Numerical subduction modeling with back-arc temperature heterogeneity using CFD Module

Changyeol Lee (changyeol.lee@gmail.com)

Faculty of Earth Systems and Environmental Sciences, Chonnam National University

33 Yongbong-no Bukgu, Gwangju, Republic of Korea 61186

Introduction: Numerical modeling study using the COMSOL Multiphysics has contributed to the evaluations of the thermal and flow structures of the subduction zones, which are directly correlated to the arc volcanism. Recently, to understand arc volcanisms, consideration of the back-arc temperature heterogeneity becomes much important along with the temperature heterogeneity of the subducting plate. This poster is prepared to demonstrate that the back-arc temperature heterogeneity can explain some of the unexplained arc volcanisms such as Northeast Japan (Quaternary), Kermadec (Quaternary) and Southwest Japan (Cretaceous).

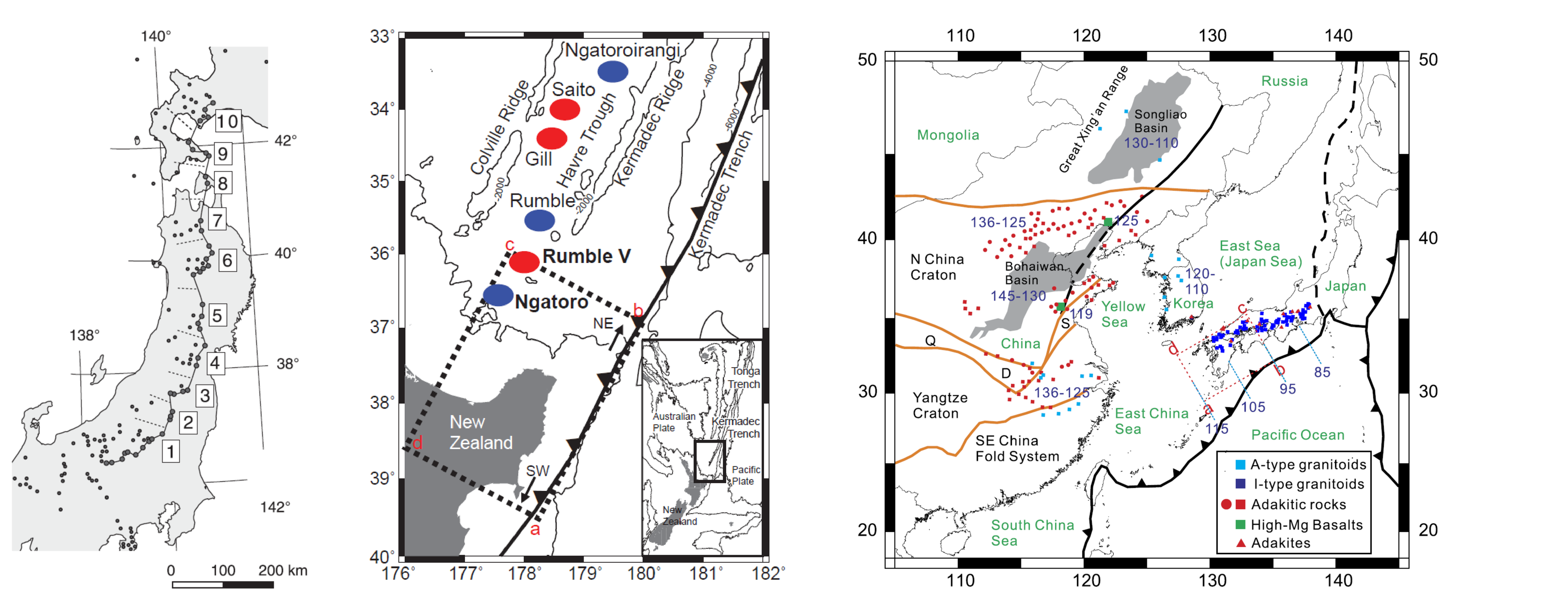

Figure 1. Distributions of igneous rocks in the subduction zones; left: Quaternary volcanoes in Northeast Japan (Tamura et al., 2002) center: Quaternary volcanoes in Kermadec (Kim and Lee, in review) right: Cretaceous igneous rocks in Northeast Asia (Ryu and Lee, 2017)

Computational Methods: The CFD module of the COMSOL Multiphysics allows me to consider the back-arc temperature heterogeneity with kinematic or dynamic implementations. Three-dimensional numerical modeling with the clustering computing allows me to conduct a large amount of calculations, which cannot be conducted using a single computer or workstation.

