Two significant earthquakes in the Rhine Valley at the end of the 18th century : the events of December 6, 1795 and April 20, 1796

Autor(en): **Gisler, Monika / Fäh, Donat / Schibler, Reto**

Objekttyp: **Article**

Zeitschrift: **Eclogae Geologicae Helvetiae**

Band (Jahr): **96 (2003)**

Heft 3

PDF erstellt am: **22.07.2024**

Persistenter Link: https://doi.org/10.5169/seals-169026

0012-9402/03/030357-10
DOI 10.1007/s00015-003-1095-0
Birkhäuser Verlag, Basel, 2003

Eclogae geol. Helv. 96 (2003) 357–366

Two significant earthquakes in the Rhine Valley at the end of the 18th century: The events of December 6, 1795 and April 20, 1796

MONIKA GISLER, DONAT FÄH & RETO SCHIBLER

Key words: Historical earthquake, Macroseismicity, Region of Rhine Valley, Switzerland

ABSTRACT

The reassessment of the 1795 and 1796 earthquakes is part of the upgrade of the Earthquake Catalogue of Switzerland (ECOS). It is of major importance with respect to both history and seismology. Although the events have been the subject of a large number of publications, none of these studies was based on critical methods. The re-evaluation of the events rests on a new, reliable database established through investigations in archives and libraries. Using the data made available by the historical information, we assigned site intensities, adopting the criteria established by the European Macroseismic Scale EMS 98 (Grünthal 1998). Considering the broad spectrum of the given information, we assigned the minimum and maximum possible values (Imin; Imax) and set a most probably intensity value (Iw).

The results show that previously the intensity of the 1796 event was overestimated due to a misinterpretation of the written records. We therefore recommend a reduction of the epicentral intensity to Io = VII and a moment magnitude of Mw = 5.3. Also for the 1795 earthquake we recommend Io = VII and Mw = 5.3. Although the estimate of the strength of the 1796 event has to be reduced on the basis of our re-evalution, these two earthquakes are still significant for the region, and our results will have an impact on the seismic hazard assessment of the area.

ZUSAMMENFASSUNG

Die Evaluierung der zwei Erdbeben von 1795 und 1796 im St. Galler Rheintal (CH) ist Teil einer umfassenden Überarbeitung des Schweizerischen Erdbeben-Katalogs (ECOS). Die Neu-Beurteilung ist in historischer als auch seismologischer Hinsicht relevant, denn die Ereignisse wurden bisher nie vor dem Hintergrund kritischer historischer Methoden ausgewertet. Auf Grund der Recherche und Interpretation historischer Quellen konnte eine umfassende Datenbasis geschaffen werden. Darauf aufbauend wurde die makroseismische Auswertung vorgenommen; die makroseismischen Daten wurden entlang der Europäischen Makroseismischen Skala (EMS 98) erstellt (Grünthal 1998).

Es wird im Folgenden gezeigt, dass die Intensität des Ereignisses von 1796 aufgrund einer Fehlinterpretation der vorhandenen historischen Daten zu hoch eingeschätzt wurde. Wir schlagen deshalb eine Reduktion der Epizentral-Intensität auf Io = VII und der Momenten-Magnitude auf Mw = 5.3 vor. Für das Erdbeben von 1795 bestimmten wir Io = VII und Mw = 5.3. Die zwei Ereignisse waren also gleich stark. Sie bilden weiterhin einen relevanten Faktor für die probabilistische Gefährdungsanalyse der Region St. Galler Rheintal.

Introduction

On December 6, 1795 and April 20, 1796, two earthquakes caused damage in the eastern part of Switzerland, the Rhine Valley, a region known to be seismically active. In the Swiss catalogue, established in 1977 (Saegesser & Mayer-Rosa 1977) and published after some revisions in 1999 (Schweizerischer Erdbebendienst 1999), the epicenter of the December 6, 1795 earthquake is localized in Wildhaus/SG with intensity VII, that of April 20, 1796 in Grabs/SG, with intensity VIII to IX. The latter was thus one of the most damaging earthquakes within Switzerland. However, as will be shown, the intensity of this event was overestimated due to a misinterpretation of damage caused by a fire and not the earthquake itself.

In several catalogues, such as MECOS (Schweizerischer Erdbebendienst 1999), van Gils & Leydecker (1991) and Brügger (1888), there exists a third event on November 25, 1795 in Glarus, with intensity V. This event has been identified as a fake due to a dating error. At that time, two different calendars existed in parallel and both were in use.[1] The event has been recorded either under the Julian or the Gregorian calendar, so in consequence two different dates exist.

During the reassessment it became obvious that the event on December 6, 1795 (Gregorian calendar) is the correct

[1] During the Middle Ages and early modern times, several calendars existed in parallel. Between the 4th and the 15th of October 1582, Pope Gregory corrected the difference between the astronomical year and the Julian calendar. This new version is called the Gregorian or New Style calendar. Officially, the first Catholic cantons in Switzerland changed to the Gregorian calendar in January 1584. Others followed in several steps. However, the calendar used privately was often different from that used officially. Thus, the calendar is the reason for many event duplications during this period. See Grotefend[13] 1991.

Swiss Seismological Service, ETH Hönggerberg, 8093 Zürich, Switzerland. E-mail: gisler@seismo.ifg.ethz.ch

