieval archaeological contexts (see below, for the exceptional cases of Saranda Kolones, Cyprus and Dyrrachium, Albania) and this reinforces the impression that the recovery of bodies was normal (Gerrard and Petley 2013:1059) and, in many cases, such an obvious action that it did not need to be written down. Besides digging for the injured, assistance for survivors might also be provided. In the immediate aftermath of the destructive earthquake which struck the island of Kos and the surrounding area on October 18th 1493 (Lutrell 1999), the Knights Hospitallers (the Military Order who controlled the island at that time) sent a fleet from Leros and Kalimnos to transport doctors and surgeons of the Order to the island along with a significant provision of medicines (Figliuolo 2002:897). Reacting to the lack of essential foodstuffs during the initial emergency phase, the Hospitallers delivered hand-querns for the grinding of flour for bread.

The recovery of valuable items also occurred at the relief stage and, archaeologically, this is sometimes identified as 'salvage'. A good example comes from Saranda Kolones, the crusader castle outside Paphos, Cyprus, which was entirely destroyed by an earthquake in 1222 (Rosser 2004). Several ramps were dug down through the fallen rubble here, possibly in order to rescue victims who were trapped beneath collapsed structures; both human and animal skeletal remains were discovered

beneath the rubble. A deposit of small objects including bronze items, iron objects, pottery, nails and bronze tweezers, together with a Seljuk coin minted in 1219-1225 suggests items which had been picked out of the destruction layers in the aftermath of the earthquake (Rosser 2004: 44). Perhaps this collection of lower value objects was later abandoned in favour of more valuable ones removed from the site, but whether by rescuers or looters is not known. Looting, or more generously the 'exploitation of a recently disturbed environment', is another common feature in the aftermath of medieval disaster, and must be added to the list of adaptive strategies put in place by some survivors. When Isernia in southern Italy was flattened by an earthquake in 1456, the urban population abandoned the city but, according to a document preserved in the local archive, people from the rural area were not slow to take advantage of the situation. They entered the city and 'took away all our belongings, our money, gold and silver and all our surviving possessions' (Guidoboni and Comastri 2005:642). Archaeologically, looting may be difficult to distinguish from salvage, but written documents provide less scope for interpretation.

Regardless of whether they had experienced the destructive impacts of earthquakes themselves, medieval and later Christian societies gained some understanding from descriptions in the Bible. In particular they were familiar with the image that Christ's crucifixion coincided with a major earthquake, a scene depicted by contemporary artists such as Il Pordenone for an altarpiece in Cremona cathedral in 1521 (**fig.3**). They also knew that earthquakes would signal the end of the world. Unsurprisingly therefore, earthquakes (and other natural hazards) provoked public processions, mass demonstrations of faith to request the help or mercy of God and allow people to return home to begin the process of reconstruction. Processions like these, in which clergy and local people often participated side-by-side, predate the later Middle Ages: more than a century before processions *pro causa necessitates* (i.e. due to specific necessity) were institutionally defined by Pope Gregory the Great in the *Litania Romana*, a procession took place in AD 470 after an earthquake near Vienne in France (Hanska 2002: 34-5, 48-83). In particular, the medieval public were accustomed to the processing of relics during the annual celebration of feast days and this custom, symbolic of the town's unity and an expression of community, was repeated in response to all manner of emergencies including drought, severe weather, disease, invasion, and at any other time the populace felt insecure (Bartlett 2013, 296-303). Following the earthquake of AD 1222, the relics of St John the Baptist were exhibited to the Genoese as a medium for supernatural help; St John was notably popular in the region making up 5% of all 10-13th century church dedications in the eastern part of the diocese (Epstein 2012: 173-175; Moggia 2005). Christians understood their saints to be an intermediary who might help out in a time of danger and someone with privileged access to a loving God. As might be expected, processions like that in Ferrara (northern Italy) during a

period of high seismicity in 1570-74, mapped out a route which took in the most prominent ecclesiastical buildings and public areas of the town (Guidoboni 1984:115). In Ferrara, as elsewhere, clergy and nobles were all involved and this served to reinforce public solidarity, a tactic that was especially welcome in communities of mixed population. In Kos in 1493 the Latin and the Greek clergies organised a single procession which brought together the faithful from the two Churches (Figliuolo 2002:897).

Medieval saints number in their thousands but few are specific to earthquakes (Hanska 2002: 94-97). Those that have been identified are not surprisingly confined to the most earthquake-prone regions of Europe such as the virgin martyr St Agatha in Sicily. The Virgin Mary was also widely venerated for her intercessions in the aftermath of earthquakes and this quality found support in local Marian shrines such as the *Madonna del Terremoto* ('of the Earthquake') in Venice in 1511 (Sanudo 2011:174) and in Scarperia in central Italy, where a fresco of 1542 of the *Madonna dei Terremoti* can still be seen in an aedicule nearby a gate into the town (Arrighetti 2015:175).

Minority groups were commonly blamed for triggering natural disasters. This is because social 'difference', of a religious or sexual kind for example, was identified with human sinfulness and since natural disasters were perceived as an act of God it was necessary to purge the cause of his ill will. No matter how we might see it today, for a sometimes hysterical and paranoid medieval society this demand for conformity was a risk-reduction strategy. Non-procreative sexual activity and same-sex relations were often made scapegoats and many examples could be cited of this. When a strong earthquake shook Venice in 1511, the Patriarch specifically mentioned sodomy as the probable cause and Venetian institutions drew up new legislation in mitigation (Sanudo, 2011:110-1). Sodomy and blasphemy were also condemned by the senate of Florence when the Mugello valley was struck by a destructive earthquake in 1542 (Schenk 2010). In the 13th century *Tractatus* by Étienne de Bourbon, a work devoted to the condemnation of sins, the author asserts that many sodomites were crushed to death by the collapse of houses triggered by an earthquake in Tyre because of their *peccatum contra naturam* ('sin against nature': Hanska 2002: 119-120). The same interpretation is also seen in the Islamic world. When Ibn al-Jazzār listed the differing opinions in Cairo concerning the cause of the 1576 earthquake there, his favoured interpretation was that the event was a punishment for sodomy and adultery (Akasoy 2009:191).

