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**Autor:** Gisler, Monika / Fäh, Donat / Deichmann, Nicholas
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# The Valais earthquake of December 9, 1755

MONIKA GISLER, DONAT FÄH & NICHOLAS DEICHMANN

*Key words:* Historical seismicity, macroseismicity, Valais Region, Switzerland, Alps

ABSTRACT

The earthquake on December 9, 1755 is one of the major events in the Valais region, having an important influence on the seismic hazard assessment of the area. The re-evaluation of the event was undertaken in the course of upgrading the Earthquake Catalog of Switzerland (ECOS). It is now based on a newly investigated and reliable database created through research in archives and libraries. Using the data made available by the historical information, we assigned site intensities according to the criteria established by the European macroseismic scale EMS 98 (Grünthal 1998). Based on the broad spectrum of the available information, we assigned minimum and maximum possible values (Imin; Imax) and determined a most probable intensity value (Iw) for each site. The maximum observed intensity, $I_x$, is the largest intensity for each quake. Epicentral intensity, $I_0$, is equal to the maximum observed intensity $I_x$, if at least two data points are assigned an intensity of $I_x$. We obtained maximum $I_x = I_0 = VIII$ at Brig/VS (46.3/8.0) and moment magnitude Mw = 6.1.

ZUSAMMENFASSUNG

Das Erdbeben vom 9. Dezember 1755 ist eines der stärksten Ereignisse des Wallis; es beeinflusst die seismische Gefährdungsanalyse der Region massgeblich. Im Zuge der Überarbeitung des Schweizerischen Erdbebenkatalogs (Earthquake Catalog of Switzerland, ECOS) wurde dieses Ereignis vollständig neu erarbeitet. Das hier vorgelegte Resultat beruht auf Grundlagendaten, die in Archiven und Bibliotheken gesammelt und ausgewertet wurden. Die daraus hervorgegangenen Angaben wurden entlang der Europäischen Makroseismischen Skala von 1998 (EMS 98) (Grünthal 1998) makroseimisch ausgewertet. Da die Bestimmung der Intensitäten jeweils ein breites Spektrums erlaubt, wurde sowohl eine maximale (Imax) als auch eine minimale (Imin) Intensität für jeden Ort bestimmt. Daraus wurde der höchst wahrscheinlichste Intensitäts-Wert (Iw) abgeleitet. Die höchste Intensität eines Bebens wird mit $I_x$ angegeben. Die Epizentralintensität $I_0$ ist gleich $I_x$ wenn mindestens zwei Intensitäten $I_x$ erreichen. Für dieses Beben berechneten wir $I_0 = I_x = VIII$ in Brig/VS (46.3/8.0) und eine Momenten-Magnitude Mw = 6.1.

## Introduction

The Canton Valais is the seismically most active region in Switzerland. The historical record shows that over the last five centuries several earthquakes caused major damage (1524, 1755, 1855 and 1946). The relatively high seismicity level is also seen in the larger number of small earthquakes that have been recorded instrumentally over the last decades compared to other parts of Switzerland (Fig. 1).

The main tectonic feature of the Valais is the Rhone lineament, which separates the Austroalpine and Penninic nappes in the south from the Aar Massif and the Helvetic nappes in the north. In the central part of the Valais, the Rhone fault zone, which in the past accommodated dextral strike-slip movement, coincides closely with the outcrop of the south-dipping Penninic thrust. To the west, the Rhone lineament bends southwestward, separating the Mont Blanc massif from the Aiguilles Rouges massif. In the east, it branches off to the southeast into the Simplon fault zone, which has accommodated orogen parallel extension in early Miocene to Neogene times (e.g. Hubbard & Mancktelow 1992). Judging from the spatial distribution of the recent instrumentally recorded earthquakes, both the Rhone and the Simplon faults seem to be inactive at present (Maurer et al. 1997).

In this paper we present the results of the re-evaluation of the earthquake that occurred in the area of Brig on December 9, 1755. This re-evaluation was undertaken in the course of updating the Earthquake Catalog of Switzerland (Fäh et al. 2003). Revisions of other historical earthquakes in Switzerland, performed in the same context, have been published earlier (Gisler et al. 2003; Schwarz-Zanetti et al. 2003).

The event discussed here took place about one month after the famous Lisbon earthquake, which occurred on November

Swiss Seismological Service, ETH Hönggerberg, 8093 Zurich, Switzerland. E-mail: gisler@sed.ethz.ch

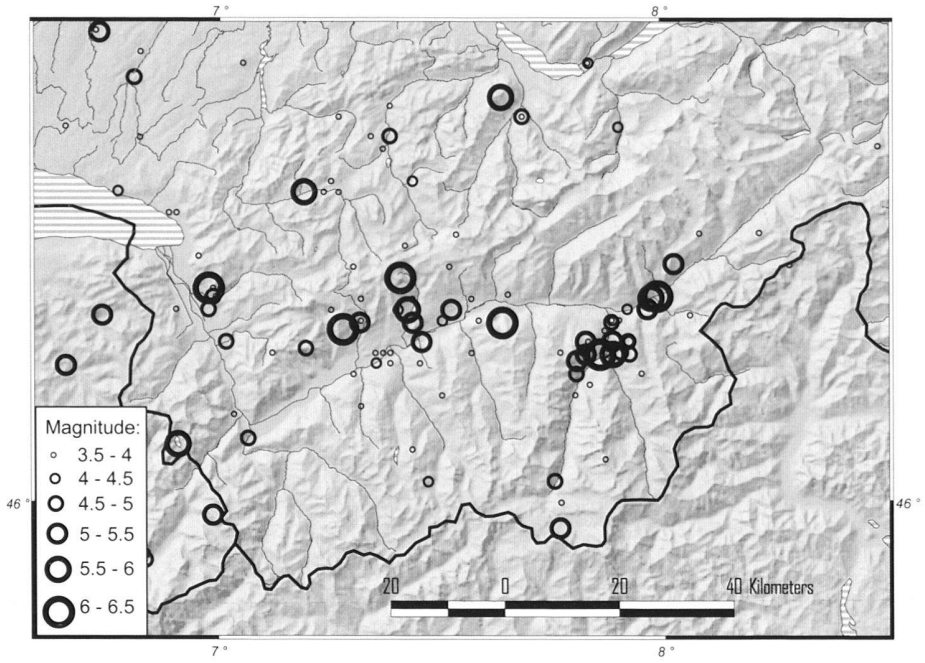



Fig. 1. Map of historical seismicity in the Valais region (years 1000–2002)

1, 1755. This event, with epicenter in the Azores area, destroyed the then famous and flourishing town of Lisbon and was perceived throughout Europe. Consequences of the Lisbon earthquake were observed also in Switzerland, mostly by its effects on lakes and rivers, and knowledge of its occurrence had consequences for the perception and description of the December earthquake near Brig. Contemporaries who experienced or knew of both earthquakes tended to misinterpret or confuse the two events. As a result, it is sometimes impossible to separate them in the literature. Occasionally the Brig earthquake was even interpreted as an aftershock of the Lisbon earthquake. Observers in Switzerland who knew of the Lisbon event were especially sensitive to earthquakes, as is shown in the following quote: "Der schreken beÿ dissem erd=beben war um so vill desto grösser, weilen erst kürzlich die betrübte nachricht eingeloffen, dass den 1. 9$^{bre}$ [i.e. November] die prächtige u. königliche Stadt Lisabona vast gänzlich ruiniert, und sonsten mehrere Stadt so wohl in Portugal als Spanien grossen Schaden durch einen Erdbidem gelitten hätten." [The fright concerning this earthquake was all the more because we recently learned about the destruction of Lisbon and other towns in Portugal and Spain by an earthquake.] (STDBWI Ms fol 132). As a consequence of the increased awareness due to the Lisbon event, the production of documents for this period was unusually large. Even the philosopher Immanuel Kant discussed the event, though based on wrong assumptions (Kant 1985). Several Swiss scientists analyzed the effects and intensities of the Brig event. The cleric Elie Bertrand (1713–1797) investigated the quake thoroughly. He furthermore compiled an early earthquake catalog going back to the year 563 (Bertrand 1756, 1766). Other clerics used the earthquake as a central theme of their sermons, which were printed immediately after the event.

