Supplement of Geosci. Commun., 9, 87–100, 2026
https://doi.org/10.5194/gc-9-87-2026-supplement

Supplement of

Science, art, and legends in geotourism: a multidisciplinary geotrail approach in Alagna Valsesia, Sesia Val Grande Geopark (NW Italy)

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I ga der enki Wäigê

I walk on narrow paths

Fer dem Kurt
I ga der enki Wäigê
Larcena und Ambeisu Kschmackh
chomemer ingägä
I bê fleigenz
wê im ä Tröim:
mi Fêês rêren inkhei Schtrevi me a
un mine Ferdreuss tzertrêkchtmi nêmmä.
Fortzu me üf…
i la hênner t Aksla
Lärcha un Tannä ;
t Luft êscht reini
schi het fa Isch;
zobrusht uf um bluttä Bärg
kshpêrämi lêchtz,
i ferlêrä der Lip,
i bê äbä me Seel.

On narrow paths
I walk;
resin and smell of ants
come towards me.
I'm flying
like in a dream:
my feet do not touch ant straw
and my pain do not press me anymore.
Up and up…
I leave behind
larch and fir trees;
the air is thin
it tastes like ice;
on top of the naked mountain
I feel light,
I loose my body,
I'm only spirit.

Anna Maria Bacher (Brendu – Formazza)