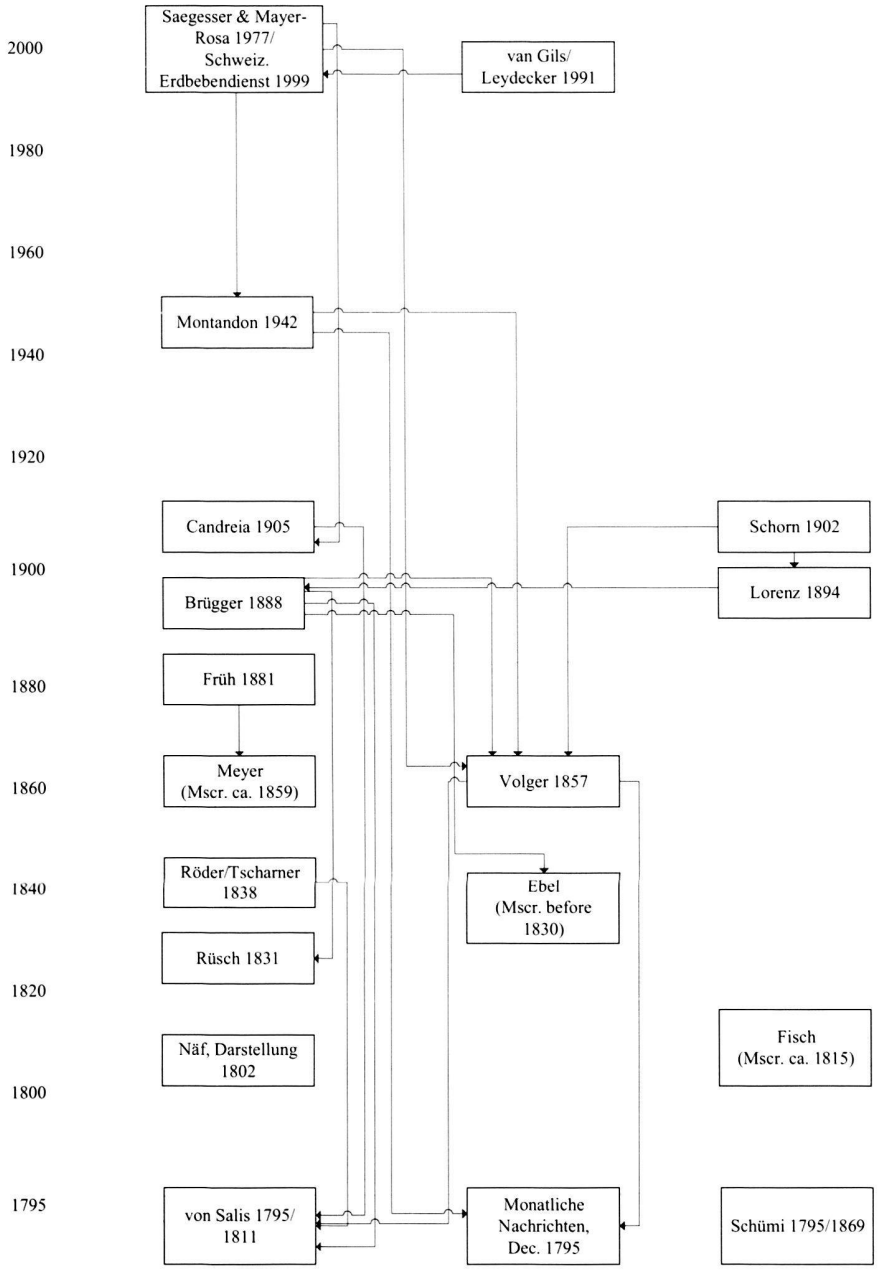

Fig. 1. Genealogical tree of the December 9, 1795 earthquake. The tree shows the dependency of the compilations starting in present time and going back to contemporary sources of the event. If you follow the lines, you get an idea on who cited whom and what problems occurred, when someone made an error.

event, while that on November 25, 1795 is a fake. It was taken by Volger (1857) from the journal *Monatliche Nachrichten* and has been recorded subsequently by several catalogues.

Corrections have therefore been made in regard to both the number of events as well as their intensity.

A number of early publications (von Hoff 1840/41; Volger 1857; Schorn 1902; Sieberg 1940 and Montandon 1942/1943) have studied either one or both events. However, these compilations must now be regarded as uncritical studies and it has to be stated that the events have not been analyzed using critical methods yet.

The issue of uncritical review of the literary tradition of an event has been brought into discussion by various authors (Vogt 1979; Alexandre 1990, 1994). Despite recent advances in the field of historical seismicity, many national and international earthquake catalogues are still based on unscreened compilations. It has been stressed several times in the literature that contemporary sources are to be preferred for historical seismology (Stucchi et al. 1991; Guidoboni & Stucchi 1993). Ambraseys et al. (1994), in their book on seismicity in Egypt, made it a general principle that no earthquake that had not been confirmed or verified in a primary source would be

included in the list of earthquakes. Alexandre proposed ignoring all compilations, convinced that they are of no use (Alexandre 1990: 5). He suggests instead that earthquake catalogues should be recompiled from a thorough research of contemporary documents, investigated in archives and libraries and based on the rules of historical criticism (Alexandre 1994: 431). However – as Ambraseys has pointed out – ignoring earthquake compilations entails the risk that later compilers simply reinstate the ignored events (Ambraseys 1994: xii). Others (Albini et al. 1996; Guidoboni & Stucchi 1993) suggest that results achieved by previous researchers should be taken into consideration after a critical review of data sets, thus making use of their seismological information. However the need for an investigation and critical interpretation of contemporary sources and the work with primary data is significant.

At the start of each chapter, the historiographic tradition of each event will be presented. It has been recommended in the literature to create *genealogical trees* in order to better understand such historiographic traditions (Albini et al. 1989; Eisinger et al. 1992). The designing of a genealogical tree enables to demonstrate how the compilations mentioning an earthquake depend on each other and on what database they rely upon (Fig. 1; Fig. 3). Earthquake compilations can then be compared to contemporary sources. Thus potential recording errors in regard to dates, places and information can be shown.

After a critical consultation of the contemporary documents available, the re-evaluation of the event will be presented by discussing each site. The contemporary sources investigated and the reflections that led to the intensity assignment will be described. The paper emphasizes the need of a critical review of historical documents and of a critical historical seismology.

Using the data made available from historical information, we assigned site intensities, adopting the criteria established by the European Macroseismic Scale EMS 98 (Grünthal 1998). Assessing strategies are far from standardized. The information given is seldom well defined, more often it allows a range of interpretation. Considering this spectrum we assigned the minimum (Imin) and maximum (Imax) possible values, and set a most probable intensity value (Iw).

The reassessment of the two earthquakes presented in this paper is part of the upgrade of the Earthquake Catalogue of Switzerland (ECOS), which will serve as an input for seismic hazard assessment for Switzerland and neighboring regions (http://www.seismo.ethz.ch/).

Even though the two earthquakes in the same area on December 6, 1795 and April 20, 1796 were not as strong as they have been assumed to be up to now, they were very intense for those who experienced them. People in the Rhine Valley became seriously frightened after the second one. Some of them believed in consequence that God was punishing them; others feared that the quakes were omens of more catastrophes to come, like war, starvation and the Black Death (Monatliche Nachrichten, May 1796).

The earthquake of December 6, 1795

Reassessment of the event

Figure 1 shows the interdependence of the compilations and their relation to contemporary sources. Several compilations quote a document of a landlord, J. R. von Salis of Marschlins, a collection of meteorological data started in 1783, where entries of earthquakes are rather haphazard (von Salis 1811). The record gives no more information than the fact that the event occurred in the Chur area. Another contemporary document is a Zurich journal. The paper is an early periodical, published once a month in Zurich by J. J. Ziegler and very reliable regarding information on earthquakes. In this case it contains two entries, one giving the date in the Julian style (November 25, 1795) and mentioning an earthquake in the canton of Glarus, the other giving the date in the Gregorian style (December 6, 1795), and giving information on several locations in the Rhine Valley. The indication that these two entries both belong to the same event is given first by the time of day – both records assert the same hour for the occurrence of the event – and second by the knowledge that the Glarus region made use of both calendar styles. Volger obviously was not aware of this fact and mentioned two events in his compilation. Brügger (1888), MECOS (Schweizerischer Erdbebendienst 1999) and van Gils & Leydecker (1991) took over the fake from Volger. Thus the entry for November 25, 1795 has to be stated as a fake.

In addition to the above-mentioned documents we enclosed a family diary, written in Latin and German in 1795 and published in 1869 (Senn 1869), and a handwritten chronicle of the Appenzellerland, compiled circa 1815 by J. Fisch. Chronicles very often summarize older texts that can no longer be identified. The fact that the database for this event is rather small can be explained by the political situation. France and Austria were at war at that time, Switzerland was quite concerned about the situation for several reasons (geographic and political). Coverage was therefore focused on events connected to the war and it is supposed that earthquakes were not that important during this period.

Damage distribution

The main shock occurred on December 6, 1795 (Gregorian calendar) between 1 and 2 a.m. Some records report a second shock that occurred only shortly after (Senn 1869, Fisch ca. 1815).

A map of the epicentral region with all available intensity site points is given in figure 2. The epicenter area covers the region of the Rhine Valley. To the south the shock was perceptible in the area of Landquart, to the north it affected Appenzellerland.

