1356 Basel Earthquake

650-Year Retrospective

Risk Management Solutions

INTRODUCTION

On the evening of October 18, 1356 the most damaging intra-plate earthquake known to have occurred in central Europe struck northwest Switzerland. This earthquake, centered near Basel, destroyed the city and caused severe damage to buildings in the surrounding region. According to historical accounts, there was a precursor between 7:00 pm and 8:00 pm local time with the main earthquake striking later in the evening – around 10:00 pm. It was felt widely across Europe, with reports of the event from as far away as Paris to the west and Prague to the east. Historical records report that virtually all major structures, including churches, castles and fortresses, were destroyed within a 30-km (19-mi) radius of Basel.

Events of this magnitude (estimated between M_W 6.0 and M_W 6.9) are very rare in central Europe and there have been few earthquakes of this intensity in Switzerland since 1356 (IX on the European Macroseismic Scale or EMS). Due to the location of the city of Basel at the southern end of the Upper Rhine Graben, there is potential for damage from large yet infrequent earthquake events. In spring 2007, RMS will release a comprehensive Central Europe Earthquake model, covering Austria, Belgium, Germany, Italy, and Switzerland, allowing a better understanding of the possible losses from these infrequent events. The 650th anniversary of the Basel Earthquake provides an opportunity to review historical accounts and the scientific debate surrounding the magnitude of the event, as well as the potential impact of a repeat of the event.

Tectonic Setting of Central Europe

Seismic activity in Switzerland is characterized by relatively low levels of background seismicity with larger infrequent events in an intra-plate setting. This is in contrast to the more tectonically active parts of Europe such as Italy, Greece, and Turkey, where very large and damaging earthquakes regularly occur. Seismic activity in these countries in and around the Mediterranean region is strongly influenced by the plate boundary zones between the Eurasian, African, and Arabian plates.

The Mediterranean-Alpine region forms part of a complex boundary zone between the African and Eurasian plates. This boundary zone has undergone multiple episodes of deformation over time, but present day deformation relates to the continuing collision of the African and Eurasian plates. Relative plate motions suggest 10 mm/yr (0.4 in/yr) of convergence between these plates in the western Mediterranean, increasing to around 20 mm/yr (0.8 in/yr) in the eastern Mediterranean. In the central Mediterranean, the majority of this convergence is accommodated by the northwards subduction of the Mediterranean Sea floor, but a fraction of this motion is accommodated further north through distributed compression in the Alps. This compression manifests itself in the form of moderate to low levels of seismic activity in the Alps and Jura Mountains.

Rhine Graben

To the north of the Alps lies the Rhine Graben, an old rift system between the western and central Alps that runs from Belgium, through western Germany and easternmost France, and into northern Switzerland. The Rhine Graben is segmented into the Lower Rhine Graben (to the north) and the Upper Rhine Graben (to the south), as marked by a significant change in orientation of the rift system. At the present day the Upper Rhine Graben is orientated northeast-southwest, whereas the Lower Rhine Graben is orientated northwest-southeast (Figure 1). At its southern end, the Upper Rhine Graben merges into the Jura Mountains; the city of Basel lies near this southern termination. To each side of the Upper Rhine Graben, oblique extension faulting occurs (i.e., a combination of faulting where either side of the rift pulls apart with some lateral strike-slip motion). Palaeoseismological studies show evidence of fault activity on the flanks of the Upper Rhine Graben in the last 10,000 years.

Historical seismicity in Switzerland and surrounding regions tends to follow the main tectonic structures with earthquakes concentrated along the Alps, Jura Mountains, and Rhine Graben. A series of moderate earthquakes have been observed along the Upper Rhine Graben over the last several hundred years, although none of these are thought to have exceeded M_W 6.0. Valais canton in southern Switzerland has seen the most earthquakes historically, including large earthquakes that occurred in 1855 and 1946. In 1946, there were two events (the Ayent earthquakes), four months apart. The larger of the two events in 1946 reached a peak intensity of VIII on the EMS scale. In addition to the earthquake in 1356, there are historical records of other moderate to large earthquakes occurring in the Basel region, including an event in 1610. Archaeological evidence also suggests that an earthquake in 250 C.E. destroyed the Roman settlement of Augusta Raurica, which was located to the east of the present day city of Basel. Large earthquakes have also been observed across the border in southwest Germany, including the earthquakes of 1911 and 1978 in the Swabian Jura Mountains.