The December event in the Valais is listed in earlier historical earthquake catalogs of Switzerland (Hoff 1840/41; Volger 1857; Früh 1882; Montandon 1942/1943; Sägesser & Mayer-Rosa 1978) as well as in all relevant European earthquake catalogs (e.g. Leydecker 1986; Van Gils & Leydecker 1991; Boschi et al. 1997; Boschi et al. 2000; Bureau de recherches géologiques et minières 2004; Istituto nazionale di geofisica 2004) with epicentral intensity between VIII and IX (MSK 1964) and location near Brig in the Valais. These catalogs usually do not provide background information (origin of historical sources, assessment strategies etc.). Albini et al. (1989) presented a study in which they focus on the process of assessment of the event, based on a database that is mainly taken from earthquake catalogs, but they do not reach any specific conclusions.

The goal of this study was to establish a reliable database for both a historical and a macroseismic interpretation. We searched for documents in archives and libraries that were previously unknown and re-evaluated all available historical sources. All collected documents were analyzed using a formalized procedure based on a historical-critical method concerning function of the document, intention of the production of the record by the author as well as time between the event and its description (Guidoboni 2000; Gisler 2003). Following the historical evaluation, all information was quantified macroseismically based on the European Macroseismic Scale of 1998 (Grünthal 1998). In this context, the term macroseismic intensity or intensity site point corresponds to a classification of the severity of ground shaking based on observed effects in a limit-

ed area. It allows the compression of very inhomogeneous information into a single value. To document the ambiguity and range of the available information, we determined a minimum (Imin) and a maximum possible intensity value (Imax) and then assigned a most probable value (Iw) to each site point (corresponding to a Swiss zip code). Due to the fact that the earthquake was also felt outside the present borders of Switzerland, we also included intensity site points from foreign databases and compilations. This permitted the construction of a broad and self-consistent macroseismic field. In what follows we give a brief description of the effects of the earthquake of December 9, 1755 at selected locations, with examples of contemporary sources, their interpretation and the assessment of intensity site points. The methodology of the parameter assessment is discussed in Fäh et al. (2003) and documented in an internal report that can be downloaded from the web page of the Swiss Seismological Service (http://histserver.ethz.ch/).

## Revision of the event

### *Discussion of sources*

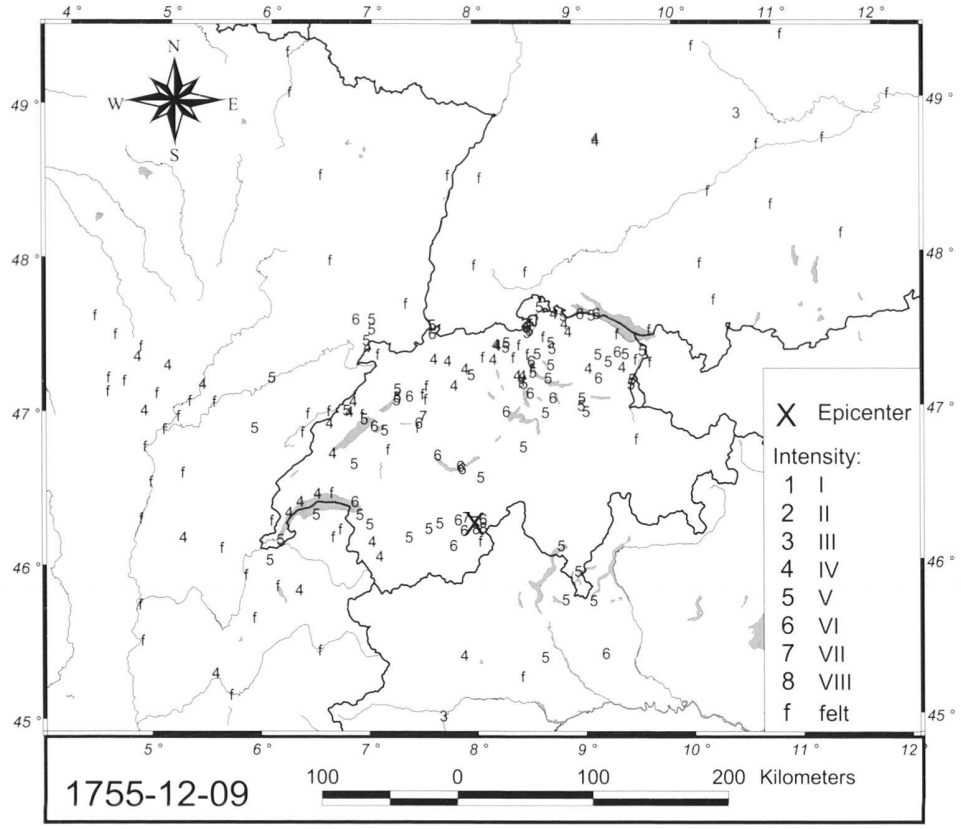
An important evidence for the event on December 9, 1755 is the compilation by the cleric Elie Bertrand who experienced the event in Bern. In order to establish the principle of cause and effect of the quake, Bertrand listed all regions of his knowledge where it occurred (Bertrand 1756, 1766). Thus we have an overview of many locations within Switzerland where the earthquake was perceived, though the information given is rather short and perfunctory. Unfortunately Bertrand does not mention his sources. We therefore tried to complete his records by gathering more information from other documents.

