Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

HCG36-05 Room:411 Time:April 29 16:30-16:45

A Bayesian approach to assess the probability of concealed active faults existing using helium isotope ratios

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In Japan, numerous studies have been carried out to assess the stability of the geological environment including in particular, the spatio-temporal distribution of active faulting in the context of site selection of a radioactive waste repository and/or assessing the safety of current nuclear facilities etc. One key concern is the existance of active faults that do not show any surface rupture.

High He-3/He-4 ratios which tend to be found in volcanic regions have also been measured in non-volcanic regions. This has been attributed to degassing from the mantle with faults potentially acting as conduits (e.g., Kennedy et al., 1997). 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 6 Oct 2000 Tottori earthquake (Mw 6.8), but which had no apparent surface indication prior to the earthquake (Umeda and Ninomiya, 2009).

Here we introduce a new technique based on Bayesian inference in an effort to quantify this theory. In the Bayesian paradigm, we make *a priori* assumptions based on the tectonic setting of the study area as a starting point. 'Known' active faults are divided into equal distant fault segments. The *a prior* assumption here is that 'unknown' fault segments do not exist far from 'known' fault segments. It is also assumed that the probability of 'unknown' faults existing decreases with distance from the 'known' faults.

2D *a priori* probability distributions of unknown fault(s) existing are then calculated using kernel functions (Martin et al., 2003) centered over the known fault segments. A Cauchy probability density function (PDF) is assigned here conservatively as the *a priori* distribution in the first step so that probability is never zero.

In the second step, the method developed by Martin et al. (2004, 2012), is adapted to remap He-3/He-4 ratios into a PDF, called a likelihood function based on Kolmogorov-Smirnov statistical tests. The *a prior* PDF from the first step above is then combined with the likelihood PDF using Bayes's rule to produce a *a posteriori* PDF.

Carrying out the calculation using data from before the Tottori 2000 earthquake, the *a posterior* 2D probability maps showed increased probability of unknown active fault(s) existing in the region above the source zone of the 2000 earthquake. Thus, in the case of the Tottori region, the *a posterior* probabilities corraborate the theory that faults could be acting as conduits for mantle helium.

The potential of the methodology to incorporate other information such as gravity and crustal strain rates will also be presented and discussed.

References
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Keywords: Active fault, Bayesian, Helium isotope ratio