

Analog Experiment of Formation of Columnar Joint using Starch

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Introduction:

Drying a starch mixed with water, we can observe a very similar structure to columnar joint formed as magma is cooled and solidified (Müller 1998). In the present study, we carried out experiments in which the evaporation rate was controlled by varying the distance between the specimen and a electric ball, in order to investigate the effect of evaporation rate on the structure of columnar joint.

Experiment:

Mean grain size of starch is approximately 31 micron meters. The starch and water were well mixed with the mass ratio 1 (both are 60g). The container used is a steel cylinder with 8.5cm in diameter and 2.8cm in height. In order to ready to put out the sample from container, we covered the inside wall with an aluminum foil. We use a 60Watt electric ball as a heat source to control the evaporation rate. The container containing a starch-water mixture was placed on an electronic balance connected with PC by which we recorded the weight data of sample every 30 minutes and calculated the evaporation rate. After drying out, we observed a sample and measured area and number of sides of polygon in cross section of columns (Softwares: Adobe Photoshop and NIHImage were used.).

Results:

Similar to the previously reported results, the development process of columnar joint-like structure has two stages: firstly the thin plate formed by cracking at the top of surface of sample, and then below it columnar joint-like structure was developed. The evaporation rate changed from 4.8g/h to 0.6g/h, corresponding to the varying distance between the electric ball and sample from 1cm to 30cm. The evaporation rate decreased with distance in proportion to $(\text{distance})^{-3/4}$, and converged to 0.6g/h approximately at 13cm distance. The mean cross sectional area of columns increased with decreasing the evaporation rate in proportion to $(\text{evaporation rate})^{-0.9}$, and became an infinity approximately at 0.5g/h beyond which the columnar joint never formed.

From the measurement of number of side of polygon in columns, it was found that the dominant number of side change from 5 to 6 as the evaporation rate increases.

Discussion: Analogy with natural columnar joint formation and the suggestion from experiment

If the contraction of material is essential for the formation of columnar joint-like structure in both the present analog experiment with starch and the basaltic rock in nature, we can think the evaporation rate as the cooling rate in nature. Consequently we can give insight into the formation process of columnar joint in nature as follows: The cross sectional area observed in natural columns decreases with the cooling rate in proportion to $(\text{cooling rate})^{-0.9}$. There is a critical cooling rate below which the columnar joint cannot form. The difference between hexagon-dominant type and pentagon-dominant type which are observed in nature, is due to the difference of the cooling rate of magma.