The Structure and Seismicity of West Antarctica and Implications for the Evolution of the West Antarctic Ice Sheet

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New seismic results from the POLENET/ANET seismic deployment provide strong evidence that the solid earth structure of West Antarctica (WA) exerts important controls on the development of the West Antarctic Ice Sheet (WAIS). The POLENET/ANET deployment, begun in 2007, involved installation of 33 seismographs across West Antarctica and surrounding regions, including a 16 station transect from Marie Byrd Land (MBL) to the Whitmore Mountains during 2010-2012. The stations operated continuously over the Antarctic winter using insulated boxes, power systems, and modified instrumentation developed in collaboration with the IRIS PASSCAL Instrument Center. We analyze the data using several different techniques to develop high-resolution models of WA seismic structure. We use Rayleigh wave phase velocities at periods of 20-180 s determined using the two-plane wave analysis of teleseismic Rayleigh waves to invert for the three dimensional shear velocity structure. In addition, Rayleigh wave group and phase velocities obtained by ambient seismic noise correlation methods provide constraints at shorter periods and shallower depths. Receiver functions provide precise estimates of crustal structure beneath the stations, and P and S wave tomography provides models of upper mantle structure down to ~ 500 km depth along transects of greater seismic station density. Results show that topographic lows such as the Bentley Trench and Byrd Basin are characterized by slow uppermost mantle velocities and thin (20-25 km) crust. These results confirm previous suggestions that the basins represent Cenozoic rift systems. Slow seismic velocities in the shallow mantle indicate that the thermal perturbation associated with the rifting has not yet dissipated, consistent with the inference that these basins were active during the last phase of WA tectonism [Granot et al. 2010]. Thermal anomalies from late Cenozoic rifting may provide an explanation for extremely high heat flow values inferred from the nearby WAIS drilling site and suggests that anomalously high heat flow may exert a profound influence on WAIS evolution. Slow mantle seismic velocities beneath MBL at somewhat deeper asthenospheric depths suggest a major thermal anomaly, possibly due to a mantle plume. The entire WA region shows thin lithosphere and slow seismic velocities, suggesting high upper mantle temperatures and low mantle viscosity. Using realistic rheological models we infer several orders of magnitude difference in viscosity between East and West Antarctica, with lowest viscosities found beneath MBL and the WA Rift System. The low WA upper mantle viscosities suggest that GIA occurs very rapidly in WA and must be taken into account in developing ice sheet models from GPS and GRACE constraints.

We also find evidence for currently active subglacial volcanism in MBL. Swarms of volcanic deep long period (DLP) earthquakes at 25-40 km depth coincide with subglacial highs approximately 55 km south of Mt. Sidley and Mt Waishe in the Executive Committee Range and demonstrate the existence of deep magmatic activity in this region. Subglacial eruptions may routinely provide sudden release of large quantities of water at the ice sheet base far from the coastline, and perturb the hydrological and glaciological conditions within the hydrological catchments of several of the major ice streams.