Enhancement of Piezomagnetic Signals Above a Borehole: The Mogi Source as an Example

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We have conducted since 1998 continuous measurements of geomagnetic total force intensity and area surveys of SP in Long Valley Caldera, California, in order to detect possible changes in the EM fields associated with some intrusive events at depth. An episodic event, i.e. swarm earthquakes and crustal inflation , was induced in the caldera by the October, 1999, Hector Mine Earthquake in southern California. We observed some noticeable change in the total intensity similar to the volume dilatation change at one of our magnetometers which was set very close to a borehole. We attempt to quantitatively evaluate how a borehole can enhance the piezomagnetic signals on the ground surface.

Suppose that the earth is an elastic half-space with a uniformly magnetized top layer and that a vertical cylindrical borehole is excavated with radius a and length L. Once the earth is strained by any internal source, an additional magnetization is produced in the whole magnetized crust owing to piezomagnetism of rocks. The magnetic field is thus estimated by volume integral of the piezomagnetization. This volumetric integral can be reduced to a surface integral over the entire surface of the magnetized area. The effect of the borehole is represented majorly by the surface integral over the cylindrical surface of the borehole. Under an appropriate approximation, it is equivalent to those produced by a line of horizontally embedded dipoles and quadrupoles along the vertical central axis of the borehole, whose intensity is a function of the displacement components at the axis. This formula is applied to the case of the Mogi model as an example. Since the equivalent magnetic source is horizontal dipoles aligned along a verical axis, the effect of the borehole is extremely local and limited near around the outlet of the borehole.