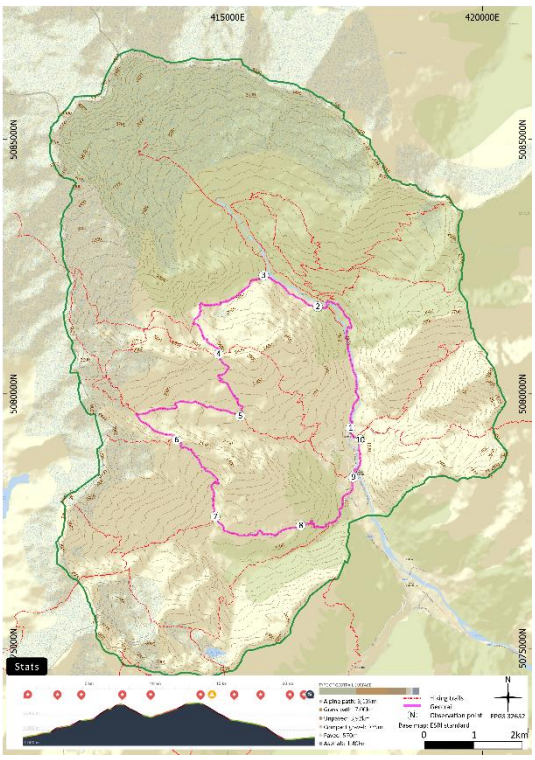

Figure S1 Map of the Geotrail. Source of the basemap: ESRI | Powered by ESRI

Geostop #1 Wold – Start

A time-travel along the Walser paths

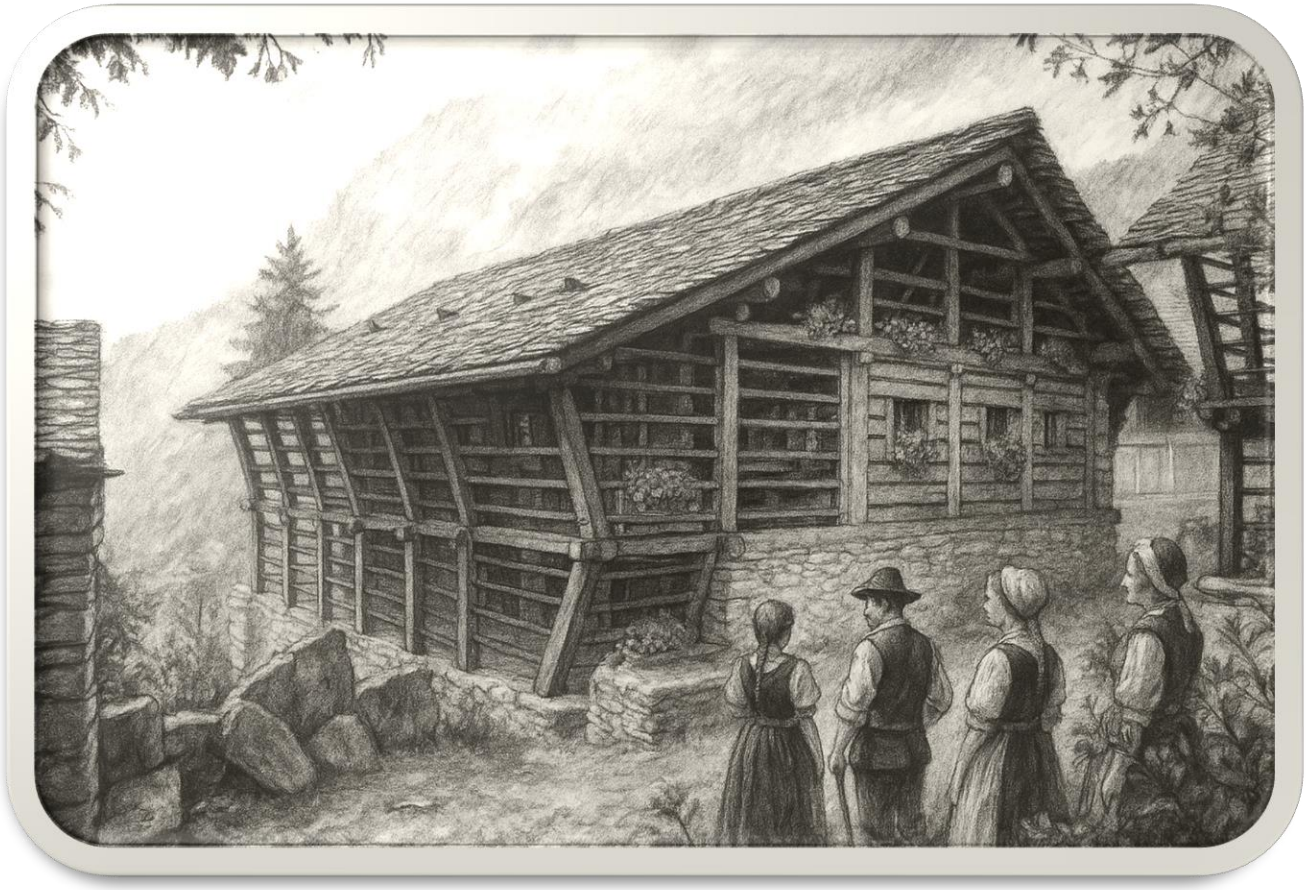

Figure S2 Illustration of a Walser's landscape

The mountains, majestic and silent, appear still and timeless. Yet, how many times have we wondered: when were they born? When did they begin to rise toward the sky? To answer these questions, we need to make an effort of imagination and venture into "geological time," a distant past that challenges our everyday understanding.

The formation of a mountain is not a simple or immediate event; it is a complex process that takes place in several stages. Usually, we distinguish three main ones: the creation of rocks, their deformation and uplift that give rise to the mountain, and finally, the shaping of the current landscape, sculpted by erosion.

With this geotrail, you are invited to take a unique journey through the time of Alagna Valsesia. Step by step, we will explore together the traces of the past that have shaped the landscape surrounding us today. We will discover how atmospheric agents and erosive forces have sculpted the mountains, but we will go even further back—to understand how these mountains rose and, before that, how the rocks that make up the Sesia-Val Grande Geopark, the extraordinary area where we stand, were formed.

