Formation of fracture surfaces during plastic deformation: a study from a natural shear zone

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A natural small-scale brittle-plastic shear zone including crush zones parallel to the shear zone boundary in the Abukuma Mountains, NE Japan, was analyzed to examine a possibility of ductile fracture in the crust. Ductile fracture occurs in metals and alloys when a material is subjected to large plastic strain under a brittle-plastic transition regime, and is brought about by the nucleation, growth and coalescence of microvoids during plastic deformation to form a fracture surface. The optical microstructural analyses revealed a spatial relationship between plastic deformation and brittle fracturing. The observations by scanning electron microscopy (SEM) revealed the existence of microvoid both in fine-grained plagioclase and quartz layers. The analysis of connectivity of microvoids suggests that the nucleation, growth and coalescence of microvoids in fine-grained plagioclase during plastic deformation played an important role in the formation of the crush zone, while the microvoids in quartz layers had never been connected each other to form a fracture surface. The observations by transmission electron microscopy (TEM) suggest piling up of dislocations at grain boundary in fine-grained plagioclase layers. The results in this study suggest the significance of the nucleation, growth and coalescence of microvoids in fine-grained plagioclase layers due to the piling up of dislocations for the formation of the crush zone. There is a possibility that the process proposed in this study plays an important role during earthquake source nucleation in the brittle-plastic transition zone of the earth crust.