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Uplift during a decade prior to great earthquakes: Interpretation and prediction by a barrier invasion/fractal asperity model

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It has been generally believed that precursory uplifts on the coast occur during a 10 year or more period prior to great earthquakes in the subduction zones near Japan. However, there has been no physical mechanism to explain this long-term precursory phenomena. In this paper, I present a model to do so. I apply this model to tide gauge data before the 1923 Kanto and 1946 Nankai earthquakes. These postdictions succeed within errors of a few years. Then I apply the model to the precise leveling data near Omaezaki, and try to predict the occurrence time of the coming Tokai earthquake.

The model follows the barrier invasion/fractal asperity model (this meeting, Seno). The basic assumptions of this model are: (1) the plate boundary fault zone consists of asperities and barriers, where asperities and barriers have negative and positive a-b values, respectively, (2) asperities are distributed in fractal, and (3) only the region where barriers are turned into zero friction due to elevated pore fluid pressure (called barrier invasion) can rupture as an earthquake.

I assume each asperity has a circular shape, and introduce order n such that order 0 corresponds to the maximum-size asperity. Let an order n asperity have a number of Na order n+1 asperities inside, and the ratio of the radius of order n asperity to that of order n+1 asperity be lambda. The fractal geometry is then described by the parameters Na and lambda; for example, the fractal (capacity) dimension D is log(Na)/log(lambda). The stress drop (shear strength), displacement, and moment can be scaled against the order.

Let a great earthquake has order 1 asperities inside of its rupture zone. The earthquake happens when the barriers surrounding order 1 asperities have been invaded, and one of the order 1 asperities breaks. In this case, it can be inferred that barriers inside of an order 1 asperity have not been invaded yet, since if so, breakage of the order 1 asperity, thus, the great earthquake, would have happened. Therefore before the earthquake, slow slip of smaller asperities within order 1 asperities occur, since they are surrounded by non-invaded barriers.

In order to calculate the crustal deformation due to the above slow slip, I assume that an order n asperity breaks when more than or equal to Nb order n+1 asperities inside has broken. Let p as a probability of breakage of an smallest-size asperity, I can calculate a probability of breakage of an any order asperity successively. Because the crustal deformation at the time of the earthquake is known and constrains the amount associated with breakage of an order 1 asperity, that associated with breakage of an any order asperity can be calculated using the scaling law of moment against the order. Therefore given p, total crustal deformation can be calculated.

Since I know the present amount of deformation, I know the present value of p. Letting the time of occurrence of the great earthquake tc, and knowing that this is the time at least one order 1 asperity breaks, I can convert p into time, assuming a linear relationship. Perturbing tc as a parameter, I can obtain the best estimate of tc as a best fit to the observed uplift data.

I use the tide gauge data at Aburatsubo and Kushimoto for the 1923 and 1946 earthquakes. I assign a range of secular subsidence rates for each data set, and subtract the secular component from the data to obtain the precursory uplift. Using the 5 points running average data during 1896.9-1920.0, and 1898.1-1940.0, respectively, I obtain tc = 1923.8 (-0.8, +0.6), 1946.7 (-5.7, +2.7), respectively. The errors of the latter are large because there is a large disturbing noise during 20-40 years before the earthquake. For the coming Tokai earthquake, using the 5 points running average leveling data between Hamaoka and Kakegawa during the period 1981.83-2000.83, I obtain tc =2007 (-+3). The errors above are contributed mostly by the errors in the estimation of secular subsidence rates.