Ethnic minorities were also targeted, especially Jewish communities. The suggestion that Jews were accused of having caused the 1348 earthquake in Austria and north-east Italy has lately been reconsidered (Rohr 2003:137). However, the Jews and *Marrani* (converted Jews) were accused of being the cause of the earthquake which hit

Ferrara in 1570 by Pope Pius II. This was because of a wider popular perception throughout the Middle Ages that Jews were expert in magic and capable of evil acts. As a solution to stop the tremendous sequence of aftershocks which hit the city during the months following the main earthquake, the Duke was required to expel both the Jews and Marrani from the town (Guidoboni 1984:117). Segregation was often seen as the most effective solution but these persecutions should be seen in the context of widespread hostility towards Jewish economic success and a more centralised Church authority which sought to exert control over a community obsessed with the imminent end of the world (Richards 1990). By 1570 Jewish communities had already been largely eliminated across western Europe.

Supernatural events were also commonly linked to later medieval earthquakes. In Villach, Austria, the 1348 earthquake razed the entire town to the ground except for the house of one very pious man; a miracle in the eyes of some observers (Borst 1988). Emperor Charles V, in a letter sent to Pope Leo X, also saw some 'mystery' behind the fact that all the buildings and the city walls in Vera la Vieja, near Almeria in Spain were completely destroyed apart from the small church of the *Corpus Domini* in 1518 (**fig. 4**; Bretón Gonzáles et al. 2014:114). Local superstition too played its part. After the 1348 earthquake, Konrad von Megenberg also reported a story which had spread among late medieval Alpine communities that the earthquake had been induced by the sudden movement of a giant fish called Celebrant on which the earth stood (Rohr 2003: 137). This fantastical creature is reminiscent of another fish, Bahamut, which according to Arab mythology was one of the layers supporting the Earth. In his 16th century treatise on earthquakes, the Egyptian Abū 'l-Fadl al Suyūtī listed thirty causes for earthquakes. One of them refers to Satan, who makes Bahamut feel proud and causes him to move about (Akasoy 2009:189). While these explanations played no direct role in the responses of local populations, at least as far as we know, they did provide an interpretative framework (Borst 1988) and helped commit the disaster to memory. Disaster management must always be judged in the light of the state of knowledge circulating in that community at that time.

'Natural' explanations for earthquakes were based on Aristotelian interpretations explained in his *Meteorology* (Book II, 7-8) which identified their cause as subterranean winds arising due to the evaporation of underground waters (Lettinck 1999). This reasoning was later transmitted by medieval Arab and Christian philosophers, among them Ibn Rushd (Averroes), Albertus Magnus, and Aquinas, and was widely understood among the literate by the 16th century. Thus, among those who voiced their opposition to the expulsion of Jews from Ferrara in 1570 was the *internuntius*, the Papal ambassador, who defined earthquakes as a 'natural thing' (Guidoboni 1984:117). He was not alone in this view. Commenting on the processions organised by the Patriarch of Venice

following the 1511 earthquake, Marin Sanudo, one of the most prominent noblemen of the *Serenissima*, observed: 'I do see they [the processions] are praiseworthy in terms of our customs and religion [*ad bonos mores et religionem*], but as remedies for earthquakes, which are natural things, they did not count at all' (Sanudo 2011:111). More specifically, Aristotelian philosophy was drawn upon both to explain damage and as a tool for mitigation. The official State account of the earthquakes which affected the valley of Mugello in Tuscany in 1542 argues that Florence was less affected because of its location on the river Arno and because the numerous wells across the city had allowed the internal vapours of the earth to reach the surface without triggering an earthquake (Schenk 2010:40-1). This rationale was repeated by later Florentine writers (Arrighetti 2015:175-6). In Udine, thirty years earlier, the civic authorities had apparently ordered to re-open the dismissed wells with the aim of preventing the aftershocks of the severe 1511 Slovenian earthquake (Battistella 1932).

3.2 Rehabilitation

Faced with the prospect of longer-term recovery for the local population following a seismic event, one of the most urgent needs to be catered for was temporary housing for the displaced population. An oil on wood Biccherna panel painted by Francesco di Giorgio Martini depicts the Virgin Mary protecting Siena from an earthquake in 1461 in which the Tuscan city is surrounded by hastily constructed shelters (**fig. 5**). No medieval 'seismic encampments' of this kind have so far been identified by archaeologists but written documents make it clear that they were usually composed of tents and wooden barracks and located either outside permanent settlements or in large open spaces, such as squares or gardens, so as to reduce the risk of injury from structural collapse. No later than five days after the main shock of the 1493 earthquake, the Hospitallers dispatched a cargo of wood to Kos to be used for building temporary housing and to reinstate the walls. A few days later, another expedition brought to the island a *protomagister murator*, builders and slaves to restore the collapsed houses of the castles of Kos and Antimahia (Antimachia) and erect shelters in the main square of the town of Kos (Figliuolo 2002:897-898).

Temporary shelters like these were not only inhabited by the poor, but by the entire evacuated population. This prompted some commentators to condemn the promiscuity which then ensued between rich and poor, the secular laity and the religious. In some cases the emergency effort was coordinated from within the encampment, so that in 1570 the court of the Duke of Ferrara lived for months in wooden structures erected in a camp in the quarter of San Benedetto, coordinating the *chaîne opératoire* of first aid (Guidoboni 1984:112-3). Likewise, in the aftermath of the earthquake of 1511, Venetian institutions gathered the *Maggior Consiglio* in an open square rather than the *Palazzo*

Ducale (Sanudo 2011:120) where it was presumably deemed to be safer. In the absence of large spaces free of buildings, the Venetians took to living on boats on the open sea for several days (Sanudo 2011:114). For those on land, temporary re-settlement could easily become a semi-permanent state of affairs: temporary settlements in Ferrara in 1570 were occupied until the earthquake aftershocks came to an end four years later (Guidoboni 1984).

