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EARTHQUAKE SCENARIOS FOR SWITZERLAND

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SUMMARY

The paper is providing an overview of the state of the project "Earthquake scenarios for Switzerland" after one year of research. This three-years program includes a study to identify prehistorical earthquakes using paleoseismological methods, the modeling and mapping of ground motion on a regional scale for the area of Switzerland, and on a local scale for the city of Basel, the classification of the vulnerability of buildings to earthquake ground motion for selected target areas, and the realization of damage scenarios using deterministic and probabilistic approaches.

INTRODUCTION

The economic and social effects of earthquakes can be reduced only through a comprehensive assessment of seismic hazard and risk that leads to increased public awareness, and consequently to the necessary seismic upgrading of existing buildings and engineering structures, as well as to reliable earthquake resistant design of new structures. Switzerland experienced several destructive earthquakes during its history (most notably the 1356 event in Basel and the 1855 event in the Valais) and is characterized by high exposure to earthquakes. The evaluation of seismic risk, the convolution of the expected ground shaking with specific site effects and with vulnerability estimators, is the required step for the mitigation of earthquake effects.

The goal of our project is to pursue the research required in key aspects of risk assessment, in order to develop a comprehensive method for the estimation of expected damage from earthquakes. Four specific research topics are targeted. The first part is a paleoseismic study based on the analysis of coring samples of lake-bed sediments to identify and date disturbances related to past earthquakes, with the goal of constraining the return time of large earthquakes and extending the earthquake record used for the probabilistic hazard assessment. The second part of this work provides a detailed probabilistic assessment of expected ground motion from earthquakes for the entire country. The required calibration of ground motion attenuation models is based on observed strong motion recordings and on theoretical computations taking into account realistic models for wave propagation as well as possible causative faults. The third part of the study includes a detailed microzonation in the region of Basel. As a basic input to the microzonation, three-dimensional structural models for the target areas are derived from in-situ measurements, borehole data, and geotechnical and geological information from the area. The fourth part of the study comprises a vulnerability analysis in selected portions of the target areas. An inventory of buildings and engineering construction in the target areas will be compiled. Based on the detailed spectral description of the expected ground motions and of the vulnerability functions adapted to local construction condition, expected damages will be calculated for different earthquake scenarios.

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PALEOSEISMIC STUDIES IN THE BASEL AREA

During the past centuries the city of Basel has suffered damage caused by earthquakes. The strongest event, for which historical descriptions exist, occurred in 1356 (EMS intensity IX to X) and caused severe damage in the city of Basel [Mayer-Rosa and Cadiot, 1979]. No other events reaching intensity VIII are known since the 1356 earthquake, but historical sources describe several earthquakes of intensity VII and less (see Figure 1). From archeological excavations, there is evidence that a destructive earthquake occurred in 250 AD and destroyed the Roman city Augusta Raurica, which was located about 10 km east of Basel.

It is the aim of the palaeoseismological investigations to find evidence for strong earthquakes in the Holocene, i.e. within the last 12000 years. For this purpose soft-sediment deformation structures in lake deposits in the surroundings of Basel have been investigated. Two sites have been selected: (1) former Lake Seewen (14 km south of Basel), and (2) Lake Bergsee (27 km east of Basel). Lake Seewen is a landslide-dammed lake, about 2.5 km long and 500 m wide, whereas Lake Bergsee is a small glacially formed depression, 350 m long and 250 m wide. In these two sites, 19 boreholes were deepened reaching depths between 1 and 27 m.

