Basalt Columns

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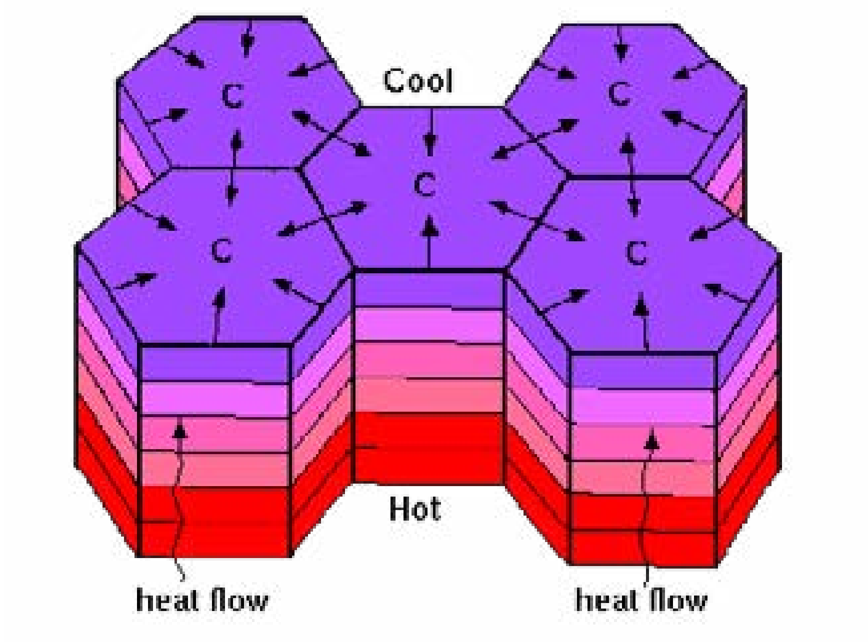
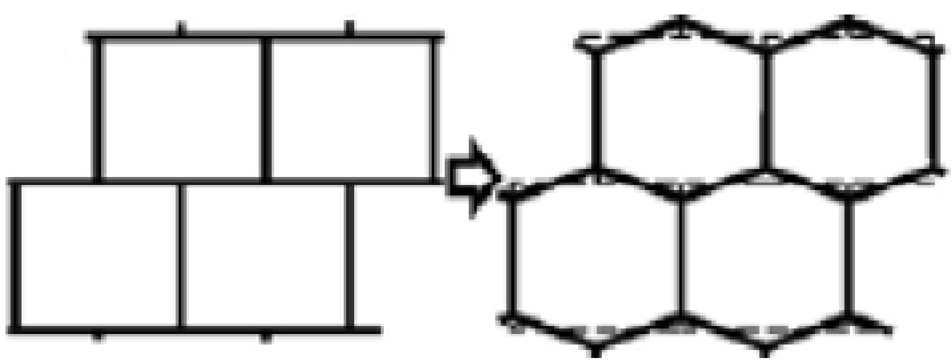
When lava settles on a surface and slowly cools down, a geometric pattern appears: long columns of basalt rock that stretch into the sky. These pillars are a result of a phenomenom known as columnar jointing. As the lava that forms into basalt cools, it contracts [1].

When objects contract, they often crack or fracture. When this contraction occurs at centers which are equally spaced, a hexagonal fracture pattern will form. Contraction will not be equally spaced if, for example, the thickness or composition of the lava varies.

