Landscapes in the region (Geomorphology)

The Natur- & UNESCO Global Geopark Mëllerdall is characterised by a rapid succession of different landscape features within a relatively small space. The sandstone and dolomite plateaus and the marl-shaped landscapes offer wonderful panoramic views. Streams have carved deep valleys into the plateaus. Steep rock cliffs of sandstone or dolomite line the valley slopes. Often, rock blocks of various sizes lie scattered around the bottom of these cliffs. Gentler slopes and wide undulating landscapes alternate with plateaus and narrow valleys. These softer landscapes are characterised by the presence of marls.
These landscapes are the result of forces shaping the surface. The oldest traces of these forces in action date back to 20 million years ago.

During the Liassic, ("tectonic") uplift pushed the ocean floor upwards above sea level. Rocks start to erode, and the resulting loose rocks and sand accumulate on the ground (where they continue to change into "soil"). When it rains, water runs off the ground and forms rivers that carry away some of the loose material, thereby cutting furrows into the ground. How a surface is shaped is influenced not only by the properties of the rocks that underpin it. Climate also plays an important role. In different climates, rocks are eroded and carried off in different ways. We know nothing about the appearance of the landscapes that formed immediately after the uplift in the late Jurassic and Cretaceous periods, because these have been completely eroded away.

During the Tertiary (65-2 million years ago, today divided into Paleogene and Neogene), the climate was warm and humid. This resulted in the formation of an extensive and relatively flat plain with very little change in elevation that lay just above sea level. This flat plain cut into several geological layers underneath it that, in the Natur- & UNESCO Global Geopark, lie as if in a trough ("syncline"). The direct ancestor of the current day river system was already in place on this plain.

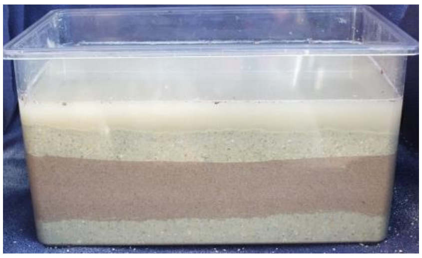
The red line above the cross-section through the Natur- & Geopark corresponds roughly to the relative position of the ground level during the Tertiary. These shallow plains lay only slightly above sea level. Now, its remains are found at an elevation of 400 m above sea level.

In the warm and humid climate of that age, iron was dissolved by seepage water, transported by groundwater, and deposited in depressions as bog iron ore.

Remains of this plain now lie on top of plateaus at an elevation of 400 m. Since about 20 million years ago, and especially during the last 800,000 years, the land has been rising again. Over this timeframe, the present-day valleys formed. The Sauer, the Black and the White Ernz and their tributaries dug into the subsoil, eroded and carried away layer upon layer of rock, and thereby exposed the former ocean floor at the valley slopes.

To understand how these landscapes formed we can turn to a model of geological layers:

As the ocean in which the layers were formed retreats, a river starts to cut into the bedrock. Because marls are too soft to sustain steep cliff walls, the river forms a wide valley. As the river cuts deeper into the underlying sandstones or dolomites, it forms a narrow valley because these rocks are much harder. Sometimes, rockfall can be found at the bottom of cliffs. Should the river cut into the underlying marls, the valley broadens quickly, because rock blocks start to slide on and with the wet marl.



In the geological layers deposited in an ocean...

... a stream cuts a valley, or...

... a cuesta forms because a large part of a layer has been eroded.

The properties of the rocks underpinning a landscape play an important role in shaping that landscape. The way in which these rocks fall apart (how they erode) is particularly important. However, the climate also plays a significant role. In the current time and climate these processes are very slow. Many features of the current day landscape originated during transitions between glacial periods to interglacial periods (and vice versa) that occurred within the current ice age, spanning the last 2 million years.