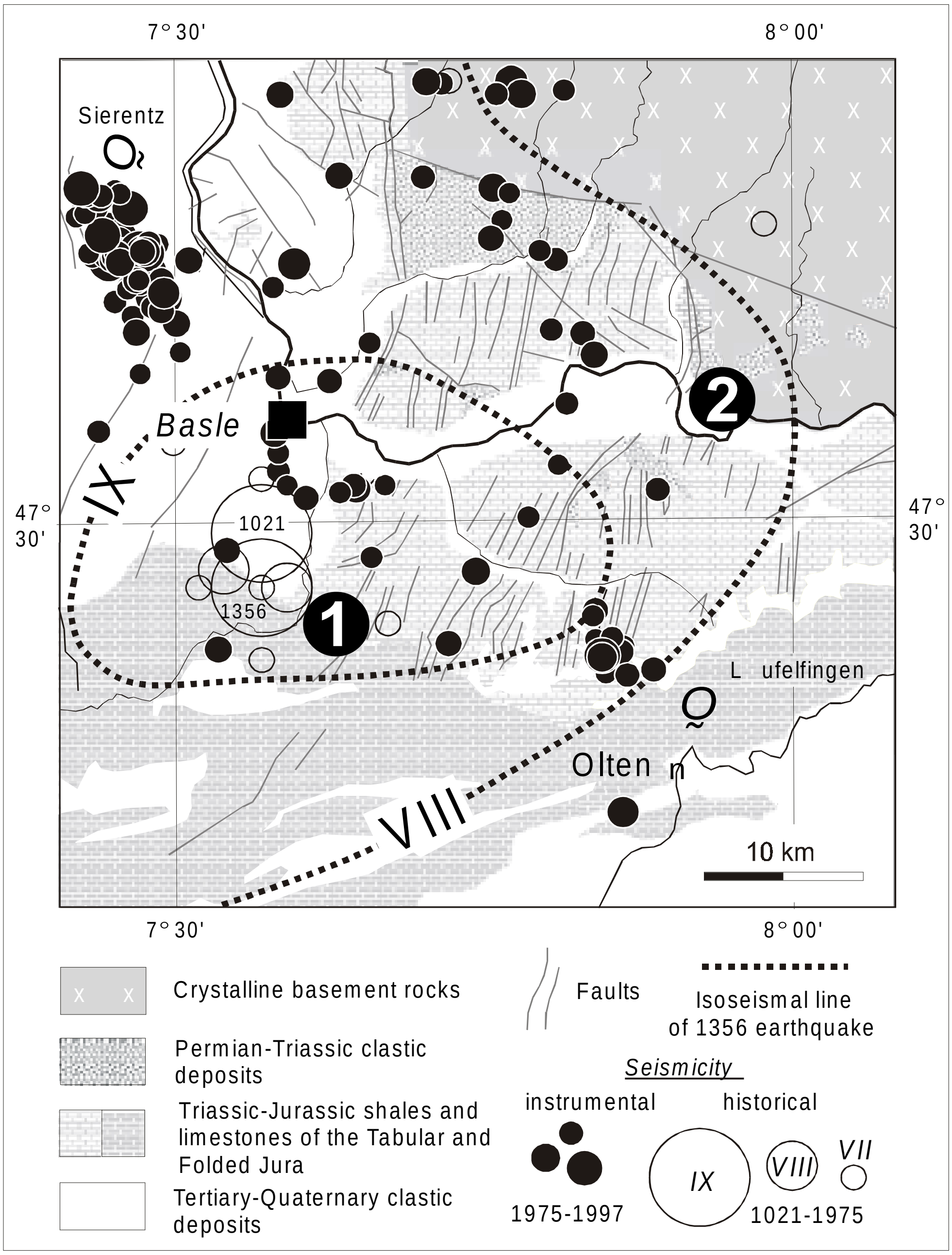

Figure 1. Overview of the seismicity and geology in Basel area, with (1) lake Seewen and (2) lake Bergsee.