Another immediate response following an earthquake was to clear the debris from the streets in order to accelerate rescue and reconstruction: the Count of L'Aquila ordered precisely this soon after the 1349 earthquake (Figliuolo 2010:327). Elsewhere, the removal of large volumes of building materials gave the opportunity to remodel urban landscapes. Archaeological excavations in the piazza Duomo in Padua, Italy between 1860 and 1874 led to the discovery of a large building 12.5m square, very probably the base of the Romanesque bell-tower of the nearby cathedral. The structure lay buried beneath a 2.5 m thick layer of collapse which included large fragments of brick wall, one of which preserved architectural elements datable to the end of the 11th century. More recently, excavations in the nearby baptistery found that the foundations of the building lay nearly 3.60 m below the current ground surface (Brogiolo 2011). The levelling of terrain in this way is not unusual in medieval cities, but in this case it seems very likely that the urban space around the cathedral was dramatically reshaped soon after the 1117 earthquake. A commemorative inscription (now lost) of 1124 recorded the reconstruction of the cathedral 'from its foundations' (Guidoboni and Comastri 2005:107).

Historical evidence often suggests that medieval settlements impacted by earthquakes and their secondary effects were frequently reoccupied and this can also be demonstrated archaeologically. Vila Franca do Campo, on the island of Sao Miguel in the Azores archipelago, was almost entirely buried by a seismically-induced landslide in 1522. Archaeological excavation in the old Azorean capital by the ArMedEa project quickly identified a mud-flow layer up to 2.00 m thick including stone boulders (**fig. 6**) and building materials (**fig. 7**). This landslide deposit was present at several locations across the existing urban area, revealing in some areas the presence of destruction layers underneath it (**fig. 8**). The evidence indicated that debris had been cleared in areas less affected by the mass movements and the original footprint of the town was then reoccupied. In particular, in one site investigated by the project, the post-landslide occupation started in the 16th century, immediately after the landslide. This included at least two phases of building construction associated with evidence for blacksmithing (**fig 9**).

Archaeology also provides good evidence for the 'exploitation of a recently disturbed environment' (Redman 2005), usually the re-use of debris from a damaged and abandoned site such as the Crusader castle of Saranda Kolones near Paphos (Cyprus) which was destroyed by an earthquake in 1222. Archaeological investigations conducted here between 1957 and the 1980s recognised salvage operations in seven robber ramps amid the rubble of the northwest tower, at the north curtain wall and along the counterscarp wall of the east ditch. These ramps seem to have been constructed to facilitate the hauling of stone blocks away from the site (Rosser 1985:85, fig. 5).

Finally, another significant measure was financial support in the form of fiscal exemption. On Crete in 1303, for example, the Venetians exempted local bakers from paying their taxes for a year to sustain bread production (Guidoboni and Comastri 2005: 337). Similarly, on Kos in 1493, the Hospitallers reduced drastically the *modiatico*, a tax paid in kind by the aristocrats on the island, and entirely exempted those millers who gave assurances that they would work uninterruptedly in the aftermath of the earthquakes which had struck the island (Figliuolo 1995:106). In the case of Mataró in NE Spain the town took advantage of the destruction caused by earthquake in 1448 to obtain a series of fiscal privileges and administrative autonomy from the Crown of Aragon (Salicrú Lluç 1995). However, tax relief was not always provided. While King Alfonso of Aragon granted a tax exemption to the inhabitants of Isernia (Molise, Italy) in order to avert the abandonment of the town in 1456, the same strategy was not adopted for other communities which also petitioned for relief. According to the King, not all the survivors needed fiscal support as they had inherited the goods of the many victims. In fact, this was the reason given for raising taxes in the year after the earthquake (Guidoboni and Comastri 2005: 631).

3.3 Reconstruction

Reconstruction comprises all those long-term actions which aim to 'return an area to normality after severe devastation' (Smith and Petley 2009: 68). In the Middle Ages it was already a common practice to undertake a detailed survey of the damage caused by earthquakes almost immediately after they had occurred. Officials in charge of listing damaged buildings or infrastructure and providing an estimate of the costs for the reconstruction are reported in L'Aquila in 1349, the central Apennines in 1456, Cyprus in 1491, Kos in 1493 and Mugello in 1542, to name a few (Arrighetti 2015:171). Highly detailed reports were expected and the reconstruction works were carried out on the basis of the survey (eg. on Kos; Figliuolo 2002: 903-904). Priority was usually given to strategic infrastructure such as city walls and fortifications and particularly with the stated aim of discouraging the departure of the inhabitants. Thus, in the town of L'Aquila, central Italy, the local Count immediately ordered the repair of the collapsed

parts of the city walls with a wooden palisade so that the urban population would be encouraged to return to the town from their temporary encampments in the countryside (Figliuolo 2010:327). The importance of the symbolic value of town or city walls in reaffirming the identity of a place clearly emerges here.

Archaeologically, post-seismic restoration of city defences is documented in Andujar, Spain, which was damaged by earthquake in 1170. The 9th century Arab fortifications were remodelled, reinforced and dramatically enlarged with the erection of a wider circuit in response to earthquake damage (Peláez et al. 2005). However, an even more remarkable example can be found at El Castillejo, an abandoned fortified medieval village in the Guajares, a valley about 30 km south of Granada (Spain, **fig. 10**). El Castillejo covers an area of c.1.5 ha (120 m x 130 m) on an isolated hilltop, encircled by a circuit wall with a fortified gateway on its western side. Excavation evidence demonstrates that the site was occupied from the beginning of the 11th century to the mid 14th century (Malpica et al. 1985; Malpica et al. 1986; Malpica and Cressier 1986; Bertrand et al. 1990; García Porras 2001).