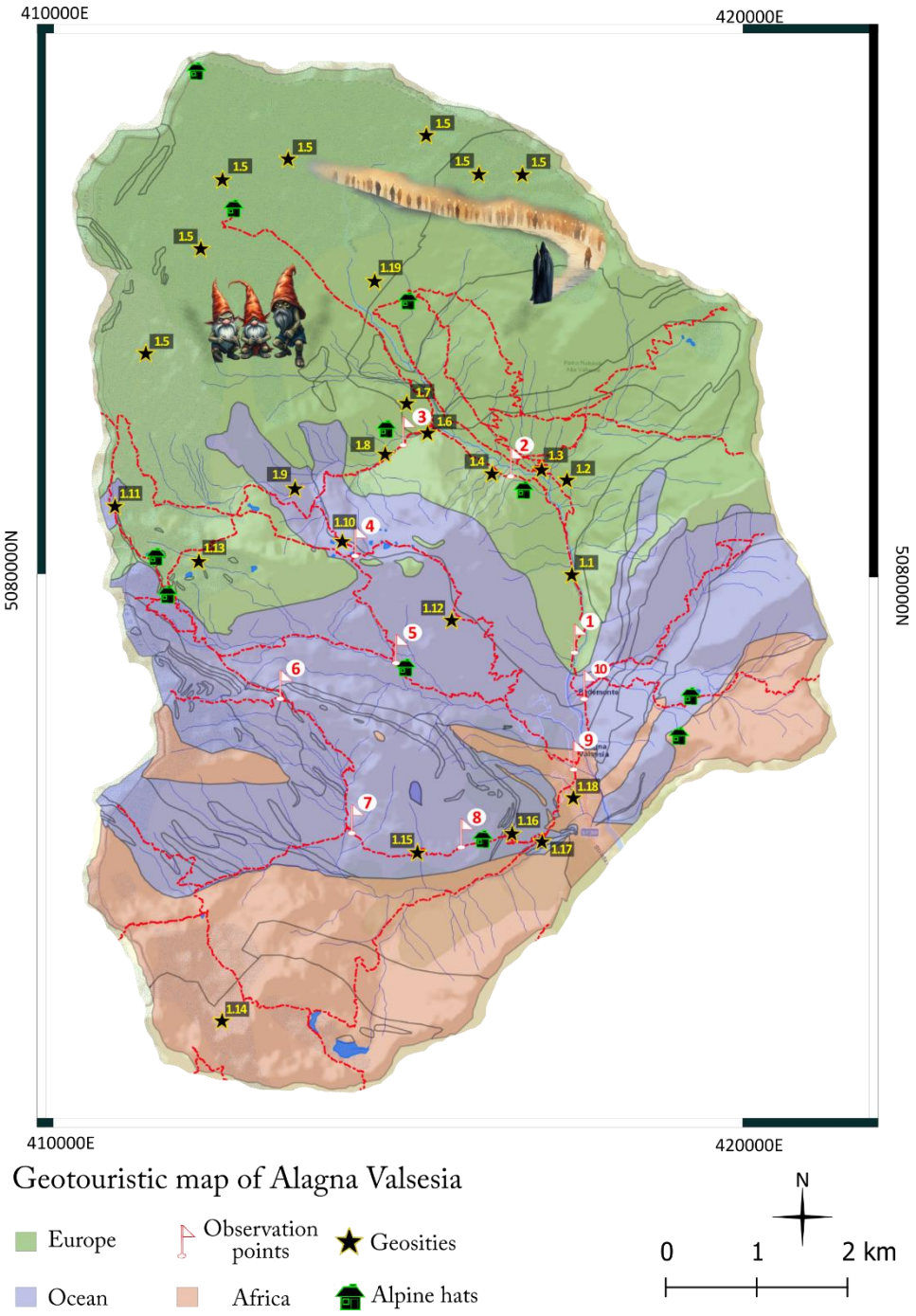

Figure S3 Geotouristic Map of Alagna Valsesia

First stage – the Monte Rosa glacial landscape

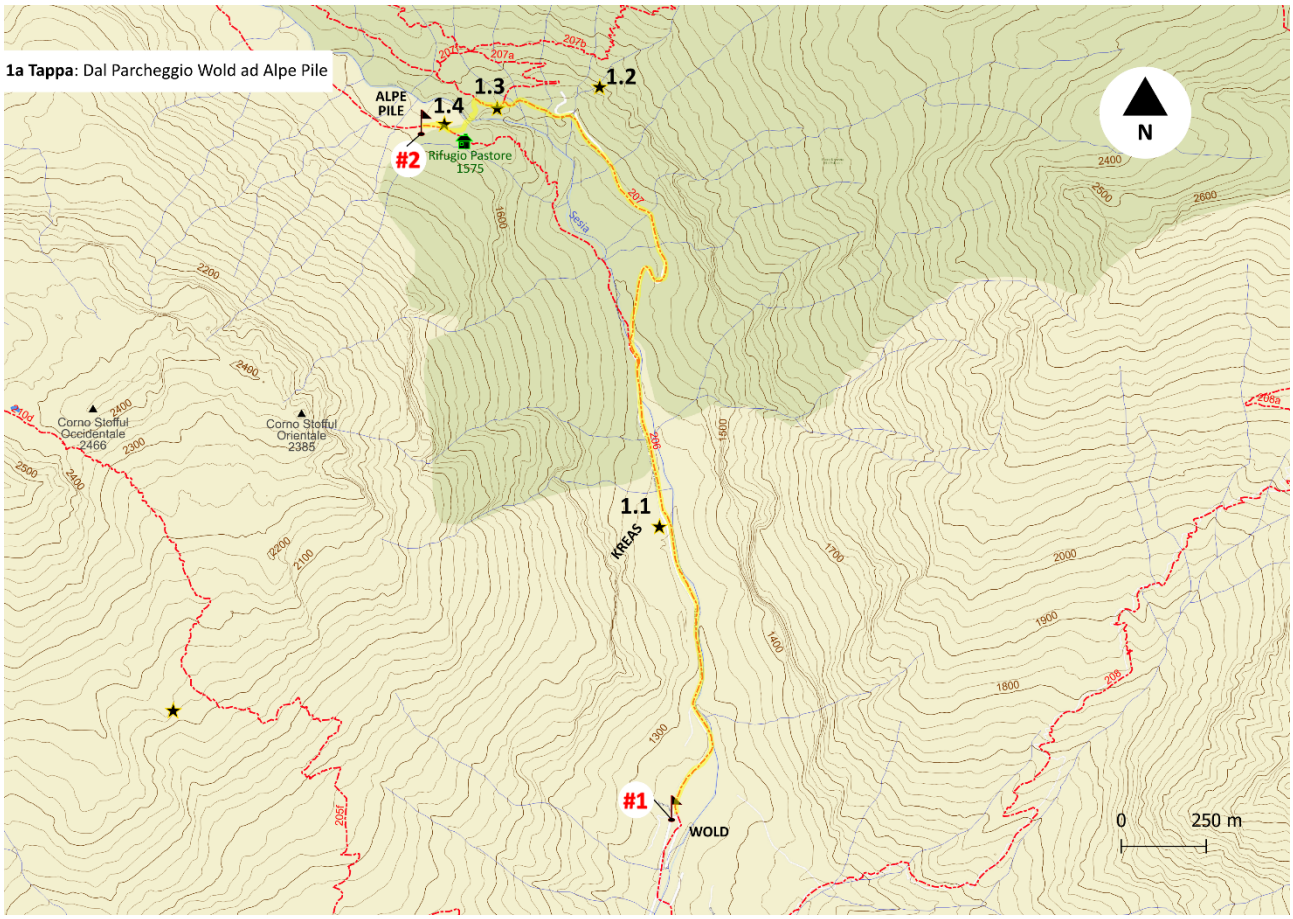

Figure S4 Map of the first stage of the Geotrail

General description:

From Wold park site to Alpe Pile

2.8 km, elevation +387, -82, 1h30

The first stage unfolds in the upper part of the Sesia River basin, on the left orographic side. The route winds between the debris slope and the undergrowth, always along an easy and well-marked path. Along the way, you can observe some geosites that reveal forms and processes related to past glaciations. Later, upon reaching the first geostop and the end of this stage, we will be able to observe the Valsesian glaciers and identify the landforms shaped by their recent retreat phase caused by current climate change.