Considering the macroseismic field, it is supposed that the shock was felt in Vorarlberg also, but no documents were to be found for this area. Table 1 shows coordinates and intensity site points respectively.

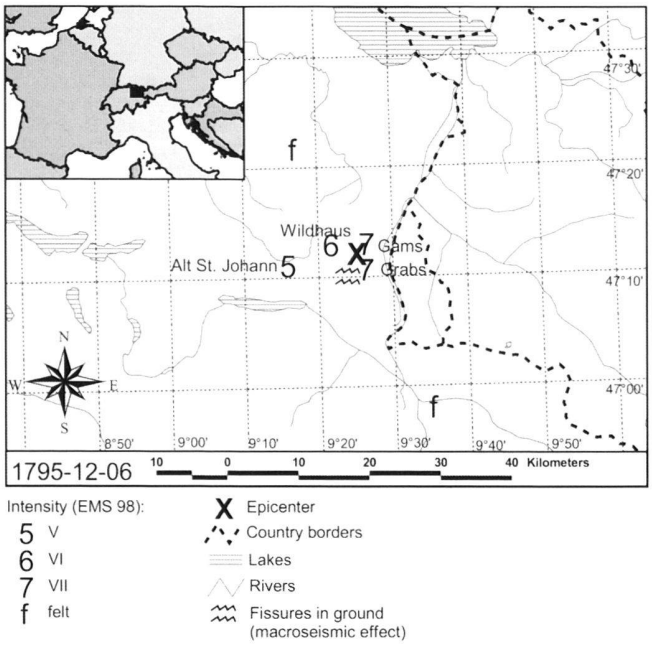

Fig. 2. Macroseismic field of the December 9, 1795 earthquake

Tab. 1. Overview of intensity site points of the December, 9 1795 earthquake

Loc	lat	lon	Imin	Imax	Iw
Grabs (SG)	47.176	9.435	6	7	7
Gams (SG)	47.214	9.437	6	7	7
Wildhaus (SG)	47.214	9.358	6	7	6
St-Johann (SG)	47.184	9.26	4	5	5
Canton Appenzell	47.36	9.279		felt	
Landquart (GR)	46.966	9.581		felt	

The record given in the journal *Monatliche Nachrichten* describes the earthquake as follows: "In der Nacht vom 5. auf den 6. Decemb. zwischen 1 und 2 Uhr wurden die Einwohner von Wildhaus, Gambs und Graps, und einigen diesen nahe liegenden Gegenden, durch eine mit fürchterlich dumpfen Getöse, dem Rollen eines entfernten Donners, oder dem Brausen eines starken Sturmwindes, ähnlich begleitete heftige Erderschütterung aufgeschrekt; welche so stark und empfindlich war, dass an allen 3. Orten die Menge Oefen und Feuermauren zerborsten." [On December 6, a strong trembling that burst stoves and fireproof walls startled all habitants of Wildhaus, Gams and Graps.] (Monatliche Nachrichten, Dec. 1795). Thus all the inhabitants of the three locations Gams, Grabs and Wildhaus awakened during the night, due to thunder and quaking of the earth. In each village the earthquake caused the destruction of firewalls and stoves.

For Gams and Grabs it has been added that "... an den 2. leztern sogar verschiedene Kamine oder Schornsteine einstürzten" meaning that several chimneys collapsed in these two villages. However, the term *einstürzende Kamine* has to be interpreted with restraint. Very often it was just part of the chimney that collapsed. We therefore assigned **Gams** Imin=VI, Imax=VII, Iw=VII and **Grabs** Imin=VI, Imax=VII; Iw=VII.

In addition to the observations described, in **Wildhaus** the church clock suffered damage (Imin=VI, Imax=VII, Iw=VI).

The second record in the *Monatliche Nachrichten* concerns **Glarus**: "Den 25. Novemb. [i.e. December 6, Gregorian style] wurde Morgens zwischen 1 und 2 Uhr, hin und wieder ein Erdbeben verspührt, das besonders im Glarnerland allgemein und mit einigen ziemlich heftigen Stössen begleitet war." [December 6, an earthquake with rather heavy trembling occurred in the Glarnerland.] (Monatliche Nachrichten, Dec. 1795). The event was widely observed though no further information is given.

However, this entry causes some problems: *Werdenberg*, an area in the Rhine Valley, covering the villages Gams, Grabs and Buchs, came under the control of Glarus in 1517 and became free only in 1798. So at the time the earthquake occurred, it belonged to *Glarus*. Therefore if Glarus is mentioned in the documents, it might also be Werdenberg that has been addressed. In a second issue of the *Monatliche Nachrichten*, published some months later, under the title of *Glarus*, Werdenberg instead was addressed: "Glarus. – Auszug eines Schreibens aus dem Werdenbergischen vom 28. Alten May oder den 8. Juni St. n. Schon in der Nacht vom 5ten auf den 6. Dec. verflossnen Jahres, zwischen 1 und 2 Uhr wurde in Graps, Gambs und Wildenhaus, durch eine heftige Erderschütterung ziemlicher Schaden verursacht." [Glarus. Excerpt of a record from Werdenberg of May 28 (old style) or June 8 (new style): Past year [1795], between December 5 and 6, around 1 and 2 am, a rather strong trembling occurred in Graps, Gams and Wildhaus, affecting some damage.] (Monatliche Nachrichten, May 1796).

Hence under the title of *Glarus* the record itself speaks of the *Werdenberg* region, where the event was strongly perceived. Unfortunately we do not have any contemporary sources for Glarus itself to verify the information. For this reason the information is too imprecise to be analyzed, and no intensity can be assigned.

In the **Appenzellerland** the event was widely observed: "Anno 1795 – Erdbidem. Den 24 November / 5. Dez. Sonntag Morgens zwischen 1. und 2. Uhr war ein Erdbidem von 2. Stöss verspührt worden." [November 24/December 5 [1795] an earthquake of two shocks occurred.] (Fisch ca. 1815). Dates are given in the Julian as well as in the Gregorian calendar, but under the date of the fifth. Thanks to the mention of the weekday, Sunday, we know for sure that the date was December 6.

As we have no further information on how strongly the shock was felt, we consequently have not assigned intensity. The macroseismic map states only the fact that it was felt (f).

For a small village in the Toggenburg, **Alt St. Johann** (SG), it was said that "Ao 1795 ... den 6ten Christ. [i.e. December, 6] morgens zwüschen 1 und 2 Uhr weit und breit einen Starken