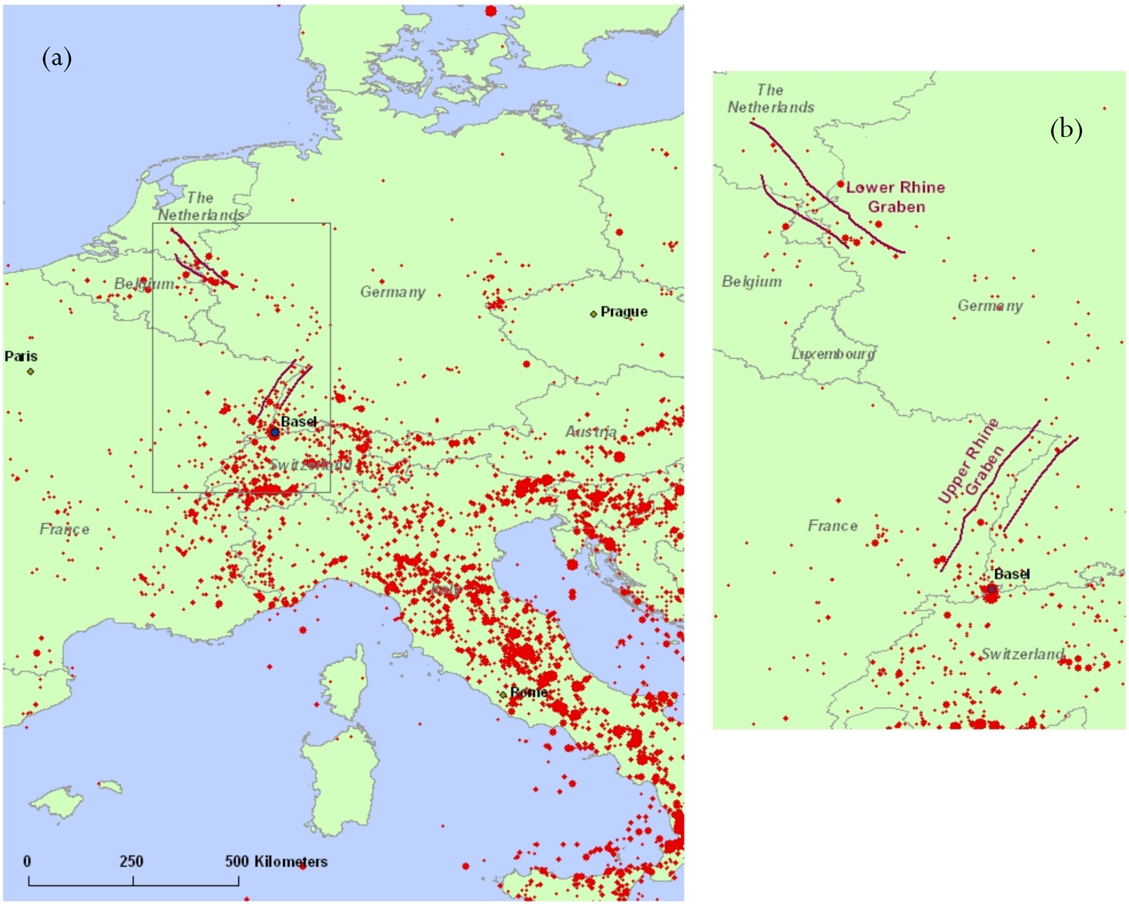

Figure 1: Historical seismicity of Central Europe, highlighting (a) the extent of the Rhine Graben and (b) a magnified view of the Lower Rhine Graben and Upper Rhine Graben

THE 1356 BASEL EARTHQUAKE

What is known about the event of October 18, 1356 is largely based on historical records of damage from the 14th through 16th centuries. This provides a considerable challenge in terms of understanding the characteristics of the event magnitude, location, and source characteristics. Researchers continue to debate the location and source of this event today (e.g., Meghraoui et al., 2001), as well as the extent of the damage area (e.g., Lambert et al., 2005). Despite the challenge of working with such historical data, researchers have managed to reconstruct intensity distributions for the 1356 event and constrain some of the source parameters.