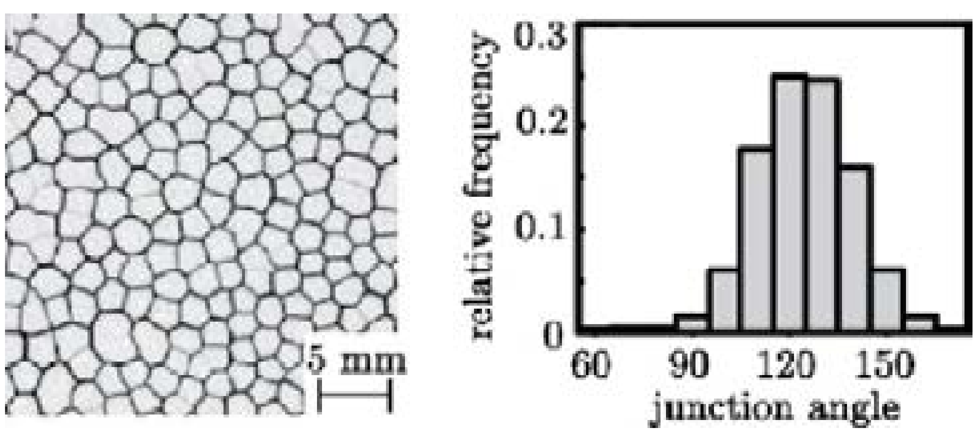
Basalt Columns in the Giant's Causeway, Northern Ireland



Heat flow diagram for lava columns [2]



Transitions from rectangular to hexagonal joints



2D slice showing a tendency towards hexagonal columns

Formation

As the lava cools there is a temperature gradient, that is, the top of the lava flow will be cooler than the bottom. The fracture pattern that forms at the cooling surfaces will tend to be propagated down the lava as it cools, forming long, geometric columns, as shown in the diagram to the left.

The size of the basalt columns depends loosely on the rate of cooling; very rapid cooling may result in small (<1 cm diameter) columns, while slow cooling is more likely to produce large columns. Moreover, water flow around the cooling lava also plays a role in both the size and twisting of basalt columns.

Hexagonal Shape

While columnar joints can have non-hexagonal patterns, ranging from 3-12 sides, the most commonly observed fracture geometry is hexagonal.

At the beginning of the cooling process, contraction stressing in the top layer of the solidified lava causes secondary cracks to meet existing ones at nearly right angles. Orthogonal cracks follow from the fact that they lead to the highest energy release.

While the cracking pattern propagates down the cooling lava, the junction angles begin to change towards 120°, leading to a hexagonal pattern.

By visual inspection of a 2D slice of a 3D model of basalt columns (starch slurry dried in a deep dish), we can see that the inner angles of columnar joints tend towards a 120°, with some irregularities.

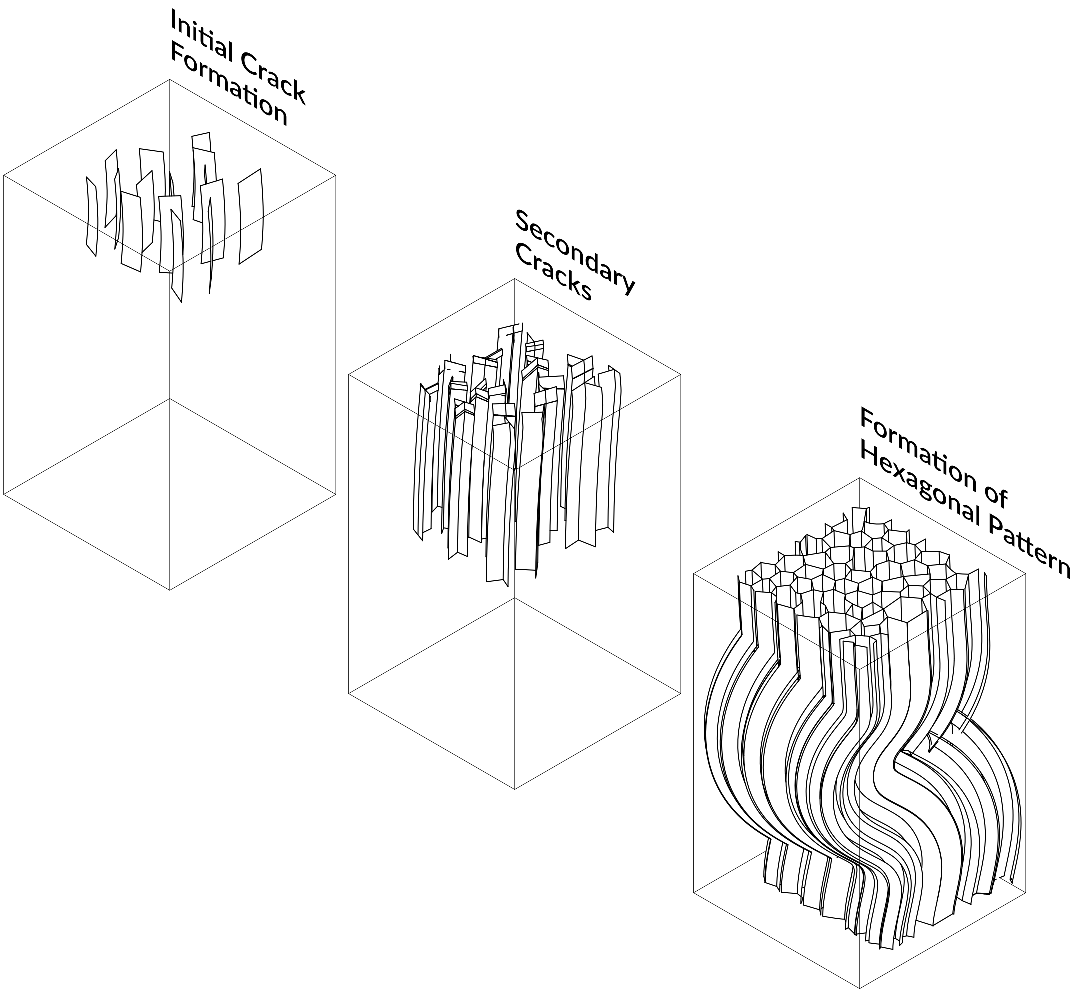
"The principles of fracture mechanics favor the formation of basalt columns with regular hexagons for cross sections." Hoffman, Martin, et al. [3]

