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Nature and occurrence of cooling-induced cracking in volcanic rocks

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Several hypotheses have been proposed regarding the role of thermo-mechanical contraction in producing cracks and joints in volcanic rocks. Nevertheless, most studies of thermally-induced cracking to date have focused on the generation of cracks formed during heating. In this latter case, the cracks are formed under an overall compressional regime. By contrast, cooling cracks are formed under an overall tensile regime. Therefore, both the nature and mechanism of crack formation during cooling are hypothesised to be different from those for crack formation during heating. Furthermore, it remains unclear whether cooling simply reactivates pre-existing cracks, induces the growth of new cracks, or both.

We present results from experiments based on a new method for testing ideas on cooling-induced cracking. Cored samples of volcanic rock (basaltic to dacitic in composition) were heated at varying rates to different maximum temperatures inside a tube furnace. In the highest temperature experiments samples of both rocks were raised to the liquidus temperature appropriate to their composition, forcing melt interaction and crack annealing. We present in-situ seismic velocity and acoustic emission data, which were recorded throughout each heating and cooling cycle. It is found consistently that the rate of acoustic emission is much higher during cooling than during heating. In addition, acoustic emission events produced on cooling tend to be significantly higher in energy than those produced during heating. We therefore suggest that cracks formed during cooling are significantly larger than those formed during heating. Thin-section and crack morphology analysis of our cyclically heated samples provide further evidence of contrasting fracture morphologies. These new data are important for assessing the contribution of cooling-induced damage within volcanic structures and layers such as sills and lava flows. Our observations may also help to constrain evolving ideas regarding the formation of columnar joints.