Crustal fluid pressure gradients and permeability estimated from fluid-rock reaction zones

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High pore fluid pressure has been recognized by geophysical observations and is generally considered as triggers of earthquakes and slow–earthquakes (e.g., Audet and Bürgmann, 2014). Although such high pore fluid pressure is recognized as mineral filled fractures in geologic observations, the actual fluid pressure gradients in the crustal rock have not been evaluated quantitatively and remain largely unknown. Here we propose a new methodology estimating the fluid pressure gradients recorded in fluid-rock reaction zones, by utilizing thermodynamic analyses in conjunction with trace element profiles along the reaction zones. With numerical analysis of reactive advection-diffusion transport profiles of Cl and F in the fluid-rock reaction zones, we constrain the duration, fluid velocity and permeability of the fluid-rock reaction zones. We have analyzed amphibolite and granulite hosted fluid–rock reaction zones at Sør Rodane mountains, East Antarctica. The analyses of decimeter scale granitic dyke–crust reaction zone at 0.5 GPa, 700˚C (Uno et al., 2017) show fluid pressure gradients of ˜100 MPa/10 cm or ˜1 MPa/mm. mm-sized hydration reaction zones around single fracture at ˜0.5 GPa, 450˚C (Mindaleva et al., in prep.) also suggest fluid pressure gradients of ˜1 MPa/mm. These extremely high fluid pressure gradients represent the low permeability of the intact amphibolite and granulite host rocks without fractures. The estimated permeabilities are ˜10^{-20} m^2 for the granulite–granitic dyke reaction zones and amphibolite–fluid reaction zones, and are several orders smaller than the widely accepted crustal permeability model (˜10^{-18} m^2; e.g., Ingebritsen and Manning, 2010). On the other hand, permeability along the fractures are estimated as high as 10^{-14-15} m^2 for the granulite and amphibolite-hosted fractures, which is analogous to the permeability estimated for the hypocenter migration for the inland earthquake swarms (˜10^{-15} m^2; e.g., Okada et al., 2014). These results show the importance of low permeability of intact amphibolite/granulite-facies metamorphic rocks in conjunction with episodic high permeability of brittle fractures even at high temperature conditions of 450–700˚C, both of which affect the regional scale permeability in the deep crust.

[References]
Audet, P., Bürgmann, R., 2014. *Nature* **509**, 389–92.
Ingebritsen, S.E., Manning, C.E., 2010. *Geofluids* **10**, 193–205.
Okada, T., Matsuzawa, T., Umino, N. et al., 2015. *Geofluids* **15**, 293–309.
Uno, M., Okamoto, A., Tsuchiya, N., 2017. *Lithos* **284–285**, 625–641.

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