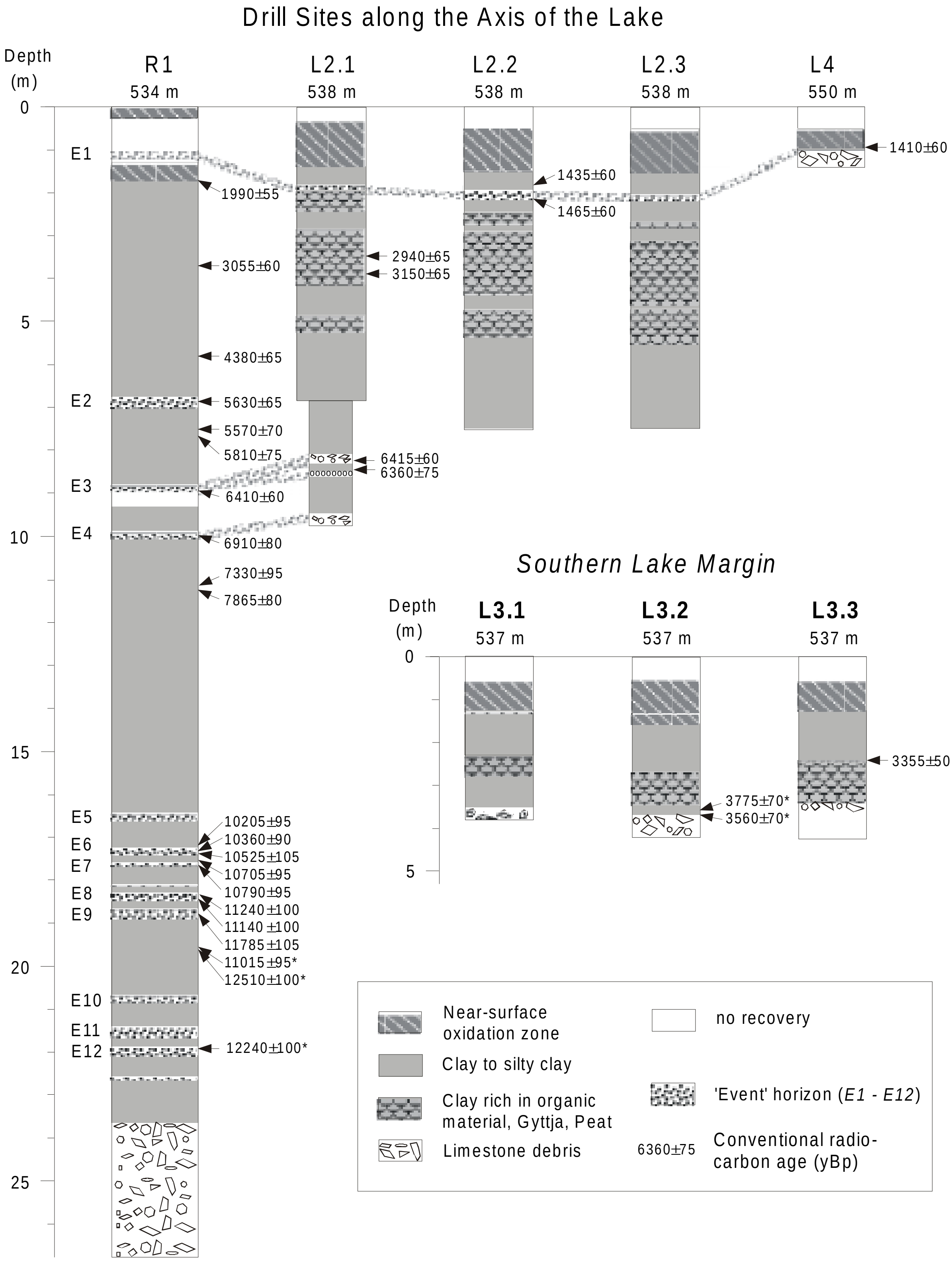

Figure 2. Some of the results obtained for lake Seewen.

The uniform clay and silt sequence in Lake Seewen (Figure 2) shows 12 extraordinary sedimentary horizons, of which at least four horizons indicate structures that could be related to earthquakes. There are soft-sediment deformation structures (convolute bedding, clay clasts in silt, pillar structures and break-up structures) combined with small fissures and silt dykes. In Lake Bergsee the Holocene sedimentary record is characterized by a very uniform organic-rich Gyttja sequence. Here at least five event horizons can be recognized based on small sedimentary structures like silt and sand pockets, lumps and layers, small fractures partly filled with sand grains or coated with minerals, simple fractures and silt dykes. At least three of these event horizons in Lake Bergsee could be correlated with three events in Lake Seewen based on radiocarbon ages. This indicates a possible regional origin of these event horizons, which could be related to palaeo-earthquakes. Ongoing investigations of the soil mechanical properties of Gyttja deposits from Lake Bergsee should supply further evidence for the seismic origin of these event horizons.

