Geophysical Research Abstracts,
Vol. 10, EGU2008-A-01859, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-01859
EGU General Assembly 2008

Non-lithostatic pressure during deformation

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A strictly lithostatic pressure distribution can only be developed in a perfect fluid at rest and this is not a realistic model for the tectonically active earth. Pressure is an instantaneous quantity and does not require strong deformation to develop significant effects - indeed in examples such as bending/folding of plates or layers the effects are often most marked at small deformation. It follows that changes in boundary conditions (e.g. plate convergence rates) can produce a change in pressure without any change in depth. Pressure has units of stress (Pa) and is non-dimensionalized relative to another stress - generally the maximum shear stress in the material. This simple consideration highlights the fundamental observation that tectonic pressure scales linearly with material strength (for a particular strain rate). It also follows that there will always be a jump in pressure across a deforming interface between two rheologically different materials. This is important because such pressure gradients drive diffusion, fluid flow and melt migration. The scaled non-dimensional pressure itself varies in space and time according to the geometry of the system and the boundary conditions. Changing the sign of the boundary conditions (e.g. of the velocity, representing for example a change from shortening to extension at the same rate) simply inverts the sign of this geometric factor, changing overpressures into underpressures but with the same pattern to the distribution. Likewise inverting viscosity ratios (e.g. a weak inclusion or layer rather than a strong inclusion or layer) has the same effect of inverting the sign on the non-dimensional pressure. The magnitude of this geometric factor is of order 1-2 for many common structures such as folds, boudins or distributions around inclusions. However, the factor can be very much larger in examples of confined flow, such as extrusion or channel flow between strong plates. Both these models have been often proposed for the exhumation of high-pressure rocks in subduction zones, which can be approximated as a long narrow channel between stronger

confining upper and lower lithospheric plates. The potential overpressure that can be reached in such a narrow channel depends primarily on the strength of the confining plates. Locally tectonic pressures in the subduction channel could be strongly amplified by the effects of marked topography on the down-going plate, such as major horst-graben structures, seamounts and volcanic plateaus, which are a typical feature of natural subduction zones. In the subducting plate itself, bending into the subduction zone produces marked underpressure on the outer (upper) arc, promoting brittle fracture (normal faulting and topography development) outboard of the subduction zone, and corresponding overpressure on the inner (lower) arc. The opposite effect develops lower down the subduction zone, where the plate is unbent. Such non-lithostatic pressure distributions are important in determining the mode of deformation (seismic fracture or aseismic creep), the direction of fluid and melt flow, and the depth of pressure-dependent metamorphic reactions, which themselves influence the density distribution and thus the driving force for subduction.