# HIGH-TEMPERATURE DEFORMATION OF DRY DIABASE, WITH APPLICATION TO CRUSTAL DEFORMATION ON VENUS

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We have performed an experimental and textural study to characterize the high-temperature creep behavior of natural diabase rock under dry deformation conditions. Samples of both Maryland diabase and Columbia diabase were investigated to measure the effects of temperature, oxygen fugacity, and ratio of plagioclase to pyroxene on the creep strength. The Maryland diabase is composed of ~56 vol% plagioclase, ~38 vol% augite, ~5 vol% pigeonite, ~1 vol% magnetite-ilmenite, and trace chlorite (altered from pyroxene); the grain size of the plagioclase is ~30 μm × 100 μm, while that of the pyroxenes is ~50 μm. The Columbia diabase is composed of ~70 vol% plagioclase, ~6 vol% augite, ~17 vol% hypersthene, ~3% magnetite- ilmenite, and ~3% chlorite (altered from pyroxene); the grain size of the plagioclase is ~100 μm × 600 μm, while that of the pyroxenes is ~200 μm. Samples of each diabase were heated in a controlled-atmosphere room-pressure apparatus at 1000°C for 50 h under controlled oxygen fugacity conditions, causing the dehydration of the hydrous minerals. In subsequent deformation experiments, the more plagioclase-rich Columbia diabase (Mackwell et al. 1995) has a significantly lower strength than the more pyroxene-rich Maryland diabase. Flow laws were determined for the deformation of the two dry diabases, yielding an activation energy for creep of Q = 510±30 kJ/mol for both rocks, and a stress exponent of n = 4.7±1.0 for the dry Maryland diabase and n = 4.8±0.6 for the dry Columbia diabase, indicative of control of deformation by dislocation creep processes. Both rocks are slightly weaker when deformed at oxygen fugacities near the iron-wüstite buffer than at the nickel-nickel oxide buffer. As the activation energies for deformation and the stress exponents are the same within the errors in the data, we took the average of the activation energies and of the stress exponents from all experiments, yielding Q = 510±30 kJ/mol and n = 4.7±0.8. Thus, we obtained the following flow laws for dry diabase:

Maryland diabase: $\dot{\varepsilon} = 77\ \sigma^{4.7}\ e^{-510/RT}$ for the Fe/FeO buffered case,
$\dot{\varepsilon} = 49\ \sigma^{4.7}\ e^{-510/RT}$ for the Ni/NiO buffered case, and
Columbia diabase: $\dot{\varepsilon} = 4000\ \sigma^{4.7}\ e^{-510/RT}$ for the Fe/FeO buffered case,
$\dot{\varepsilon} = 1550\ \sigma^{4.7}\ e^{-510/RT}$ for the Ni/NiO buffered case,

where the stress is in MPa and the activation energy is in kJ/mol.

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Investigations of the microstructures of the untreated, heat-treated, and deformed samples in the optical microscope show little change in texture due to the deformation. Transmission electron microscope investigations indicate that, while the bulk of the deformation in the Columbia diabase is localized within the plagioclase grains, the deformation in the Maryland diabase is distributed between the plagioclase and pyroxene grains. No significant quantity of glass was observed in the deformed samples, so that partial melting is not believed to contribute to deformation under the experimental conditions.

The dry creep strength of these rocks is significantly greater than previous measurements under "as-received" or wet conditions (Shelton and Tullis 1981, Caristan 1982). Application of these results to the tectonics of the lithosphere on Venus suggests a relatively deep brittle-ductile transition (~5-15 km depth, depending on the choice of thermal gradient) and a strong lithosphere, dominated by the strength of the rocks in the mid- and upper crust, with no significant weak zone in the lower crust. As the contrast in rheology between these diabase rocks and dry dunite is small at depths greater than 15 km, strong coupling between the crust and mantle seems likely. Thus, it may be possible to maintain topography dynamically on Venus for long periods without recourse to active tectonism or mantle upwelling, and much of the observed large-scale tectonism may be accounted for by the strong coupling between the lithosphere and convection in the mantle.

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