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Rayleigh wave tomography in the North Atlantic: high resolution images of the Iceland, Azores and Eifel mantle plumes

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Abstract

Presented in this paper is a high resolution S_v-wave velocity and azimuthal anisotropy model for the upper mantle beneath the North Atlantic and surrounding region derived from the analysis of about 9000 fundamental and higher-mode Rayleigh waveforms. Much of the dataset comes from global and national digital seismic networks, but to improve the path coverage a number of instruments at coastal sites in northwest Europe, Iceland and eastern Greenland was deployed by us and a number of collaborators. The dense path coverage, the wide azimuthal distribution and the substantial higher-mode content of the dataset, as well as the relatively short path-lengths in the dataset have enabled us to build an upper mantle model with a horizontal resolution of a few hundred kilometers extending to 400 km depth. Low upper mantle velocities exist beneath three major hotspots: Iceland, the Azores and Eifel. The best depth resolution in the model occurs in NW Europe and in this area low S_v-velocities in the vicinity of the Eifel hotspot extend to about 400 km depth. Major negative velocity anomalies exist in the North Atlantic upper mantle beneath both Iceland and the Azores hotspots. Both anomalies are, above 200 km depth, 4–7% slow with respect to PREM and elongated along the mid-Atlantic Ridge. Low velocities extend to the south of Iceland beneath the Reykjanes Ridge where other geophysical and geochemical observations indicate the presence of hot plume material. The low velocities also extend beneath the Kolbeinsey Ridge north of Iceland, where there is also supporting geochemical evidence for the presence of hot plume material. The low-velocity upper mantle beneath the Kolbeinsey Ridge may also be associated with a plume beneath Jan Mayen. The anomaly associated with the Azores extends from about 25°N to 45°N along the ridge axis, which is in agreement with the area influenced by the Azores Plume, predicted from geophysical and geochemical observations. Compared to the anomaly associated with Iceland, the Azores anomaly is elongated further along the ridge, is shallower and decays more rapidly with depth. The fast propagation direction of horizontally propagating S_v-waves in the Atlantic south of Iceland correlates well with the east–west ridge-spreading direction at all depths and changes to a direction close to NS in the vicinity of Iceland.

Keywords: Surface wave tomography; Azimuthal anisotropy; Mantle plumes; Iceland; Azores; Eifel; Mid-Atlantic Ridge

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1. Introduction

The two major tectonic features of the North Atlantic Ocean are the mid-Atlantic Ridge and the oceanic plateau surrounding Iceland (Fig. 1). The volcanic edifice on which Iceland sits results from enhanced melting due to the interaction of the mid-Atlantic Ridge and the Iceland Plume (McKenzie, 1984; Sleep, 1990). While the crustal structure of Iceland has been intensely studied with a variety of geophysical methods (Bjarnason et al., 1993; Staples et al., 1997; Darbyshire et al., 2000a,b; Allen et al., 2002b), the width and depth extent of the plume core in the mantle beneath Iceland is controversial (e.g., Wolfe et al., 1997; Bijwaard and Spakman, 1999; Keller et al., 2000; Foulger et al., 2001), and very little

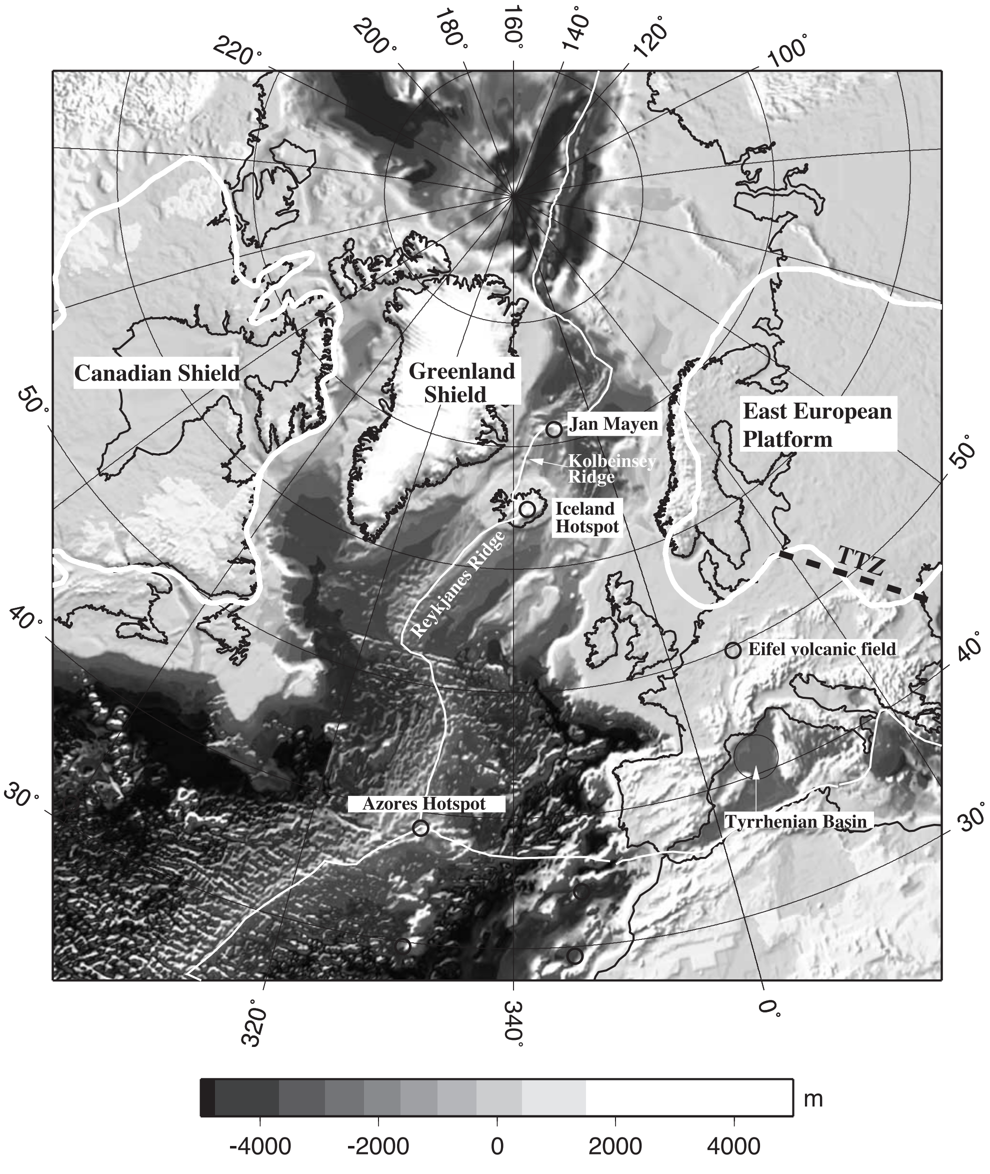

Fig. 1. Topography and bathymetry of the North Atlantic area. The thin solid white line defines the plate boundaries and the thick solid white lines refine the Canadian and East-European craton boundaries. The small black circles represent the locations of known hotspots (Sleep, 1990).