Logic Diagrams

In order to explore the fundamental patterns that surround basalt columns via logic diagrams, we must consider the following variables:

- Lava (arrangement & amount)
- Cooling rate
- Water flow
- Time passed

There are two main aspects to the formation of basalt columns.



The first is the development of the hexagonal pattern on the column face. As mentioned before, initial cracks appear at the top and secondary cracks soon follow at orthogonal angles. These combine to form what are called *T junctions*. As cracks begin forming due to cooling, they transform with the lava, sometimes growing in size or disappearing. These transformations lead to *Y junctions* - that is, 120° junctions that form a hexagonal pattern by the time the lava is completely cooled down.

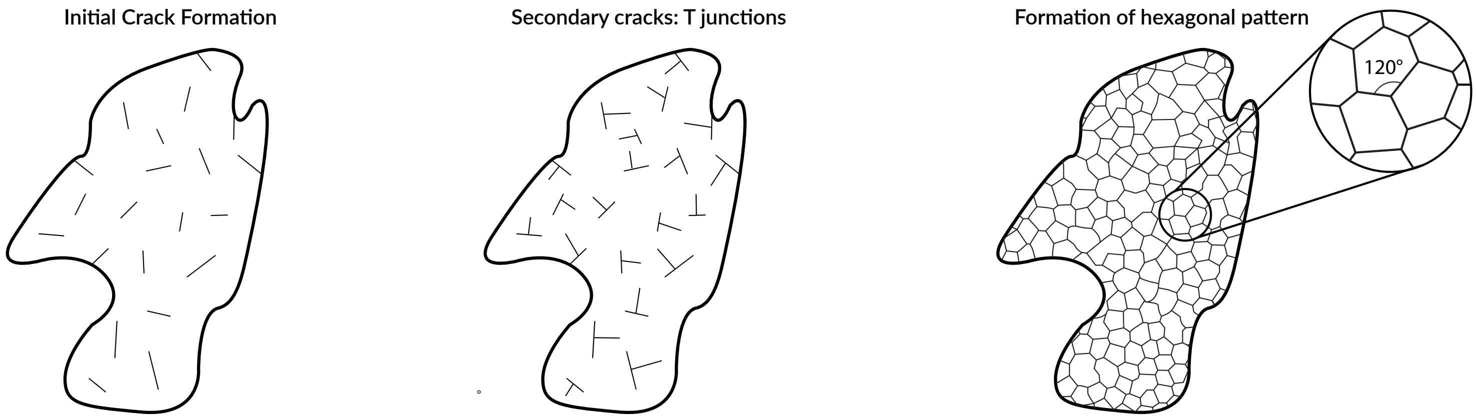
The second aspect diagrammed is the vertical progression of the column. Cracks begin appearing from the top and then propagate downwards. While this happens, the cracks are simultaneously evolving, which leads to small changes in the column shape.