Fundamentally, rocks are classified into two types that erode differently:

- "hard" rocks contain many joints and have good water permeability, their layers erode relatively slowly, and
- "soft" rocks, which contain clay minerals, do not contain joints, have low water permeability, and erode relatively quickly.

Both sandstone and dolomite are counted among the “hard” rocks. They are very durable and take a long time to erode. They form steep cliff walls, from which stones and boulders occasionally fall off. Rock massifs consisting of sandstone or dolomite are cut through every few meters from top to bottom by effectively vertical cracks (joints). This way, the massif is cut up into many rock towers. When entire cliff faces collapse at the edge of a rock formation, these joints serve as “predetermined breaking points”: the collapse of one tower exposes the one behind it, and the joint between them has already shaped the new cliff face when it was still hidden within the rock massif. Should a stream cut into a bedrock like this, the resulting valley will at first be narrow and have steep slopes. If the stream cuts even deeper, more and more rocks fall into the valley. This rockfall is either carried off by the stream (except for boulders that are too large), or remains as slope debris (if it does not reach the stream). Over time the valley expands and the valley slopes move ever further away from each other.

A stream has cut into “hard” dolomite bedrock. The dolomite rock has formed steep cliff faces, and any blocks that fall out of them are carried off by the stream.

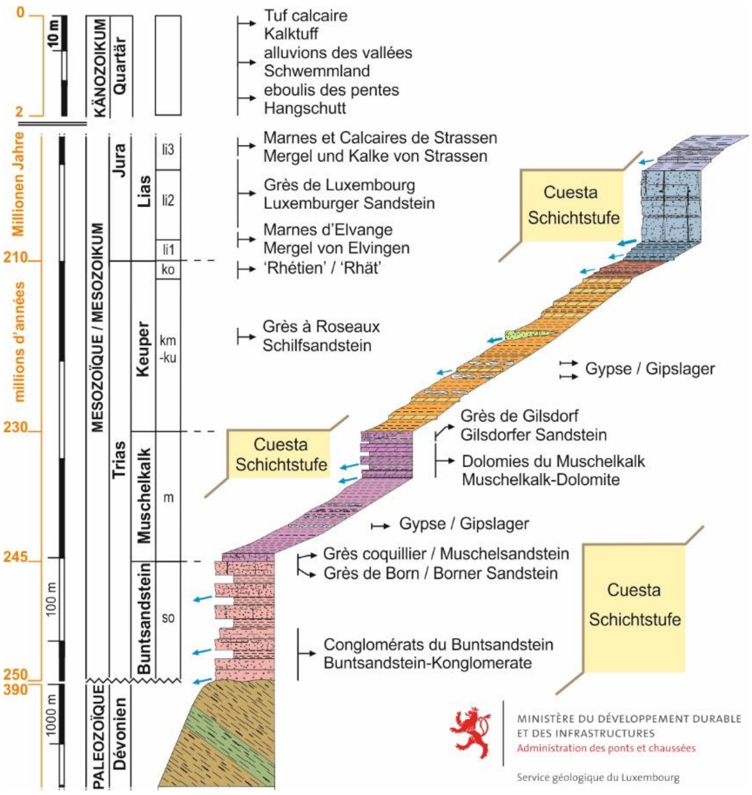
A steep cliff face of "hard" sandstone stands at the fringe of the valley. Over time, blocks and boulders have fallen out off the cliff face. A part of this rockfall has been carried off by the stream, and a part remained as debris to form the slope in front of the cliff.

Upon exposure to the surface the "soft" clay-rich marls also common in the Natur- & UNESCO Global Geopark behave differently: they rapidly fall apart and therefore cannot form steep cliff faces. It is therefore quite uncommon to find marls as blocks of stone. However, one can easily spot landscapes lying on a marl subsoil: these landscapes have shallow slopes and, in general, gently rolling hills.

A block of marl crumbling over 8 weeks.

Landscape shaped by "soft" marls (Photo: Uli Fielitz).