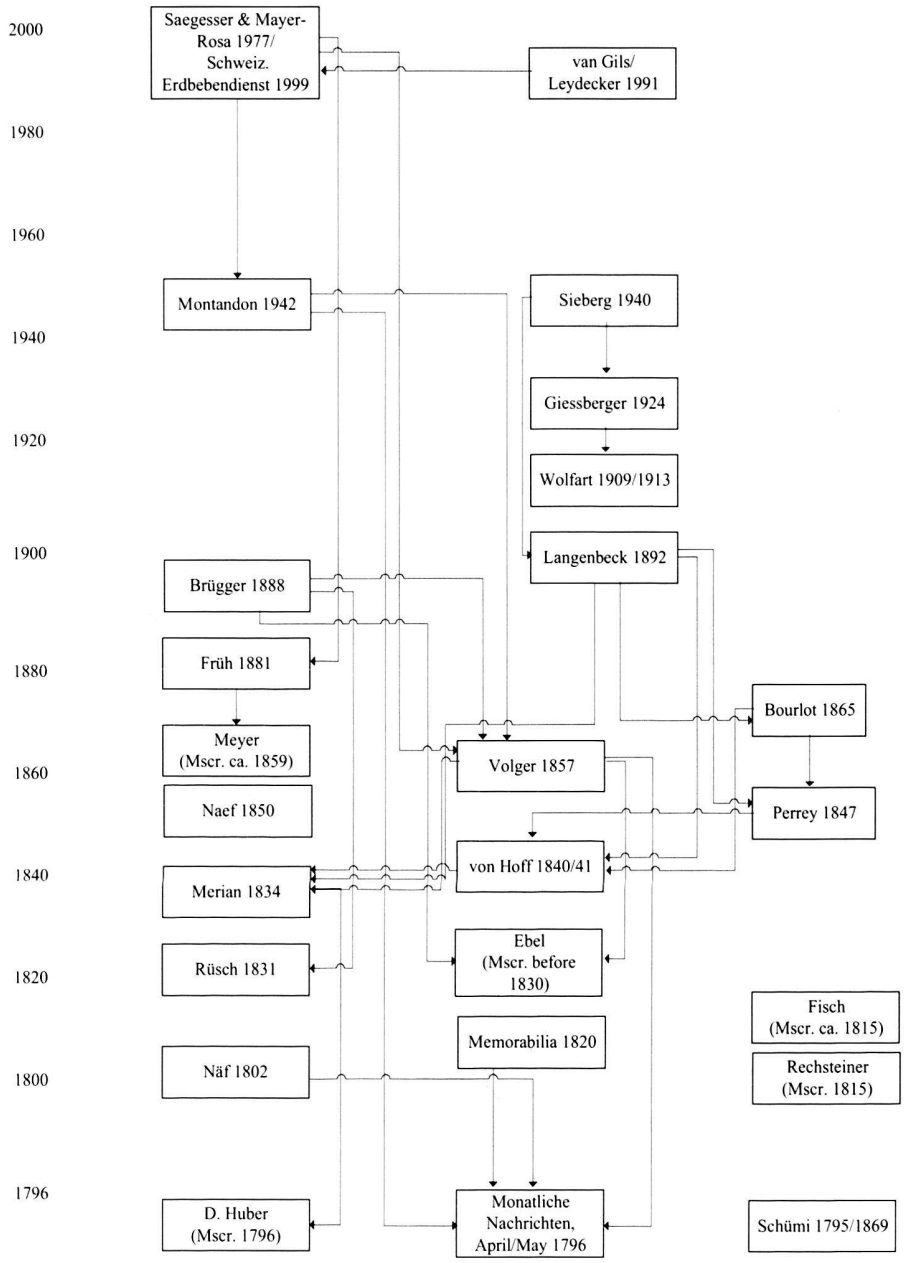

Fig. 3. Genealogical tree for the April, 20 1796 earthquake

Erdbeben Stos und Hernach zwahr etwas gelind verspürt worden." [1795, December 6, between 1 and 2 a.m., a large and strong earthquake occurred, followed by a small one.] (Senn 1869). Again, no damage is reported, though the event was widely observed (Imin=IV, Imax=V, Iw=V).

A meteorological record by J. R. von Salis (1811) mentions the earthquake observed in the area of Marschlins, close to **Landquart**, but lacks more detailed information (f).

Furthermore, in an area close to Grabs, cracks and fissures in the ground were observed: "An dem Grapserberg (einer Berggegend mit vielen zerstreuten Häusern) sollen einige sehr bedenkliche und beträchtliche Erdspalten dardurch verursacht worden seyn." [At Grapserberg, the quake caused some significant fissures in the ground.] (Monatliche Nachrichten, Dec. 1795). No intensity has been assigned for this entry, though the map shows a symbol for the seismogeological effect.

Magnitude assessment and location

For all earthquakes with a sufficient number and distribution of intensity points in the ECOS catalogue, we derived the source parameters (epicenter, hypocentral depth class, epicen-

tral intensity, maximum intensity, macroseismic magnitude) and the uncertainties using a regression scheme that accounts for regionalized intensity attenuation and hypocentral depth (Fäh et al. 2003). We adopted moment magnitude M_W as the size estimator for all events in ECOS, because M_W is directly related to source physics, unlike other magnitude scales based on seismogram amplitude measurements (like the body wave, surface wave, and local magnitude scales).

The magnitude/intensity calibration required a range of investigations (Braunmiller et al. 2002, Fäh et al. 2003). Direct measurements of seismic moment (and thus Mw) exist only for a small subset of recent, relatively strong earthquakes that could be analyzed using waveform-modeling techniques. For stronger 20th century earthquakes in and near Switzerland, we determined surface wave magnitude M_S from original analog recordings. To convert these historic M_S measurements to Mw, we regressed M_S versus Mw for recent events and ported the calibration function to the older events. For these stronger events well-distributed macroseismic fields have been established. The final set of calibration events consists of 15 earthquakes spanning the whole Swiss region and a wide magnitude range.

From this set we derived empirical intensity-magnitude relations. Earthquake parameters for all historical events were then determined directly from the intensity data points by applying the Bakun & Wentworth (1997) grid search approach. Associated uncertainties in source parameters determinations in this approach are controlled by the number and azimuth distribution of available intensity site points, by the degree to which intensity site points are available at near distances, and by the internal consistency of the intensity site points. The details of the procedure are described in Fäh et al. (2003) and in an internal report of the Swiss Seismological Service that can be downloaded from the Website of the Swiss Seismological Service [http://www.seismo.ethz.ch].

For the December 6, 1795 earthquake, intensity site points exist for 6 locations. We assessed the epicentral intensity Io = VII at the location Wildhaus/SG (47.2/9.4) with an estimated error of < 20 km. The location is given in figure 2. Moment magnitude has been estimated to Mw = 5.3 with an uncertainty of ≤ 0.5.

Aftershocks

The previously cited journal *Monatliche Nachrichten* gives a hint on aftershocks: "Seit dieser ersten heftigen Erschütterung verspührte man bis dato an die 30. mehr oder weniger empfindliche, meistens von Nordosten gegen Südwesten, von bemeldtem Getöse begleitete Stösse." [From the first large quake up to now, 30 or more shocks have been observed, undulating mostly from northeast to southwest.] (Monatliche Nachrichten, Dec. 1795). Thus the main shock was followed by several aftershocks, which continued over several days. However, due to the lack of more precise information about place, day and time it is not possible to differentiate between the shocks.

The earthquake of April 20, 1796

Reassessment of the event

The large number of compilations given in figure 2 suggests that the event of 1796 has been studied exhaustively. This leads to a first impression that this event must have been much stronger than the one in December 1795, discussed above. This is a false conclusion. Though we do have more information so as to establish a wider macroseismic field, yet the event is, in intensity, more or less equal to the earlier event. We suppose that the reason for increased attention to the event resulted from the fact that it was the second event occurring in the area within a short period. It therefore attracted greater interest.

Several contemporary sources are available concerning the event, but only those that give new and reliable information have been taken into consideration. An extensive report by an eyewitness in the Rhine Valley has been published in the journal *Monatliche Nachrichten* (1796). The above-mentioned diary by Schümi family (Senn 1869) recorded this event also, as did the chronicle from Appenzell (Fisch ca. 1815). Furthermore, a meteorological recording for Basel is available (Huber 1796), whereas two chronicles using a database of contemporary manuscripts, one of St. Gallen (Naef 1850), the other of Lindau/Germany (Wolfart 1912), were published some decades later. All historical sources have been analyzed critically in order to make an approximation.