Columnar basalt can have two major forms: *colonnade* and *entablature*. In a colonnade, individual columns remain mostly parallel and can be traced from top to bottom. An entablature exhibits curved or fanning columns, and it is caused due to water flooding into the cracks and altering the cooling rate of the lava [4].

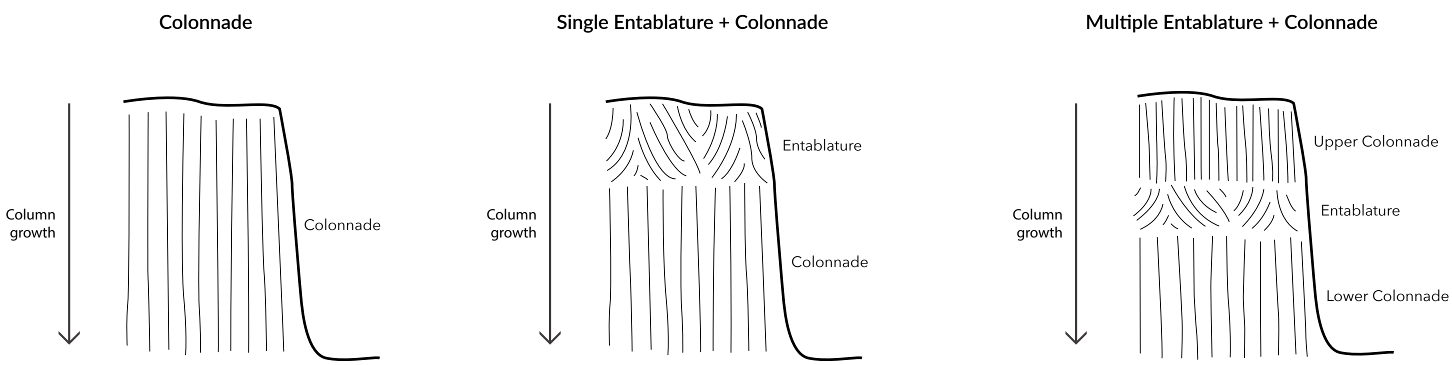
In the diagram above, the final stage of the columns displays a colonnade, followed by an entablature due to water flooding and then another colonnade at the bottom.

Logic Diagrams

Top View



Side View



Moments

The first moment I wanted to capture in my drawing is when the lava begins to cool down and initial cracks appear. The arrangement of the lava would depend on the amount and speed of the lava as well as its surrounding environment that determines its overall shape.