Because “hard” and “soft” rocks alternate in the stratigraphic record, steep cliff faces (sandstone or dolomite) and shallow slopes (marl) alternate with one another. The resulting landscape looks a bit like a staircase, and every “step” is called a cuesta after the Spanish word for “slope”.



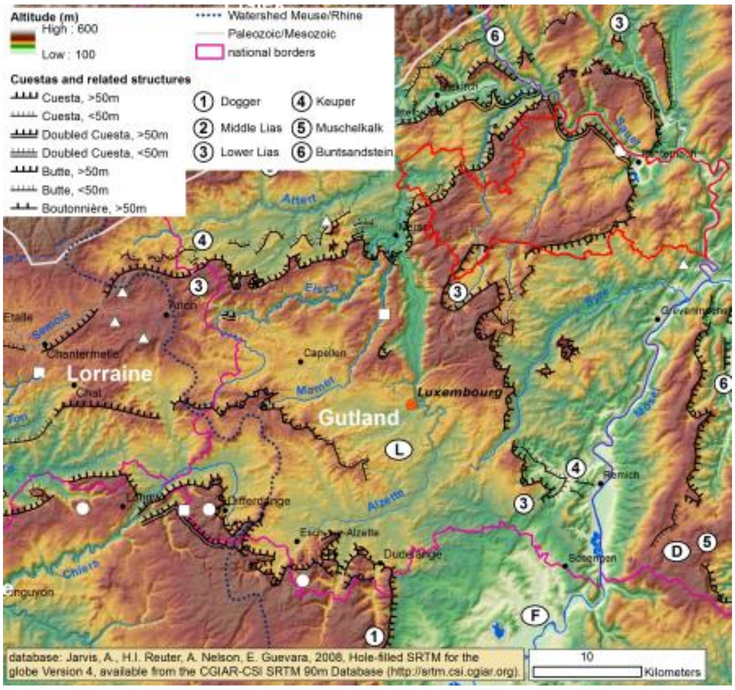
This diagram shows the usual sequence of geological layers and their corresponding geomorphological formations. The succession of shallow and steep slopes led to the formation of a cuesta landscape (copyright: Service Géologique de l'Etat, www.geologie.lu).

Right in the middle of the region, plateaus of the Luxembourg Sandstone, with narrow valleys cut deep into them, extend from roughly the southwest to the northeast (“Weilerbach syncline”). At their limits lie the forested cuestas, which tower high above the gently undulating lowlands made out of marl dating from the Keuper. These lowlands can be found in the southeast of the Natur- & UNESCO Global Geopark, in the municipalities of Bech, Rosport, and Echternach. In the northwest they can be seen in the municipalities of Larochette and Nommern. The characteristic combination of gently undulating plains in front of a cuesta is particularly evident in the southeast and northwest of the Natur- & UNESCO Global Geopark (ku-km on the geological map). In the east and west, the marl-based plains gradually give way to plateaus made of dolomite, into which deep valleys have been cut. These dolomite cliff faces are particularly spectacular in the Sauer valley, in the east of the Natur- & UNESCO Global Geopark. The outermost dolomite cuestas are found north of the

region in the Sauer valley close to Diekirch/Ettelbrück, and in the southeast beyond the Moselle valley.
In the landscapes with "soft" marl as the subsoil, rainwater rapidly flows away over the clay-rich marls, taking small particles of marl with it. Many small valleys are formed that lend this landscape its typical appearance. The resulting landscape is not uniform, because not all marls contain the same amount of clay, and at times it also contains some stones or sand.

A cuesta made of Luxembourg Sandstone near Echternach

The Black Ernz has cut deep into layers of sandstone and marl, thereby separating the plateaus of Beaufort and Berdorf. The upper part of the slope, made of Luxembourg Sandstone, is steep and forested, while the lower part of the slope, made of marl, is less steep and used agriculturally.



