The Boyabat Basalt Cliffs

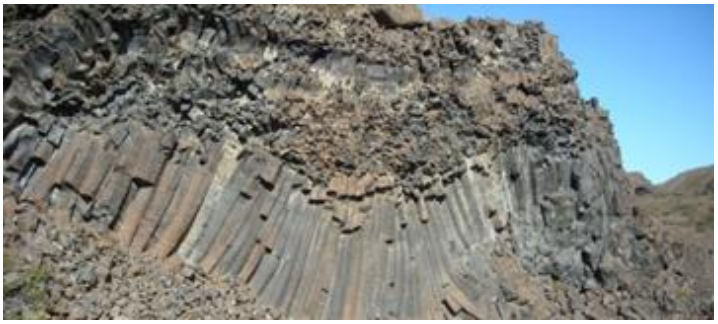
Basalt columns

Basalt is the most common volcanic rock. It often forms columns. The hexagonal joints, which border the columns, are due to slight shrinking. They form because hot lava needs more space than cold basalt rock. Therefore a cooling lava-flow is under tension. If this tension is large enough, the rock will tear in form of columns perpendicular to the cooling front.

Basalt columns from above (Iceland; photo: M. Kölbl-Ebert).

Ideally, the columns are hexagonal. This is the energetically simplest form. However, a lava-flow has no uniform thickness and therefore the cooling front is a curved plane. This is the reason, why irregular columns with five to eight sides are formed as well.

Basalt columns form, when a thick lava flow cools rapidly, for example due to lots of rain water or due to river water, because then the tension in the cooling rock is especially great. Water seeps into the joints and fissures of the lava flow surface and from these joints and fissures the cooling starts. Consequently, cooling is irregular near the surface of the lava flow and a chaotic "entabulature" forms. The more the cooling advances into the flow, the more these irregularities disappear until a smooth cooling surface is reached and the regular columns, the "colonnade", form.



Lava flow with basalt columns in Iceland (above the colonnade the irregular entabulature is formed (photo: Martin Ebert).

Thus, the basalt columns and the more chaotic region on top belong to the same lava-flow.

Colonnade (below) and irregular entabulature (above) at Boyabat basalt cliffs (photo: Martin Ebert).

At Boyabat basalt cliffs, much of the entabulature has already been erode, but the remains can still be seen on the left side of the cliffs, high above the colonnade.

The basalt columns at Boyabat Basalt Cliff are remarkably long, i.e. the lava flow was exceptionally thick, presumably due to ponding in the narrow river valley, through which the lava once flowed. In the upper third of the colonnade the columns show conspicuous wave undulations. It may be assumed that the cooling lava flow was disturbed by an earthquake.

Active lava-pond in Hawaii (photo: M. Kölbl-Ebert)

Colonnade with undulations at Boyabat basalt cliffs (left photo: Bruno Colicchio; right photo: Martin Ebert).

The ancient river valley

The Boyabat lava has flown into a river valley some five million years ago. The bottom of this valley was covered with round pebbles, which have been deposited by the river. The pebbles can still be seen underneath the basalt.

Brownish river pebbles underneath the lava flow (photo: Bruno Colicchio).

The direct contact to the lava-flow is marked by a red band, which is witness to the oxidation of the river sediments in direct contact to the hot lava. Normal river sediments are grey or light brown in colour mostly due to the presence of organic material and iron as Fe^{2+} in form of yellowish iron hydroxide. When heated by the lava flow, the organic material burned away and the iron present was oxidized to Fe^{3+}, which is red (rust).

River sediments with pebbles (brownish layer below), red oxidized band at the contact to the lava-flow, inclined basalt columns (above) at the edge to the former river valley and vertical basalt columns (background) in the centre of the valley filling (photo: Bruno Colicchio).

Cooling of the lava set in from top and bottom of the lava flow but also from the sides of the narrow river valley. Since basalt columns form perpendicular to the cooling front, only those in the centre of the flow are vertical, while those close to the sides of the steep-walled river valley are inclined, resting perpendicular to the valley walls. They then curve upwards, becoming eventually vertical the further away they reach from the valley walls.

Evidence for explosive water/lava interaction

Since the Boyabat lava-flow invaded an older river valley, the rapid cooling of the flow (leading to the formation of the columns) was probably facilitated by river water. Water trickled down into fissures and fractures, was heated and expelled again as hot water vapour in fumaroles. When, however, water was trapped in some crevice and the ensuing water vapour was unable to escape easily, a water vapour explosion was caused, fragmenting the basalt and forming pockets of basalt breccia, i.e. a rock type made of angular rock fragments.

Light grey pockets of explosion breccia in the upper part of the lava-flow (photo: Bruno Colicchio).

Fumaroles at Mount Etna (photo: M. Kölbl-Ebert).

Remains of a lava tube

As long as a lot of lava is ejected from the eruption fissure, the lava will flow freely on the surface. When, eventually, the flow rate is declining, the lava tends to be restricted to narrow lava flows following depressions. These narrow flows often acquire a solid crust of solidified lava on top and the lava continues for some time to flow underneath the surface in lava tubes. These tubes are later present either as elongated caves within the cooled lava-flow or they completely fill concentrically, when the lava finally stops to flow.
On the right side of the path to Boyabat basalt cliffs, at the upper edge of the valley the eroded remains of such a concentric tube structure can be seen.

Left: Remains of a lava tube at Boyabat basalt cliffs (photo: Bruno Colicchio); Right: Open lava tube at Mount Etna (photo: M. Kölbl-Ebert).

The old and the new river valley

After the lava flow had completely plugged the old river valley, the river had to carve a new bed for itself. While the chaotic entabulature of the lava-flow with its numerous cracks and fissures is easily eroded by a strong enough water current, the colonnade of the flow is much more stable. Therefore most of the present day river valley is excavated in the softer country-rock, a greenschist.
Where the water followed the old valley and encountered the solid interior of the lava-flow, a waterfall formed over the steep basalt cliffs.
Along the road, leading to the entrance of the Boyabat Basalt Cliffs, a part of the old river valley can be seen that has been in use by the river before as well as after the volcanic event.
Here younger, basaltic pebbles have been deposited on top of older, light brown pebbles, which are free from basalt.
The younger basalt pebbles are far less rounded, still showing a conspicuous hexagonal shape, than the

Newly formed river valley after the volcanic event, carved into greenschist (photo: Bruno Colicchio).

Two generations of river pebbles: below are the older brownish pebbles, which characterized the river bed before the lava-flow, above are the basaltic, still angular basalt pebbles from the erosion of the lava-flow (photo: Bruno Colicchio).

older river pebbles, because they have not been transported as far as the older pebbles. The basaltic pebbles are erosion products of the basalt flow in the immediate vicinity of the river deposit.

Both pebble deposits rest much higher than the present river bed, because the river has been deepened by water erosion since the pebbles have been deposited.

Basalt Columns in the Alsace

In Alsace, in the Rossberg mountain massif near Sentheim (Boyabat's French Geovillages partner), there are the oldest lava columns in France. These andesitic rocks date from the Late Visean in the Carboniferous period, some 340 million years ago.

The Rossberg columns (photo: Daniel Rudler)