Damage distribution

The main shock occurred on April 20, 1796 (Gregorian calendar) at 7.12 a.m. (6.12 a.m. GMT) with several aftershocks in quick succession. Rumblings and cracking that lasted several minutes accompanied the shocks. The epicenter area covers the Rhine Valley and its main villages Gams and Grabs. In the west the shock was perceptible as far as Basel, in the northeast as far as Lindau in Germany (see figure 4 and table 2). While assessing intensities it has to be kept in mind that buildings may already have been damaged, so that a second relatively weak shock can cause disproportionate damage, including collapse.

The most detailed observations exist for the epicentral area. The author claims at the beginning that his story is fully true: "Von der Stärke dieser Erbebung kann man sich durch folgende wahrhafte Erzählung überzeugen: Die Häuser schwankten wie Schiffe auf dem Wasser, dass eine grosse Anzahl Kamine gänzlich zerstört und hinuntergeworfen, und sehr viele Oefen nicht nur stark beschädigt wurden, sondern vollkommen einstürtzten in Graps, Gambs und Wildhaus. Milch, Wasser und andere Flüssigkeiten wurden aus ihren Gefässen verschüttet." [The extent of the quake has been reported by the following: The houses were shaken like boats on the water; a large number of chimneys were destroyed completely; many stoves collapsed. Milk, Water and other liquid spilled from vessels.] (Monatliche Nachrichten, May 1796). Thus the event was felt strongly in all three locations Gams (SG), Grabs (SG)

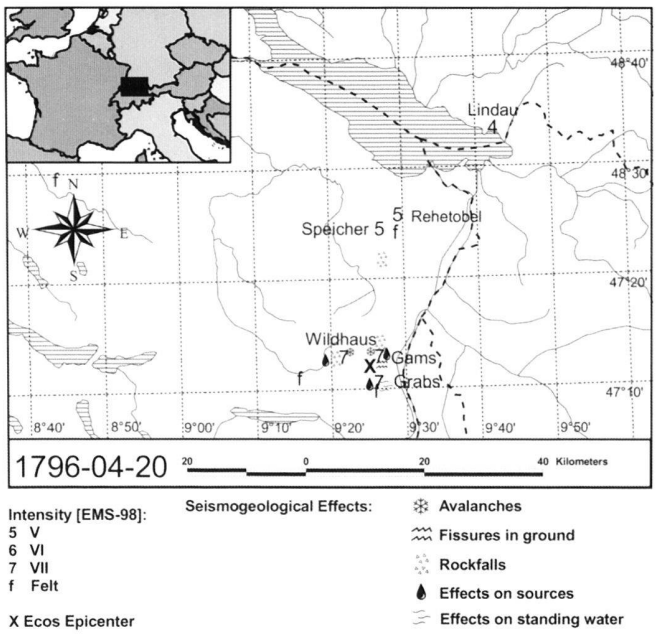

Fig. 4. Macroseismic field of the April, 20 1796 earthquake

Tab. 2. Overview of intensity site points of the April, 20 1796 earthquake

Loc	lat	lon	Imin	Imax	Iw
St. Johann (SG)	47.184	9.26			felt
Basel (BS)	47.553	7.586			felt
Binningen (BL)	47.536	7.568			felt
Eglisau (ZH)	47.572	8.527			felt
Gams (SG)	47.214	9.437	7	7	7
Grabs (SG)	47.176	9.435	6	7	7
Canton Appenzell	47.36	9.279			felt
Lenzburg (AG)	47.385	8.175			felt
Lindau (Germany)	47.557	9.704	4	5	4
Rehetobel (AR)	47.428	9.485	5	6	5
Speicher (AR)	47.408	9.444	4	5	5
Trogen (AR)	47.402	9.482			felt
Wildhaus (SG)	47.214	9.358	6	7	7
Winterthur (ZH)	47.491	8.728			felt
Zürich (ZH)	47.372	8.542	5	6	5

and Wildhaus (SG), where the houses were severely shaken, chimneys collapsed completely and many fireplaces were seriously damaged. Liquid spilled from containers.

Of **Gams** it was said additionally and in detail that the church was damaged: "Die auf einer sehr angenehmen, mit Reben bepflanzten Anhöhe gelegene Pfarrkirche in Gambs, und vornehmlich das Chor derselben, wurden durch viele Neben- und wiedereinander laufenden Risse so stark beschädigt, dass das Einstürzen des leztern sehr zu vermuthen, und bereits ein ziemliches aus der Wölbung hinuntergefallen. Die Gloken wurden etliche Mahl geklängt." [Large fissures affected the church of Grabs, namely the nave, so that it collapsed partly. The bells of the church rang several times.] (Monatliche Nachrichten, May 1796) (Imin=VII, Imax=VII, Iw=VII).

The **Wildhaus** church sustained cracks in the walls: "Die kat[holische] Kirche in Wildhaus soll auch Risse darvon getragen haben." [Fissures affected the Catholic Church in Wildhaus.] (Monatliche Nachrichten, May 1796); (Imin=VI, Imax=VII, Iw=VII). No greater detail has been added for **Grabs** (Imin=VI, Imax=VII, Iw=VII).

A **St. Gallen** chronicle (Naef 1850) notes heavy damage that frightened the people of St. Gallen and neighboring regions. Some chimneys and stones fell from the roofs. No more details are given about the damage or the circumstances. We presume therefore that there was no heavy damage (Imin=VI; Imax=VII; Iw=VI).

In a village close to St. Gallen, **Rehtobel (AR)**, a stove surrounded by wood was broken and caused a fire. As a consequence, 10 houses and seven barns burned down. Evidently it was the fire that caused such heavy damage and not the earthquake itself. Therefore the information on the broken stove has been analyzed, while information on damage caused by the fire has been ignored (Imin=V; Imax=VI; Iw=V).

Other information on the perception of the earthquake is given for **Speicher (AR)** (Rechsteiner 1815) and the whole **Canton of Appenzell** (Fisch ca. 1815). The earthquake was widely observed, but no damage is reported (Imin=IV; Imax=V; Iw=V).

For **Alt St. Johann (SG)** (Senn 1869), **Winterthur (ZH), Trogen (AR)** (Monatliche Nachrichten, April 1796), **Basel (BS), Binningen (BL)**, and **Lenzburg (AG)** (Huber 1796) there exist reports that the event was felt, with no further detail given. Therefore intensities have not been assigned; the map lists only the information that the earthquake was felt (f).

For **Zurich** a second record in the *Monatliche Nachrichten* says: "Mittwochs den 20. Morgens um 7 Uhr 12 _ Minuten wurde in unsrer Stadt eine starke Erderschütterung verspürt, man zählte 2 Stösse, in der Richtung von Südost nach Nordwest. Der zweyte war so heftig, dass in mehrern Häusern Bücher und kleines Hausgeräth von Tischen und Gestellen herunterfiel. Gott sey Dank wurde gar kein Schaden verursacht." [On April 20 [1796] a large earthquake occurred in our city, with two shocks undulating from southeast to northwest. The second shock was so strong that it caused the falling of objects though no damage was to be observed.] (Monatliche Nachrichten, April 1796). Thus two successive shocks, widely observed, caused small objects to fall from tables and shelves, yet no damage is mentioned (Imin=V; Imax=VI; Iw=V).