The cuestas of the Luxembourg's Gutland and its neighbouring regions (after Kausch & Maquil 2018). Red line: Border of the Natur- & UNESCO Global Geopark. The Luxembourg's Gutland is characterised by alternating steep cuestas and gently undulating landscapes. In the northwest, it is continued by the Bitburger Gutland, while in the southeast it extends into the cuesta landscapes of the "Parisian basin", namely into the cuesta landscape of the Lorraine.

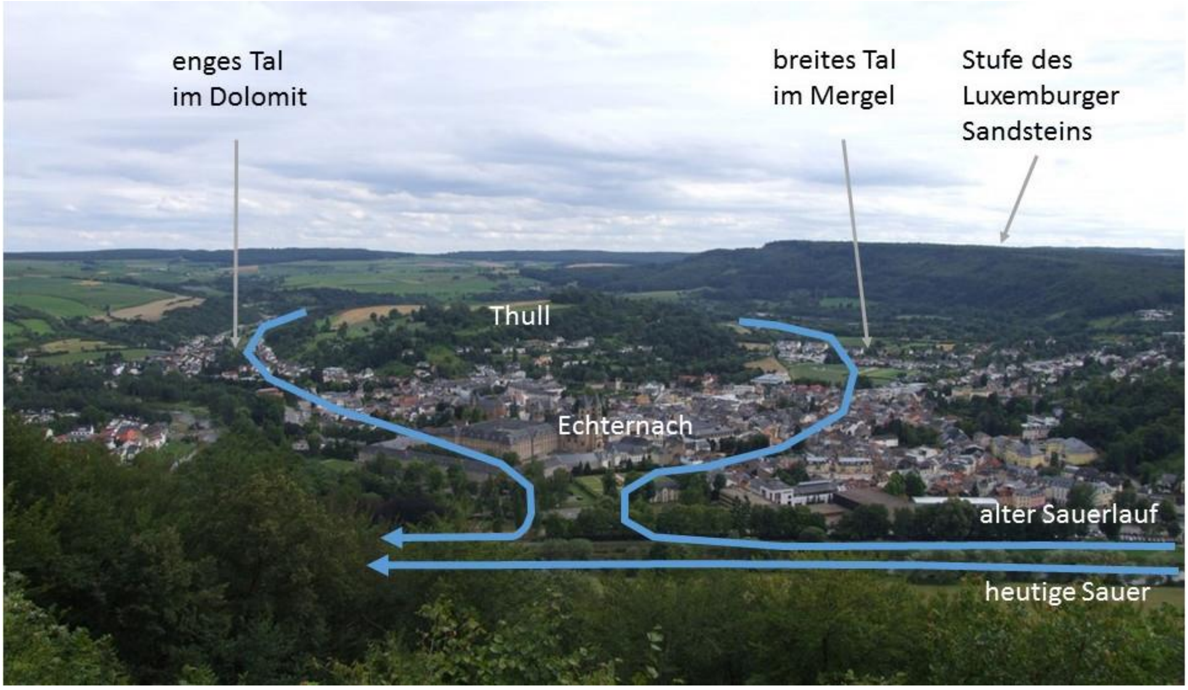
In those places where a valley slope shifts from a layer of permeable ("hard") sandstone or dolomite to an underlying layer of ("soft") impermeable marl, groundwater emerges at a spring. This is often visible in valleys where a stream suddenly emerges in the middle of a valley while the upper part of the valley is dry. In this transitional zone, peculiar rock formations can be found. Water softens the unstable marls, making them pliable and slippery (well known from pottery) or they break. At the valley slope, the sandstone or dolomite towers resting upon the marl begin to slide downwards. As they slide, they may lean away from the cliff or stay upright, creating narrow passageways between the rock tower and the edge of the plateau. However, if they lean towards the cliff as their bases slide down, they form a triangular cave. When the towers collapse, they leave great boulders lying around in front of the cliffs. The debris that slides or falls to the bottom of the valley is partially carried off by the rivers that flow through them. The remainder stays at the bottom of the cliffs, as slope debris.