For the Valais area we have several eyewitness records at hand. The provost and archivist of a convent, Joseph-Hilaire Charles (1717–1782), experienced the quake in Brig and noted his observations of damage to churches and houses in his chronicle a few months later (Charles 1954). Another anonymous observation report exists in the form of a chronicle written in February 1756. It is the record of a rector of the Jesuit College in Brig (ACVS AV L 151). The author emphasizes that his writing is a true report of the earthquake ("Relatio vera et Genuina de Terrae motibus ferme Continuis, Brigae in Vallesia exortis"). He even criticizes earlier reports of the event for their exaggeration. The record itself is very helpful, for it gives much detailed information on the earthquake and on aftershocks, listing every single day on which an aftershock occurred. From this same college rector a letter exists in which he informs a friend of the earthquake. This letter was published shortly after the quake, in 1757, in the *Philosophical Transactions* (Anonymus 1756). It then became a basis for later publications, which referred to this letter (e. g. Grenat 1904; Ruppen et al. 1988). In addition there exists another contemporary chronicle for Brig and its surroundings by an anonymous (ACVS AV L 140). Additionally we are in possession of many eyewitness reports from all over Switzerland. Several governors of country estates in the regions of Zurich, St. Gallen and Schaffhausen reported the earthquake to their superiors, listing damage sustained even in regions far from the Valais. An important source for the Zurich region is an article in an early periodical, published once a month in Zurich, which is very reliable regarding information on earthquakes. Over several pages it compiles effects in the Zurich area caused by the earthquake. As a consequence of the event quite a few sermons were published. Though the pastors focus mainly on admonishing the people to behave better, so that God will not punish them again by sending natural catastrophes, we still learn something about the event itself, for example for the Canton of Basel. Furthermore, an interest in meteorological observations was quite common in the 18$^{th}$ century and earthquakes were also mentioned in compilations of climate data. We know of such observations for example for Chur and Basel. In addition we know of a number of chronicles from towns or communities in different parts of Switzerland that mention the event more or less at length. We consider that some chroniclers were in possession of documents that are not known anymore and can no longer be verified. The quality of such chronicles is therefore very uncertain. A few of the chronicles were written shortly after the event whereas others were written only some centuries later. Records from such chronicles have to be interpreted with care and restraint. However, they contribute to an overview of the event. If possible they have to be complemented by other historical documents.

### *Damage distribution*

The main shock occurred on December 9, 1755 between 13.30h and 13.45h (UTC). Some reports say it lasted the length of a *pater noster* (ABKEG Cod. 344) or several minutes (ABKEN no Sign.). More likely it lasted not more than half a minute (Bertrand 1756, 1766; STAZH A 346.6). Figures 2a & 2b show a map of the macroseismic field, including the epicenter of the event. The epicenter area covers the region of Brig and its surroundings. The shock was perceived all over the country and it caused damage even in places far from the epicenter. To the south the shock was perceptible in the Piedmont region, to the north up to Metz and Nuremberg, to the west it affected the region around Dijon, and to the east the Regensburg region. Table 1 lists intensity site points and coordinates.

The macroseismic map (Fig. 2) shows a rather inhomogeneous macroseismic field. As expected, site points in the area close to the epicenter are of high intensity. High intensities are also visible at many site points at greater distances from the epicenter, as for example in the eastern part of Switzerland, whereas other site points relatively close to the epicenter are rather low, as for example in Martigny and St. Maurice in the western part of the Valais. This may be for several reasons, both historical and seismological. First it is the uneven distribution of historical documents that has to be taken into consideration. While we do have a few very detailed



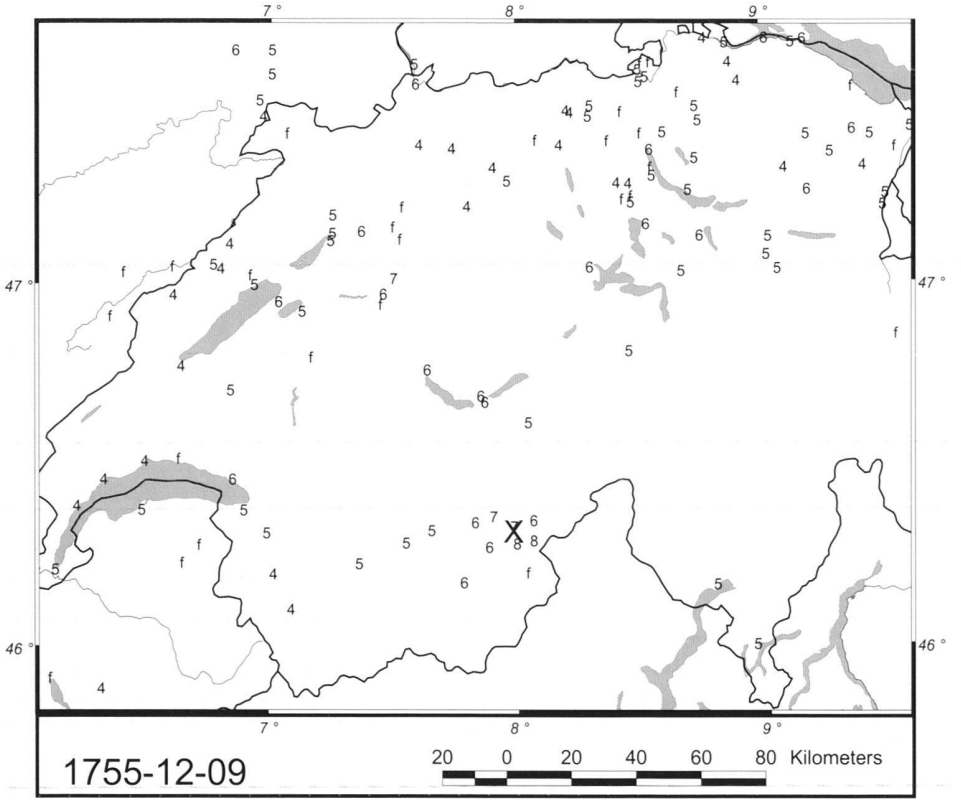




Fig. 2a & 2b. Macroseismic map of the main shock of the December 9, 1755 earthquake

Table 1. Intensity site points for Switzerland of the December 9, 1755 earthquake (for site points outside the country please check http://www.sisfrance.net/sommaire.asp and http://emidius.mi.ingv.it/DOM/consultazione.html)