A contemporary chronicle (Näf 1802) added that the event was felt even in **Eglisau (ZH)** (f).

For the city of **Lindau in Germany** we have a record by Wolfart (1912): "1796. Mittwochs den 20. April ward eine starke Erderschütterung verspürt." [1796, April 20, a rather strong earthquake was observed.] Hence in Lindau the event was widely perceived but no damage is reported (Imin=IV; Imax=V; Iw=IV).

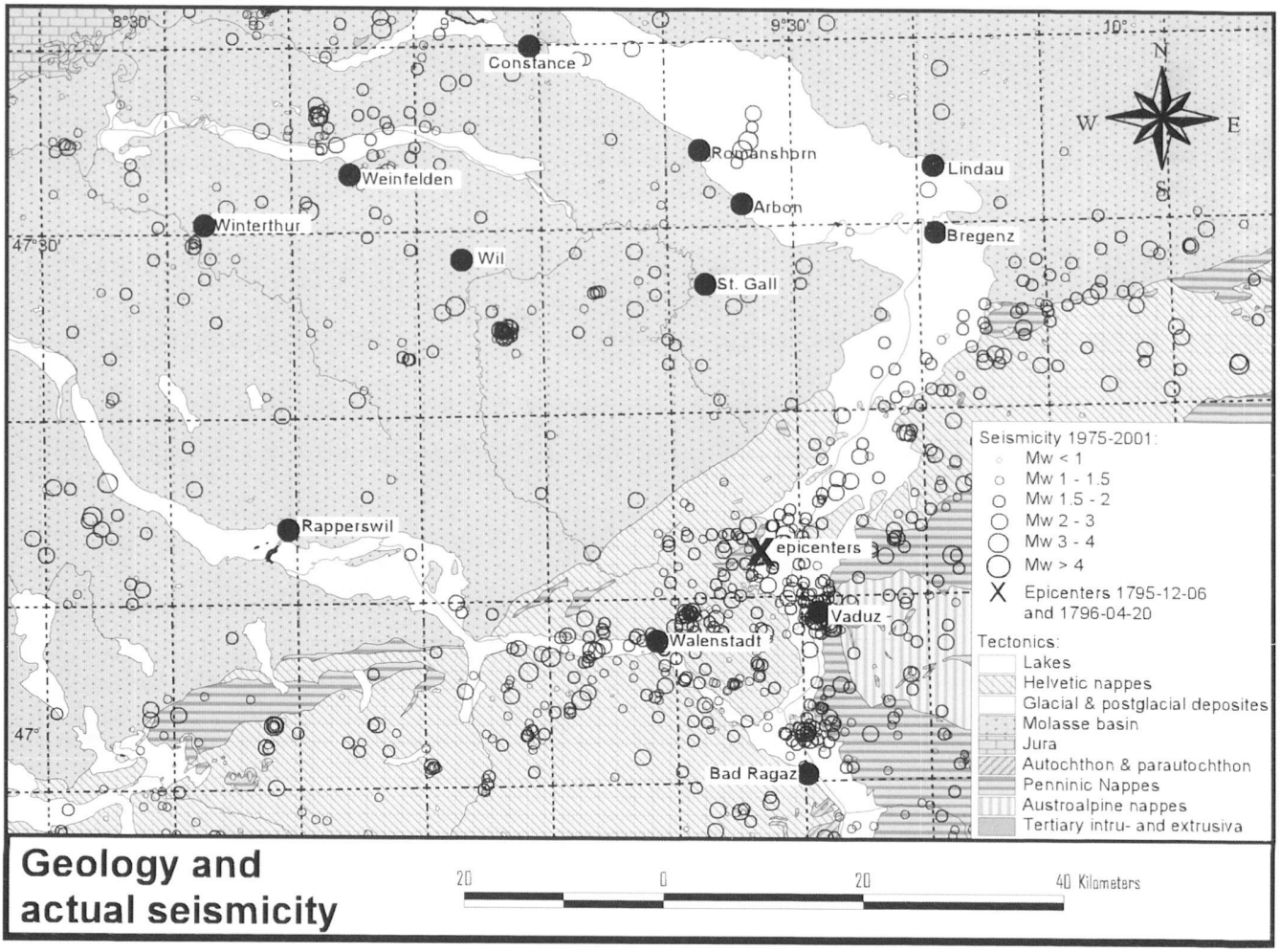

Fig. 5. Comparison of the two historic events with recent instrumental data

As was the case with the 1795 earthquake, several effects on the environment were recorded. Large fissures in the ground and springs that stopped and started were observed close to the area most affected (Gams, Grabs and Werdenberg). We have even the report of two rockfalls and a number of avalanches in the neighboring of Gams and Wildhaus (Senn 1869; Monatliche Nachrichten, May 1796). The map in figure 4 shows the symbols for these seismogeological effects.

Magnitude assessment and location

The accuracy of the intensity estimations is again 0.5 intensity units. From the estimates of intensities made at 15 sites we assessed epicentral intensity (Io) = VII at Grabs/SG (47.2/9.4), with an estimated error of <20 km. The location is given in figure 4. Moment magnitude has been assessed at Mw = 5.3 with an uncertainty of ≤0.5.

Aftershocks

An aftershock occurred on 15 April 1796 (no time of day given). Apparently it was felt weakly in Appenzell (Rüsch 1831; Fisch ca. 1815). No further information is added on other locations. Therefore we presume that the localization of the aftershock cannot be set very precisely and therefore has a rather high uncertainty. The intensity assignment (Iw) is not higher than IV.

Discussion

The 1796 earthquake was long considered an earthquake that inflicted heavy damage in the Rhine Valley region. The area is well known to be seismically active; we know of earthquakes back to the 16th century. A comparison of our results with epicenter maps based on recent instrumental data shows that the macroseismically determined locations of these two historical

earthquakes coincide with a concentration of epicenters that is part of a region of enhanced seismicity, which extends from south of the Walensee to the Bregenzer Wald (Fig. 5). In general the epicentral locations shown in figure 5 are not optimally constrained in this region due to its situation at the periphery of the Swiss national seismometer network, and the data in the Walensee area is certainly contaminated by several unidentified and mis-located explosions from the active quarries near Quinten and Walenstadt. Nevertheless, the overall SW-NE trend of the epicenters parallel to the northern Helvetic front and the various event clusters NE of Walenstadt, around Vaduz and near Bad Ragaz are well documented. The cluster around Vaduz includes an event with Mw = 4.3 (1992/05/08) and Imax = V, which caused light damage in Vaduz and Schaan. Focal depths of events SE of the Helvetic front are generally restricted to the upper 15-20 km of the crust (e.g. Roth et al. 1992, Pavoni et al. 1997, Deichmann et al. 2000). However, below the Molasse of the northern foreland, focal depths of up to 30 km are not uncommon. An example of the latter is the Ml 2.9 event (2001/03/14) near Oberriet, SG (Deichmann et al. 2002). Focal mechanisms in this region correspond either to strike slip or to thrust faults (Roth et al. 1992, Pavoni et al. 1997, Baer et al. 2001, Deichmann et al. 2002). Of particular relevance to the 18th century earthquakes discussed in this paper is the Mw 3.6 event near Buchs (2000/03/04): its epicenter (47.22/9.48) matches the inferred location of the 1795 and 1796 events very closely, its focal depth, estimated at 3 km, puts it within the sedimentary cover, and its focal mechanism corresponds to a pure thrust fault (Baer et al. 2001). The orientation of the P-axes of all the focal mechanisms in this region indicates a NW-SE direction of maximum crustal shortening, perpendicular to the local strike of the Alpine front.

