グローバルＣＯＥ地球惑星科学
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Formation of Hydrothermal Extension Veins by Natural Hydraulic Fracturing: Implications for Fluid Overpressures in the Crust

講演者　：　リック･シブソン　教授

所　属　：　オタゴ大学(ニュージーランド)

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担当教員：　岡田　知己　准教授

内線#3919 / E-mail:okada@aob.gp.tohoku.ac.jp

講義内容：

Hydrothermal veins occupying extension fractures are widespread in sedimentary cover sequences but also occur within crystalline basement assemblages and appear to have formed (often incrementally) under tensile effective stress ($\sigma_3' < 0$ or $P_f > \sigma_3$) by natural hydraulic fracturing. From classical rock mechanics, a necessary condition for the development of hydraulic extension fractures in rock with tensile strength, T, is that the differential stress, $(\sigma_1 - \sigma_3) < 4T$, limiting the stress levels allowing formation of extension veins. Another prerequisite for hydraulic extension fracturing is the absence of low-cohesion faults that are favourably oriented for reactivation in the prevailing stress field. In fact, hydraulic extension fracturing often predates the development of throughgoing faults within intact rock. Because of changing stress configurations, the fluid-pressure requirement for hydraulic extension fracturing (as defined by the pore-fluid factor, $\lambda_v = P_f/\sigma_v$) varies with different tectonic regimes. In extensional regimes ($\sigma_v = \sigma_1$) (and to a lesser extent is strike-slip regimes where $\sigma_v = \sigma_2$), hydraulic extension fractures may form under hydrostatic fluid-pressures (i.e. $\lambda_v \sim 0.4$) in the near-surface, but suprahydrostatic fluid-pressures ($0.4 < \lambda_v < 1.0$) are required for hydraulic fracturing at greater depth, the transition depth increasing with rock tensile strength. The ease of hydraulic extension fracturing in the near-surface of extensional regimes is a key factor in the formation of epizonal mineral deposits. In contrast, hydraulic extension fracturing at all depths in compressional regimes ($\sigma_v = \sigma_3$) requires supralithostatic fluid-pressures ($\lambda_v > 1.0$) unless stress heterogeneity exists such that $\sigma_v \neq \sigma_3$. That such extreme fluid overpressures are achieved is testified by the occasional occurrence of swarms of subhorizontal hydrothermal veins. In the largest known example (Minas da Panasqueira, Portugal) the vein swarm extends over 10 km^2 with individual W-Sn-Cu-Quartz veins reaching dimensions approaching 1 km and retaining evidence of gaping (<20 cm) fluid-filled apertures. Arrays of flat-lying hydrothermal veins are also associated with steep reverse faults hosting mesozonal Au-quartz mineralization at depths corresponding to the lower seismogenic zone (10±5 km). Such arrays of flat-lying hydrofractures could be responsible for the bright-spot reflectors reported from areas of compressional tectonics, in particular from regions where compressional inversion is ongoing such as NE Honshu.

主　催　：　東北大学　グローバルCOEプログラム
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連絡先:　宮城県仙台市青葉区荒巻字青葉
東北大学大学院理学研究科　地学棟 404 号
GCOE地球惑星科学事務室　苫米地　由布
TEL/FAX 022(795)6668