History of a metamorphic rock

Text by Stefan Sädbom, geologist, Bergskraft Bergslagen AB

The sculpture *Blue Marble* (2020) is made of 13 marble boulders from the Ekeberg and Älteruds quarries some 15 km northeast of Örebro. The marble boulders from Ekeberg are generally grey-white in color whilst the boulders from Älterud are generally more grey-bluish in color. Although slightly different, they are all composed of a rock type that is called marble.
Marbles are formed from calcium- and magnesium-carbonate rich mud which is compacted and recrystallized under high temperature and pressure. This marble in particular, was formed some 1900 000 000 years ago (=1,9 billion years) when this particular place of Sweden was drifting around in a continental plate close to the equator.
We know the age because there are volcanic rocks, ashes and tuffs in the surrounding bedrock that have been age-dated, and we have an idea about the locality and the conditions of the place because this particular rock contains remnants of a special type of organism that created something called stromatolites. Stromatolites was a "simple" life form that lived in colonies and they incapsulated carbonate minerals as they thrived in the warm, shallow water close to the shore of an unknown continent. The stromatolites where simple organisms, related to blue – green algae, and they formed a filt-like coating on the seafloor. They did not "do much", except to capture carbon-dioxide and use photosynthesis to get energy for their growth. And yes, whilst in that process, they also created oxygen that contributed to shape the atmosphere, into something we humanoids, once we "emerged" on the earths surface, only some 2 million years ago from now, appreciated.

The carbonate rich mud left behind by the stromatolites was subsequently buried as the sea-floor was gradually sinking. For a long time the stromatolites could keep up with the sinking allowing the entire horizon of carbonate mud ("later to be marble"), to grow in thickness to more than several hundreds of meters. There where periods of volcanic eruptions that introduced layers of ash into the mud-sequence, but as soon as the eruption was finished, and as long as the water was warm and there was enough sunlight, the stromatolites started to grow again. This continued until the sea-floor had sunk so deep that the suns light could no longer reach the stromatolites and keep up the photosynthesis, eventually, the stromatolites moved to another place and the biological activity ceased and normal sedimentation dominated the continued build up of the sea floor.
As the carbonate rich mud and the remnants of the stromatolites was buried, they were slowly compressed by the weight of the overlaying sediments and was gradually transformed into what we call a limestone. Simultaneously, the tectonic plates surrounding the area kept on moving and pushed the old sea floor with its limestone deep down into the earths crust. The movement of the

tectonic plates was so forceful that the limestone became buried in the roots of an ancient mountain chain kilometers under the earths surface. Down there, the pressure and the temperature was so high that the minerals in the limestone started to react chemically and new minerals where formed. Molecules rearranged into new minerals and the mud that had once been transformed into a limestone now experienced a new transformation, a metamorphosis, into what we today call a marble, a hard, dense rock composed of the minerals calcite and dolomite and with pale-green needle like crystals of a mineral called tremolite. The variation in color depends on low amounts and variations in the content of silica, iron, calcium and magnesium. In some of the boulders it is possible to see the parallel bands that was created by the sedimentation and the stromatolite activities (for instance boulder 12, 13) and in number 11 and 1 it is easy to see green shiny tremolite crystals on the surface of the boulders.

The story does not end deep under that mountain chain, eons later, the tectonic plates had pushed the rocks up in to the air and they where exposed to weathering and the forces of erosion. The mountain chain was gradually eroded and rock was turned, first into boulders, boulders to rocks, rocks to gravel, gravel to sand and sand to mud. Water and winds removed and relocated the sand into the sea, released the weight from the roots of the mountain chain and eventually, it lifted upwards and finally our now transformed marble reaches the erosional surface! This did not last long though, the times where rough and several ice ages took turn to erode the area. About 25 000 years ago there was an ice cap more than 3000 meters thick over Örebro and at the bottom of the ice cap, the ice slowly crunched away on the roots of the mountain chain and eroded the bedrock. The climate got warmer and the ice cap retreated, and at about 9500 years before today, the ice cap left this area and was replaced with an inland fresh water lake full of ice bergs drifting around. The land that had been pushed down by the weight of the ice cap, rebounced and started to rise. Finally the outcrops with Ekeberg marble was emerging from the water and was, once again exposed to the suns light!

After the ice age, the Ekeberg marble at surface has been exposed to erosion and weathering. Since the ice age some of the minerals in the marble have been eroded. On the vertical part of boulder no 1, there are elevated surfaces composed of hard so called skarn-minerals that have been polished by the ice age some more than 10 000 years ago (feel the soft surface low down on the left part of the vertical surface), and the “valleys” in between show how much erosion can remove from a rock surface in the period after the ice age ended. One can estimate that 10-15 mm of rock has been removed, which equals to about 1 mm per 1000 years from this kind of 1 900 000 000 years old rock.