In the process of re-evaluating contemporary sources instead of earthquake compilations, site intensities have been reassessed. From the documents at hand we learned of some damage occurring in the area of the Rhine Valley and of individual impressions of people who experienced the event. It is of importance to be aware that the damage occurring in Rehetobel was not the result of the earthquake itself, but of a fire caused by a broken stove. As a result, epicentral intensity (Io) as well as macroseismic magnitude (Mw) has been reduced for this event, whereas for the 1795 event intensity assessment has been verified. With Io = VII and Mw = 5.3 the two events are still the largest earthquakes ever recorded in this region. These new findings have to be taken into consideration when assessing seismic hazard for the area.

Acknowledgements

The revision of the December 6, 1795 and April 20, 1796 events was part of the upgrading of the Earthquake Catalogue of Switzerland (ECOS), a project of the Swiss Seismological Service. We thank several agencies and archives for their support. Furthermore we would like to thank Nicolas Deichmann, Zurich, for discussing actual seismicity and Philipp Kästli, Zurich, for designing the maps.

REFERENCES

ALBINI, P., AMBRASEYS, N. N. & VOGT, J. 1994: Some aspects of historical research on "over borders" earthquakes in eighteenth century Europe. Ann. Geofis. 36, 541–549.

ALBINI, P., BELLETTATI, D., STUCCHI, M., & ZERGA, A. 1996: Exploring the potential of seismological compilations: J. Schorn (1902) and the seismicity of Tyrol. Ann. Geofis. 34/5, 1055–1067.

ALEXANDRE, P. 1984: Problèmes de méthode relatifs a l'étude des séismes médiévaux. In: Association pour la promotion et la diffusion des connaissances archéologiques. IV^{èmes} rencontres internationales d'archéologie et d'histoire d'Antibes. Tremblement de terre – Histoire et archéologie, Novembre 1983, Valbonne, 221–226.

– 1990: Les séismes en Europe occidentale de 394 à 1259. Nouveau catalogue critique. In: Observatoire Royal de Belgique/Koninklijke Sterrenwacht van Belgie. Série Géophysique N° Hors-Série/Reeks Geofysica Nr Buiten Reeks, Bruxelles, 5–267.

– 1994: Historical seismicitiy of the lower Rhine and Meuse valleys from 600 to 1525: a new critical review. Geol. en Mijnb. 73, 431–438.

AMBRASEYS, N. N., MELVILLE, C. P. & ADAMS, R. D. 1994: The Seismicity of Egypt, Arabia and the Red Sea. A historical review, Cambridge.

BAER, M., DEICHMANN, N., BRAUNMILLER, J., BALLARIN DOLFIN, D., BAY, F., BERNARDI, F., DELOUIS, B., FAEH, D., GERSTENBERGER, M., GIARDINI, D., HUBER, S., KASTRUP, U., KIND, F., KRADOLFER, U., MARAINI, S., MATTLE, B., SCHLER, T., SALICHON, J., SELLAMI, S., STEIMEN, S., & WIEMER, S. 2001: Earthquakes in Switzerland and surrounding regions during 2000. Eclogae Geol. Helv. 94/2, 253–264.

BAKUN, W. H. & WENTWORTH, C. M. 1997: Estimating earthquake location and magnitude from seismic Intensity data. Bull. Seismol. Soc. Am. 87, 1502–1521.

BOURLOT, J. M. 1865: Histoire des tremblements de terre ressentis en Alsace et dans le Pays de Bâle. Bulletin de la société d'histoire naturelle de Colmar 6, 213 ff.

BRAUNMILLER, J., KRADOLFER, U., BAER, M. & GIARDINI, D. 2002: Regional moment tensor determination in the European-Mediterranean area – initial results. Tectonophysics 356, 5–22.

BRÜGGER, CHR. G. 1888: Beiträge zur Natur-Chronik der Schweiz insbesondere der Rhätischen Alpen, Beilage zum Programm der bündner'schen Kantonsschule, Chur.

CANDREIA, J. 1905: Zur Chronik der Erdbeben in Graubünden bis zum Jahre 1879, Bern.

DEICHMANN, N., BAER, M., BRAUNMILLER, J., BALLARIN DOLFIN, D., BAY, F., BERNARDI, F., DELOUIS, B., FAEH, D., GERSTENBERGER, M., GIARDINI, D., HUBER, S., KRADOLFER, U., MARAINI, S., OPRSAL, I., SCHIBLER, R., SCHLER, T., SELLAMI, S., STEIMEN, S., WIEMER, S., WOESSNER, J. & WYSS, A. 2002: Earthquakes in Switzerland and surrounding regions during 2001. Eclogae Geol. Helv. 95/2, 249–261.

DEICHMANN, N., BAER, M., BRAUNMILLER, J., BALLARIN DOLFIN, D., BAY, F., DELOUIS, B., FAEH, D., GIARDINI, D., KASTRUP, U., KIND, F., KRADOLFER, U., KUENZLE, W., ROETHLISBERGER, S., SCHLER, T., SALICHON, J., SELLAMI, S., SPUEHLER, E. & WIEMER, S. 2000: Earthquakes in Switzerland and surrounding regions during 1999. Eclogae Geol. Helv. 93/3, 395–406.

EBEL, J. G. [1830]: Abhandlung über Erdbeben (Mscr. StAZH, Sign. B IX).

EISINGER, U., GUTDEUTSCH, R. & HAMMERL, C. 1992: Historical Earthquake Research – an Example of Interdisciplinary Cooperation between Geophysicists and Historians. In: GUTDEUTSCH, R., GRÜNTHAL, G. & MUSSON, R. (eds.), Historical Earthquakes in Central Europe 1, Wien, 33–50.

ERNI, J. H. (ed.) 1820: Memorabilia urbis et agri Tigurini, Zürich.

FÄH, D., GIARDINI, D., BAY, F., BERNARDI, F., BRAUNMILLER, J., DEICHMANN, N., FURRER, M., GANTNER, L., GISLER, M., ISENEGGER, D., JIMENEZ, M.J., KÄSTLI, P., KOGLIN, R., MASCIARDI, V., RUTZ, M., SCHEIDEGGER, C., SCHIBLER, R., SCHORLEMMER, D., SCHWARZ-ZANETTI, G., STEIMEN, S., SELLAMI, S., WIEMER, S. & WÖSSNER, J. 2003, Earthquake Catalogue Of Switzerland (ECOS) and the Related Macroseismic Database. Eclogae geol. Helv. (96/2).

FISCH, J. [1815]: Chronick oder Beschreibung des Canton Appenzell der Ausseren und Inneren Rhoden ... von Anno 1789 bis Anno 1798 verfasset von IOHANNES FISCH Herisau (Mscr. StAAR, Sign. Ms 21).

FRÜH, J. 1881: Die schweizerischen Erdbeben im November 1881. Nach den von der schweizerischen Erdbebenkommission gesammelten Berichten, Bern.

GIESSBERGER, H. 1924: Die Erdbeben Bayerns, II. Teil, München.

GROTEFEND, H. [13]1991: Taschenbuch der Zeitrechnung des deutschen Mittelalters und der Neuzeit, Hannover.

