論文内容の要旨

論文題目

Quantitative examinations of mass transfer by pressure solution and fluid flow in natural deformation zones

(圧力溶解・流体流入による変形帯物質移動の定量的考察)

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The mass transfer and its evolution of heterogeneous structure of concentrated deformation zone in Earth's crust are important in controlling geological and geodynamical processes as rifting, fault formation, seismic activity and ore deposit. Mass transfer has been estimated in deformation zone such as mature fault and ductile shear zone, and then formation processes were clarified. However these estimations include duplicated mass transfer, and then they could not give mass transfer corresponding to respective deformation mechanisms. In upper crust, most important deformation mechanism for mass transfer is pressure solution. Pressure solution mechanism comprises three elementary processes of dissolution, diffusion and precipitation. Concurrently with mass transfer, pressure solution act as fault healing by compacting and sealing of fault zone. While, fluid flow strongly affect mass transfer by enhancing chemical reaction via fluid and its flow. In this thesis, I try to quantify mass change as mass transfer by pressure solution and fluid flow, respectively. For analysis mass change by respective mechanisms, first I performed detailed observation and chemical analysis.

Fluid flow through deformation zone is studied using simple shear zone in the Ryoke Older granitoids. Analyzed faulted shear zone included huge quartz vein at center of the fault, suggesting fluid flow in fault zone. Results of mesoscopic and microscopic observations show that the fault zone is classified into five domain and all rocks including quartz vein in each domain are

mylonitized. Furthermore, it is clarified by observations that the fault zone deformed at brittle-plastic transition zone interpreted as seismogenic depth. Temperature condition of deformation speculated by microscopic mineral behavior is ranging from 250 °C to 400 °C. Estimation of mass change using Grant's method indicates that mass change occurred closely zone of the fault zone. Almost all samples except for quartz vein and very closely samples from fault zone in stepping domain present mass decrease. Considering stress field estimated by density of foliation, most samples presenting mass loss are situated in tension field, would implying that mass change was occurred depending on stress field. Fluid would flow into tension zone field more easily rather than compression zone. Mineral composition analysis displayed that the mass changes were caused mainly by quartz increase or decrease. Thus fluid flow controlling stress field of fault zone would yield heterogeneity of mass change with fluid (water)-quartz reaction. Relation of time scale between precipitation and dissolution was indeterminate, then I estimates two deformation and alteration histories of the fault zone as described Chapter 2.

For pressure solution, I analyzed shale of Shimanto accretionary complex, that well developed pressure solution seems (PSS) are observed. For clarifying relationship between deformation intensity and degree of mass change, I quantified deformation intensity using PSS in natural shale. As described Chapter 3, immobile element Ti concentrated within PSS, and furthermore PSS occupied area for total area, which called PSS density, correlated to bulk TiO_2. The results suggest that PSS is residue during development of pressure solution and relate to dissolution value, indicating PSS density is useful index of bulk pressure solution deformation. Volume changes calculated by whole rock chemical analysis using Grant's method also correlate to PSS density. Using the correlation, volume change would be calculated simple equation as described in Chapter 3. The correlation and equation suggest that volume is decreased with development of pressure solution. The PSS density also correlated to paleotemperature as describe Chapter 3, development of pressure solution strongly depend on temperature. The relationships enable us to calculate activation energy of deformation. Then I calculated activation energy and estimate basic process of pressure solution in natural condition. As a result of estimation, very low value of activation energy is appeared. Comparing experimental activation energy value of basic process such as dissolution, diffusion and precipitation, diffusion is suitable for this case. As a conclusion, analysis of natural shale for pressure solution shows that large mass transfer occurred by pressure solution development depending on temperature and limiting process of mass transfer would be diffusion in natural shale.

As conclusions, it is clarified that large mass loss and gain were caused by fluid flow and pressure solution, respectively. Chemically, structurally and resulting strength heterogeneity of fault zone was largely enhanced by fluid flow even simple deformation zone. These results imply initial heterogeneity of fault evolution. While, mass change by pressure solution mechanism could be displayed using PSS density, which would be controlled by diffusion. Large heterogeneity by pressure solution is evolved as formation of black seems (foliation) and quartz dissolution. These results for pressure solution imply that if similar mechanisms operate in fault zone, we provide deformation intensity and its mass transfer.