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Disequilibrium dihedral angles as a proxy for cooling rate: new opportunities for decoding the effects of liquid migration in dolerites and basalts.

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The geometry of clinopyroxene-plagioclase-plagioclase junctions in mafic rocks, measured by the median dihedral angle, Θcpp, is created during solidification, with junction geometry a function of the initial impingement angle of the two plagioclase grains together with the relative rates of growth of augite and plagioclase. Rapid solidification results in Θcpp ∼78˚, whereas more slowly cooled rocks have higher Θcpp. Θcpp varies symmetrically across dolerite sills, with the lowest values at the margins. Simple thermal models of sills, based on a crystallization interval of 1200-1000°C and including consideration of latent heat, suggest that Θcpp ∼78° signifies crystallisation times of less than a few years. The symmetrical variation of Θcpp across the sills is in marked contrast to the variation of average plagioclase grain size – generally the coarsest rocks are in the upper third of the sills. The straightforward mapping of Θcpp onto crystallization times means dihedral angles provide a robust measure of cooling rates, in contrast to the more commonly used method based on crystal size distributions which is limited by an incomplete knowledge of crystal growth rates.
While sills lose heat equally from both top and bottom surfaces, lava flows and lakes primarily cool from the upper surface, especially when flooded with water. This is reflected in a highly asymmetric Θcpp variation, with maximum values close to the floor. Comparison of average plagioclase grain size, calculated extent of compaction and Θcpp through the thickest part of the Holyoke Flood-Basalt Flow, sampled at North Branford and Tariffville, demonstrates the slowest-cooled parts of the body (i.e. that part with maximum Θcpp and % compaction) underlie those of maximum grain size. We interpret the horizon with the coarsest grain size to contain significant volumes of relatively evolved liquids, derived by compaction of the underlying layers, in which crystallization continued to temperatures well below 1000˚C.