Three-dimensional kinematic-dynamic subduction model. Our subduction model[22] is developed using the commercial finite element package COMSOL Multiphysics. The governing equations consist of equations of conservation of mass, momentum, and energy,

$$0 = \nabla \cdot \mathbf{v}, \quad (1)$$

$$0 = \nabla \cdot \sigma' - \nabla P + \rho \mathbf{g}, \quad (2)$$

$$\rho_c c_p \frac{DT}{Dt} = \nabla \cdot (k \nabla T), \quad (3)$$

respectively, where $\mathbf{v}$ is velocity (m s^{-1}), P is pressure (Pa), σ' is deviatoric stress tensor (Pa), ρ is density defined as $\rho = \rho_c(1 - \alpha T)$ (kg m^{-3}), ρ_c is reference density (kg m^{-3}), α is thermal expansivity (K^{-1}), T is temperature (K), $\mathbf{g}$ is gravitational acceleration vector (m s^{-2}), c_p is specific heat at constant pressure (J kg^{-1} K^{-1}), t is time (s), and k is thermal conductivity (W m^{-1} K^{-1}).

Figure 2. Governing equations for the three-dimensional numerical modeling, captured from Lee and Wada (2017)

Results: Numerical subduction models for the subduction zones were formulated by considering the their subduction parameters and geometries. The back-arc mantle heterogeneity inflowed into the mantle wedge contributes to the thermal and flow structures of the mantle wedge and subducting slab, which explains the temporal and spatial distributions of the arc volcanisms in the studied subduction zones.

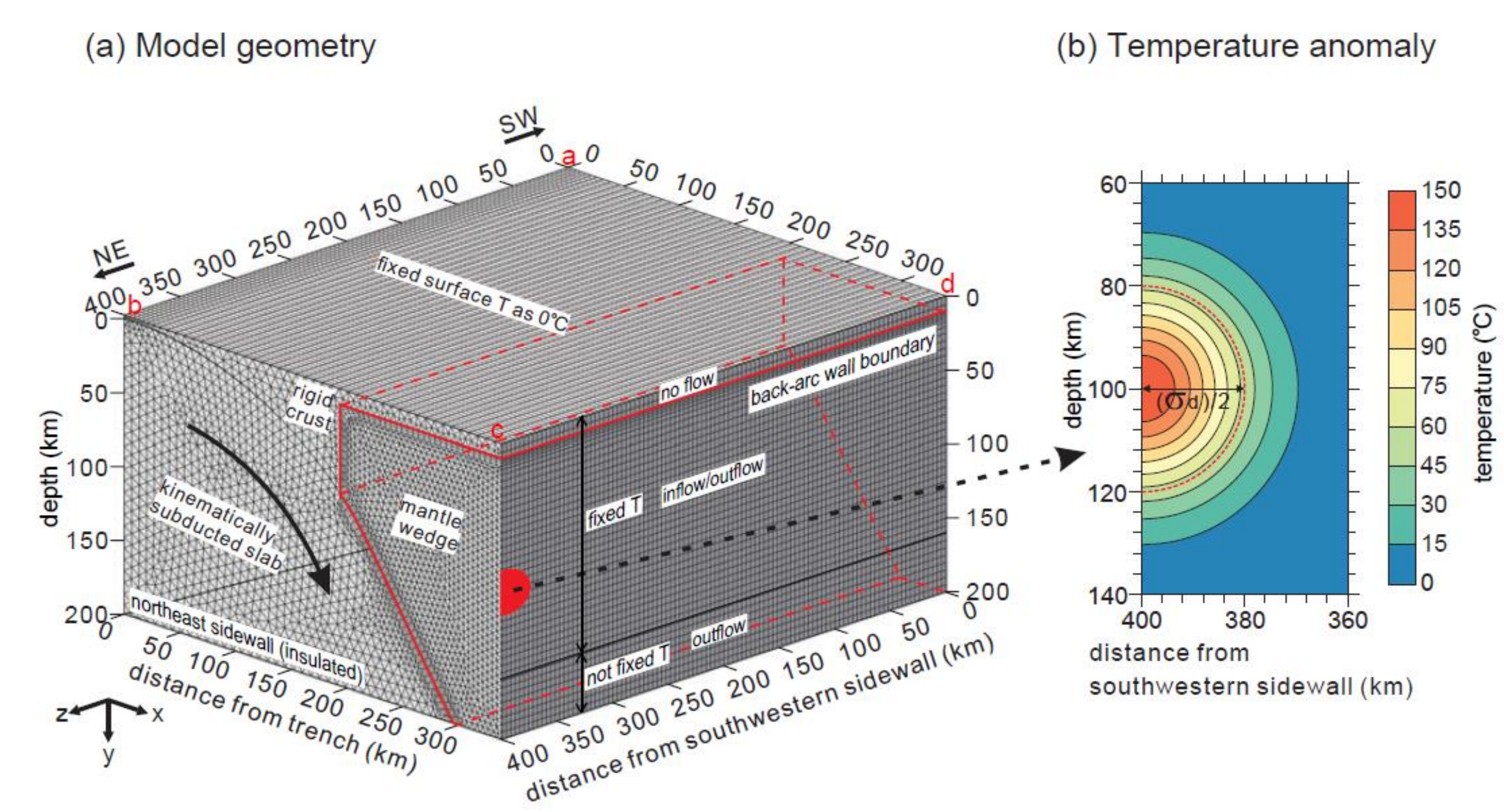

Figure 3. Three-dimensional subduction model which considers the injection of the back-arc mantle heterogeneity into the mantle wedge, from Kim and Lee (in review)

