Ceramah Teknik (Technical Talks)

M.H.P. Bott: Origin of stress in the lithosphere and plate boundary forces

Laporan (Report)

The talk by Prof. M.H.P. Bott (Research Professor of Geophysics, University of Durham) was held on 27th March 1992 at 5.00 pm at the Geology Department, University of Malaya. Prof. Bott is currently the external examiner for Applied Geology, University of Malaya.

Abstrak (Abstract)

There are various sources of stress in the lithosphere including membrane stress, thermal stress, tidal stress (small) and stress caused by surface and subsurface loading. It is, however, loading stresses which give rise to most tectonic activity including plate motions.

Loading stresses mainly originate from major lateral variations of density within the lithosphere and asthenosphere, such as crustal roots beneath mountains, crustal transitions at continental margins, low density upper mantle beneath ocean ridges and continental plateau uplifts and dense subducting lithosphere. Such deep loads give rise to surface topography in isostatic equilibrium with the deep load. The combined surface and subsurface loading, if in local isostatic equilibrium, gives rise to equal but opposite loads acting on the intervening region. This gives rise to the loading stress between the surface and deep loads. Where flexural isostatic occurs, there will also be bending stresses.

The result of such loading is to increase the vertical principal pressure between the surface and subsurface loads by the magnitude of the load (i.e. ρgh, where ρ is the anomalous load density, h is the depth extent and g is gravity). As a result its vertical deviataric stress is increased by 1/2 ρgh and the horizontal deviataric stress is decreased by –1/2 ρgh. Such deviataric stresses persist until the loading has been dissipated by tectonic processes and erosion. Loading stresses concentrate upwards into the upper strong elastic part of the lithosphere, so that the thinner the elastic layer the bigger the stress in it. Another important feature of loading stress is that the deeper the subsurface loading, the larger the loading stress (provided the load is wide compared to its depth).

Loading stress can be effectively modelled by elastic/viscoelastic finite element analysis. Using this method, it is shown that a deep, hot region 500 km wide between 200 and 400 km depths, with an excess temperature of 100K corresponding to a density anomaly of –10 kg/m^3 gives rise to a horizontal deviataric tension of about 100 MPa in a 20 km thick elastic layer in the upper crust above the load. Deviataric tension originating in this way can explain continental rifting in uplifted regions such as East Africa, Baikal and the Basin and Range province of U.S.A.

When a major stress system originating in this way is intersected by a zone of weakness such as occurs at plate boundaries, the inability to withstand large shearing stress causes a major redistribution of stress within the adjacent plates. It is the modification of the stress system which also gives rise to the plate boundary forces. It is demonstrated by finite element analysis that deviatari compression in old ocean lithosphere and the ridge push force originate in this way due to the weak zone at an ocean ridge. Similarly, it is shown that dense subducting lithosphere would give rise to local compression above it when its subduction fault is locked, but when this fault is unlocked the stresses are redistributed, giving rise to subduction pull (slab pull and trench suction) on the adjacent plates.

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