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In-situ changes in the elastic wave velocity of rock with increasing temperature using high-resolution coda wave interferometry

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Rock undergoes fluctuations in temperature in various settings in Earth's crust, including areas of volcanic or geothermal activity, or industrial environments such as hydrocarbon or geothermal reservoirs. Changes in temperature can cause thermal stresses that can result in the formation of microcracks, which affect the mechanical, physical, and transport properties of rocks. Of the affected physical properties, the elastic wave velocity of rock is particularly sensitive to microcracking. Monitoring the evolution of elastic wave velocity during the thermal stressing of rock therefore provides valuable insight into thermal cracking processes. One monitoring technique is Coda Wave Interferometry (CWI), which infers high-resolution changes in the medium from changes in multiple-scattered elastic waves. We have designed a new experimental setup to perform CWI whilst cyclically heating and cooling samples of granite (cylinders of 20 mm diameter and 40 mm length). In our setup, the samples are held between two pistons within a tube furnace and are heated and cooled at a rate of 1 °C/min to temperatures of up to 300 °C. Two high temperature piezo-transducers are each in contact with an opposing face of the rock sample. The servo-controlled uniaxial press compensates for the thermal expansion and contraction of the pistons and the sample, keeping the coupling between the transducers and the sample, and the axial force acting on the sample, constant throughout. Our setup is designed for simultaneous acoustic emission monitoring (AE is commonly used as a proxy for microcracking), and so we can follow thermal microcracking precisely by combining the AE and CWI techniques. We find that during the first heating/cooling cycle, the onset of thermal microcracking occurs at a relatively low temperature of around 65 °C. The CWI shows that elastic wave velocity decreases with increasing temperature and increases during cooling. Upon cooling, back to room temperature, there is an irreversible relative decrease in velocity of several percent associated with the presence of new thermal microcracks. Our data suggest that few new microcracks were formed when the same sample was subject to subsequent identical heating/cooling cycles as changes in the elastic wave velocity are near-reversible. Our results shed light on the temperature conditions required for thermal microcracking and the influence of temperature on elastic wave velocity with applications to a wide variety of geoscientific disciplines.