Quadrant II – Transcript and Related Materials

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NOTES:

ISOSTASY

Isostasy is a term used in Geology to refer to the state of gravitational equilibrium between the Earth's lithosphere and asthenosphere such that the tectonic plates "float" at an elevation which depends on their thickness and density. It is invoked to explain how different topographic heights can exist at the Earth's surface.
When a certain area of lithosphere reaches the state of isostasy, it is said to be in isostatic equilibrium. It is important to note that isostasy is not a process that upsets equilibrium, but rather one which restores it. It is generally accepted that the earth is a dynamic system that responds to loads in many different ways, however isostasy provides an important 'view' of the processes that are actually happening. Nevertheless, certain areas (such as the Himalayas) are not in isostatic equilibrium, which has forced researchers to identify other reasons to explain their topographic heights (in the case of the Himalayas, by proposing that their elevation is being "propped-up" by the force of the impacting Indian plate).
In the simplest example, isostasy is the principle observed by Archimedes in his bath, where he saw that when an object was immersed, the weight of water displaced was equal to the weight of the object (the upthrust on the body is equal to the weight of the liquid displaced).
On a geological scale, isostasy can be observed where the Earth's strong lithosphere exerts stress on the weaker mobile asthenosphere which, over geological time flows laterally such that the load of the lithosphere is accommodated by height adjustments.

Local models
Initial concepts of isostasy proposed that the Earth was in hydrostatic equilibrium at depth,

requiring topography to be compensated either by lateral variations in crustal thickness (Airy,
1855) or crustal density (Pratt, 1855).

A) Airy model
The model can be explained using blocks of wood (all same density), of different heights, immersed and floating in water (fluid). The higher the height of a block, the deeper it will be immersed to compensate for its weight. According to this model, it is assumed that the crustal density is constant and the isostatic compensation is produced by variations of the crustal thickness. Isostatic compensation means that the crust is in a static equilibrium and the topographic loading is compensated by buoyancy forces acting on the surface of equilibrium.

B) Pratt model

Here blocks of different heights all sink to the same level of compensation because of their different densities; the least dense block is therefore the tallest According to this model, it is assumed that all topographic masses are compensated at a constant depth. In reality, this would mean that the crust in mountain regions has a tower density than in plane regions. The topographic loading is compensated by the buoyancy forces that are produced due to lateral density variations within the crust.
The picture within the earth is probably a combination of both models; the oceanic crust is indeed thinner and denser than the continental crust, but mountains also have roots (i.e. the crust is thicker below them).

Effects of Isostacy

1. Isostatic effects of deposition and erosion

When large amounts of sediment are deposited on a particular region, the immense weight of the new sediment may cause the crust below to sink. Similarly, when large amounts of material are eroded away from a region, the land may rise to compensate. Therefore, as a mountain range is eroded down, the (reduced) range rebounds upwards (to a certain extent) to be eroded further. Some of the rock strata now visible at the ground surface may have spent much of their history at great depths below the surface buried under other strata, to be eventually exposed, as those other strata are eroded away and the lower layers rebound upwards again.
An analogy may be made with an iceberg - it always floats with a certain proportion of its mass below the surface of the water. If more ice is added to the top of the iceberg, the iceberg will sink lower in the water. If a layer of ice is somehow sliced off the top of the iceberg, the remaining iceberg will rise. Similarly, the Earth's lithosphere "floats" in the asthenosphere.

2. Isostatic effects of plate tectonics

When continents collide, the continental crust may thicken at their edges in the collision. If this happens, much of the thickened crust may move downwards rather than up as with-the

iceberg analogy. The idea of continental collisions building mountains "up' is therefore rather a simplification. Instead, the crust thickens and the upper part of the thickened crust may become a mountain range.
However, some continental collisions are far more complex than this, and the region may not be in isostatic equilibrium, so this subject has to be treated with caution.

3. Isostatic effects of ice-sheets

The formation of ice-sheets can cause the Earth's surface to sink. Conversely, isostatic post-glacial rebound is observed in areas once covered by ice-sheets which have now melted, such as around the Baltic Sea and Hudson Bay. As the ice retreats, the load on the lithosphere and asthenosphere is reduced and they rebound back towards their equilibrium levels. In this way, it is possible to find former sea-cliffs and associated wave-cut platforms hundreds of metres above present-day sea-level. The rebound movements are so slow that the uplift caused by the ending of the last Ice Age is still continuing.