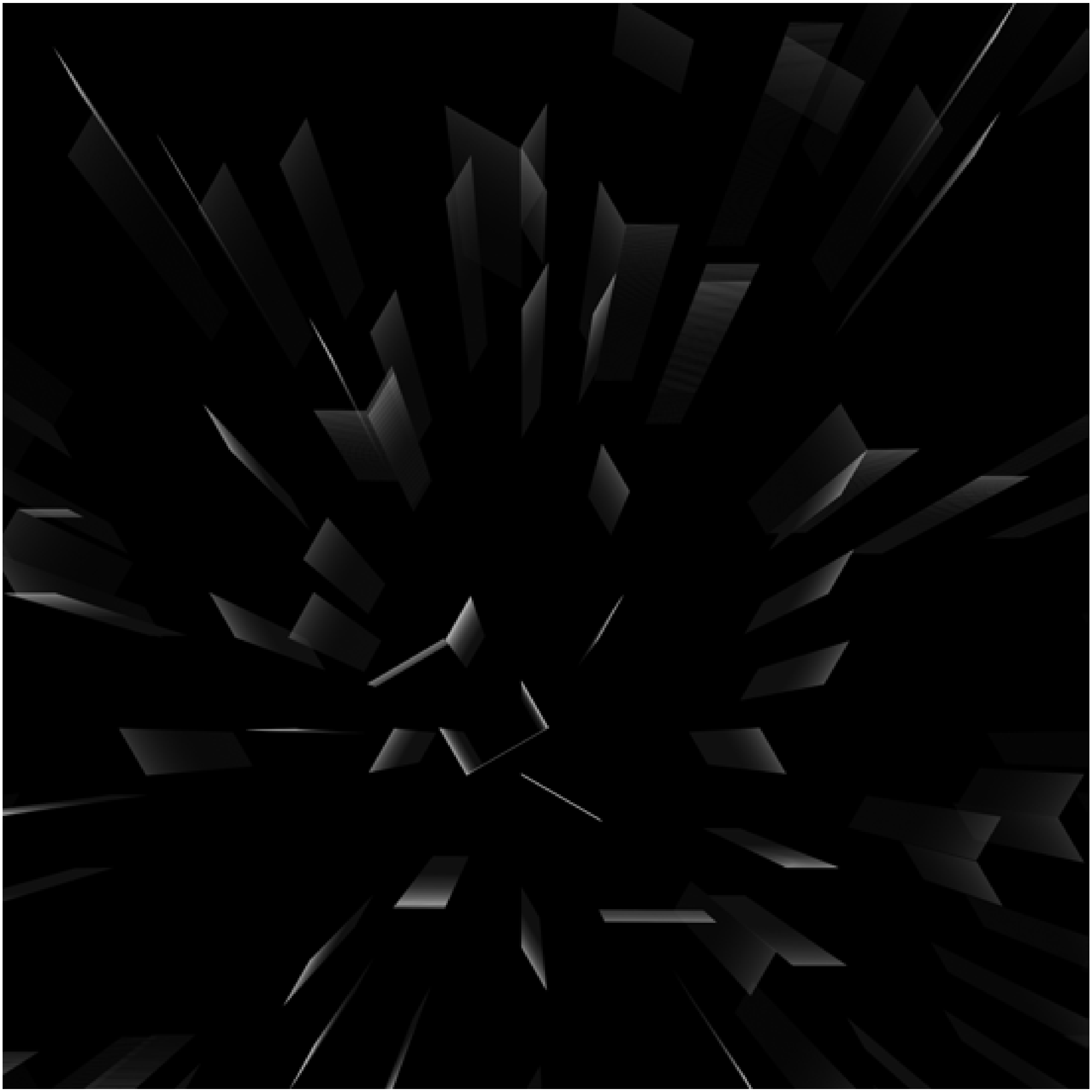
The second moment falls under the cooling stage, when secondary cracks appear in the cooling basalt. This is the most interesting stage of the process, as we see the development of the hexagonal pattern and the transformations of the basalt columns due to water flow around the cooling lava.

Finally, the third moment I capture occurs when the basalt is completely cooled down and, as such, we see a hexagonal pattern.

