Reconsideration of moment tensor: two different representations and their physical meanings

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Seismic moment is a well-known quantity to measure the scale of seismic events, which is usually defined as the product of rupture area, average fault-slip, and the rigidity of surrounding elastic medium (Aki, 1966). More precisely, the seismic moment is nothing but the magnitude of (seismic) moment tensor. For the moment tensor, curiously, there are two different definitions, proposed by Gilbert (1971) and Backus & Mulcahy (1976). In either definition, the moment tensor is represented by the volume integral of moment tensor density over the source region. So, the difference between these two definitions is due to difference in physical quantity chosen as the moment tensor density; Gilbert (1971) chose stress drop (difference between static stresses before and after the event), while Backus & Mulcahy (1976) chose stress glut (difference between elastic model stress and actual physical stress). As pointed out by Backus & Mulcahy (1976), the definition of moment tensor by Gilbert (1971) is certainly incorrect, but, if the volume integral of stress drop is carried out over the whole region, it will give the same tensor as in the case of Backus & Mulcahy (1976).

The Earth's crust is basically treated as a linear elastic body, but it includes a number of defects. The occurrence of inelastic deformation such as brittle fracture and/or plastic flow at the defects brings about elastic deformation in the surrounding regions. So, the actual constitutive equation of the Earth's crust, which relates actual deformation with actual stress, is different from that of linear elasticity. Nevertheless, we aim to solve the equation of motion in the framework of linear elasticity with the help of seismological and geodetical observations. In this paper, through simple theoretical consideration to the equation of motion in continuum mechanics, we show that there exist two different representations of moment tensor, which have essentially different physical meanings. From these two different representations, we can obtain two fundamental equations; that is, the equivalence relation of the moment tensor of a seismic event and the volume integral of stress release over the whole elastic region surrounding the source, which gives a theoretical basis of the CMT data inversion method (Terakawa & Matsu'ura, 2008), and the conservation of the total sum of elastic and inelastic strain (Noda & Matsu'ura, 2010), which gives a theoretical basis of the principle of deformation piling-up in geomorphology.

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