Path description

The first stage of the geotrail begins from the Wold hamlet of Alagna Valsesia. You can reach it on foot from Alagna or by car, parking in the large lot where the shuttle bus to Acqua Bianca departs. The route starts along the paved road, following trail 206 toward “Acqua Bianca.” After crossing the iron bridge, continue to the left of the Sesia River along a dirt mule track, gently uphill with accessible slopes. On the left, you will see the entrance of the Kreas gold mine (Geosite 1.1). Upon reaching the next bridge, do not cross the river but turn right following the signs for the mountain huts. The trail rises slightly and leads through a debris slope, bringing you back to the paved road.

From here, you can continue on trail 206 to Rifugio Pastore, with steeper slopes in the forest, or follow the paved road which, after approximately 800 meters, reaches the area known as Acqua Bianca (Geosite 1.2). In Acqua Bianca, take trail 207, paved, which passes by the Caldaia del Sesia (Geosite 1.3), the park house, and then, after crossing the Sesia River via a wooden bridge, arrives at Alpe Pile (Geosite 1.4). From here, you can observe the Valsesian glaciers (Geosite 1.5).

Short story – the procession of the deaths

Figure S5 illustration of the first tale

Every year, on November 2nd, the Walser souls of the dead from Alagna Valsesia awaken. The spirits, condemned for the sins committed in life, gather and solemnly set out in procession. The souls raise the pinky of their right hand, which glows with a ghostly blue flame, and parade through the ancient hamlets of Alagna; their destination is the great glacier of Monte Rosa. As they recognize their former homes, some souls let out laments that reach the ears of the living only as distant whispers. The souls ascend, recalling their life's mistakes and seeking to repent in hope of redemption. Upon reaching the glacier, the souls are drawn back into the earth, knowing that their suffering is destined to repeat.

Year after year, the souls who walk towards the Monte Rosa glacier on November 2nd must climb further and further, chasing the glacier as it recedes higher each time. They cry out to the mountain the torment of their ever-growing struggle, yet deep down they await the day they will ascend the slope to the top and find no glacier. When the penitents' procession loses its destination, they will finally vanish upwards, freed from their now expiated sins, leaving the world of the living and never to return. At that point, this story will no longer serve as a warning to the living, but will become a tale of the past, of souls who will have finally paid their penance. And what of the living?

Figure S6 Illustration of the first tale

Geostop #2 Alpe Pile

Figure S7 Landscape view from Alpe Pile

This observation point offers a unique opportunity to begin understanding the geomorphology of the surrounding landscape. From Alpe Pile, you can admire the south face of Monte Rosa and observe two of Valsesia's main glaciers: the Piode glacier and the Sesia-Vigne glacier. These glaciers have fundamentally shaped the morphology of this territory. Valsesia has not always looked as it does today; even if the mountain landscape seems unchanging, it is constantly evolving due to erosive processes, although these are often slow and nearly imperceptible. Glaciers sculpt the scenery through the powerful erosion of rocks and the creation of depositional features. Even though such changes occur over geologic time, we can still observe their traces and understand how the landscape has been shaped. A clear example of this glacial action is shown in the accumulations and erosive structures created during the **Little Ice Age** (1450–1850), when the climate was colder and glaciers were far more extensive. Even going back only to 1850, the south face of Monte Rosa would have been much more covered by ice than it is today. One of the most striking features visible from this observation point are the moraines, made of rocky debris deposited during the glacier's expansion. These well-preserved structures are direct evidence of the ancient glaciers' extent and shape. Similarly, you can observe polished bedrock outcrops, which emerge as glaciers retreat—their rounded surface results from glacial erosion. By comparing the current positions of the glaciers to these traces, the dramatic retreat of the ice in the past 150 years becomes clear. In Valsesia, this loss amounts to more than 60% of glacial surface area. Projections suggest that the area's glaciers might disappear entirely by 2100. In addition to shaping the landscape, glaciers are key indicators of climate

Figure S8 Interpreted periglacial landscape

change. Their retreat and the resulting geomorphological changes have direct impacts on the region's stability. For the south face of Monte Rosa, this means increased rock instability and a higher risk of landslides and collapses.