CHRONICLED DAMAGE

Damage to buildings was observed in the Basel, Blauen, and Hauenstein regions of Switzerland, the Sundgau region of France, and the Baden-Wurtemburg region of Germany. The city of Basel itself was destroyed with historical records reporting that "no church, tower, or house of stone in this town or in the suburb endured, most of them were destroyed…" Buildings in the surrounding region that were damaged or collapsed were well documented by chroniclers in the 14th to 16th centuries (Figure 2). The detailed information that is known about the 30 castles located within a 10-km (6-mi) radius around Basel is what researchers have used primarily in order to understand the source and effects of this event.

The total number of casualties in the Basel Earthquake is uncertain. Fatality estimates range from several hundred to several thousand. The "Chronicle of Basel" suggests that around 300 fatalities occurred within the city of Basel alone. It is possible that the occurrence of a precursor event several hours beforehand may have contributed to the relatively few casualties for an earthquake of this size.

Figure 2: Artist's impression of damage to Basel after the 1356 earthquake

Intensity Distribution, Seismic Source, and Recurrence

Reconstructions of the damage distribution of the Basel Earthquake have been used to infer an epicentral intensity of IX on the MSK scale (which was the predecessor to the EMS scale). Such reconstructions place the peak intensity to the south of Basel and assign an intensity of VIII-IX in the city itself. Magnitude estimates for the Basel Earthquake range from M_W 6.0 to M_W 6.9 based on modeling of such intensity distributions.

The intensity distribution of the Basel Earthquake has been the subject of much debate in recent decades. In 1979, a reconstruction by Mayer-Rosa and Cadiot (1979) used historical damage reports and relocations of damaged castles to estimate the macroseismic intensity field of the earthquake. Their intensity distribution is elongated in an east-west direction and is asymmetrical north and south of Basel, with intensity decreasing more rapidly towards the south than towards the north (Figure 3). Subsequent work has revisited the historical evidence and questioned the extent of peak intensities (i.e., intensity levels VIII and IX). The most recent research (Lambert et al., 2005) proposes that the castles used to establish the intensity distribution were incorrectly located and assuming alternative castle locations results in an intensity distribution that is more tightly focused around the Basel region (Figure 4). This reduction in the extent of the reconstructed intensity distribution results in correspondingly lower estimates of the magnitude of the 1356 event (M_W 6.2-6.3).