The medieval houses at El Castillejo were built in lifts of rammed earth with foundations of stone masonry. Two phases of occupation can be identified; the first phase being damaged by a seismic event which completely destroyed the eastern part of the site and badly affected the western area. Typical archaeological earthquake effects (EAEs; Rodríguez-Pascua et al 2011) are recognisable on the standing walls such as penetrative shear cracks, displacement of blocks of rammed earth and tilting effects (**fig. 11**). The damage caused in the western part of El Castillejo and the complete destruction of the eastern area, possibly due to a so-called “site-effect”, are compatible with an Io=IX-X yet El Castillejo was not abandoned. In a second phase of occupation, the building debris from the first phase was reworked. The damaged buildings were repaired with re-cut blocks of rammed earth, as well as re-used bricks, roof tiles and stone. The eastern area was left completely abandoned, although it was presumably quarried for useful materials for the reconstruction phase. Notably, the circuit of walls and the fortified entrance were completely restored (**Fig. 12**) using a lower quality of rammed earth which is also less thick (70-88 cm as oppose to 107 cm). The priority was clearly the repair of the site’s fortifications rather than any improved seismic resilience, something which might suggest the intervention of civic authorities in the post-disaster stage. Similar cases can be cited, for example, when a severe earthquake hit the eastern Mediterranean causing widespread damage in Crete in August 1303, the Republic of Venice sent a team of 28 builders and carpenters to coordinate the repairs (Guidoboni and Comastri 2005:343). Likewise, the town of Kos was only fortified after the 1493 earthquake, when its castle was provided with an additional circuit wall by the Hospitallers (Heslop 2014:49).

Further archaeological evidence of reconstruction can be found at Dyrrachium (Durrës) in Albania where archaeological investigation in the Roman amphitheatre showed that squatters had occupied its galleries during the 12th and 13th centuries (Santoro and Hoti 2014). When the region was hit by severe earthquake in about 1270 (Ducellier 1996:73) these galleries collapsed, trapping those inside. Despite the level of destruction, however, the area was not abandoned. The ruins of the amphitheatre were levelled, and evidence from storage pits and a hearth suggests that occupation soon began again. Just south of the amphitheatre, the walls of a large 12th century building described as a 'palace' collapsed almost entirely and the fallen roof was documented archaeologically. Beneath the destruction layers, three victims were recovered. However, the building was still not abandoned. Once the debris had been levelled and repairs and remodelling completed at the beginning of the 14th century, the building continued to be occupied until the 16th century. One curious feature are the number of wells sunk on the site, which seem too numerous to be merely a practical response to the paucity of drinking water. Given later practices at Udine in 1511 and Mugello in 1542, it may be that they were intended to provide an 'antiseismic' function.

The option of reconstruction was sometimes rejected. Well before the construction of 'new towns' such as Noto Nuova or Ragusa in 17th century Sicily (Tobriner 1980), badly damaged sites were abandoned completely and new towns built nearby. Vera la Vieja in Almeria was built from new after the old hilltop town was largely destroyed in 1518 (Gerrard and Petley 2013). Of the old town, only the chapel of the Holy Spirit survived the earthquake and this site was acknowledged as a place of pilgrimage by Pope Leon X, who declared a jubilee (remission of sins) in 1520 for all those who visited the miraculous church. This action was intended to support the funding of the construction of the new cathedral and the town (Bretón Gonzáles et al. 2014:114-115). Rebuilding projects undoubtedly provided a stimulus to the local economy and, in the right circumstances, this can also be seen archaeologically. Excavations at Vila Franca do Campo in the Azores recovered brick and roof tile from pre-1522 contexts and the landslide deposit which had been imported from mainland Portugal. Following the landslide, only locally produced building materials are present and this suggests that local manufacture in the Azores may have been encouraged by the demand created by the reconstruction phase as well as by the need to moderate expensive imports.

3.4 Learning review

This is the final stage of Post-disaster Recovery and one of the most important because it links with Pre-disaster Protection, in our model corresponding to the r and k phases respectively (Smith and Petley 2009:65). It addresses the question of whether or not

medieval societies made efforts to learn from past experience. We would argue that they did.

One way to guarantee that some memory of a disaster lived on was to write it down and to make the account available for future generations. This process can be clearly seen in Venice in the aftermath of the earthquake which hit north-east Italy and western Slovenia in 1511 (Camassi et al. 2011). Listing the damage caused by this seismic event in Venice, the patrician Marin Sanudo records that the worst affected building was the church of St Basilio. Then he notes that ‘the same happened in 1347 [AD 1348], the 25th of January, the day of St Paul [actually, of his conversion], as we can read in the chronicles of our city, when a large earthquake hit this city, and many houses and chimneys collapsed, along with the church of St Baseio (Basilio) as it is written in marble letters upon the School of Carità’ (Sanudo 2011:105). The importance of civic archives as a reference point for recent history is unambiguous as is the wish to create a lasting public memorial of the event. The ‘marble letters’ refer to a Gothic inscription which is still visible within a lunette in the cloister of the Carità. Another 14th century stone-carved inscription inside the bell tower of the church of Saint Mauro at Costozza in Veneto also records the same seismic event together with two other earthquakes of 1117 and 1222. Seismic memory was long and constantly reiterated among the most affected rural medieval communities (Guidoboni and Comastri 2005:106). The tower of Saint Mauro is completely covered with an exterior render today (**fig. 13**), but earthquake damage and repairs were possibly visible when the inscription was first carved. Inscriptions like this one recording restorations or repairs are extremely widespread in medieval Italy, for instance in Romanesque churches (Guidoboni and Comastri 2005). Aside from the archives and public inscriptions, local collective memory was reinforced by cults such as the Holy Virgin of Earthquakes in Mugello and Venice (see above) and through visual display. Although Mary was a universal saint, there were many local and popular adaptations of her cult (Bartlett 2013:151-162). The 15th century fresco showing the ‘Madonna dei Terremoti’ in Scarperia, in the Mugello Valley, Florence, was at the centre of liturgical and popular religious practice in 1660-1661 when another earthquake hit the same area (Arrighetti 2005: 175). The feast of the Guardian Angel is still celebrated in Almeria today every 2nd March in memory of the day the 1522 tsunamigenic earthquake that hit the city and the nearby region (Vincent 1974:580).