Glaciers

Glaciers originate from the gradual accumulation of snow over time. In favorable climatic conditions, the snow does not completely melt and the flakes that settle are compacted under the weight of the upper layers. Over time, firn—a material with an intermediate density between snow and ice—transforms into glacial ice through further compaction and crystallization. This ice reaches a density about 90% that of water, giving rise to glaciers. While glaciers might appear static, they are constantly in motion. Polar ice caps expand radially, whereas mountain glaciers slide downhill due to gravity. This movement can be slow but is continuous: in the upper part of a glacier, accumulated snow exceeds melting losses, while in the lower part, the reverse occurs. Thanks to this movement, sometimes only a few centimeters per day, the glacier is able to erode rock, shape slopes, and transport material, eventually depositing it to create new forms of accumulation.

A glacier can be divided into three main zones:

1) The accumulation zone, where more ice collects than is lost. This is the upper part of the glacier where snow accumulates and gradually becomes glacial ice.

2) The ablation zone, where ice loss (due to melting, sublimation, or calving) exceeds any accumulation. This is typically the lower portion of the glacier.

3) The equilibrium zone, which is the transition area between accumulation and ablation, where gains and losses of ice are balanced.

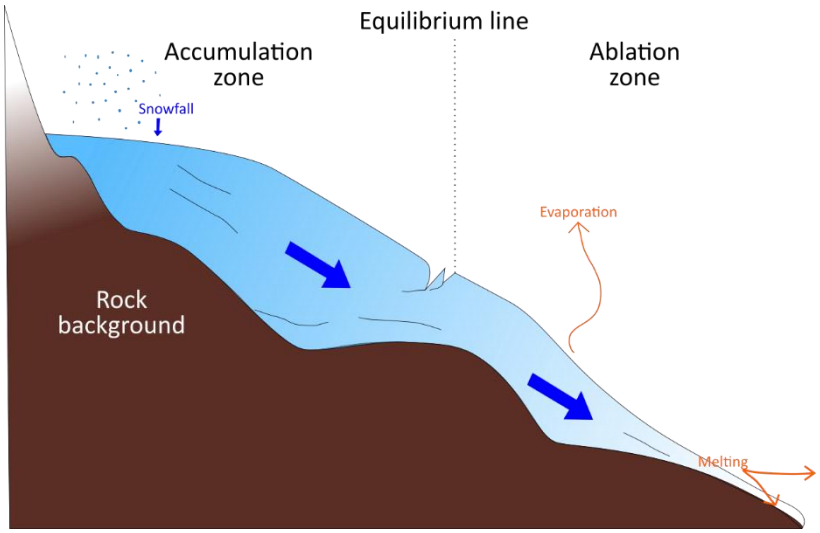

Figure S9 Illustration of the glacier behaviour

Due to glacier movement, ice accumulated in the accumulation zone is constantly transported toward the ablation zone. When it crosses the equilibrium line, it increasingly melts until it disappears. Because of climate change, in the Alps, the glacier equilibrium line is rising to higher

altitudes, which expands the ablation zone and reduces the accumulation zone. This shift causes glaciers to lose more mass overall, accelerating their retreat.

Geosites

1.1 Gold mine of Kreas

The Kreas mine, located at the head of the valley, is one of the main gold-bearing veins in the area and part of a complex system of tunnels used for gold extraction. This area is an extension of the productive district of Pestarena – Val Quarazza – Val Quarazzola, nestled in the heart of the Alps within the Monte Rosa massif. The central vein of Kreas is in Alagna, with several smaller deposits distributed along an axis running west-northwest to east-southeast.

In 1753, construction of service buildings for the mines began in Alagna, led by the local entrepreneur Pietro Giordano. These buildings, completed in 1755, were designed to withstand avalanches and reflect the military architecture of the Savoy period. Two of these buildings, located north of the Pedemonte hamlet, still survive today. One of them, known as the "fabbrica di San Lorenzo," was part of the Kreas "Gold District" and was used for crushing gold ore before its processing at the Alagna foundry.

1.2 Acqua Bianca waterfall

The Acqua Bianca (lit.:"white water") waterfall is located at the start of the glaciological trail in Alagna Valsesia and is fed by the Rio Acquabianca. This spectacular waterfall, with a drop of 130 meters, forms where the stream flows over a suspended valley in a typical glacial landscape. When the Valsesian glacier covered the entire area, a

Figure S10 Geosite Acqua Bianca waterfall

smaller glacier extended from the current Alpe Grafenboden and Alpe Jazza, joining the larger glacier at this point. As the glaciers retreated due to climate change, the suspended valley from which the waterfall now originates remained. This landscape is typical and frequent in this area, exemplified by the Cascata delle Pisse located further upstream in a section where the valley bends northwest, near Alpe Pile and the Valsesian glaciers. Here too, glacial erosion formed a suspended valley. This process also characterizes the Acquabianca geosite, featuring steep slopes shaped by the ancient glacier, which today exhibit accelerated erosion. Surrounded by peaks of the Alpine massif, this corner of Valsesia offers breathtaking panoramas opening southward towards Alagna.

1.3 The Sesia plunge pool

This geosite is a classic result of glacial geomorphological processes, consisting of three elements: the gorge (forra), which channels water from above, the waterfall, and the plunge pool (caldaia), a semicircular cavity at the bottom that collects falling water. These landforms—the gorge and the plunge pool—were carved by water flowing beneath the glacier base, eroding the underlying rock. The erosive power was strong due to the large solid load carried by the water, mostly sediment from previously eroded rock, which made the water highly abrasive. This abrasive action carved out the gorge and, through swirling motion, formed the plunge pool. After the glacier's retreat, the Sesia River occupied these glacially sculpted morphologies.