If the river cuts into the marls beneath the dolomite or sandstone, the valleys expand faster than would be expected if the valley had consisted only of a "hard" rock. This happens because large blocks of rock slide into the valley on and with the softened marl. The majority of this material is currently carried off by rivers towards the North Sea.

Rock cliffs starting to tip over (dolomite on top of marl, geosite Alkummer near Rosport)

A rock tower sliding downwards (Luxembourg Sandstone on top of marl, Räiberhiel (robber's cave) near Berdorf, geosite Wanterbaach-Siweschlëff)

In Echternach, one can witness a special case of valley formation. Here, Thoull hill is surrounded at all sides by a large valley through which small streams flow. The streams did not create this valley. In fact, it is a former meander of the river Sauer. Long ago, the Sauer flowed around the Thoull. As it did so, it cut a large and shallow valley into the "soft" marls to the west, and a narrow valley into the dolomites to the east. As the last glacial period came to its end, continued erosion (leading to a meander cutoff) caused the Sauer to abandon its old course around the Thoull and instead flow straight past.



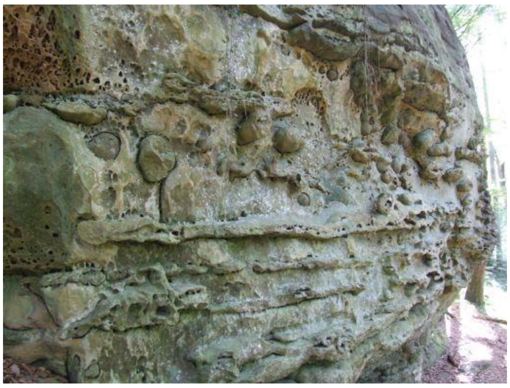
The course of the river Sauer today and at the end of the last glacial period. Back then, the Sauer flowed around Thoull hill.

The weathering of Luxembourg Sandstone in particular can result in impressive patterns and shapes of various sizes. Honeycomb weathering is especially eye-catching. As the calcium carbonate (lime) cement gets dissolved in water and recrystallizes elsewhere, the part of the rock it is leached from reverts to sand. This sand can trickle away, while other parts that retained calcium carbonate and are still solid remain in place. This process forms bizarre honeycomb-shaped structures. In other locations one can observe how some sandstone layers richer in calcium carbonate are more resistant to erosion than layers that contain less calcium carbonate. Upon exposure and weathering, these calcium carbonate rich layers jut out between the layers with less calcium carbonate content. They contain many more joints, and so look a bit like a row of teeth. As the calcium carbonate cement is progressively dissolved, small cavities, cracks, and joints form and expand until the rock is completely weathered away.

At the utmost north-western limit of the sandstone formations in the Natur- & UNESCO Global Geopark there is the “Champignon”. Because the cap and the stem have a different resistance to erosion, the rock has ended up looking like a mushroom.

Some examples of the shapes and patterns of various sizes caused by the weathering of Luxembourg Sandstone in the Natur- & UNESCO Global Geopark:

honeycomb weathering



weathering caused calcium carbonate rich layers to jut out

the "Champignon", remainder of a layer of Luxembourg Sandstone that has weathered away

A typical small-scale feature of the region is the so-called "mardel". These are small basins without an outlet, commonly filled with water. They form when underground gypsum or dolomite lentils embedded in marl dissolve. As a consequence, the ground above drops a bit, and a low-lying depression forms that fills up at least semi-permanently with water.

Within decades, the mardel becomes covered with soil carried in from all sides. Because the constant high humidity within a mardel aids the preservation of pollen, mardels are valuable archives documenting the vegetation, climate, and agricultural practices of former ages.

A mardelle in Hierberbësch.

Birgit Kausch, 2020