The Lithosphere-Asthenosphere Boundary Underneath Ireland:

Data - Interpretation – Unknowns

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Summary: The Irish Seismological Lithospheric Experiment (ISLE) was conducted from November 2002 until July 2003 with 27 stations in Ireland (Landes et al., 2004). We measured and analysed teleseismic wave fronts in order to determine the deep lithospheric structure, especially close to the Iapetus suture zone. A major discovery during ISLE was the finding that the lithosphere thins from the southern part of Ireland (~85±5 km thickness) to the northern part of Ireland (~55±5 km). This thinning is interpreted to be related to the spreading of the Proto-Iceland plume and opening of the North Atlantic (Landes et al., 2007).

Receiver Functions: Mapping of seismic discontinuities with data from ISLE was done with converted teleseismic body wave phases. Observed P-to-S conversions and their synthetic models indicate a flat Moho at about 30 km depth underneath Ireland (Landes et al., 2006). This is consistent with a 3-D crustal model constructed from all available seismic refraction models (Landes et al., 2005). The upper mantle discontinuities, which confine the mantle transition zone at 410 km and 660 km depth, are also flat and found at their predicted depth according to the iasp91 global earth model (Landes et al., 2006). This result means that there should be no thermal anomaly in the deep upper mantle. The S-to-P receiver functions are consistent with a flat Moho; however, the S-to-P receiver functions reveal another discontinuity that is at 85±5 km depth below the southern part of Ireland and 55±5 km depth below the northern part of Ireland. This sloped discontinuity is interpreted as lithosphere-asthenosphere boundary which rises towards the north of Ireland.

Teleseismic Tomography: Delays of teleseismic P-wave travel times (residuals) were inverted into a 3-D seismic velocity model. The ISLE tomography model (Wawerzinek et al., 2008) contains faster seismic velocities in the south of Ireland compared to the centre to north at about 30-120 km depth. This seismic velocity contrast (-1% to -2.5%) can be interpreted as a shallower asthenosphere in the centre to north compared to the south. Previous long-range seismic refraction models do not show a low-velocity anomaly at subcrustal depth, possibly due to missing ray paths (for a summary see Landes at el., 2005).

Petrology: Geochemical data from basalts of the volcanic Tertiary Antrim Plateau presented by Barrat and Nesbitt (1996) also indicate tremendous lithospheric thinning in the northern part of Ireland during the magmatic activity. Based on REE pattern of the Causeway basalts they propose an initial melting at about 80 km depth

(garnet field) and rapid eruption of lavas. Then the melting region moved upwards: “As the lithosphere-asthenosphere boundary moved upward in response to the invasion of the plume, a series of low-*P* lavas were generated which for the most part reacted with continental crust to produce the contaminated Causeway Member” (Barrat and Nesbitt, 1996). Later the melting depth descended again. The whole cycle occurred just within a few million years at about 62-60 Ma. A similar lithospheric thinning was proposed for Mull, Scotland (Kerr, 1994). In Ireland volcanism with strong indications for a deep mantle source continued until 42 Ma (Kirstein and Timmerman, 2000).

Model: Our conceptual model (Figure 1) explains the thinning of the lithosphere towards north as a result of thermal erosion. At about 62 Ma the Proto-Iceland plume spread across vast regions of the place of birth of the North Atlantic. The British Tertiary Volcanic Province is a strong evidence for this event. Our structural models are interpreted such that the spreading plume head thermally eroded the lower lithosphere and that this erosion is still preserved.

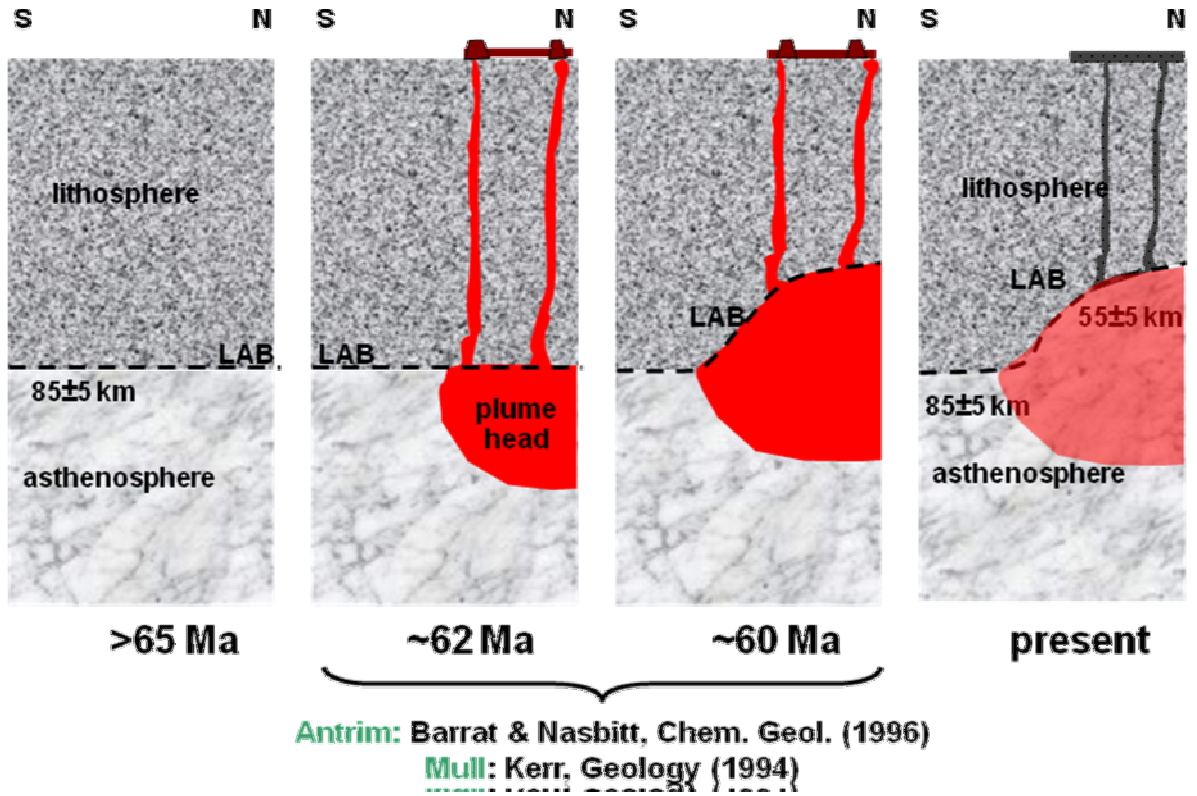

Figure 1: Model for the shallowing of the lithosphere-asthenosphere boundary underneath Ireland (modified after Landes et al., 2007). The spreading head of the Proto-Iceland plume rapidly thins the lithosphere underneath the northern part of Ireland at about 62-60 Ma. Presently the remaining heat and/or altered lower lithospheric / upper asthenospheric material causes reduced seismic velocity.

Unknowns: The northernmost part of Ireland was not covered with sufficient seismic rays during ISLE. Therefore additional seismological waveforms from this region would be important for additional S-to-P receiver function and surface wave modelling. Electro- and magnetotelluric measurements and their interpretation should be conducted in order to get a more comprehensive knowledge about the physical state of the lithosphere-asthenosphere boundary region in the area. Our model may be also tested with gravity measurements and modeling; however, small temperature and melt content may be not resolved at depth. In summary our model in Figure 1 may be used as a starting point for a much more comprehensive study including geophysics, geochemistry and geodynamic modelling.

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