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On the upper limit of in situ piezomagnetic stress sensitivity in the Earth's crust: insights from geomagnetic observation during earthquakes in Japan

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Changes in the Earth's magnetic field that accompany tectonic events such as earthquakes and volcanic eruptions are frequently interpreted in terms of the piezomagnetic effect. The piezomagnetic effect describes changes in the magnetization of ferromagnetic minerals when under mechanical stress. Experimental and theoretical studies have shown that the change in the magnetization due to the piezomagnetic effect is approximately proportional to the product of the applied stress and the initial magnetization when the amplitude of applied stress is the same order of magnitude to that in the Earth's crust.

However, quantitative aspect of the piezomagnetic effect remains poorly understood. The proportional coefficient of the piezomagnetic effect is referred to as the stress sensitivity of the piezomagnetic effect. The stress sensitivity is determined by means of laboratory experiments. However, changes in the geomagnetic field calculated based on stress sensitivity obtained via experimental studies are sometimes underestimated compared with observed values. In other words, the stress sensitivity for rock samples used in laboratory experiments may be considerably smaller than that of the accrual crust. Because the value of the stress sensitivity is essential in evaluating the potential of magnetic measurements as a reliable tool in monitoring stress changes within the Earth's crust, it is desired to determine the value of the stress sensitivity by several ways

I have tried to determine a possible range of the stress sensitivity by means of comparisons between theory and observation during large earthquakes. In Japan, we have experienced two earthquakes during which the geomagnetic field has been continuously recorded; one is the 2007 Noto Earthquake (Mw 6.6), and the other is the 2011 Off the Pacific Coast of Tohoku earthquake (Mw. 9.1). I have calculated expected changes in the geomagnetic field by means of the piezomagnetic field considering fault models corresponding to these earthquakes; then compared them with observed variations in the geomagnetic field.

For both cases, the stress sensitivity is determined to be rather small values. In the case of Tohoku earthquake, comparison between the data and results of calculation suggests that the stress sensitivity for this event was about $2-3\times10^{-9}$ Pa^{-1}. In the case of Noto earthquake, the comparison suggests that the stress sensitivity was as small as 1×10^{-9} Pa^{-1}. Both of these values are on the same order as that suggested by laboratory experiments. This result implies detection of changes in the geomagnetic field generated by stress changes in the crust is generally difficult, unless sufficient number of observation sites are deployed.