| Name | lat | lon | Imin | Imax | Iw |
|---|---|---|---|---|---|
| Aarburg | 47.32 | 7.90 | 3 | 5 | 4 |
| Affoltern am Albis | 47.28 | 8.46 | 4 | 5 | 4 |
| Aigle | 46.32 | 6.99 | 4 | 5 | 5 |
| Appenzell | 47.32 | 9.41 | 4 | 5 | 4 |
| Baden | 47.47 | 8.29 | 4 | 5 | 5 |
| Basel | 47.56 | 7.59 | 5 | 6 | 6 |
| Bern | 46.98 | 7.46 | 5 | 7 | 6 |
| Berneck | 47.43 | 9.61 | 5 | 6 | 5 |
| Biel/Bienne | 47.14 | 7.25 | 5 | 6 | 5 |
| Brig | 46.29 | 8.06 | 7 | 8 | 8 |
| Brugg (AG) | 47.48 | 8.20 | 4 | 5 | 4 |
| Cudrefin | 46.95 | 7.03 | 6 | 7 | 6 |
| Diessenhofen | 47.68 | 8.77 | 4 | 5 | 4 |
| Eglisau | 47.57 | 8.53 | 5 | 5 | 5 |
| Einsiedeln | 47.13 | 8.74 | 5 | 6 | 6 |
| Engelberg | 46.82 | 8.45 | 4 | 6 | 5 |
| Flawil | 47.41 | 9.18 | 4 | 5 | 5 |
| Frauenfeld | 47.56 | 8.90 | 4 | 5 | 4 |
| Geneva | 46.21 | 6.14 | 5 | 6 | 5 |
| Glarus | 47.04 | 9.05 | 5 | 6 | 5 |
| Glattfelden | 47.56 | 8.50 | 5 | 6 | 5 |
| Glis | 46.29 | 7.99 | 7 | 8 | 8 |
| Gottlieben | 47.66 | 9.13 | 4 | 6 | 5 |
| Grindelwald | 46.62 | 8.04 | 5 | 6 | 5 |
| Haag (SG) | 47.21 | 9.49 | 4 | 5 | 5 |
| Hüntwangen | 47.59 | 8.50 | 5 | 6 | 5 |
| Hüttwilen | 47.61 | 8.87 | 4 | 5 | 4 |
| Canton Appenzell AR | 47.36 | 9.28 | 4 | 5 | 5 |
| Knonau | 47.23 | 8.46 | 4 | 6 | 5 |
| Constance | 47.67 | 9.18 | 5 | 6 | 6 |
| Krummenau | 47.26 | 9.18 | 6 | 7 | 6 |
| Kyburg | 47.45 | 8.74 | 4 | 5 | 5 |
| La Brevine | 46.97 | 6.60 | 4 | 5 | 4 |
| La Chaux-de-Fonds | 47.11 | 6.83 | 4 | 5 | 4 |
| La Sagne (NE) | 47.05 | 6.80 | 4 | 5 | 4 |
| Langenthal | 47.22 | 7.80 | 4 | 5 | 4 |
| Le Locle | 47.06 | 6.76 | 4 | 5 | 5 |
| Lenzburg | 47.39 | 8.17 | 4 | 5 | 4 |
| Leuk Stadt | 46.32 | 7.65 | 4 | 5 | 5 |
| Lichtensteig | 47.32 | 9.09 | 4 | 5 | 4 |
| Lucens | 46.71 | 6.84 | 5 | 6 | 5 |
| Lucerne | 47.05 | 8.29 | 6 | 6 | 6 |
| Männedorf | 47.26 | 8.70 | 4 | 5 | 5 |
| Martigny | 46.11 | 7.09 | 4 | 5 | 4 |
| Mörel | 46.35 | 8.06 | 5 | 6 | 6 |
| Morges | 46.51 | 6.49 | 4 | 5 | 4 |
| Mund | 46.36 | 7.90 | 7 | 8 | 7 |
| Murten | 46.93 | 7.13 | 5 | 6 | 5 |
| Näfels | 47.08 | 9.01 | 4 | 5 | 5 |
| Naters | 46.33 | 7.98 | 7 | 8 | 7 |
| Neuchâtel | 47.00 | 6.93 | 5 | 6 | 5 |
| Nidau | 47.12 | 7.24 | 5 | 6 | 5 |
| Niederurnen | 47.13 | 9.02 | 5 | 6 | 5 |
| Noville | 46.38 | 6.89 | 4 | 5 | 5 |
| Nyon | 46.39 | 6.23 | 4 | 5 | 4 |
| Ottenbach | 47.28 | 8.41 | 4 | 5 | 4 |
| Raron | 46.35 | 7.83 | 5 | 6 | 6 |
| Rolle | 46.46 | 6.33 | 4 | 5 | 4 |
| Salez | 47.24 | 9.50 | 5 | 6 | 5 |
| Schaffhausen | 47.72 | 8.63 | 4 | 5 | 5 |
| Schönbühl | 47.02 | 7.50 | 6 | 7 | 7 |
| Schwyz | 47.04 | 8.67 | 4 | 5 | 5 |
| Sierre | 46.29 | 7.55 | 4 | 5 | 5 |
| Sion | 46.23 | 7.36 | 4 | 5 | 5 |
| Speicher | 47.41 | 9.44 | 4 | 5 | 5 |
| St. Gallen | 47.42 | 9.37 | 5 | 6 | 6 |
| St. Niklaus (VS) | 46.18 | 7.78 | 5 | 6 | 6 |
| Stein am Rhein | 47.67 | 8.86 | 4 | 6 | 5 |
| St-Maurice | 46.20 | 7.01 | 4 | 5 | 4 |
| Uster | 47.35 | 8.72 | 4 | 5 | 5 |
| Vevey | 46.46 | 6.85 | 5 | 6 | 6 |
| Visp | 46.28 | 7.88 | 6 | 7 | 6 |
| Waldenburg | 47.38 | 7.74 | 4 | 5 | 4 |
| Wallisellen | 47.42 | 8.60 | 4 | 5 | 5 |
| Windisch | 47.48 | 8.22 | 4 | 5 | 4 |
| Winterthur | 47.49 | 8.73 | 5 | 6 | 5 |
| Yverdon-Les-Bains | 46.78 | 6.64 | 4 | 5 | 4 |
| Zofingen | 47.29 | 7.96 | 5 | 5 | 5 |
| Zurich | 47.37 | 8.54 | 5 | 6 | 6 |
| Zug | 47.17 | 8.52 | 5 | 6 | 6 |
| Zullwil | 47.39 | 7.60 | 4 | 5 | 4 |

reports of sites far from the epicenter, a thorough description of effects at several sites in the Valais are lacking, as for example for Sion, Sierre or Leuk. It is acknowledged that in urban centers the production and archival storage of scriptural records was much more common than in rural regions, like the Valais. The result is that quality and quantity of written records vary for different regions. Moreover it was usual that observers focused mainly on important buildings, such as churches, castles etc., due to their importance to the respective communities. As a consequence we have a higher quantity of reports of places that located important buildings, such as the cities of St. Gallen, Basel or Lucerne with its monasteries and large churches, but also Engelberg in Central Switzerland with its important monastery. On the other hand, geological aspects have to be taken into consideration, such as site responses caused by soil conditions. It is well known that in large cities such as Lucerne, Zurich or St. Gallen, where parts of the cities are built on soft soil and parts on rock, seismological ef-

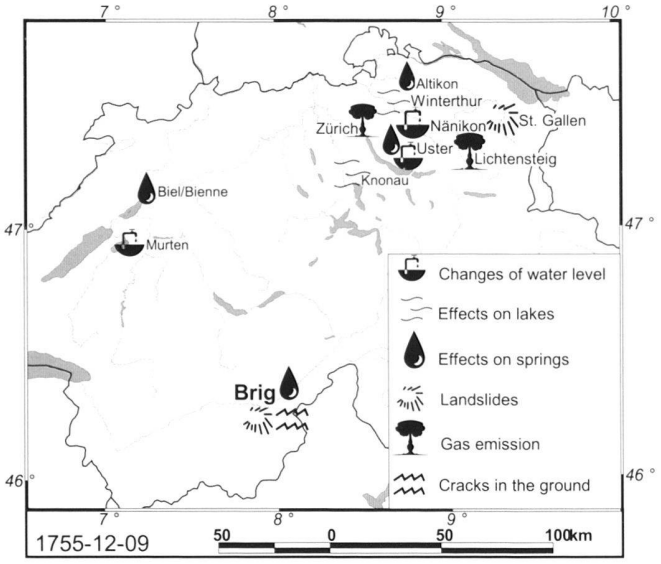



Fig. 3. Map of seismogeological effects of the main shock of the December 9, 1755 earthquake

fects show large variations. This is well documented for the city of Lucerne during the earthquake of 1601 where, due to its marshland subsoil, the so-called little town was much more affected by the quake than the upper town (Schwarz-Zanetti et al. 2003). Yet, the fact that in northern Switzerland intensities are larger than in the east or west of the epicentral area, and that there are many reports of seismogeological effects in this region (changes of water level in streams in the Zurich region, small landslide in St. Gallen; see Fig. 3) leads to the conclusion that the energy radiation at the source was largest to the north. "Pourquoi cette différence dans les effets?" Bertrand already asked, though he was not able to answer the question (Bertrand 1766).