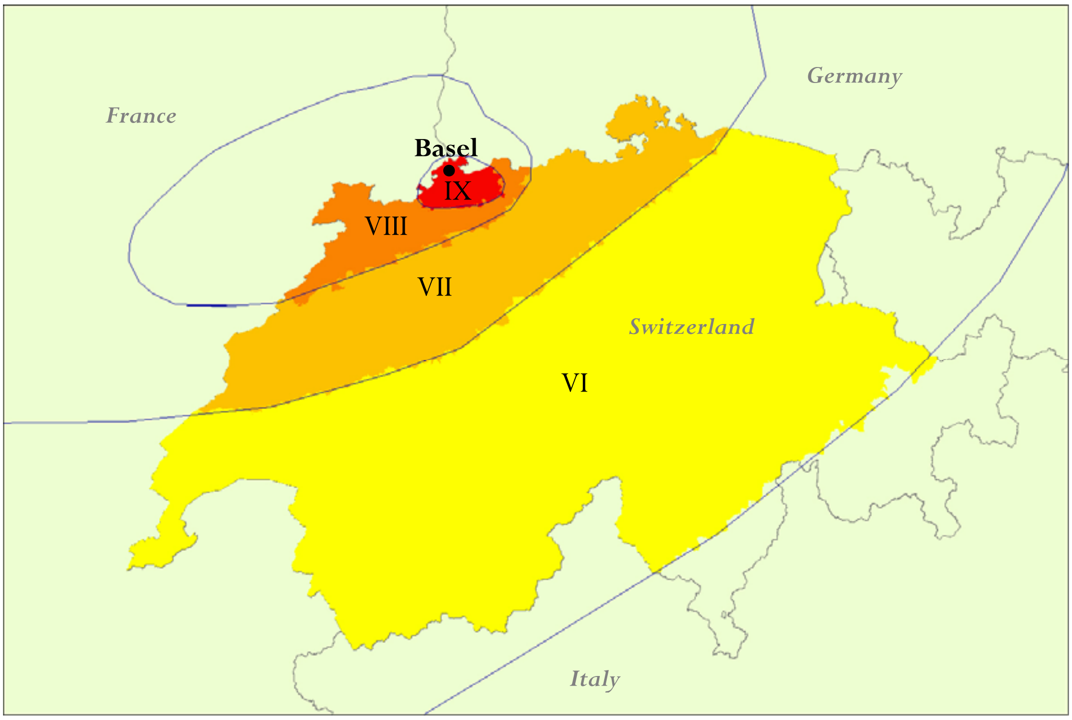

Figure 3: Intensity distribution of 1356 Basel Earthquake in Switzerland based on Mayer-Rosa and Cadiot (1979)

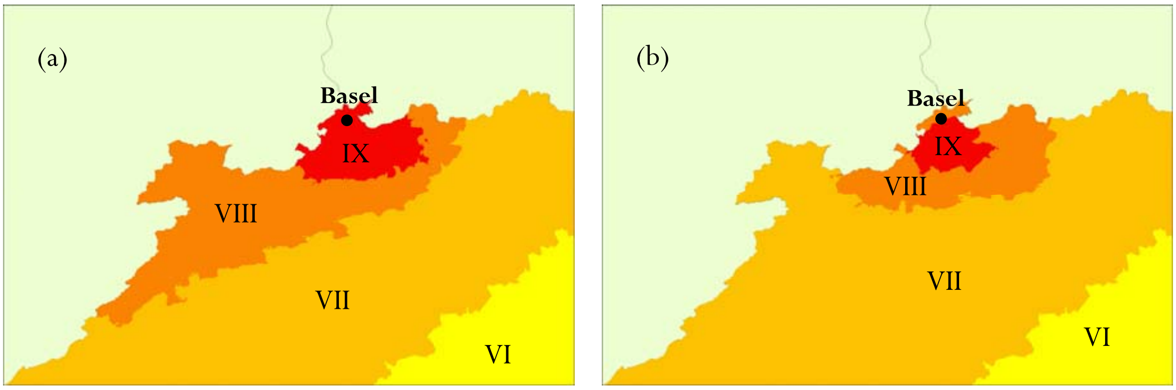

Figure 4: Comparison of intensity distribution of 1356 Basel Earthquake in Switzerland based on (a) Mayer-Rosa and Cadiot (1979) and (b) Lambert et al. (2005)

Locating the source of the 1356 Basel Earthquake has proved a significant challenge. On the basis of the peak intensity observations, the source of the event was most likely located around 10 km (6 mi) to the south of the city. Several authors have proposed sources of this earthquake, ranging from a north-northeast to south-southwest trending normal fault along the Basel-Rheinach scarp that bounds the Rhine Graben to an east-west trending thrust fault beneath the Jura Mountains. It is not clear from the historical record whether or not this event ruptured the surface. However, global studies suggest that an event of this magnitude occurring at a shallow depth would be capable of producing a surface rupture.

Recent palaeoseismological studies propose that the Basel-Rheinach fault is the most likely source of the 1356 earthquake (Figure 5). Meghraoui et al. (2001) demonstrated that at least three earthquakes have occurred in the past 8,500 years on this fault and that the most recent event (constrained to have occurred between 650 and 1475 C.E.) may correspond with the 1356 event. The debate continues and, in the absence of primary evidence, there remains some uncertainty around the exact source of the 1356 event. However, if the Basel-Rheinach fault was responsible for the Basel Earthquake, then a repeat of the 1356 earthquake is estimated to have a recurrence interval of 1,500 to 2,500 years (e.g. Meghraoui et al., 2001).