From the 15th century onwards, there were also ‘scientific’ treatises on earthquakes. One of the earliest published examples is *De terraemotu libri tres* by the Florentine ambassador Gianozzo Manetti, which provided a detailed and systematic survey of the damage inflicted by the southern Apennines 1456 earthquake (Manetti 2013). A century later no less than seven treatises debated the effects of the 1570 earthquake in Ferrara.

One of these, the *Libro di Diversi Terremoti* ('Book of Many Earthquakes') by Pirro Ligorio, includes the earliest architectural design for a seismically-resistant building. This consists of brick walls interconnected by iron and wooden chains and reinforced corners with arches inserted over windows and doors (D'Antonio 2013: 55-59). In this specific case therefore the learning review phase is related directly with the successive Pre-Disaster Protection stage.

4. Pre-Disaster Protection

The final stage of the risk management process is Pre-Disaster Protection (PDP) when efforts are made to reduce or minimise the impact of future disasters. In our adaptive cycle, PDP corresponds with the k phase, during which a seismically-affected community takes advantage of an 'apparent equilibrium' (definition in Holling and Gunderson 2002) before being interrupted by another earthquake. According to Smith and Petley (2009:65-68), the modern PDP depends on risk assessment (based on hazard identification), mitigation (by means of the adoption of protective structures, for instance), preparedness (i.e. forecast systems) and emergency plans. Although no forecast systems for seismic events existed in the Middle Ages (as in the contemporary world, to some extent) and no specific emergency plans were defined in advance, at least to our knowledge, some elements of PDP were implemented. After Nicosia on Cyprus was badly affected by an earthquake in 1491, for example, the Venetian authorities were unwilling to invest in the repopulation of the island because of the risk of reoccurrence (Ambraseys 2009:408). The risk was therefore acknowledged although the mitigation strategy might be regarded as wholly negative. Religious practises were designed to ensure protection against future earthquakes. The formula "a flagellus terraemotus, libera nos, domine" ('liberate us from the earthquake') was included in the rogations since the Early Middle Ages (Hanska 2002).

In some parts of medieval Europe such as Italy, southern Spain, Greece and Cyprus, hazards were repeated, often came with forewarning and, when they struck, could inflict significant damage on human and natural resources. Here there is a growing portfolio of evidence for the emergence of local 'seismic cultures' in which vulnerable local communities learnt to adapt to the hazards they faced (eg. Wenger and Weller 1973:9; Bankoff 2015:55). Much of this evidence comes from historic buildings. Commenting on the effects of a violent earthquake which struck Crete in 1494, one French monk was told by the inhabitants of the island that they built their houses with earthquake-proof solutions in mind. The houses were seated on a platform supported on arches filled with stones which were said to be resistant to earthquakes (cited in Guidoboni and Comastri 2005:823). Elsewhere in the eastern Mediterranean earthquake-resistant construction techniques can be found in Greece and Turkey where the use of timber-framed

masonry and narrow courses of materials such as brick is known as *hatillar* (singular *hatil*) are a feature of Byzantine and Ottoman structures (Bankoff 2015:58). The most impressive example of this technique can be seen in the Constantinople's Theodosian city walls, built in courses of stones alternating with red brick belts (Langenbach 2007).

In southern Italy, the so-called *casa baraccata* (barracked house), and the *pombalina* or *gaiola* in Portugal (Tobriner 1980) employ a similar although more sophisticated technique, based on the use of a wooden cage to minimize seismic damage. These methods of construction were both introduced in the 18th century as a response to seismic disasters, respectively in Lisbon in 1755 and in Calabria in 1783. However, the *casa baraccata* designed by the engineer La Vega was inspired by the Roman houses built in *opus craticium* which he had seen at the excavations of Pompeii and Herculaneum (Ruggieri 2015). A similar building typology can be traced in southern Italy since the late Middle Ages (Dutu et al. 2012), although exactly when and where this technique appeared remains unclear at present.

In central Italy four types of anti-seismic protection have been identified in historic architecture in Lunigiana and Garfagnana (northern Tuscany, eastern Liguria). They are: (i) stone, wooden, and iron chains; (ii) buttresses and barbicans; (iii) arches to discharge structural stress, and; (iv) contrasting arches connecting facing buildings. In particular, stone, wooden and iron chains were employed, for example at the church of San Lorenzo in Borgo San Lorenzo, Florence (Arrighetti 2015: 98). [In Abruzzo, the introduction of interlocked wooden timber cages which were inserted at several levels of Renaissance walls with the aim of interconnecting the structure as a whole date to a period immediately after the 1456 southern Apennines and 1461 L'Aquila earthquakes. Iron chains were employed in many late medieval buildings in L'Aquila and surrounding centres. The flower, cross and snake-shaped decorative ornamentation on the ends of the chains provides a secure 15th century chronology \(D'Antonio 2013: 91- 172\).](#)

In other earthquake-prone regions, such as Cyprus (**fig. 14**), the construction of exaggerated buttresses in civic and religious architecture is common (O'Neill *in press*). All these techniques share the ability to absorb and distribute seismic loads as well as the capacity to provide greater structural flexibility under deformation stresses.

Mitigation measures were also adopted in urban design. As a consequence of the destruction and abandonment of Vera la Vieja, the new town of Vera la Nueva incorporated wide streets and large open squares (Bretón Gonzáles et al. 2014), a mitigation solution which made allowance for collapsing buildings and provided open spaces for emergency supplies and temporary encampments. This may be the first

example of a solution which was more widely adopted later, for example at Noto Nuova, [Avola](#), Catania (1693), and Lisbon (1755) (Tobriner 1980).