Many records of the earthquake start with reports of rumbling and thunder, followed by a number of shocks in quick succession. The main shock, which caused the most severe damage, was announced by weaker shocks that started an hour in advance. The inhabitants were fortunate to have this warning.

In **Brig** several chimneys collapsed and many buildings sustained cracks in the walls, so that most people ran outdoors. The rector of the Jesuit college reports in a letter to a friend in Geneva: "The earth at first made a great noise, and seemed, as it were, to give a signal for immediately retiring. This was, not long after, followed by repeated, but slight motions. At a quarter after two, the earth was again shaken, and a much louder noise heard: at last, a little before half an hour after two, all Valais seemed upon the point of destruction; for the earth began not only to tremble, but to send forth a horrible noise, and to shake all the buildings with so violent a motion in the space of two *pater nosters*, that the houses inclined on each side alternately, and rocked like a cradle: almost all the chimnies [sic] were thrown down; all the churches suffered very great damage; the towers gaped; a considerable number of walls fell down; and stones of all sizes poured down from all the buildings, so that no house at Brig escaped some injury. It was a singular instance of the goodness of God, that when all the inhabitants fled amidst the dreadful showers of stones falling every where, not one of them was hurt." (Anonymous 1756; see also ACVS AV L 151). And another report adds: "Entstunde den 9 decembris anno 1755 um halber 3 uhr nach mittag ein solches scheuliches und entsezliches Erdbeben ungefehr ein 4tel einer Minuten lang oder zwar noch weniger, das jederman nicht zweiflete die Burgschaft Brig und alle umliegende stein gebäuw im zehnden müssen ohnfehlbarlich über ein hauffen fallen, und unter dem Schutt vergraben werden, welches auch die mehristen gezwungen ihre häuser und wohnungen ein zeitlang vollig zu verlassen, und auf dem freyen feld unter dem himmel ihr Lager aufzuschlagen." [On december 9, 1755 at 14.30h, a disastrous earthquake occurred, lasting less than a quarter of a minute. Everyone expected Brig and all its buildings to collapse. Many people felt impelled to leave their houses and to settle on the fields.] (ACVS AV L 140). Obviously all houses were damaged in some way. Charles (1954) gives precise details, recording that most houses suffered cracks in the walls, depending on the materials of the house. Wooden houses were of course the most stable. Certain houses were uninhabitable for a while. Many chimneys were damaged or toppeled from the roofs. Several churches suffered damage, especially the bell towers (Bertrand 1756, 1766; Gruner 1913). An observer adds that they even fell apart completely (ACVS AV L 140). The *Stockalperpalast* sustained severe damage to the outer walls. Various people escaped to the country and returned to Brig only two days later (Charles 1954). These descriptions refer to very heavy damage to even rather stable buildings such as churches and palaces. Many people ran outdoors, though no panic has been described. We therefore assessed this event as heavily damaging for Brig and assigned Imin=VII, Imax=VIII, Iw=VIII. The rector of the Jesuit College also reports that around Brig cracks and fissures in the ground were observed, as well as springs that started to flow. Furthermore, waves in the ground caused a slight slump of the earth (ACVS AV L 151). Figure 3 shows the distribution of the reported seismogeological effects.

In **Glis**, the village next to Brig, damage was also severe. Observers' reports tell of the church having suffered seriously. Part of the bell tower collapsed and destroyed the arch of the church (ACVS AV L 151; Bertrand 1756, 1766). This damage was so severe that the church could not be used until February of the following year (Wolf 1860). The top level of a house, accommodating a chapel, was also completely destroyed. The rector of the Jesuit College adds that Glis suffered more damage than Brig (ACVS AV L 151). The partial destruction of stable buildings, as churches usually are, implies serious damage to other buildings, even if they are not mentioned in the reports. We therefore assigned Imin=VII, Imax=VIII, Iw=VIII.

Heavy damage was also reported for **Naters**. The arch of the bishop's church collapsed, taking with it two bells and destroying the organ and part of the interior (Bertrand 1756, 1766; Charles 1954; Roten 1991) (Imin=VII, Imax=VIII, Iw=VII). In **Mund** part of the church was damaged. The rafters of the bell tower collapsed and destroyed part of the church (Boccard 1844); (Imin=VII, Imax=VIII, Iw=VII). All observers report unanimously that in **Visp** the earthquake was felt less severely (Bertrand 1756, 1766; Boccard 1844; Charles 1954). Still it is reported that the gallery of the bell tower of the church as well as 14 chimneys collapsed (Courrier 1855); (Imin=VI, Imax=VII, Iw=VI). This underlines the severe destruction in other villages such as Brig, Glis and Naters, where it has been said that damage was serious. In **Mörel** the rectory suffered large cracks in the wall, causing partial collapse of the building (Courrier 1855) (Imin=V, Imax=VI, Iw=VI). For **Raron,** Boccard (1844) reports that the earthquake was somewhat less heavy than in other places, even though the rectory suffered of small damage (Imin=V, Imax=VI, Iw=VI). In **St. Niklaus** part of the chapel collapsed (Courrier 1855); (Imin=V, Imax=VI, Iw=VI). In places in the Valais more distant from the epicenter, such as **Sion**, **Sierre**, **Leuk** and **Simplon village**, the earthquake was broadly observed, though no damage was reported. Thus the earthquake did not affect all of the Valais in the same way.

It becomes obvious from these reports that in most cases major buildings of a settlement, such as rectories, churches or palaces, are mentioned. Hence it is important to be aware that they might not be the only buildings that were destroyed, though others were not worth mentioning.

Although close to the Valais, the French part of Switzerland was not affected as strongly as other regions in Switzerland (Bulletin 1861: 721f.; AEGE Ms. Hist. No 19). The mathematician Trembley, who observed the quake in **Geneva**, wrote to his brother: "There was felt here in all the houses in general a very great shock of an earthquake; but it did no damage. The motion was particularly remarked in looking glasses and windows. Those who were sitting perceived, that their chairs shook; and many thought, that they were going to fall." (Trembley 1756). Furthermore the bells of houses and churches rang. Damaging effects on buildings were not reported (AEGE Ms. Hist. No 19; Journal de Genève 1855); (Imin=V, Imax=VI, Iw=V). In **Neuchâtel** it is said that a stove was split into several pieces (Imin=V, Imax=VI, Iw=V). In **Cudrefin**, at the border of Lake Neuchâtel, a number of chimneys collapsed (De Vautravers 1756); (Imin=VI, Imax=VII, Iw=VI). For **Vevey**, Bertrand (1755, 1756) reports that the shock was perceived mostly on the streets alongside the lake. A few bells rang and inside the houses objects fell down. Moreover, tiles fell from the roofs. On the other hand it is said that a few people working in the fields did not perceive the earthquake at all (Imin=V, Imax=VI, Iw=VI). The french part of Switzerland therefore experienced no serious damage.

