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From a physical approach to earthquake prediction, towards long and short term warnings ahead of large earthquakes

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For 20 years the South Iceland Seismic Zone (SISZ) was a test site for multinational earthquake prediction research, partly bridging the gap between laboratory tests samples, and the huge transform zones of the Earth. The approach was to explore the physics of processes leading up to large earthquakes.

The book Advances in Earthquake Prediction, Research and Risk Mitigation, by R. Stefansson (2011), published by Springer/PRAXIS, and an article in the August issue of the BSSA by Stefansson, M. Bonafede and G. Gudmundsson (2011) contain a good overview of the findings, and more references, as well as examples of partially successful long and short term warnings based on such an approach.

Significant findings are:

Earthquakes that occurred hundreds of years ago left scars in the crust, expressed in volumes of heterogeneity that demonstrate the size of their faults. Rheology and stress heterogeneity within these volumes are significantly variable in time and space. Crustal processes in and near such faults may be observed by microearthquake information decades before the sudden onset of a new large earthquake.

High pressure fluids of mantle origin may in response to strain, especially near plate boundaries, migrate upward into the brittle/elastic crust to play a significant role in modifying crustal conditions on a long and short term.

Preparatory processes of various earthquakes can not be expected to be the same. We learn about an impending earthquake by observing long term preparatory processes at the fault, finding a constitutive relationship that governs the processes, and then extrapolating that relationship into near space and future. This is a deterministic approach in earthquake prediction research. Such extrapolations contain many uncertainties. However the long time pattern of observations of the pre-earthquake fault process will help us to put probability constraints on our extrapolations and our warnings.

The approach described is different from the usual approach of statistics of universal precursors or stress level. The approach is more related to failure physics, by studying the ongoing failure. But it requires watching and relevant modeling for years, even decades. Useful information on fault process and warnings can be issued along the way, starting when we discover a fault showing signs of preparatory processes, up to the time of the earthquake. Such information and warnings could be issued by government agencies in cooperation with scientists to the local Civil Protection committee closest to the fault with information about how to prepare, including directives about enhanced watching. For such a warning service we need a continuously operating geo-watching system, applying modern computing technology to the multidisciplinary data, and a rule based schedule to prepare adequate warnings.