MICROZONATION

The Basel earthquake in 1356 with epicentral EMS98 intensity between IX and X was one of the largest known events in Northern Europe, and severely damaged the city of Basel. For this reason, in 1998, a qualitative microzonation was performed for the city [Fäh et al., 1997; Noack et al., 1997; Noack and Fäh, 1999]. The microzonation study includes the mapping of the geological and geotechnical soil conditions which are known from over 2700 shallow wells. This comprises also detailed lithological descriptions of the cores, thickness of the strata, groundwater data, and SPT measurements. The microzonation was performed by means of a qualitative rating scheme that takes into account the influence of seven characteristic parameters of the local soils which can be the cause of amplification of ground motion during earthquakes. Four parameters account for the influence of the Quaternary gravels. These are the consolidation of the gravels, the type of the Quaternary sediments, the thickness and the lateral variations of the thickness. A fifth parameter considers the potential of liquefaction. Finally two parameters account for the influence of the Prequaternary sediments and of the Rhinegraben master fault. The numbers of the rating scheme (which vary from 0 to 22) characterize the susceptibility of the local soil to amplify a seismic signal.

The area of interest is divided into regular cells, 25m by 25m each. The resulting rating for each cell is displayed in a map for the city of Basel (Figure 3). High numbers (given in red colours) indicate an increased susceptibility and low numbers (given in blue colours) show a reduced susceptibility with respect to a regional value. On the basis of the variability of observed macroseismic intensity data during the last 100 years, it is estimated that the obtained variation from 0 to 22 points in the rating scheme corresponds to plus and minus one intensity degree from an average regional intensity value [Fäh et al., 1997]. The value of 11 corresponds to the regional average of the seismic hazard.

Within this project the amplification effects will be numerically simulated in order to obtain a quantitative estimate. As a first step the physical parameters seismic velocities, damping factors and thickness of the different soils are estimated in order to derive a 3D structural model of the area. From the classification of the different local soil conditions, test sites have been selected for specific in-situ measurements. Methods involved are mostly low-cost methods: small-scale S- and P-refraction measurements with hammer seismics and with seismic ambient noise, and the polarization analysis of seismic ambient noise.

So far there has been a campaign of systematic ambient noise measurements in the Basel area, involving over 250 measurements [Kind et al., 1999]. The measurement points have been selected to give a good coverage of the model area, a large selection of different quaternary sediments and sediment thicknesses, and a good coverage of the prequaternary geological structures. The ambient noise recordings are analysed with the polarization technique, also known as horizontal to vertical spectral ratio (HVSR) method, which was developed in Japan and first published in English by Nakamura [1989]. Several studies have been done about the interpretation of these polarization spectra [e.g. Lermo and Chavez-Garcia, 1994; Lachet and Bard, 1994; Fäh et al., 1997] and the interpretation of its first peak as fundamental frequency of resonance of the local ground is commonly accepted. From the ambient noise measurements we are able to map the fundamental frequency of resonance in the Basel area, which is shown in Figure 4.

Clearly, the main geological structure is reflected in the measurement results: The flexural monocline of the Upper Rhine Graben separates the measurements, where the quaternary deposits cause the main peak in the polarization analysis over the Tabular Jura, while the softer prequaternary materials show up in the Rhine

Graben itself. In the Rhine Graben also the division in the deeper syncline of St. Jakob Tuellingen and the less deep area further to the west are visible.

