Assessing the probability of concealed active faults existing through Bayesian analysis of known active faults, historical seismicity and helium isotopes

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Assessing the stability of the geological environment including the spatio-temporal distribution of active faulting is of particular concern in the context of site selection of critical facilities such as nuclear power plants, spent fuel reprocessing facities as well as geological repositories or surface storage facilities of radioactive waste etc. Understanding the spatial distribution of active faulting is one of the challenges facing geologists in that not all active faults have surface experessions. This is especially so for active faults that initiated within the last 0.5 Ma due to their smaller cummulative displacements compared with older and more mature active faults (e.g. faults that have been active for 1 –2 Ma or longer) (Doke et al., 2012).

The western Tottori regions is an area where two recent earthquakes occurred along two separate unknown faults; the 2000 Tottori earthquake (6 October 2000; Mw 6.6) and the 2016 Tottori Earthquake (21st October 2016; Mw 6.2).

We present here a probabilistic approach based on Bayesian statistics that can be used to combine multiple datasets (in this case historic seismic data and helium isotopes sampled from wells) to produce hazard maps showing the likelihood of active faults existing or not.

In order to assess the spatio-temporal distribution of active faults, we start by looking at mapped active faults to estimate spatial frequencies and orientations. This data is sporadic as active faults listed in current databases do not necessarily represent all active faulting, as not all active faults have a surface evidence and their existence might be unknown. In this case, additional datasets are needed that may imply the existance of active faulting. Datasets such as high He-3/He-4 ratios which tend to be found in volcanic regions have been attributed to degassing from the mantle. Studies carried out in the western Tottori district have shown the potential of using He-3/He-4 ratios as a means of providing indirect evidence of the existence of source fault(s) that caused the 2000 and 2016 Tottori earthquakes (e.g., Umeda and Ninomiya, 2009).

We applied our Bayesian model in the Tottori district as a case study. In the first step, present known active faults are divided into equal fault segments. 2-D prior probability distributions are calculated using probability density functions (PDFs) centered over the fault segments with varying values of standard deviation depending on the degree of conservation required. A non-conservative PDF is assigned in the first step so that probability is never zero. In the second step, statistical tests are used to remap additional datasets, here He-3/He-4 and estimated historic seismic souce zones into a likelihood PDF. The prior PDF from the first step above is then combined with the likelihood PDF using Bayes' rule to produce a posterior PDF. The posterior PDF is then evaluated using recent seismic activity.

References

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Keywords: Active Fault , Bayesian, Probability

