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Multiarchive paleoseismic record of late Pleistocene and Holocene strong earthquakes in Switzerland

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Abstract

A multiarchive approach has been applied to the investigation of the late Pleistocene and Holocene record of strong earthquakes in Switzerland. The geological archives used for this study include active faults, lake deposits, slope instabilities, and caves. In the Basle area, eight trenches were opened across the Basle–Reinach fault, nearby rockfall deposits were systematically investigated, sediment cores were taken from two lakes, and nine caves were studied. In Central Switzerland, five lakes were investigated by means of high-resolution seismic lines and sediment cores. Furthermore, three caves were studied in Central Switzerland. Altogether, the investigations are based on more than 350 km of high-resolution reflection seismic lines, 450 m of core samples, 260 m of trenches, and 245 radiocarbon age determinations. The measured co-seismic displacements along the Basle–Reinach fault supply independent information for the magnitude of the AD 1356 Basle earthquake exclusively based on geological evidence. Deformation features related to three well-documented strong historic earthquake shocks were identified. Deformation features of the AD 1774 Altdorf and AD 1601 Unterwalden earthquakes can be used to calibrate paleoseismic evidence in Central Switzerland. Altogether, traces of 13 earthquakes could be found in the two study areas, all of them with magnitudes $M_w \sim 6$ or greater. For the first time, the earthquake catalogue for Switzerland can be extended back beyond historic records, into the late Pleistocene, spanning 15,000 years.

Keywords: Switzerland; Paleoseismicity; Historic earthquakes; Pleistocene; Holocene; Earthquake catalogue

1. Introduction

Palaeoseismic investigations have been successful in many areas of the world in complementing historic earthquake record with prehistoric events. These investigations are focussed on surface faulting (Camelbeeck and Meghraoui, 1998) and on a variety of

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geological archives that contain earthquake-related damage and deformation features such as soft-sediment deformation in lakes (Sims, 1973, 1975; Rodriguez-Pascua et al., 2000), sand injections in flood plain deposits (Obermeier, 1996), slope instabilities (Keefer, 1984), or cave collapse (Postpischl et al., 1991). The potential for identifying a complete record of major prehistoric events is restricted to areas where the geological record is complete and earthquake-induced deformation structures are preserved in a wide range of environments. Paleoseismological research is particularly important in regions where recurrence intervals for strong earthquakes are long and exceed the time span covered by the instrumental and historic earthquake catalogues.

Intraplate Europe is classified among the stable continental regions because of the low rate of deformation (Johnston, 1996; Camelbeeck and Meghraoui, 1998). However, the historic seismicity is noteworthy, and moderate to large damaging earthquakes have occurred in the past (Camelbeeck et al., 2000). In this context, the October 18, 1356 Basle (Northern Switzerland) earthquake with M_w 6.9 ± 0.5 and the September 18, 1601 Unterwalden (Central Switzerland) earthquake with M_w 6.2 ± 0.5 are among the largest historic seismic events in Western Europe (Fäh et al., 2003). At Basle and Lucerne (Fig. 1), the two strongest earthquakes in Switzerland damaged two cities, which are now major regional centres with high population density, key communication nodes, lifelines, and critical facilities. It is therefore vital for these cities to evaluate the likelihood of the occurrence of such strong earthquakes. As the Basle and Unterwalden earthquakes are unique events within their respective regions, recurrence intervals are obviously larger than the 1000 years time span covered by the historic documents. Hence, the question was raised whether Switzerland has a record of such strong earthquakes. The answer to this question can only be achieved by paleoseismological investigations on different geological archives where traces of strong seismic events are recorded. These archives include fault scarps as well as lake, slope, and cave deposits. Investigations were carried out in

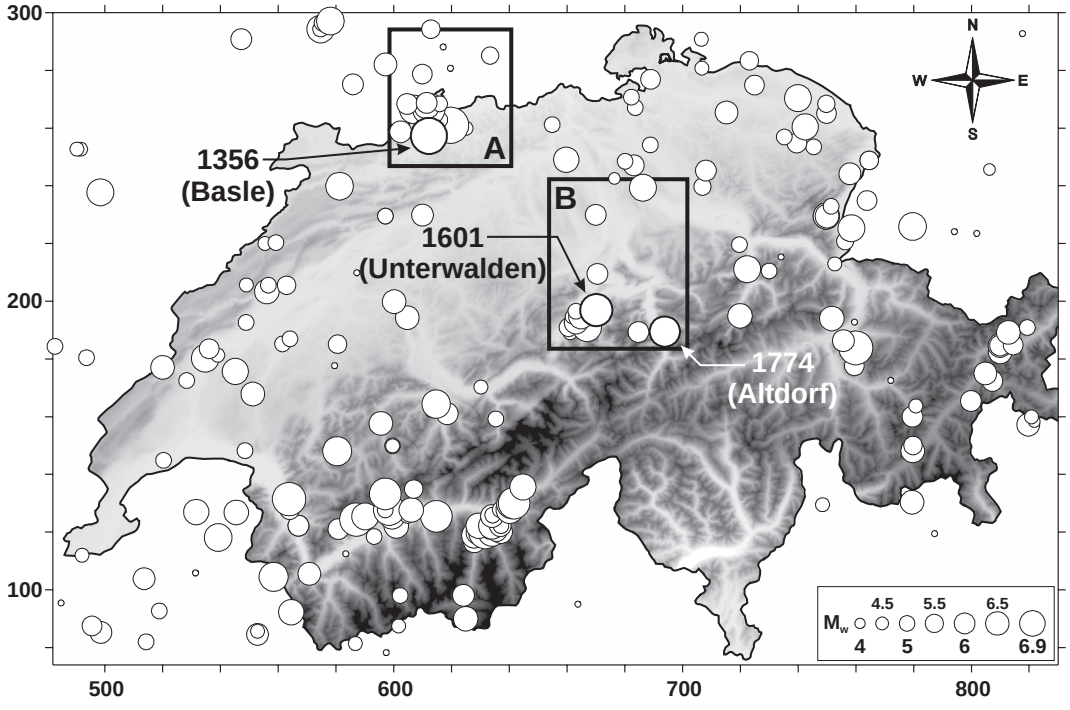

Fig. 1. Historic seismicity in Switzerland, study areas A and B, and topography.