Figure S11 Geosite Sesia plunge pool

This explanation fits with the geomorphological features observed at the Acquabianca geosite, which exhibits steep slopes shaped by ancient glacier activity and ongoing accelerated erosion. The site thus vividly demonstrates how subglacial waters have historically shaped the landscape and how river action has since modified these features.

1.4 Alpe Pile

Figure S12 Geosite Alpe Pile

This glacial terrace is located at an altitude slightly above 1500 meters and bears clear marks of intense past glacial activity, evident in its typical landforms such as polished bedrock (rocce montonate) and giant's kettles (marmitte dei giganti). It is surrounded by the peaks of the crystalline massifs of the Pennine Alps and offers direct access to the south face of the Monte Rosa massif. From this terrace, the glaciers on this side—Piode, Sesia, and Vigne glaciers—and key peaks like Punta Gniffetti, home to the Capanna Regina Margherita, are prominently visible. The site also includes an ancient Walser hamlet with recorded history dating back to the 1500s, now converted into an alpine refuge (Rifugio CAI Pastore).

1.5 Ghiacciai della Valsesia

The Valsesian glaciers lie on the southern side of the Monte Rosa massif at altitudes between about 2600 and 4000 meters above sea level. They serve as the main morphogenetic agents shaping the local landscape and are direct evidence of the glacial forces that have modeled the entire Valsesia region, including Alagna. The steep orography of the upper Valsesia, mainly due to the gneissic rock substrate, the limited extent of glacier accumulation zones above 3000 m, and the south-facing orientation of Monte Rosa's southern flank result in relatively limited glacier development in this valley today, despite the basin's maximum altitude of 4554 m. Additionally, the permanent snow line is influenced by precipitation levels, which determine how much new snow feeds the glaciers. Due to climate change, Valsesian glaciers are retreating rapidly, giving way to other morphogenetic processes, especially gravity-driven phenomena like landslides and rockfalls.