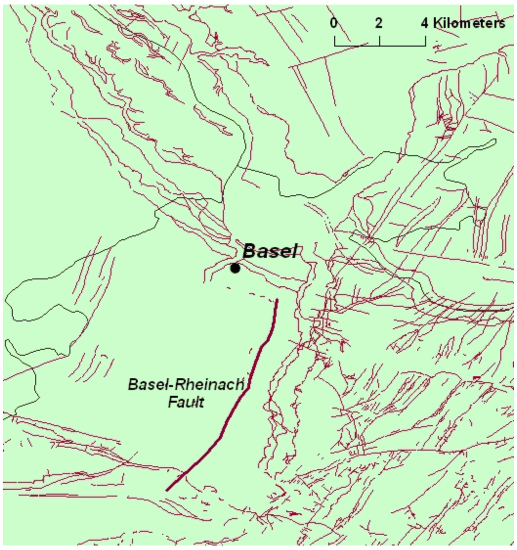

Figure 5: Active and inactive faults in the Basel region, highlighting the Basel-Rheinach fault

The Basel Earthquake in 2006

For the 650th anniversary of the 1356 Basel Earthquake, RMS evaluated the potential impacts of an earthquake of a similar magnitude striking the city of Basel in 2006. The uncertainty in the earthquake's magnitude, as well as the extent of the intensity distribution, presents a challenge for the event reconstruction. Therefore, a series of magnitudes and range of intensity distributions were considered, including those documented in recent publications (Mayer-Rosa and Cadiot, 1979; Meghraoui et al., 2001; and Lambert et al., 2005). It should be noted that the earthquake considered in this study is not the most likely earthquake, but a very infrequent event likely to cause extensive damage.

RMS estimates the value of the building inventory in Switzerland, including structures and their contents, at over CHF 1.8 trillion (US$1.4 trillion) for residential, commercial, and industrial properties. Residential exposures make up the majority of the inventory at risk (Figure 6) with an estimated value of close to CHF 1 trillion (US$0.8 trillion). These inventory estimates are 2006 vintage and are derived from various sources, including the Swiss Federal Statistical Office (SFSO), the Organization for Economic Cooperation and Development (OECD), and the World Bank. The value of the exposure within the peak intensities (i.e., intensity levels VIII and IX) range from 3% to 10% of this total value, depending on the intensity distribution considered.