On the other hand, **Bern** and its surroundings suffered severe damage. Bertrand, who experienced the event in Bern, was very much impressed by the great intensity of the shaking. He reports of a church bell ringing and of moderate damage at two churches: "La cloche du grand horloge sonna quelques coups, & une pyramide de pierre fut renversée de dessus la grande Eglise. Il se fit deux fontes légères dans l'Eglise Françoise." Thus the bell of a large church rang and tiles fell from the roof of the very same church. The French church suffered of cracks in the wall (Imin=V, Imax=VII, Iw=VI). So did two castles outside of Bern: "Il y a eu quelques Châteaux du Pays, qui ont été un peu plus ébranlés, & où il s'est fait aussi quelques légères fentes, comme à ceux de *Lucens* & de *Nidau*." [Severel castles suffered of cracks in their walls as did the ones of Lucens and Nidau] (Bertrand 1766: 821 f.); (**Lucens** and **Nidau** Imin=V, Imax=VI, Iw=V). In **Schönbühl**, close to Bern, a contemporary reports that two poorly built houses ("schlechte Häuser") collapsed (Gruner 1913); (Imin=VI, Imax=VII, Iw=VII). In **Biel** no damage was reported (Imin=V, Imax=VI, Iw=V).

The earthquake was widely observed in Central Switzerland, too. In Lucerne many buildings suffered cracks in the wall. For the Jesuit church the fall of fairly large pieces of plaster was reported, and a church bell was affected so seriously that it struck (STALU AKT 12/224). These observations have been confirmed by the journal *Monatliche Nachrichten*, which adds that the top of a chimney of the Franciscan monastery collapsed and fell. No other damage was reported (Ziegler 1755; Bertrand 1756, 1766); (Imin=VI, Imax=VI, Iw=VI). In **Zug** several chimneys were damaged and the cross of St. Michaels church was thrown down (Zuger Nachrichten 1911); (Imin=V, Imax=VI, Iw=VI). In **Einsiedeln** people experienced the earthquake so heavily that they expected the church to collapse. In fear they escaped from it. Nevertheless no heavy damage occurred (ABKEN no Sign.); (Imin=V, Imax=VI, Iw=VI). Due to the experiences of the earthquake the clerics of Einsiedeln and Zug arranged a day of repentance, to apologize and to avert further danger (STASZ PA 9 Bd. III; STAZG BÜA Zug A 1/32). In **Engelberg** it was reported that the earthquake was perceived, though no damage was observed (ABKEG Cod. 344); (Imin=IV, Imax=VI, Iw=V).

A good number of reports mention the earthquake in **Zurich**. Observers tell of the fear of many people, some of whom lost their balance while walking. The buildings must have shaken so strongly that it was feared they were going to collapse. Tiles fell from the roofs of houses and the tops of some chimneys collapsed. From a high steeple one chimney fell into pieces. Furthermore several church bells rang (Ziegler 1755; Werdmüller 1780); (Imin=V, Imax=VI, Iw=VI). The surroundings of Zurich were also affected. Observers from several different places alongside the lake and in the northern part of the Canton report a generally felt earthquake, though no damage was observed (STAZH E III 62.3; STAZH E III 71.3).

To the east of Switzerland and in the Lake Constance region the earthquake was also widely felt. In particular the cities of St. Gallen and Constance reported damage. In **St. Gallen** two chimneys collapsed (Imin=V, Imax=VI, Iw=VI), in **Con-**

Table 2. Aftershocks of the December 9, 1755 earthquake (hours given in UTC)

| year | mt | day | h | m | lat | lon | Mw | Io | Ix | Ax |
|---|---|---|---|---|---|---|---|---|---|---|
| 1755 | 12 | 21 | 3 | 30 | 46.29 | 8.06 | 3.9 | 50 | 60 | Brig/VS |
| 1755 | 12 | 27 | 13 | 30 | 46.29 | 8.06 | 3.2 | 40 | 50 | Brig/VS |
| 1755 | 12 | 27 | 19 | | 46.32 | 6.99 | 3.9 | 50 | 50 | Aigle/VD |
| 1755 | 12 | 28 | 5 | 0 | 46.29 | 8.06 | 1.7 | 20 | 30 | Brig/VS |
| 1755 | 12 | 30 | | | 46.29 | 8.06 | 3.2 | 40 | 50 | Brig/VS |
| 1756 | 1 | 2 | 20 | 30 | 46.29 | 8.06 | 2.4 | 30 | 30 | Brig/VS |
| 1756 | 1 | 3 | 9 | | 46.29 | 8.06 | 2.4 | 30 | 40 | Brig/VS |
| 1756 | 1 | 6 | 19 | | 46.29 | 8.06 | 3.2 | 40 | 50 | Brig/VS |
| 1756 | 1 | 7 | 16 | | 46.29 | 8.06 | 1.7 | 20 | 30 | Brig/VS |
| 1756 | 1 | 8 | 18 | 30 | 46.29 | 8.06 | 1.7 | 20 | 30 | Brig/VS |
| 1756 | 1 | 11 | | | 46.29 | 8.06 | 1.7 | 20 | 30 | Brig/VS |
| 1756 | 1 | 12 | | | 46.29 | 8.06 | 1.7 | 20 | 30 | Brig/VS |
| 1756 | 1 | 13 | | | 46.29 | 8.06 | 1.7 | 20 | 30 | Brig/VS |
| 1756 | 1 | 14 | 1 | 30 | 46.29 | 8.06 | 3.2 | 40 | 50 | Brig/VS |
| 1756 | 1 | 15 | 4 | 30 | 46.29 | 8.06 | 3.2 | 40 | 50 | Brig/VS |
| 1756 | 1 | 18 | 23 | | 46.29 | 8.06 | 2.4 | 30 | 40 | Brig/VS |
| 1756 | 1 | 18 | 23 | 45 | 46.29 | 8.06 | 2.4 | 30 | 40 | Brig/VS |
| 1756 | 1 | 20 | 10 | | 46.29 | 8.06 | 2.4 | 30 | 40 | Brig/VS |
| 1756 | 1 | 22 | 22 | | 46.29 | 8.06 | 3.2 | 40 | 50 | Brig/VS |
| 1756 | 1 | 23 | | | 46.29 | 8.06 | 2.4 | 30 | 40 | Brig/VS |
| 1756 | 1 | 24 | | | 46.29 | 8.06 | 1.7 | 20 | 30 | Brig/VS |
| 1756 | 1 | 25 | | | 46.29 | 8.06 | 1.7 | 20 | 30 | Brig/VS |
| 1756 | 1 | 26 | 22 | | 46.29 | 8.06 | 3.2 | 40 | 40 | Brig/VS |
| 1756 | 1 | 27 | | | 46.29 | 8.06 | 3.2 | 40 | 50 | Brig/VS |
| 1756 | 2 | | | | 46.29 | 8.06 | 2.4 | 30 | 40 | Brig/VS |
| 1756 | 2 | 6 | 5 | | 46.33 | 7.98 | 2.4 | 30 | 40 | Brig/VS |
| 1756 | 2 | 15 | 1 | 30 | 46.33 | 8.00 | 2.4 | 30 | 40 | Brig VS |
| 1756 | 2 | 15 | 4 | 30 | 46.33 | 8.02 | 2.4 | 30 | 40 | Brig/VS |
| 1756 | 2 | 18 | 0 | 30 | 46.29 | 8.06 | 2.4 | 30 | 40 | Brig/VS |
| 1756 | 2 | 18 | 6 | 30 | 46.29 | 8.06 | 2.4 | 30 | 30 | Brig/VS |
| 1756 | 2 | 19 | 10 | 30 | 46.3 | 8.20 | 3.2 | 40 | 50 | Brig/VS |
| 1756 | 2 | 23 | | | 46.29 | 8.06 | 1.7 | 20 | 30 | Brig/VS |
| 1756 | 2 | 26 | 0 | 30 | 46.29 | 8.06 | 1.7 | 20 | 30 | Brig/VS |

