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# 比抵抗の時間変化の観測研究のレビューと展望
# Reviews and future perspectives of studies on temporal resistivity change

小川 康雄[1*]
OGAWA, Yasuo[1*]

[1] 東京工業大学火山流体研究センター
[1]Volcanic Fluid Research Center, Tokyo Institute of Technology

3D magnetotelluric (MT) modeling is now in practice and is becoming a routine. It is time to start challenges on temporal changes of resistivity structures for active volcanoes or crustal-scale temporal resistivity changes.

Aizawa et al. (2011) made continuous MT measurements at two stations around the Sakurajina volcano and found that the apparent resistivities decrease after the onset of tilt measurement. They interpreted that the volatiles from the magmatic gas may decrease the resistivity of ground water. Honkura et al. (2013) analyzed the array MT data over the North Anatolian Fault during the 1999 Izmit earthquake and found the abrupt coseismic resistivity change at the fault zone.

Peacock et al. (2012, 2013) used MT method to monitor the temporal change of fluid distribution during the fluid injection for enhanced geothermal system. They used phase tensor (Caldwell et al., 2004) in order to avoid effect of temporal change of shallow local structure. MacFarlane et al. (2014) tried to explain the temporal change of phase tensor by two-dimensional resistivity model with anisotropy.

Saito et al. (2015) focused on the crustal resistivity change before and after the Tohoku-Oki earthquake. He used a profile MT data in 2003 passing through Naruko volcano (Asamori et al., 2010) and another repeated profile MT data in 2013. He also used phase tensor to detect the significant resistivity change. MT monitoring has an intrinsic problem of noise contaminations and unstable signal strengths, although it does not require any artificial sources.

Shallow resistivity monitoring by DC resistivity methods is well known. Izu-Oshima eruption in 1986 was successfully monitored by the apparent resistivity change using two sets of dipole-dipole array over the edifice (Yukutake et al., 1990). Although this experiment was successfully detected the rising magmatic melt at the vent, imaging the time-dependent structure was only possible by forward modeling with a priori volcanic knowledge (Utada, 2003)

Smaller scale 4D resistivity monitoring at Onikobe Geyser was successfully performed using multiple-source, multiple-receiver pole-pole method. Kouda (2009) report the case of time switching the current poles, but Jinguuji et al. (2012) report the case with multi-low-frequency current injection at different current poles. The latter has an advantage of continuously monitoring the 3D structure.

Volcano monitoring using controlled source electromagnetic induction is in practice at Izu-Oshima and Aso volcano using ACTIVE system (Utada et al., 2007). They use electrical grounded dipole with step waveform and measure vertical magnetic sensors at many locations. This has an advantage of covering a large area and wide frequency range. Theoretically, multiple sources are recommended, as the response functions are functions of resistivity structures including the transmitter and the receivers. Coincident loop system (VOLCANO LOOP) at the volcanic crater is proposed to monitor the phreatic eruption at Kusatsu-Shirane volcano (Hino, 2014). This has an advantage of an easy installation without digging and burying current or potential electrodes and monitoring the structure directly below the loop. However, the monitoring area is limited. The merit of the system is the detection of the secondary field when the primary source field is absent.

EM ACROSS (Kumazawa et al., 2015) is a frequency domain technique. The frequency domain techniques measures primary and secondary fields together and care must be taken when the source receiver distance is smaller than the skin depth, where primary field dominates. Tensor measurements using multiple sources will be important.

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