GRÜNTHAL, G. (ed.) 1998: European Macroseismic Scale 1998 EMS-98. Cah. Centre Europ. Géodynam. Séismol. 15.

GUIDOBONI, E. & STUCCHI, M. 1993: The contribution of historical records of earthquake to the evaluation of seismic hazard. Ann. Geofis. 36, 201–215.

GUTDEUTSCH, R., HAMMERL, C., MAYER, I. & VOCELKA, K. 1987: Erdbeben als historisches Ereignis. Die Rekonstruktion des Bebens von 1590 in Niederösterreich, Berlin/Heidelberg.

HUBER, D. [1829]: Meteorologische Beobachtungen 1784–1829 (Mscr. UBBS, Sign. L I b).

LANGENBECK, R. 1892: Die Erdbebenerscheinungen in der oberrheinischen Tiefebene und ihrer Umgebung. In: GERLAND, G. (ed.), Geogr. Abh. Reichsl. Elsass-Lothringen, Stuttgart, 1–120.

LEYDECKER, G. 1986: Erdbebenkatalog für die Bundesrepublik Deutschland mit Randgebieten für die Jahre 1000–1981. In: Geol. Jb., Reihe E Geophysik 36, Hannover, 3–83.

LORENZ, P. 1894: Einiges über Erdbeben im Kanton Graubünden. In: Jb. natf. Ges. Graubünden, N. F., 37 Band, Vereinsjahr 1893/94, Chur, 118–156.

MERIAN, P. 1834: Über die in Basel wahrgenommenen Erdbeben, nebst einigen Untersuchungen über Erdbeben im Allgemeinen, Basel.

MEYER, D. [1859]: Verzeichnis von Erdbeben und Vulkanischen Ausbrüchen besonders mit Bezug auf Erdbeben in der Schweiz (Mscr. Vadiana SG, Sign. S 109).

MONATLICHE NACHRICHTEN SCHWEIZERISCHER NEUHEITEN 1795, Zürich, [December].

– 1796, Zürich, [April & May].

MONTANDON, F. 1942/1943: Les Séismes de forte intensité en Suisse, Genève (Revue pour l'étude des calamités, Bull. Union internat. Secours).

NAEF, A. 1850: Chronik oder Denkwürdigkeiten der Stadt und Landschaft St. Gallen. Mit Inbegriff der damit in Verbindung stehenden Appenzellischen Begebenheiten, von den ältesten Zeiten bis auf das Jahr 1848, Zürich/St. Gallen.

NÄF, J. C. (ed.) 1802: Kurze Darstellung der Merkwürdigkeiten des Achtzehnten Jahrhunderts in unserm Vaterland. Geweiht den Freunden der vaterländischen Geschichte, Zürich.

PAVONI, N., MAURER, H., ROTH, P. & DEICHMANN, N. 1997: Seismicity and seismotectonics of the Swiss Alps. In: Deep Structure of the Alps, Results of NRP 20, Basel, 241–250.

PERREY, A. [1847]: Mémoire sur les tremblements de terre dans le bassin du rhin, t. 19, Bruxelles.

RECHSTEINER, J. B. 1815: Speicher Gemeindechronik – Teil 2. "Sammlung der Geschichten, so theils auf das Land Appenzell bezug haben, anders theils auch die alte Rood und Kirchenhöri Speicher betrefend." (Mscr. StAAR, Sign. Mg 26/2).

RÖDER, G.W., v. TSCHARNER, P.C. 1838: Der Kanton Graubünden, historisch, geographisch, statistisch geschildert ... Ein Hand- und Hausbuch für Kantonsbürger und Reisende, St. Gallen/Bern (= Historisch-geographisch-statistisches Gemälde der Schweiz, Fünfzehntes Heft. Der Kanton Graubünden).

ROTH, P., PAVONI, N. & DEICHMANN, N. 1992: Seismotectonics of the Eastern Swiss Alps and evidence for precipitation induced variations of seismic activity. Tectonophysics 207, 183–197.

RÜSCH, G. 1831: Der Appenzeller-Chronik von Gabriel Walser vierter Theil, in welchem alle Begebenheiten, so sich von 1772 bis 1798 zugetragen, unpartheisch beschrieben sind, Trogen.

SAEGESSER, R. & MAYER-ROSA, D. 1977: Erdbeben-Risikokarten der Schweiz. Bestimmung der Erdbebengefährdung, ed. Eidgenössisches Amt für Energiewirtschaft – ASK, Zürich.

SCHORN, J. 1902: Die Erdbeben von Tirol und Voralberg. Zeitschrift des Ferdinandeums für Tirol und Voralberg 46, Innsbruck.

SCHWEIZERISCHER ERDBEBENDIENST ETHZ 1999: MECOS – Macroseismic Earthquake Catalogue of Switzerland,
URL http://seismo.ethz.ch/products/catalogs (March 2002).

SENN, N. (ed.) 1869: Tagebuch der Familie Schümi am Unterwasser, bei St. Johann, Chur.

SIEBERG, A. 1940: Beiträge zum Erdbebenkatalog Deutschlands und angrenzender Gebiete für die Jahre 58 bis 1799. In: Reichsanstalt für Erdbebenforschung in Jena. Mitt. Dtsch. Reichs-Erdbebendienst, Heft 2, Berlin, 3–111.

STUCCHI, M. 1993: Through catalogues and historical records: an introduction to the project "Review of Historical Seismicity in Europe". In: STUCCHI M. (ed.), Historical Investigation of European Earthquakes, Materials of the CEC Project "Review of Historical Seismicity in Europe" 1, Milano, 3–14.

STUCCHI, M., BELLANI, A. & CHIGNOLA, E. 1991: Behind the intensity map: assessing the quality of historical-seismological information. In: KOZÁK, J. (ed.), Proceed 3rd Int. Symp. Historical Earthquakes in Europe, Prag, 41–57.

VAN GILS, J.M. & LEYDECKER, G. 1991: Catalogue of European earthquakes with intensities higher than 4. Final report, ed. Comm. European Communities, Luxembourg.

VOGT, J. 1979: Problèmes de Méthode. In: CADIOT, B. et al. (ed.): Les tremblements de terre en France, (publié sous la direction de JEAN VOGT), Orléans, 9–15.

VOGLER, O. G. H. 1857: Untersuchungen über das Phänomen der Erdbeben in der Schweiz, 3 Teile, Gotha.

VON HOFF, K. E. A. 1840/41: Chronik der Erdbeben und Vulcan-Ausbrüche. Mit vorausgehender Abhandlung über die Natur dieser Erscheinungen, Erster Teil, Gotha.

VON SALIS MARSCHLINS, J. R. 1811: Einige Resultate aus sechs und zwanzigjährigen Witterungsbeobachtungen in Marschlins. In: Der neue Sammler, ein gemeinnütziges Archiv für Bünden 6, 193–209.

WOLFART, K. 1909: Geschichte der Stadt Lindau im Bodensee. Im Auftrag der Stadtgemeinde unter Mitwirkung von Dr. FR. JOETZE, DR. H. LOEWE, DR. TH. STETTNER u.a., Zweiter Band, Lindau.

– 1912: Lindauer Erdbeben=Chronik. Neujahrsblätter des Museumsvereins Lindau i. B., Lindau, 29–32.

Manuscript received July 30, 2002
Revision accepted June 21, 2003