**stance** several bells rang and tiles fell from roofs (SDTAKO no Sign.) (Imin=V, Imax=VI, Iw=VI). No damage was reported for the localities in the surroundings of these two cities and for the **Appenzellerland**. Still, the earthquake was largely observed here, for in a few houses furniture and objects shook unmistakably (STAAR Mg 26/2, Ms 18; Walser 1829); (Imin=IV, Imax=V, Iw=V). In the Rhine Valley, the earthquake was observed in several communities, mainly by the shaking of hanging objects. (STAZH A 346.6); (Salez Imin=V, Imax=VI, Iw=V; **Haag** Imin=IV, Imax=V, Iw=V). In **Krummenau**, a village at the border of the two cantons St. Gallen and Glarus, a later chronicle reports of several chimneys that collapsed (Rothenflue 1887); (Imin=VI, Imax=VII, Iw=VI). In **Glarus** (Imin=V, Imax=VI, Iw=V) as well as **Näfels** (Imin=IV, Imax=V, Iw=V) the event was generally observed but no damage was reported (LAGL no Sign.; Bertrand 1755, 1756; Trümpi 1774).

Concerning the northern part of Switzerland, the event was perceived in **Schaffhausen**, where it caused much alarm, some people experienced a disturbance of equilibrium but no damage was reported (Ziegler 1755); (Imin=IV, Imax=V, Iw=V). In **Stein am Rhein** a governor reported to his superiors that he observed the event by a violent shaking of kitchen furnishings and other objects (STAZH A 146.14). Still no damage occurred (Imin=IV, Imax=VI, Iw=V). For **Basel** we have contradictory remarks. The journal *Monatliche Nachrichten* of December 1755 (Ziegler 1755) reports heavy shaking of buildings and frightened people, but emphasizes that no damage was observed. On the other hand both Bertrand (1756, 1766) and a resident priest, Buxtorf (1755), tell of chimneys that collapsed and houses that were damaged (Imin=V, Imax=VI, Iw=VI). This is an example of wide range of observations that is the basis for a simple intensity value. It gives a good idea of the difficulties one encounters when assessing intensity site points.

Of the cantons of Graubünden and the Ticino we know but little. Lambert, a naturalist, mentions **Chur** in his meteorological observations but with no further information on the intensity (Lambert 1758). Thus we assume that in both regions the earthquake was observed even though no damage occurred.

### *Epicentral intensity, magnitude and location*

For all earthquakes with a sufficient number and distribution of intensity site points in the revised Earthquake Catalog of Switzerland (ECOS), source parameters (epicenter, hypocentral depth class, epicentral intensity, maximum intensity, macroseismic magnitude) and the respective uncertainties were derived using a regression scheme that accounts for regionalized intensity attenuation and hypocentral depth. We adopted moment magnitude $M_W$ to quantify earthquake size, because $M_W$ is directly related to a physical measure of the earthquake source (Fäh et al. 2003). Following Gasperini et al. (1999) the epicentral intensity, $I_0$, is equal to the maximum observed intensity, $I_x$, if at least two data points have been assigned an intensity of $I_x$; otherwise, $I_0$ is set equal to the second highest observed value. For the earthquake of December 9, 1755, $I_0 = I_x$ = VIII. Based on the evaluation of the resulting macroseismic field out to 200 km, the epicenter is near the town of Brig (46.3N/8.0E) with an estimated uncertainty of < 20 km (see Figs. 2a & 2b) and the moment magnitude is estimated as Mw=6.1 with an uncertainty of ≤ 0.5.

### *Aftershocks*

The main shock was followed by numerous aftershocks, though they were much weaker and were reported mainly for Brig. Several reports mention that no day passed without a slight shock or trembling. The rector of the Jesuit College (ACVS AV L 151) gives a general overview of aftershocks by listing them for every day (see Tab. 2; hours given in UTC). According to this list, the shaking was perceived daily between December 9 and 21. As site intensity is usually given for Brig only, maximum observed intensity, $I_X$, is set as largest intensity for each quake.

On December 21, 1755 at 3.30h in the morning, a rather strong shock occurred. In Brig tiles fell from the roofs and