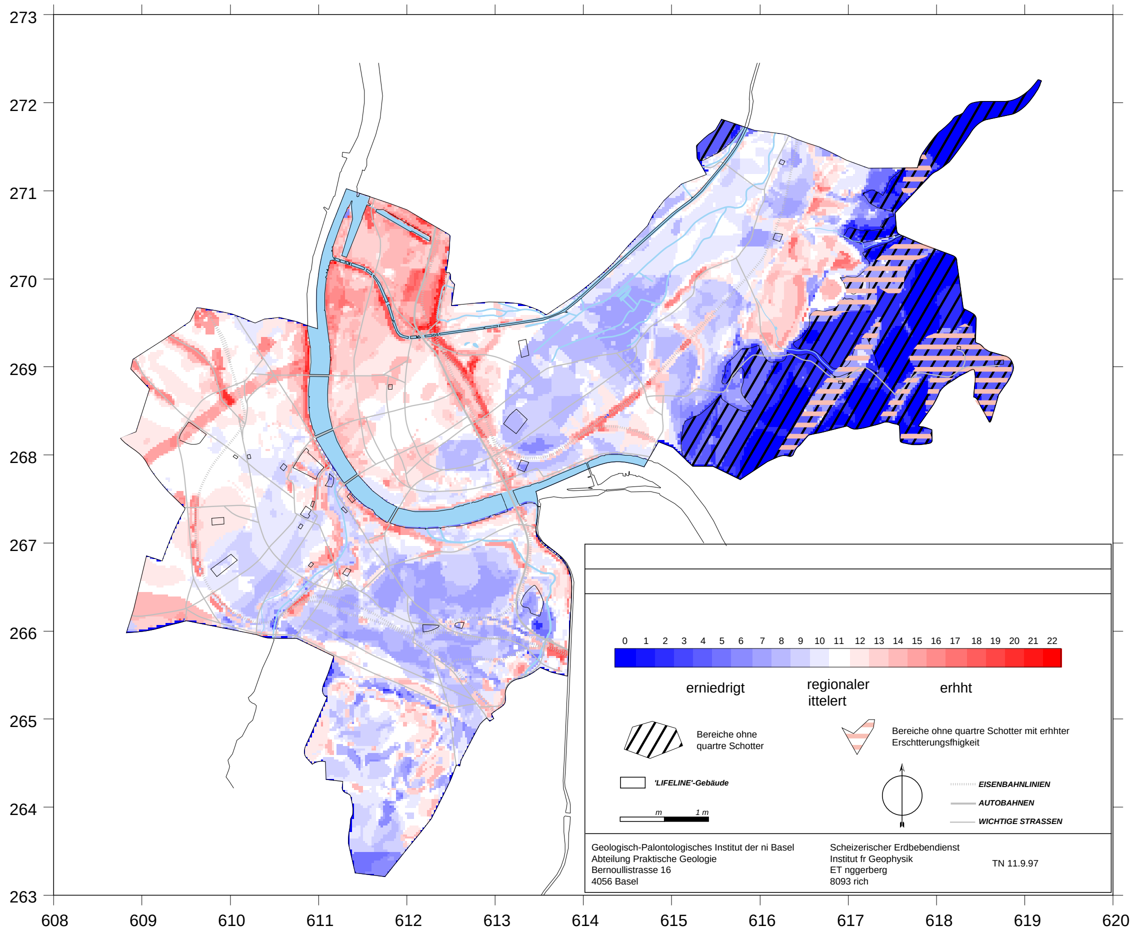

Figure 3. Qualitative microzonation map of the city of Basel. The numbers of the expected amplification characterize the relative susceptibility of the local soil to amplify a seismic signal. The obtained variation from 0 to 22 points corresponds to plus and minus one intensity degree (EMS-scale) from an average regional intensity [from Noack and Fäh, 1999].

The use of the ambient noise measurements is not limited to the interpretation of the first peak. In many places in the Rhinegraben, further peaks can be seen at higher frequencies, which can be explained by the resonances of the quaternary layer. As there is an abundance of boreholes in the Basel area giving detailed geotechnical information about the quaternary sediments, a combination of several methods can be used to infer seismic properties for the structure.

DAMAGE SCENARIOS

One of the goals of the project is to compute damage scenarios by considering different ground motion parameters and different levels of detail. As a first step, this can be done with a rapid technique, based on the qualitative microzonation study and the inventory of buildings in the area [Fäh et al., 1999]. The method is applied to the city of Basel which is an area with a high density of population and industry. The scenario modelling is based on the advantage of the EMS98 [European Macroseismic Scale 1998, Grünthal, 1998] to include both a qualitative and a quantitative approach to damage. The qualitative aspect deals with the type of the buildings and its vulnerability; the quantitative aspect with the probability of different grades of damage occurring.

