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Analogue experiments of columnar jointing: Focus on entablature

Ai Hamada[1*], Atsushi Toramaru[2]

[1]Earth and Planet. Sci., Kyushu Univ., [2]Earth and Planet. Sci., Kyushu Univ.

Columnar joint is the fracture in igneous rocks or welded tuffs, which is formed by volume contraction due to temperature decrease during cooling. There are two types of forms: colonnade and entablature. Colonnade consists of relatively wide and straight columns, whereas entablature consists of relatively narrow and curved columns. The fractures in colonnade are formed perpendicular to the isotherm, and propagate inwards as the cooling proceeds. On the other hand, the formation process of entablature is still unclear.

The formation of fractures in desiccation experiments using starch-water mixture so far is well analogous to colonnade formation. In this study, we tried to reproduce entablature structure by the analogue experiments in which we changed some experimental conditions: the direction of vaporized water and the desiccation rate. From the observational fact of a threefold structure with upper-colonnade, entablature and lower-colonnade, we presume that the fractures develop from top and bottom, and the approach of both-side-columns at the central part causes entablature. At first, to reproduce this threefold structure, we set up the direction of vaporized water not only from the top but also from the bottom. In addition, in previous experiments, some of cracks stop advancing inwards and the coarsening of columns occurs because the desiccation rate decreases with the advancement of cracks. In threefold structure in natural examples, however, even though entablature is located in inside, the width is smaller than colonnade suggesting the sudden increase of cooling rate. So we tried to change the desiccation rate abruptly increased during desiccating on the basis of the analogy between the desiccation rate and cooling rate. During the experiment, we control the desiccation rate controlled by the distance between the lamp and the surface of the starch mixture. In order to abruptly increase the desiccation rate, we shorten the distance. In the case that the desiccation rate is kept at constant until complete desiccation, it is observed that a lot of narrow columns near the upper surface became wider by column coarsening. All columns are straight forms. In the case that the desiccation rate abruptly increased after the elapse of a certain period of time, we found a discontinuous plane near the upper surface and curved columns at the upper side of the contact of both-side-columns.

Because the horizon of the discontinuous plane corresponds to the point of fracture proceeded before the desiccation rate change, it is plausible that the discontinuous plane was formed by the change of the desiccation rate on the column formation. Curved columns develop by the difference between the upper and lower desiccation rates.

Comparing this results to the natural columnar joint structure, in the case of the constant desiccation rate, colonnade structure occur that columns contact from the top and from the bottom, and in the case of the abrupt change of the desiccation rate, curved columns form after the rate change and we believe that they are analogous to entablature structure.

Keywords: columnar joint, morphology, analogue experiment, formation process, crack, fracture