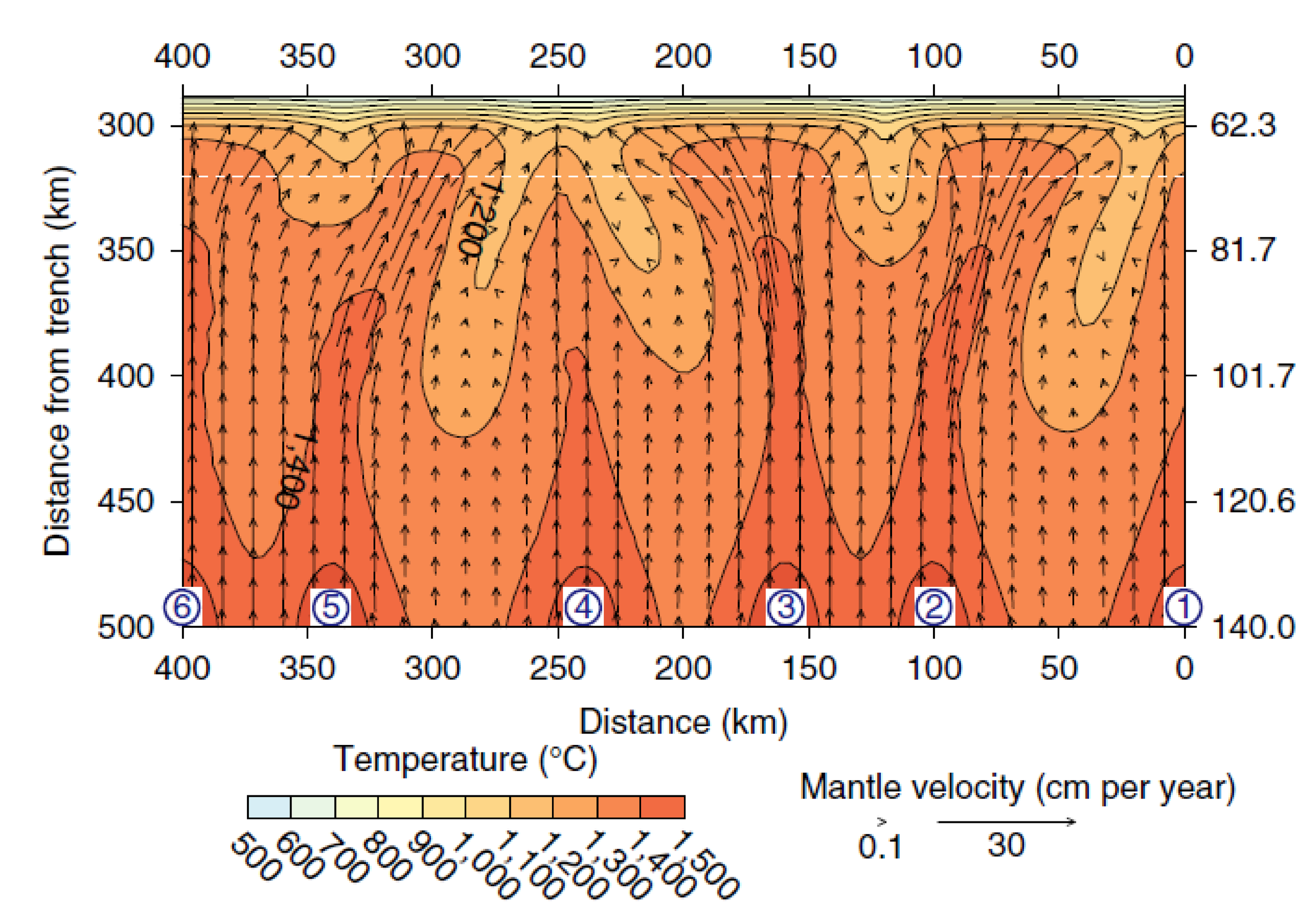

Figure 4. Model calculations (map-view) which show thermal and flow structures of the mantle wedge with the inflowing back-arc mantle heterogeneity, from Lee and Wada (2017)

Conclusions: The model calculations using the COMSOL Multiphysics show that the back-arc temperature heterogeneity plays a crucial role in the evolution of the thermal and flow structures of the mantle wedge, which is well correlated to the unexplained arc volcanisms in the subduction zones. For details, please contact me through an e-mail.

References:

1. Kim, Y.-M. and Lee, C., Mantle Temperature Anomaly in Southern Kermadec Speculated by Three-Dimensional Numerical Subduction Modeling, *Physics of the Earth and Planetary Interiors*, in review
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3. Ryu, I.-C. and Lee, C., Intracontinental mantle plume and its implications for the Cretaceous tectonic history of East Asia, *Earth and Planetary Science Letters*, 479, 206-218 (2017)
4. Tamura, Y., Hot fingers in the mantle wedge: new insights into magma genesis in subduction zones, *Earth and Planetary Science Letters,* 197, 105-116 (2002)