Factors controlling entablature formation in columnar joints: Suggestions from the analogue experiments and texture observation of water interacted structure in columnar joints in Iceland

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Columnar joints of lava and ignimbrite often feature two styles of jointing: colonnade and entablature. Columns in colonnade are relatively wide, straight and directionally organized, whereas the entablature features relatively narrow, curved and disorganized in terms of orientation. The formation of colonnade is generally well understood; it develops perpendicular to the isotherm because of volume contraction due to temperature decrease during cooling, while the formation of entablature still poorly understood; how the complex structure is related to the isotherm and what causes such an abrupt structural change between colonnade and entablature. In order to investigate what factors are important in formation of entablature and threefold structure of upper colonnade, entablature and lower colonnade, we have undertaken desiccation experiments using starch-water mixtures, which are similar to that used in earlier study examining the mechanics of colonnade formation. In order to simulate cooling of lava, the mixture is desiccated by using heat lamp. The drying rate (= cooling rate in case of lava or ignimbrite) is controlled by the distance between the surface of mixture and heat lamp. We conducted two experiments under different experimental setups; one is conducted under constant drying rate throughout and another is conducted where the drying rate is increased halfway. Experimental setup 1 is designed that it allowed the water to be evaporated from both upper and lower surfaces of the mixture by attaching a membrane to the basal surface. With a constant lamp distance of 10cm, the colonnade structure developed from both upper and lower surface without entablature between them. Experimental setup 2; Using the same starting condition of Experimental setup 1 (lamp distance of 10cm), when the colonnade structure developed halfway, the drying rate is increased abruptly by shortening the lamp distance to 1.5cm. As a result, the upper colonnade changed discontinuously forming curved and irregular jointing pattern. Analysis using Micro-focus X-ray CT images show the following: 1) Column size and number density of fractures suddenly decrease after changing the drying rate, 2) the new columns form at the triple or quadruple junctions of pre-existing cracks by which ordinary columns are constructed before changing the drying rate. In addition, the X-ray CT images show that crack tips develop perpendicular to an iso-surface of water concentration. Our results suggest that waved and smaller-scaled columns characteristic of entablature related to sudden change of contraction or cooling rate and inhomogeneous thermal structure of lava and ignimbrite.

Our experimental results will be compared to ongoing investigations of jointing patterns in the Thjorsa and Thjorsardalur lava flow in Iceland, which exhibit the threefold structure of upper colonnade, entablature and lower colonnade.