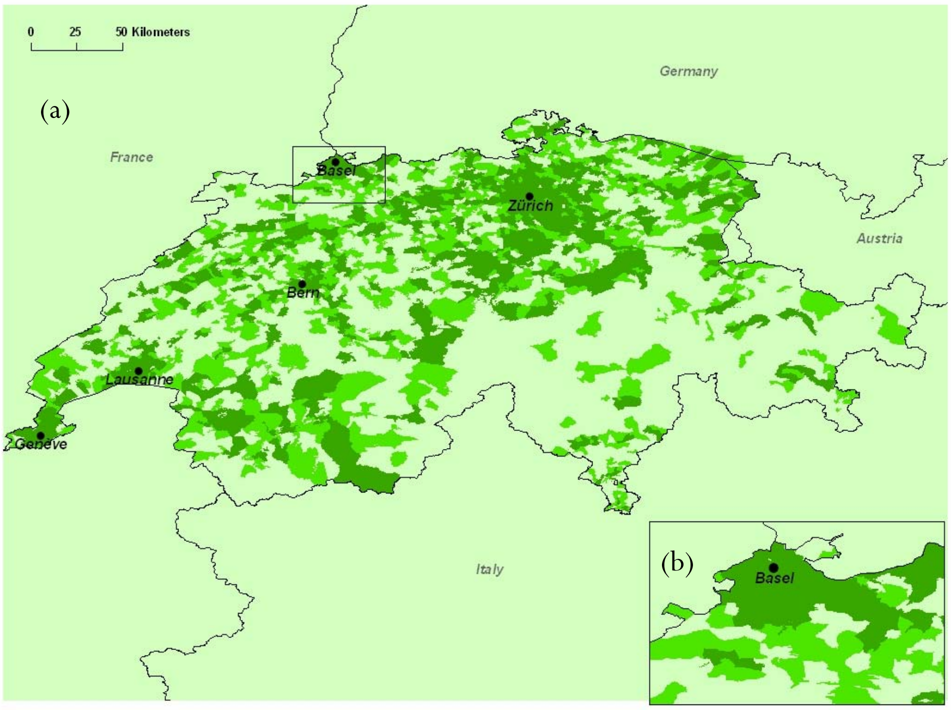

Figure 6: Concentration of residential exposure (a) across Switzerland and (b) a magnified view of the Basel region

The majority of the buildings in Basel that would be most susceptible to damage in a repeat of the 1356 event have been constructed in the past 150 years. The age and height of the buildings in the region are two key parameters in discerning vulnerability to damage. Construction methods vary over time, as different types of construction materials are available or preferred for building and new building codes are enforced. Different types of structures respond to the same earthquake ground motion in different ways. For example, an unreinforced masonry structure is more susceptible to damage than a reinforced concrete structure due to its ability to withstand the lateral load from the earthquake ground motion.

A building's height is an additional important driver of risk, as structures of various heights also respond differently to ground motions. Generally, low-rise structures (less than 3 stories) are stiff buildings damaged in earthquakes with 'high frequency' energy and tall structures (15 or more stories) are flexible buildings damaged in earthquakes with 'low frequency' energy.

Before 1950 in Basel, buildings were low to mid-rise (2 to 5 stories) and constructed using unreinforced brick masonry. Beginning in the 1960s, structures were built slightly higher (up to 7 stories) using reinforced concrete in combination with masonry. For historic buildings constructed in the 19th century, natural stone was used as the building material (Fäh et al., 2001).

Figure 7: The city of Basel in 2006

Based on preliminary RMS research, the most likely range of economic loss to the residential, commercial, and industrial property in Switzerland due to a repeat of the 1356 Basel Earthquake is between CHF 30 and 70 billion (US$ 25 and 55 billion). The release of the RMS® Central Europe Earthquake Model in spring 2007 will provide increased modeling detail and resolution to aid in refining these loss estimates to account for additional factors such as the susceptibility of structures to landslide and liquefaction. Additionally, insured loss estimates accounting for loss amplification will be assessed.

Earthquake Insurance in Switzerland

Earthquake is potentially the most hazardous natural peril to which Switzerland is exposed, although the recurrence interval of a major event is relatively long in comparison with more seismically active parts of Europe, such as Greece or Turkey. The 1356 Basel Earthquake highlights the potential damage that a similar earthquake could cause if it were to recur today. Concern about Switzerland's exposure to earthquake risk has compelled insurers to cover the earthquake peril. A total of 19 of the 26 Swiss cantons have their own insurance institutions known as 'cantonal building insurers' or 'cantonal fire offices.' In 1975, the insurer in Zurich canton began offering earthquake insurance for building damage only, and Zurich remains the only canton where there is a legal obligation to pay claims. In 1979, the remaining 18 cantons agreed to cover earthquake damage to buildings on a voluntary basis, and an earthquake pool was set up to cover potential earthquake losses.

In addition, while earthquake insurance coverage is often excluded from private insurers' standard policies, there is growing demand for this coverage. In 2006, several private insurers offer earthquake cover, particularly for larger insureds. The Swiss Insurance Association (SVV) operates an earthquake fund for these policies, which would pay claims resulting from an earthquake. In recent years, the concern over earthquake exposure has also prompted attempts to include earthquake within the elemental risks pool, the Swiss market pool for windstorm, flood, and other 'elemental' perils (e.g., landslide, avalanche). This has not occurred to date, but current intentions are that earthquake will be included in the elemental pool at some stage, possibly by the beginning of 2008.

As coverage for earthquake exposure expands in Switzerland, there is a growing need to better understand and accurately model earthquake risk. As leaders in our field, RMS remains committed to the continual research and implementation of improved approaches to modeling potential catastrophic losses in Central Europe – including losses from an event on the scale of the 1356 Basel Earthquake.

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