Second stage – Hanging valleys and former glacial lakes

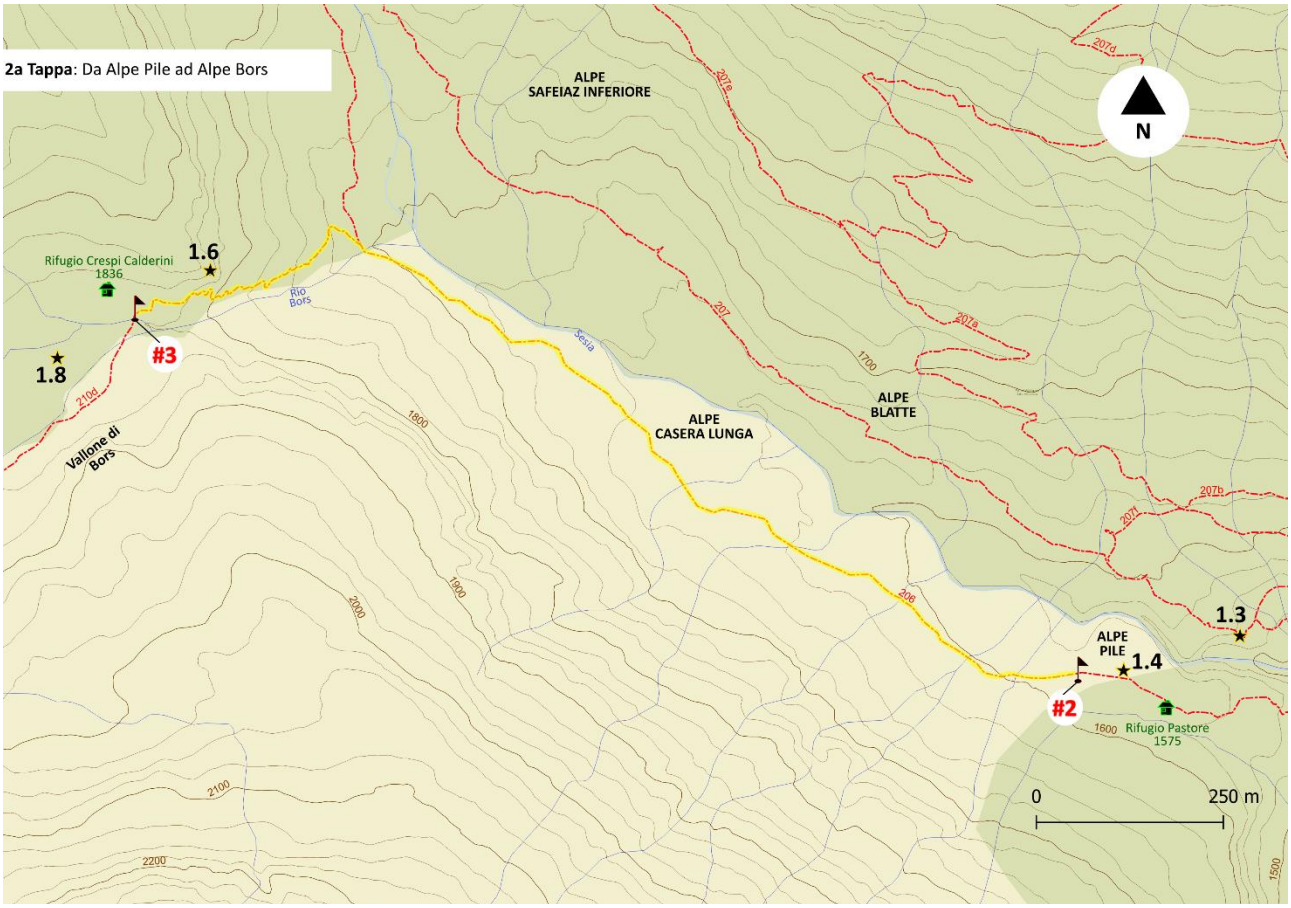

Figure S13 Map of the second stage of the Geotrail

General description:

From Alpe Pile to Alpe Bors

1.7 km, elevation +278, -15, 1h15

The second stage unfolds between the upper part of the Sesia River valley on the right orographic side and the entrance to the Bors valley. The path runs across meadows and undergrowth, culminating in the ascent of a glacial step near the end. The trail is easy and well-marked, although steep slopes are present toward the finish. Otherwise, the route is mostly flat and allows observation of terrain morphologies particularly linked to glacial activity. Walking this segment effectively takes you back in time, showing how large glaciers, much older than those from the Little Ice Age, have deeply shaped this territory.

Path descrition

Starting from Alpe Pile, the route follows trail 206 through meadows and undergrowth, initially flat. Continuing, the path rises along the right orographic bank of the Sesia River, passing Alpe Caseralunga (1644 m) and crossing a wooden bridge over Rio Bors (1700 m). After crossing the Bors torrent bridge, the path turns left onto trail 210, leading up to Alpe Bors and the Rifugio Crespi-Calderini (1836 m). Here the route becomes steeper due to a glacial step covered over time

by the Fondecco moraine (Geosite 1.6). The trail climbs steep switchbacks on the left bank of the Bors torrent. Although the ascent is demanding, the path is well marked and requires no mountaineering equipment. Along the way, the excavation site of the St. Maurizio gold mine (Geosite 1.7) is visible on the right. After the climb, the trail reaches the wide plateau of Alpe Bors (Geosite 1.8), site of the Rifugio Crespi-Calderini. This section is part of the Glaciological Trail, which continues beyond Bors following itinerary 210a.

Short story – hanging women

Figure S14 illustration of the second tale

From the Bors glacier rises the stream of the same name, which follows the terraced valley until it meets a large rock wall, from which the Pisse waterfall is formed. It is in this place that the dead souls of women are condemned to atone for their sins. After death, passing through the small window carved into the soapstone, the souls of the wicked women of the Walser community do not find the hoped-for salvation, but are destined for this place, which becomes their Calvary. Over the years, the Walser community forgot this feature and the Bors valley remained simply a secondary valley, high enough and shaded enough. All this made it a perfect place for off-piste skiing. So, rumors began to spread in the village about an expansion of the ski lifts right in this valley. As often happens in small mountain villages, rumors pass from mouth to mouth and run from house to house, light as whispers and dancing like the wind, and in a short time in Alagna no one talked about anything else. At the shop, in front of the school, in church, at the post office, at the dairy, everyone talked, commented, annotated and discussed the new lifts in the Bors valley. One evening, two ski lift workers were at the bar they usually frequented after the working day to eat a miaccia before going home. Sitting at their usual table, they saw an old man, an elder of the village, approach them. With the confidence typical of the elderly or the drunk, the man stated: “Do not go and build up there, it is dangerous,” and left. The two workers paid no attention to those words; they could have been nonsense spoken by an old man in a bar. They went home and went to sleep. The night, however, was sleepless. For some unknown reason, both of them could not get the encounter with the old man out of their heads. What did he mean? They knew that the studies carried out on the Bors valley had shown that the area was not subject to particular

geomorphological risk. Why then had that man told them it was dangerous? They told themselves that perhaps he was just trying to obstruct the works, offended by the fact that a landscape, a territory that also belonged to him, would be altered against his will, but they could not trust their own thoughts.

