Crustal xenoliths from central Montana: heterogeneity and incremental assembly of high seismic velocity (7.x) lower crust in cratonic North America

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The presence (or absence) of continental lower crustal layers with unusually high seismic P velocities of over 7 km/s provides fundamental information about lithospheric growth and destruction processes. Where such layers are present, their thickness, composition and degree of heterogeneity can also have a profound influence on the rheological properties and behavior of the lower crust during younger tectonic events. In Montana and Wyoming, seismic experiments reveal an anomalously thick 7.x layer that comprises up to half the ~55 km thickness of the crust in the region. Our studies of xenoliths exhumed in Eocene volcanics in central Montana emphasize the heterogeneity in composition, age, physical properties, and modes of formation of the lower crust. The sample suites include mafic garnet granulate, mafic eclogite, and felsic granulate. Multiple samples preserve evidence for prograde burial and some are polymetamorphic. Peak pressures of some samples exceed 1.7 GPa whereas pressures interpreted to represent residence depths are consistent with derivation from 25-50 km. Calculated seismic velocities are also heterogeneous with data from samples within the seismically defined 7.x layer ranging from 6.9 to >8.0 km/s. A variety of U-(Th)-Pb data from zircon, monazite, titanite, and rutile record multiple igneous, metamorphic and/or fluid flow events from Archean to Mesoproterozoic time with discrete pulses at 2.1 Ga, 1.8 Ga, 1.7 Ga, and 1.3 Ga. Collectively, the data suggest a protracted history of incremental assembly of the 7.x layer in Montana, allowing significant improvements to models for the formation, evolution and present day structure of the North American lithosphere.