5. Conclusion

The application of resilience theory and adaptive cycle to the archaeology of disasters implies a number of assumptions which for some would invite scepticism. The first of these is that the human response to disaster is necessarily channelled through a pre-determined series of phases. There are real challenges in this. It is clear from the case studies cited above that few medieval disasters followed a predictive 'grammar' of responses. To some extent, this reduces the power of the general model because it does not easily permit a comparative approach between medieval European societies, at least at present and for all phases of the cycle. It would also be a mistake to conceptualize medieval society as a homogeneous entity, nor can the Middle Ages be seen simply as static in its thinking and responses. Reactions across Europe differed and must be contextualised, the 12th century was very different from the 15th century and the responses of the community cannot be largely presumed to be normative responses, an assumption which loses many of the nuances of medieval social behaviour which acknowledged gender, identity and power. However, just because it objectifies its subject matter this does not mean the approach is discredited. There are many advantages to generalising rather than focusing on the detail of site biographies, something to which all histories and archaeologies of disaster are particularly prone. Rather than merely cataloguing of damage, the perspective is more holistic and facilitates the collection and categorization of evidence taken from a wide range of European case studies. For one thing, it emphasises gaps in our understanding very effectively (for example in pre-disaster protection measures). Moreover, it emphasises the multi-disciplinary nature of the debate, underlining the need for archaeologists and historians to work together (**fig. 15**).

The strategies adopted in order to reduce vulnerability to natural disaster are complex and should include a consideration of symbolic, ideological, technological, political and economic factors. They must also embrace a full appreciation of social dynamics. Adaptive cycles provide an accurate framework against which responses can be measured and this highlights the need for more specific research into selected study areas and across wide chronological windows so that we can understand better how risk-sensitive tactics evolved in time and space. Only through this comparative approach we can better understand how reactions to seismic disasters developed far beyond medieval Europe.

Captions

Fig. 1: The adaptive cycle in a seismically-affected society (modified after Holling, Gunderson 2002:34)

Fig. 2: The 'risk-management' flow-chart modified after Smith and Petley (1009:65). Note the four stages of the adaptive cycles, where the Ω corresponds with the earthquake's occurrence.

Fig. 3 The crucifixion by Il Pordenone, Cathedral of Cremona (ca. 1521) The artist impressively depicted the surface ruptures caused by the earthquake associated with the death of Jesus: "the earth shook, the rocks split", Matthew, 27:51. (source: https://it.wikipedia.org/wiki/Crocifissione_del_Duomo_di_Cremona#/media/File:Golgotha-Il_Pordenone-Cremona_Cathedral.jpg)

Fig. 4 Vera la Vieja, Spain. The church of *Corpus Domini* (photo: ArMedEa project, Paolo Forlin)

Fig. 5 Particular of the Biccherna by Francesco di Giorgio Martini depicting tents and wooden barracks surrounding Siena *al tempo de tremuoti* (at the time of the earthquake) in 1461 (source: <https://uk.pinterest.com/pin/546624473496018465/>)

Fig. 6. Vila Franca do Campo, Azores (Portugal). Area 1, Trench 4. The 1522 landslide deposit with boulders at its base. In the section, the buried soil is clearly visible at the bottom (red dotted line; photo: ArMedEa project, Paolo Forlin).

Fig. 7. Vila Franca do Campo, Azores (Portugal). Area 6, trench 22. Building materials included within the body of the 1522 landslide. Note the sealed, pre-disaster stratigraphy at the bottom of the section (Photo: ArMedEa project; Paolo Forlin).

Fig. 8. Vila Franca do Campo, Azores (Portugal). Area 8, trench 26. A destruction layer identified immediately underneath the 1522 landslide deposit. The archaeological record was reduced in size by later activities (Photo: ArMedEa project; Paolo Forlin).

Fig. 9. Vila Franca do Campo, Azores (Portugal). Area 5, trench 18. The post-1522 reoccupation phase is represented by the foundation of a building with blacksmithing activity (Photo: ArMedEa project; Edward Treasure).

Fig. 10. El Castillejo, Guajar Faragüit, Granada (Spain). View of the western buildings. (Photo: ArMedEa project; Paolo Forlin).

Fig. 11. El Castillejo, Guajar Faragüit, Granada (Spain). Penetrative fractures visible on building 4. (Dotted red lines; photo: ArMedEa project; Paolo Forlin)

Fig. 12. El Castillejo, Guajar Faragüit, Granada (Spain). Orthophoto of the internal face of the fortified entrance (*baluarte*). Note the second phase rebuilt after seismic damage occurred (the interphase is marked by the continuous red line; photo: ArMedEa project; Paolo Forlin)

Fig. 13. The tower of San Mauro of Costozza (Vicenza, Italy) and its 14th century inscription recording the 1117, 1222, and 1348 earthquakes. (Photo: ArMedEa project; Paolo Forlin)

Fig. 14. The exaggerated buttresses of the church of Saint Peter and Paul in Famagusta, Northern Cyprus.

Fig. 15. The 'risk-management' flow-chart modified after Smith and Petley (1009:65), including the reactions discussed in this contribution.