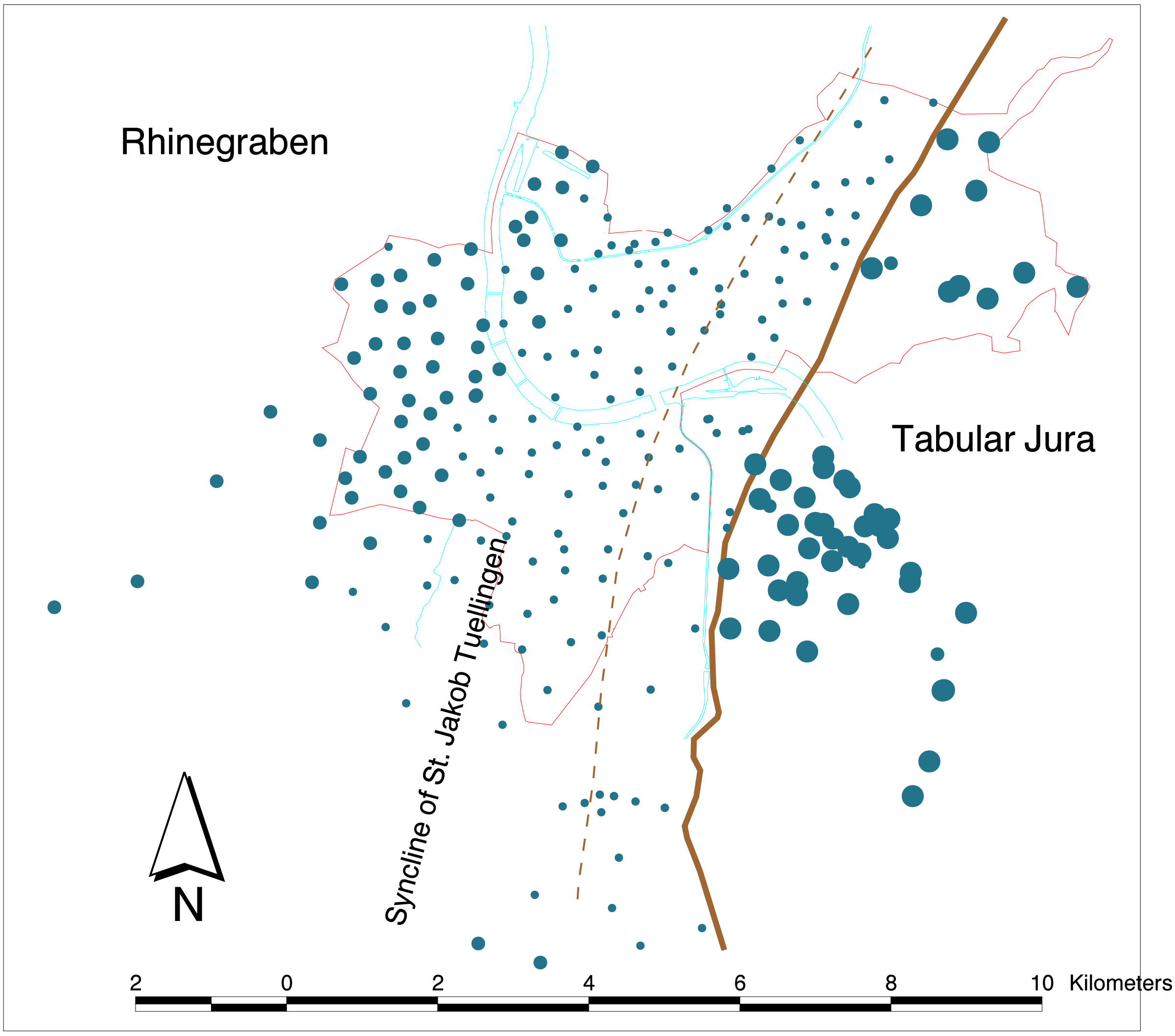

Figure 4. Ambient noise measurements: Drawn are the city limits of Basel, the rivers and the flexural monocline of the Upper Rhine Graben. Large points indicate a fundamental frequency higher than 2Hz, medium points are in the range of 0.75-1.2Hz and the small points represent frequencies of 0.3-0.75Hz.

The damage scenario is computed with the following scheme. As input, we assume two scenario earthquakes, the first one corresponds to an event with an intensity between VII and VIII and with a return period of 475 years (90% probability of non-exceedance in 50 years) [Grünthal and Mayer-Rosa, 1998], and the second event simulates the 1356 Basel earthquake with an Intensity of IX in the city [Mayer-Rosa and Cadiot, 1979]. We compute to these earthquakes the expected intensity variations in the different quarters of the city using the results of the microzonation study [Fäh et al., 1997; Noack et al., 1997; Noack and Fäh, 1999] where it is assumed that the degree of regional seismic hazard is already known from the probabilistic hazard maps or for deterministic earthquake scenarios and expresses an increased or reduced hazard with respect to a regional average. The increase or reduction is due to local site effects, and can be given in terms of intensity variations. Therefrom, with the approximate knowledge of the building types and their distributions within the city, and by assuming reasonable vulnerability curves based on EMS98, a damage degree is established for the different quarters of the city.

