Edge of a conductivity anomaly in the crust

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SUMMARY

I present the result of recent dense MT surveys including unpublished new case studies, and hypothesize that macroscale fracture networks exist at the edge of conductive zones, serving as preferential pathways for fluid migration, thereby causing various dynamic phenomena within the crust. The case studies mainly focus on the results around volcanoes, geothermal zones, and seismogenic zones on Kyushu island, Japan.

Keywords: Crust, magnetotelluric, edge, resistivity, earthquake, deformation, geothermal activities, review

INTRODUCTION

Recent dense magnetotelluric observations employing approximately 100 sites with a spacing of less than 2 kilometers show that initiations of large earthquakes, occurrence of deep low-frequency earthquakes, pressure increases, and geothermal activities, predominantly occur at the structural boundary especially edges of electrical conductive zones (e.g., Aizawa et al. 2021, 2022, Triahadini et al. 2023, Usui et al. 2024). One potential driver behind these dynamic phenomena is mobile high-temperature fluids, implying a preferential migration of fluids along the edges of conductive zones. This idea challenges the conventional interpretation that fluids moves through the entire region of conductive zone. To consider the movement of the fluids subsurface, permeability is the most important parameter. It merits attention that permeability does not exhibit a linear relationship with conductivity. If connectivity and porosity have similar values, permeability depends on the size of the pore space, but conductivity does not. Therefore, it is possible that connection of large-pores like macroscale fracture networks can possess high permeability but do not show high conductivity. This is well-documented in geothermal reservoirs globally, where high permeability coexists with modest conductivity.

Method

In this study, I present the result of recent dense MT surveys including unpublished new case studies, and hypothesize that macroscale fracture networks exist at the edge of conductive zones, serving as preferential pathways for fluid migration, thereby causing various dynamic phenomena within the crust. The case studies mainly focus on the results around volcanoes, geothermal zones, and seismogenic zones on Kyushu island, Japan. Kyushu University, in collaboration with other academic institutions, has conducted broadband MT surveys at more than 1000 sites over the past decade. Typical recording duration for a site was two weeks, yielding high-quality MT response functions.

Conclusions

The findings by high resolution 3-D resistivity structure are summarized as follows,

(1) Large earthquakes tend to initiate ruptures at the outer edge of conductive zones, whereas smaller earthquake ruptures initiate everywhere.

(2) Deep low-frequency earthquakes occur at the outer edge of conductive zones

(3) Pressure sources inducing ground deformation are located at the edge of conductive zones.

(4) A high-temperature zone revealed by deep (~3 km) drillings for geothermal development is located at the edge of a conductive zone.

(5) Surface manifestations of active geothermal areas and historical volcanic eruptions frequently align with the edge of conductive zones at depths of 2–6 kilometers.

These shows that active phenomena occur at the edge of conductive zones. Thus, it is important to investigate physical properties of both the conductive zones and their edges to elucidate fluids movement and its relation to active phenomena within the crust.

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