New ref:

[D'Antonio M \(2013\) Ita terraemotus damna impedire. Note sulle tecniche antisismiche storiche in Abruzzo, Carsa edizioni, Pescara](#)

[Manetti G \(2013\), De terraemotu. Edited by Pagliara D, Sismel, Firenze](#)

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References

- Akasoy AA (2009) Interpreting earthquakes in medieval islamic texts. In: Mauch C, Pfister C (eds) Natural Disasters, Cultural Responses. Case Study toward a Global Environmental History. Rowman & Littlefield, pp 183–195
- Ambraseys NN (2006) Earthquakes and archaeology. *J Archaeol Sci* 33:1008–1016. doi: 10.1016/j.jas.2005.11.006
- Ambraseys NN (2009) Earthquakes in the Mediterranean and Middle East : a multidisciplinary study of seismicity up to 1900. Cambridge
- Arrighetti A (2015) L'archeosismologia in architettura. Per un manuale. Firenze University Press, Firenze

- Bankoff G (2015) Design by Disaster. Seismic architecture and cultural adaptation to earthquakes. In: Krüger F, Bankoff G, Cannon T, et al. (eds) *Cultures and Disasters. Understanding cultural framings in disaster risk reduction*. Routledge, Abingdon, Oxon, pp 53–71
- Bartlett R (2013) *Why can the Dead Do Such Great Things? Saints and Worshippers from the Martyrs to the Reformation*. Princeton
- Battistella A (1932) *Udine nel secolo XVI*. Udine
- Bertrand M, Cressier P, Malpica A, Rosselló G (1990) La vivienda rural medieval de “El Castillejo” (Los Guájares, Granada). In: *La casa hispano-musulmana. Aportaciones de la arqueología*. Granada, pp 201–227
- Borst B (1988) *Il terremoto del 1348*. Pietro Laveglia Editore, Salerno
- Bretón González M, Espinar Moreno M, Grima Cervantes J, Vidal Sánchez F (2014) *El terremoto de 1518 en Vera y su comarca (Almería)*. Arraez editores, Albolote, Granada
- Brogliolo GP (2011) Architetture religiose a Padova alla fine dell’XI secolo. In: Chavarria Arnau A (ed) *Padova architetture medievali (progetto Armap 2007-2010)*. SAP, Mantua,
- Camassi R, Caracciolo CH, Castelli V, Slejko D (2011) The 1511 Eastern Alps earthquakes: A critical update and comparison of existing macroseismic datasets. *J Seismol* 15:191–213. doi: 10.1007/s10950-010-9220-9
- Caputo R, Helly B (2008) The use of distinct disciplines to investigate past earthquakes. *Tectonophysics* 453:7–19. doi: 10.1016/j.tecto.2007.05.007
- Ducellier A (1996) Les Tremblements de terre balkaniques au Moyen Âge: aspects matériels et mentaux. In: Bennassar B (ed) *Les catastrophes naturelles dans l’Europe medieval at moderne*. Toulouse, pp 61–76
- Dutu A, Gomes Ferreira J, Guerreiro L, et al (2012) Timbered masonry for earthquake resistance in Europe. *Mater Construcción* 62:615–628. doi: 10.3989/mc.2011.01811
- Epstein SA (2012) *The medieval discovery of Nature*. Cambridge University Press, New York
- Figliuolo B (2010) I terremoti in Italia. In: Matheus M, Piccinni G, Pinto G, Varanini GM (eds) *Le calamità ambientali nel tardo medioevo europeo: realtà, percezioni, reazioni*. Firenze, pp 319–336
- Figliuolo B (2002) Il fenomeno sismico nel bacino del Mediterraneo in età rinascimentale. *Stud Stor* 43:881–919.
- Figliuolo B (1995) Terremoti, Stati e Società nel Mediterraneo nel XV secolo. *Acta Hist Archaeol Mediaev* 16/17:95–124.
- Forlin P, Gerrard CM, Petley DN (2015) ArMedEa project: archaeology of medieval earthquakes in Europe (1000-1550 AD). First research activities. In: Blumetti AA, Cinti F, De Martini P, et al. (eds) *6th International Inqua Meeting on Paleoseismology, Active Tectonics and Archaeoseismology*. 19-24 April 2015, Pescina, Fucino Basin, Italy, pp 166–169
- Galadini F, Hinzen KG, Stiros S (2006) Archaeoseismology: Methodological issues and procedure. *J Seismol* 10:395–414. doi: 10.1007/s10950-006-9027-x
- García Porras A (2001) *La cerámica del poblado fortificado medieval de “El Castillejo” (Los Guájares, Granada)*. Granada

- Gerrard CM, Petley DN (2013) A risk society? Environmental hazards, risk and resilience in the later Middle Ages in Europe. *Nat Hazards* 69:1051–1079. doi: 10.1007/s11069-013-0750-7
- Guidoboni E (1984) Riti di calamità: terremoti a Ferrara nel 1570-74. *Quad Stor* XIX:107–136.
- Guidoboni E, Comastri A (2005) Catalogue of earthquakes and tsunamis in the Mediterranean area from the 11th century to the 15th century. Bologna
- Guidoboni E, Ebel JE (2009) Earthquakes and Tsunamis in the Past. A guide to techniques in Historical Seismology. Cambridge University Press, Cambridge
- Hanska J (2002) Strategies of Sanity and Survival. Religious Responses to Natural Disasters in the Middle Ages. Finnish Literature Society, Helsinki
- Heslop M (2014) The search for the Defensive System of the Knights in the Dodecanese (Part II: Leros, Kalimnos, Kos and Bodrum). In: Piana M, Carlsson C (eds) *Archaeology and Architecture of the Military Orders. New Studies*. Ashgate, Farnham, Surrey, pp 29–68
- Holling CS, Gunderson LH (2002) Resilience and Adaptive Cycles. In: Holling CS, Gunderson LH (eds) *Panarchy: Understanding Transformations in Human and Natural Systems*. Island Press, Washington, DC, pp 25–62
- Juneja M, Mauelshagen F (2007) Disasters and Pre-industrial Societies: Historiographic Trends and Comparative Perspectives. *Mediev Hist J* 10:1–31. doi: 10.1177/097194580701000201
- Jusseret S (2014) Earthquake Archaeology : A Future in Ruins? *J Contemp Archaeol* 1.2:277–296.
- Langenbach R (2007) From “Opus Craticium” to the “Chicago Frame”: Earthquake-Resistant Traditional Construction*. *Int J Archit Herit* 1:29–59. doi: 10.1080/15583050601125998
- Lettington P (1999) Aristotle’s “Meteorology” and its reception in the Arab world. Brill, Leiden
- Luttrell A (1999) Earthquakes in the Dodecanese: 1303–1513. In: Zachariadou E (ed) ,” in *Natural Disasters in the Ottoman Empire. A Symposium Held in Rethymnon, 10–12 January 1997*. Rethymnon, pp 145–151
- Malpica A, Barceló M, Cressier P, et al (1985) Excavación de El Castillejo (Los Guájares, Granada), 1985. In: *Anuario Arqueológico de Andalucía 1985*. Sevilla, pp 436–446
- Malpica A, Barceló M, Cressier P, et al (1986) Informe de la campaña de excavación sistemática del yacimiento medieval de El Castillejo (Los Guájares, Granada), 1985. In: *Anuario Arqueológico de Andalucía*. Sevilla, pp 487–492
- Malpica A, Cressier P (1986) Informe sobre la campaña de excavación sistemática de “El Castillejo” (Los Guájares, provincia de Granada). Año 1989. In: *Anuario Arqueológico de Andalucía 1986*. pp 287–289
- Moggia C (2005) Il culto dei santi nel medioevo: Alcune considerazioni quantitative e tipologiche sulle dediche pievane e parrocchiali nella arcidiocesi Genovese di levante (secoli X-XIII). *Mélanges l’Ecole Française Rome Moyen Age* 117 305–311.
- O’Neill R (in press) Gothic on the Move: Reading Seismic Re-Adaptation in the Medieval Latin Churches of Cyprus.
- Peláez J, Castillo J, Sánchez Gómez M, et al (2005) Fuentes medievales y posibles