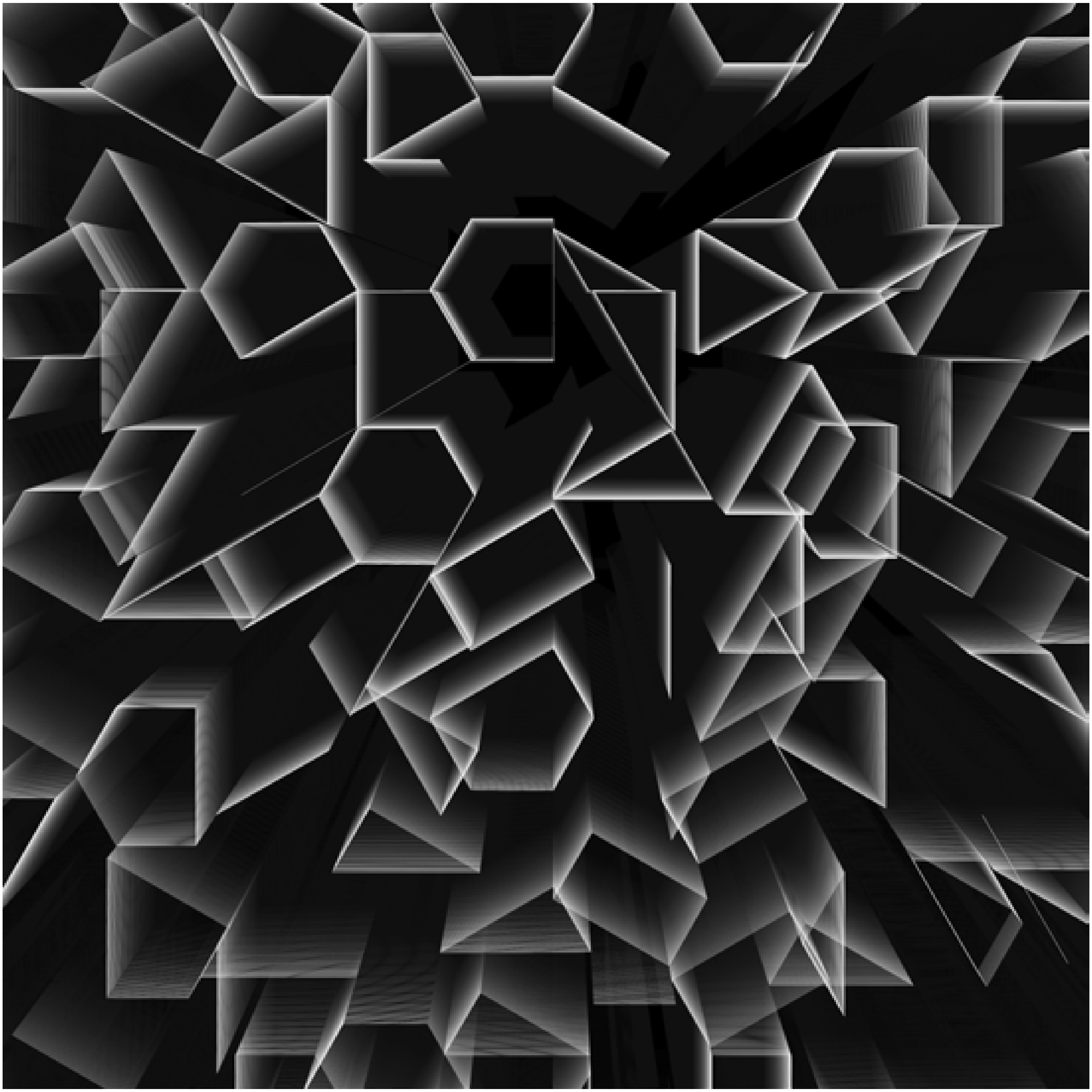
In my Processing generative drawing, I deviate from a natural basalt column system by allowing the endless growth of cracks in the columns.

You can run the online drawing here.

