Geophysical Research Abstracts, Vol. 7, 09526, 2005
SRef-ID: 1607-7962/gra/EGU05-A-09526

Towards long-term and short-term warnings before large earthquakes

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In the PREPARED project, we aim to create methods to assess the place, the size and the time (immediacy) of large earthquakes. For this, we use the special conditions in the South Iceland seismic zone (SISZ), intensive research work during several decades, to understand the crustal and subcrustal process that can lead to large earthquakes. Our observational material is multidisciplinary, seismic, geodetic, hydrological, and chemical. The observations range from available modern microearthquake and deformation monitoring, towards historical earthquakes and geological studies of fault slips. The various models that are in construction, to explain the observations, take into account rheological heterogeneities of the SISZ, both horizontally and vertically. These models take into account the transition from a lithostatic pore pressure gradient at depth in the crust to hydrostatic gradient near surface.

The SISZ is an EW trending fault zone in South Iceland, perpendicular to the general direction of the Mid Atlantic ridge. It reveals 2 cm/year left lateral motion to cope with the general present time rifting speed of 2 cm at this part of the ridge. SISZ is usually only considered 70 km long zone, where earthquakes reaching magnitude 7 occur. It has an oblique continuation into zones of mixed volcanic and earthquake activity, towards west in the Reykjanes Peninsula, and to east towards the Eastern Volcanic zone. The SISZ is around 10 km broad as indicated by micro seismic activity. GPS observations indicate a somewhat broader zone. Besides transform motion, the zone extends NS in the long term. According to the NUVEL 1A plate model this extension may be of the order of one fifth of the transform motion. The large earthquakes in the zone, historical or seismologically measured, all seem to have vertical fault planes perpendicular to the direction of the SISZ, with right lateral slip. The NS earthquake faults

are only repeated on a time scale of several hundreds of years. The mapped historical and monitored faults in the zone indicate a tectonic fabric in this zone heterogeneous on a small scale, only on a scale of a few km. The depth to the brittle/ductile boundary varies within the zone, i.e. from around 5-6 in the west to around 10-12 km in the easternmost part. An “everyday” activity of small earthquakes (high b) concentrates near the brittle ductile boundary, locally elevated due to an interplay between high stresses and high pore pressures. Larger earthquakes tend to occur at shallower depths (low b). Observations exist of swarms migrating upward from the brittle/ductile boundary, suggesting fluid flow. The microearthquakes show varying patterns both in distribution and possibly also in mechanisms, from before the earthquake, to the nucleation phase, and to the time after the large earthquake.

In Iceland, there is much experience in useful short-term warnings for volcanic eruptions and some significant warnings exist also for some aspects of impending large earthquakes. All seismically well-observed earthquakes in Iceland larger than five are preceded by anomalous activity expressed in small earthquakes. Rheological heterogeneities and observable fluid rock interaction at depth is the common denominator that favors the prediction. Some aspects of the two Ms 6.6 earthquakes in the year 2000 in the SISZ were predicted.

The main objective of the PREPARED project is to discover potentially dangerous faults, in their build up stage, by various methods. To develop methods that can help in monitoring and understanding the physical processes that can lead to a large earthquake from long before to the nucleation phase. Develop methods that can help to assess any significant aspect that describes a coming earthquake and its effects, on a long term as on a short-term basis. A very significant technology aims to understand coupling between earthquakes, to warn for post earthquake activity, as well as coupling between earthquakes and other hazardous processes like volcanic eruptions, landslides and avalanches. In the same way, it is investigated and modelled how dyke intrusions and other deforming processes can trigger earthquakes.

The results of PREPARED as well as earlier research and continuous monitoring of geoparameters goes into the information and warning tool EWIS, which is our continuous link to the society on the internet as well as a common table for the scientists for real time evaluation of hazard situation.