- evidencias arqueológicas del terremoto de Andújar de 1170. *Bol del Inst Estud Giennenses* 192:139–178.
- Pfister C (2009) Learning from Nature-Induced Disasters: Theoretical Considerations and Case Studies from Western Europe. In: Mauch C, Pfister C (eds) *Natural Disasters, Cultural Responses. Case Study toward a Global Environmental History*. Rowman & Littlefield, Lanham, MD, pp 17–40
- Redman CL (2005) Resilience Theory in Archaeology. *Am Anthropol* 107:70–77. doi: 10.1525/aa.2005.107.1.070
- Redman CL, Kinzig AP (2003) Resilience of past landscapes: resilience theory, society, and the longue durée. *Conserv Ecol* 7:****. doi: 10.2489/63.1.6A
- Richards J (1990) *Sex, dissidence and damnation. Minority groups in the Middle Ages*. Routledge: London, London
- Rodríguez-Pascua M a., Pérez-López R, Giner-Robles JL, et al (2011) A comprehensive classification of Earthquake Archaeological Effects (EAE) in archaeoseismology: Application to ancient remains of Roman and Mesoamerican cultures. *Quat Int* 242:20–30. doi: 10.1016/j.quaint.2011.04.044
- Rohr C (2003) Man and Natural Disaster in the Late Middle Ages : The Earthquake in Carinthia and Northern Italy on 25 January 1348 and its Perception. *Environ Hist* 9:127–149.
- Rosser J (2004) Archaeological and literary evidence for the destruction of “Saranda Kolones” in 1222. *Cyprus Res Cent Annu Rev* 30:39–50.
- Rosser J (1985) Excavations at Saranda Kolones, Paphos, Cyprus, 1981-1983’. *Dumbart Oaks Pap* 39:81–97.
- Ruggieri N (2015) *L'ingegneria antisismica nel Rego di Napoli (1734-1799)*. Ariccia (Roma)
- Salicrú i Lluch R (1995) The 1448 earthquake in Catalonia. Some effects and local reactions. *Ann Geophys* 38:503–513.
- Santoro S, Hoti A (2014) Epidamnos/Dyrrachium/Dyrrachion/Durres: le trasformazioni della città antica e medievale attraverso gli scavi e le ricerche italo-albanesi. In: *International Congress of Albanian Archaeological Studies*. Tiranë, p 578
- Sanudo M (2011) *I Diarii*. Tomo XII (1511) ; on-line source: http://www.liberliber.it/mediateca/libri/s/sanudo/i_diarii_tomo_xii/pdf/sanudo_i_diarii_tomo_xii.pdf.
- Schenk GJ (2015) “Learning from history”? Chances, problems and limits of learning from historical natural disasters. In: Krüger F, Bankoff G, Cannon T, et al. (eds) *Cultures and Disasters. Understanding cultural framings in disaster risk reduction*. Routledge, Abingdon, Oxon, pp 72–87
- Schenk GJ (2010) Dis-astri. Modelli interpretativi delle calamità naturali dal Medioevo al Rinascimento. In: Matheus M, Piccinni G, Pinto G, Varanini GM (eds) *Le calamità ambientali nel tardo medioevo europeo: realtà, percezioni, reazioni*. Firenze University Press, Firenze, pp 23–76
- Silva PG, Sintubin M, Reicherter K (2011) New advances in studies of earthquake archaeology and palaeoseismology. *Quat Int* 242:1–3. doi: 10.1016/j.quaint.2011.05.001
- Sintubin M (2011) Archaeoseismology: Past, present and future. *Quat Int* 242:4–10. doi: 10.1016/j.quaint.2011.03.056

- Smith K, Petley DN (2009) Environmental Hazards. Assessing risk and reducing disasters. Routledge, Abingdon, Oxon
- Tobriner S (1980) Earthquakes and Planning in the 17th and 18th Centuries. *J Archit Educ* 33:11–15.
- Vincent B (1974) Les tremblements de terre dans la province d'Almeria (XVe-XIXe siècle). *Ann Économies, Sociétés, Civilisations* 29:571–586.
- Wenger DE, Weller JM (1973) Disasters Subcultures: The Cultural Residues of Community Disasters, Preliminary Paper No. 9.