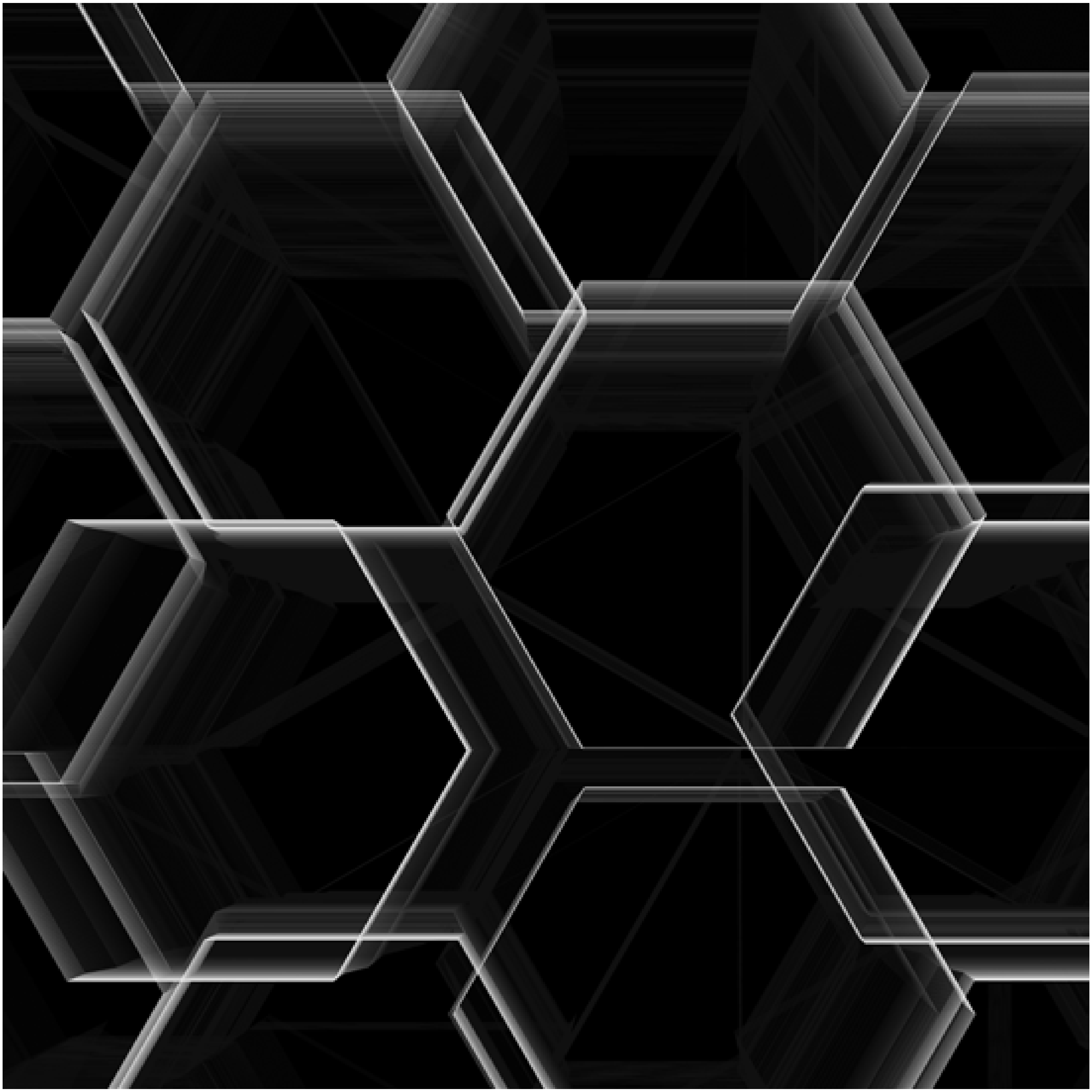
Generative Drawings



Generative Drawings



Generative Drawings




Cracks forming in cooling lava


The Hexagon Pool, Golan Heights

Works Cited

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2. Reeves, Malcolm. "Igneous Joints." GEOE, University of Saskatchewan, homepage.usask.ca/~mjr347/prog/geoe118/geoe118.054.html.

3. Hofmann, Martin, et al. "Why Hexagonal Basalt Columns?" Physical Review Letters, American Physical Society, 7 Oct. 2015, journals.aps.org/prl/abstract/10.1103/PhysRevLett.115.154301#fulltext.

4. Budkewitsch, Paul, and Pierre-Yves Robin. "Modelling the Evolution of Columnar Joints ." Journal of Volcanology and Geothermal Research, 18 Aug. 1993, ac.els-cdn.com/0377027394900922/1-s2.0-0377027394900922-main.pdf?_tid=26a1ffb4-1683-11e8-bb6b-00000aab0f6b&acdnat=1519161498_8e7aeef5142fa7dc8d55a4c9f555f06f.

The Cliff of Stone Plates (Ghềnh Đá Dĩa) near Tuy Hòa city, Phú Yên Province, Vietnam