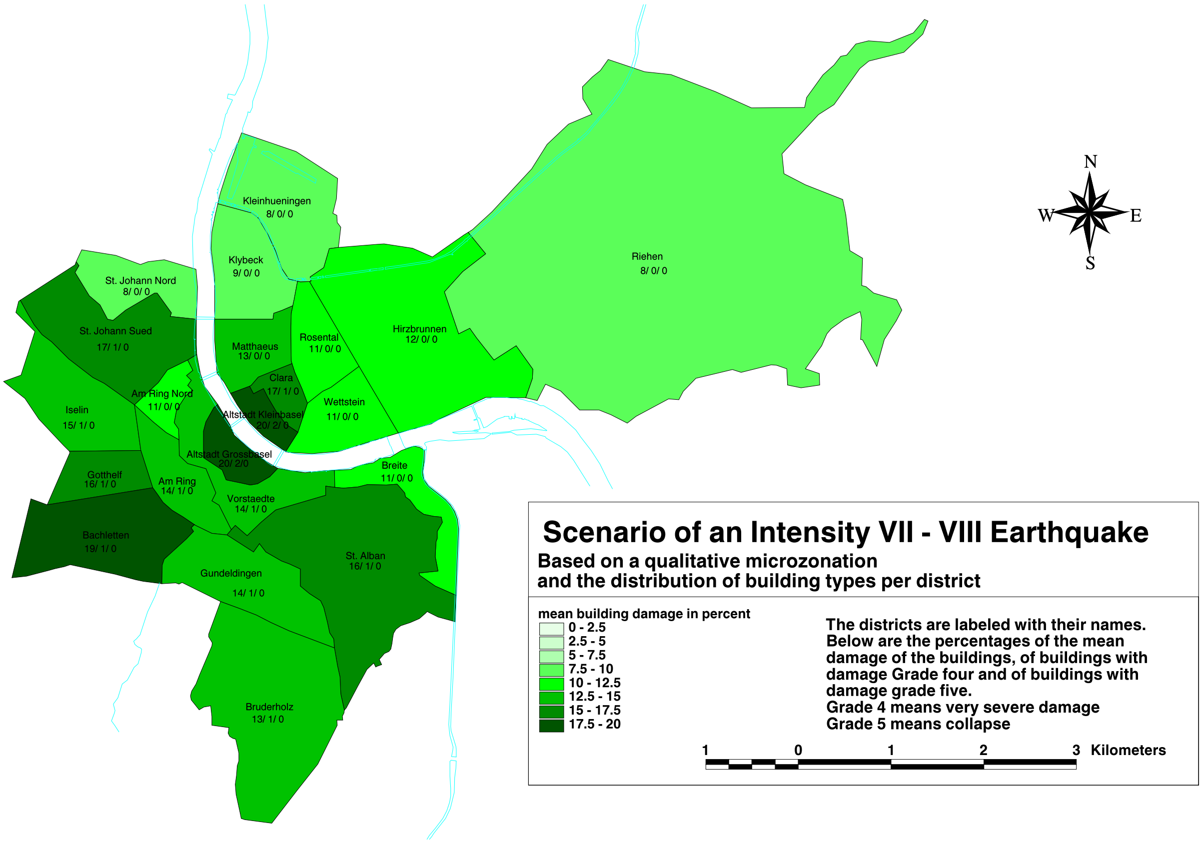

Figure 5. Preliminary results of a damage scenario in Basel assuming an earthquake with an intensity between VII and VIII.

The calculated scenario with an intensity VII - VIII earthquake represents the earthquake with return period 475 years which is generally used in building codes. Preliminary results of this scenario modeling are shown in Figure 5. Average damage to buildings in the districts range between five and twenty percent for the intensity VII - VIII scenario, while the intensity IX scenario values range from 28 up to 56 percent. The variation in building types within the city and the variability of local ground conditions affect the mean damage significantly, so that their influence on earthquake damage can accumulate or cancel for single districts [Fäh et al., 1999]. The distribution of building types, the average soil conditions, the deviations in intensities from the regional mean in the microzonation, and the vulnerability functions have been approximated for this study. Further refinements are foreseen in the future within the current project, including uncertainty estimates.

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