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Monitoring volcanic eruption phase using Vp/Vs ratios

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Volcanic evolutions typically accompany significant changes of medium properties. Monitoring of seismic properties may be useful for inference of eruption state. Temporal variation of shallow crustal Vp/Vs ratios before and during the 2009 eruption of Redoubt volcano, Alaska is investigated using local seismicity. The Vp/Vs ratio of medium is calculated using a modified Wadati analysis that is based on the P and S traveltimes. The dense monitoring system and high seismicity around the volcano enable stable estimation of Vp/Vs ratios for small discretized regions. The stability of Vp/Vs estimates is tested through a bootstrapping resampling analysis. Also, the effects of plausible errors in phase arrival times and origin times on Vp/Vs estimates are quantified. The tests present that the results are stable and rarely dependent on the data sets selected and possible errors in data sets. High Vp/Vs ratios of $\sim$1.9 is observed over a wide region in the precursory phase, suggesting presence of partial melts in the medium at least several months before explosive eruptions. The high Vp/Vs ratios decrease until the early effusive phase with rates of -0.179 per year in the precursory phase (for 65 days) and -2.147 per year in the explosive phase (for 40 days), which equivalent to decreases in bulk modulus of fluids by about 1.1 and 7.9 GPa, respectively. The decreasing Vp/Vs ratios in the precursory phase suggest increasing overpressurized gas and water vapors in the medium. The rapid decrease of Vp/Vs ratios in explosive phase may be due to composite effect of melt eruption and gas emission. The Vp/Vs ratios were observed to be nearly stationary since middle effusive phase, suggesting rare or low amounts of overpressurized gas in the medium due to sufficient amount of gas emission. The observations suggest that monitoring of Vp/Vs ratios may be useful for identification of the eruption state.