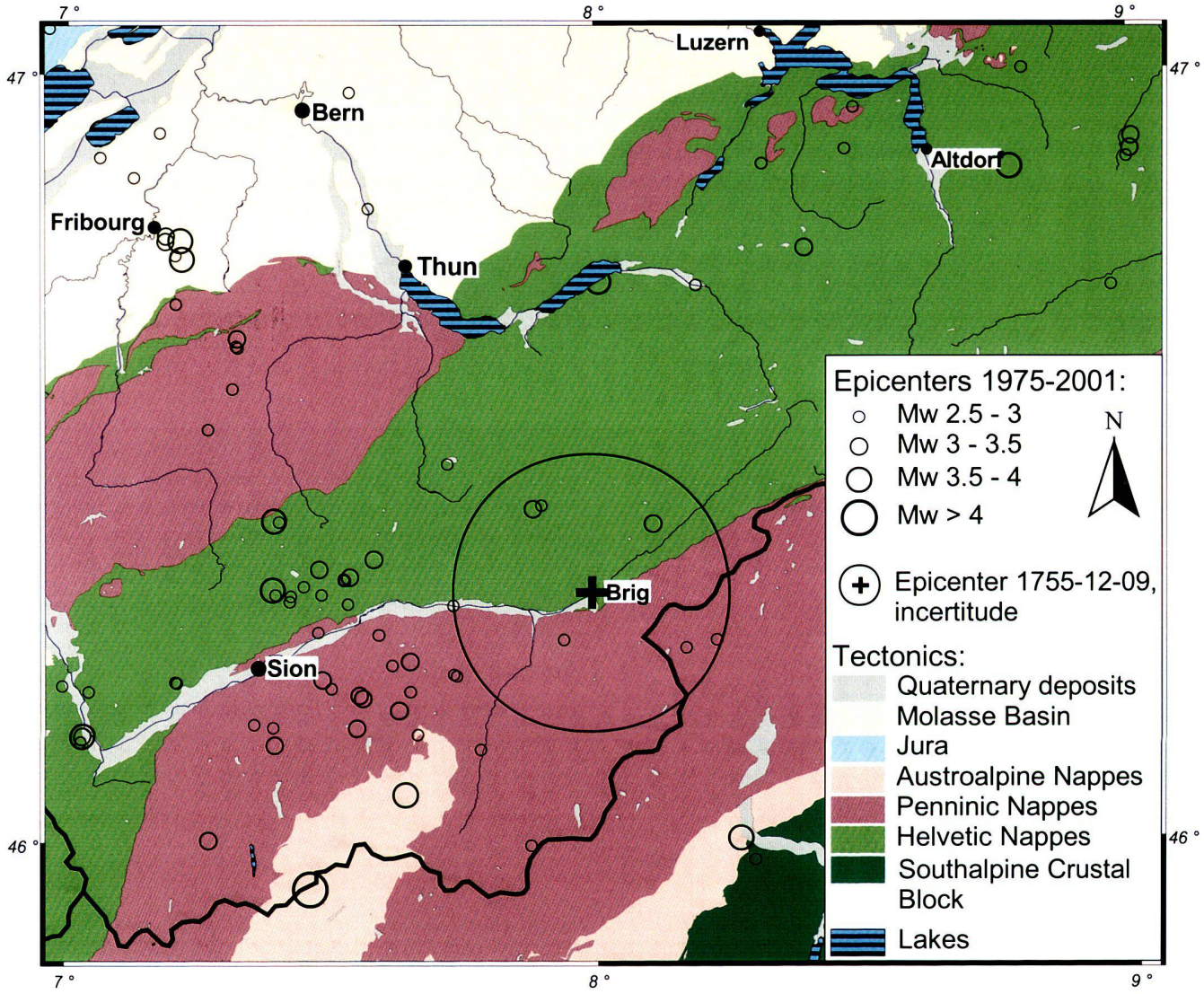



Fig. 4. Tectonic map with recent seismicity (1975–2001) in the Valais region

walls of some houses were damaged (ACVS AV L 151) (Maximum Intensity $I_x$=VI). Shocks occurred daily between December 21 and 27. On December 27, 1755 at 13.30h, Brig was heavily shaken so that people compared it with the quake of December 9, 1755 (ACVS AV L 151). According to Bertrand (1756, 1766) the shock was also felt in other parts of Switzerland, as well as in France and Italy. No more precise details are given ($I_x$=VI). On the same day, at 19h, a shock occurred near Aigle/VD (Bertrand 1756, 1766) ($I_x$=V).

More rather strong shocks occurred in Brig on December 30, 1755 ($I_x$=V), January 6, 1756 ($I_X$=V), January 14, 1756 with little damage ($I_x$=V), and on January 15, 1756 when some books fell from shelves ($I_x$=V). On January 22, 1756 people at Brig where again reminded of December 9, 1755, due to two strong shocks that were felt strongly, but caused little damage (ACVS AV L 151) ($I_x$=V). On January 26, 1756, a shock was largely felt in several places ($I_x$=IV) and on January 27, 1756, as well as on February 19, 1756, some tiles fell from the roofs ($I_x$=V). All other aftershocks during this period were also clearly observed, though they were of short duration and did not cause any damage. Overall, the sequence of felt aftershocks of the December 9, 1755 earthquake is documented to have lasted at least until February 26, 1756 (ACVS AV L 151; Anonymous 1756; Bertrand 1756, 1766; Grenat 1904).

## Discussion

The event of December 9, 1755 ranks among the most heavily damaging earthquakes in the Valais region. The epicentral region around Brig sustained severe damage by the quake. Dam-

age was reported in places as far as 400 km from the epicenter and the shaking was felt also beyond the Swiss borders, in northern Italy, southern Germany and France. The fact that in northern Switzerland intensities are larger than in the east or west of the epicentral area and that there are many reports of seismogeological effects in this region leads to the conclusion that the energy radiation of the source was strong to the north. The estimated epicentral intensity ($I_0$) is VIII. When comparing it to former studies (Swiss Seismological Service 1999), the intensity value did not change in the course of the revision of the event. Main result of the re-evaluation is an enlarged and homogeneous database that allows to draw a macroseismic field (Figs. 2a & 2b) and to estimate the magnitude.

Figure 4 shows the location of the 1755 event of Brig on a tectonic map of southwestern Switzerland together with the epicenters of the instrumentally recorded earthquakes since 1975. From this map it is clear that the recent instrumental seismicity is concentrated mainly in the helvetic domain of the Lower Valais north of Sion, while the Upper Valais and in particular the region of Brig has been relatively quiet. However, to conclude from this that there has been a systematic migration of seismic activity from the Upper to the Lower Valais over the last 300 years would be wrong. In fact, the historical record shows that earthquakes with intensities greater than VI have occurred in the Lower Valais also in the 18th and 19th century and that the area around Brig has sustained intensity VII – VIII earthquakes as recently as 1924 and 1960 (Swiss Seismological Service 2002, Fäh et al. 2003). The apparent concentration of the instrumental seismicity north of Sion most likely corresponds to a long-lasting activity in the aftermath of the intensity VIII events of 1946. In fact the location of these earthquakes coincides with the area associated with most of the aftershocks of 1946 (Wanner 1955) and the hypocenters of the events with well-constrained locations define a nearly vertical ENE-WSW striking fault (Maurer 1993; Pavoni et al. 1997). Focal depths of earthquakes beneath the Swiss Alps determined routinely by the Swiss Seismological Service are generally limited to the upper 15 km of the crust (e.g. Deichmann et al. 2000). More precise earthquake relocations with a simultaneous inversion for seismic velocities in the Valais (Maurer & Kradolfer 1996) confirm this observation.

Overall, the instrumentally determined epicenters show that, at least over the last 20–30 years, the earthquake activity occurs mainly beneath the mountainous flanks north and south of the Rhone Valley, while the valley itself is largely aseismic. Nevertheless, the Rhone Valley seems to act as a boundary or transition between two quite different seismotectonic provinces, as is apparent both from the spatial hypocenter distribution and from the different focal mechanisms. In fact, compilations of fault-plane solutions show that strike-slip mechanisms predominate in the Helvetic domain, whereas normal faulting predominates in the Penninic domain to the south (Maurer et al. 1997, Pavoni et al. 1997, Eva et al. 1998). Moreover, a recently completed systematic analysis of the strain and stress fields derived from focal mechanism data across all of Switzerland (Kastrup 2003, Kastrup et al. 2004) shows that the change from a strike-slip to an extensional regime across the Rhone Valley is accompanied by a significant rotation of the stress field. This rotation can be explained by the superposition of a large-scale regional stress and a uniaxial tension that is perpendicular to the strike of the Alpine belt. Whereas the regional stress on a Central European scale is caused by the ongoing convergence of Africa and Europe, the local tensional stress is thought to be induced by gravitational spreading associated with lateral density changes due to the existence of a crustal root beneath the orogen (Kastrup et al. 2004; Delacou et al. in press). However, given the general lack of instrumentally recorded seismicity and thus only few available focal mechanisms in the Upper Valais, it is impossible to even speculate about the nature of the stress field that is actually responsible for the earthquakes in the region of Brig. The proximity of the most probable epicenter of the earthquake of 1755 with the Simplon fault suggests the latter as a possible source for this event. However, there is no other independent evidence that this fault is active at present or has been active recently, so that a causal relation between the two is purely speculative.

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