The next morning, the two workers decided to go and check for themselves. They climbed from the Pastore refuge and easily passed the Fondecco moraine to climb to the Bors alp. They opened the geomorphological map they had brought with them and looked around. Everything matched: they saw the glacio-lacustrine deposits at the entrance to the valley, noticed the two small dormant rockfall landslides on the southern slope, and the glacial deposits higher up. Slowly, they climbed the valley, looking for geomorphological elements like two kids having fun in a treasure hunt. As they walked, they could not find any geomorphological feature out of place, anything that would make building in that area dangerous. However, as they approached the Pisse waterfall, they saw something. There was something on both sides of the waterfall, something small, like elongated spots that blended into the rock behind them. The two stared intently and, as in a sky studded with stars, the more they looked, the more of these shapes they noticed. Some low down, some high up, some halfway up the waterfall. The closer they got, the clearer they became, even though they had never seen shapes like these in any book. They could not understand what they were or what had generated them. One spot in particular, just to the right of the waterfall, had the shape of a human being. It looked just like a woman floating with her face turned toward the waterfall, with long wet hair, a slender body, a tattered dress, and a rope around her neck suspending her in the sky. In the water mist created by the waterfall, the spot almost seemed to move. Suddenly, the two workers saw the woman turn her neck and look at them. They were terrified by what they were seeing, but could not look away. Her eyes were black, piercing, and reflected a deep pain that does not belong to this world. The woman was expiating her sins there, at the Pisse waterfall. Her face was sad, resigned. The place many knew as the freeride paradise represented purgatory for her. She too saw the two workers watching her and felt ashamed. She could not accept being seen in that condition, humiliated by the weight of her sins.

The woman let out a scream that echoed throughout the Bors valley. At that moment, a huge mass of water swelled the waterfall. It seemed as if the entire glacier had turned into a lake and was being dragged down by the force of gravity. The two workers took cover and watched the power of the water, which rushed furiously, piercing the Fondecco moraine and pouring down into the main valley. In a few seconds, it was all over. Calm quickly returned, and the workers noticed that the women near the waterfall had disappeared. Taking advantage of this moment of calm, they ran down the valley, wanting to return home as soon as possible. In a state of shock, running as fast as they could, they thought again about what the old man had told them: “Do not go and build up there, it is dangerous.” It was clear that by “dangerous” he did not mean a geomorphological risk. Once back in the village, still shaken, they wondered whether what they had seen was real.

Figure S15 illustration of the second tale

Geostop #3 Alpe Bors

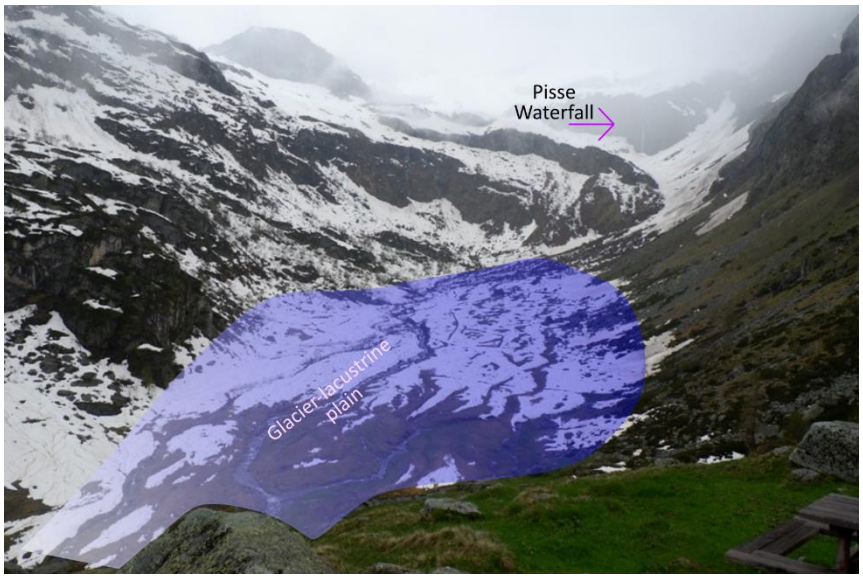

Figure S16 Interpreted landscape at Alpe Bors

This vantage point allows exploration of a much earlier phase in the valley's geological history. From Alpe Pile, the story reached up to about 1850, when the Little Ice Age ended and the climate began to warm, but now it steps back roughly 15,000 years.

During its geological past, the valley went through several phases of glacial expansion, and the last time the ice reached its greatest extent (a period geographers call the "Last Glacial Maximum") was about 15,000 years ago. At that time, the Valsesia glacier was a single great mass of ice filling the entire valley that has just been followed.

One of the clearest traces of this glacier is the right-hand moraine known as the "Fondecco moraine." This name comes from the Walser dialect, where "ekku" means "on the moraine." The moraine formed along the edges of the glacier during its expansion phase, as debris carried by the ice accumulated at its margins.

Today, the Fondecco moraine clearly shows how far the Valsesia glacier extended, occupying the full width of the valley and reaching up to the crest of the moraine. Turning instead toward the Bors valley, a typical example of a hanging secondary glacial valley appears. Around 15,000 years ago, Bors valley too was filled by a glacier that flowed down to join the larger Valsesia glacier, like two rivers at a confluence.

From about 10,000 years ago, however, the glacier began to retreat, making room for the subglacial meltwater stream. This stream now flows along a stepped profile, alternating flat stretches with vertical drops, which are typical of glacial shaping. The Pisse waterfall, located at one of these steps, clearly highlights the change in slope along the profile of the secondary valley.

Figure S17 Interpreted landscape at the low Alpe Bors

Focusing on the features closer at hand, namely the plain in front and the U-shaped “hole” at the top of the Fondecco moraine, the morphological evolution of this area can be reconstructed. Even though the plain has a glacial origin, it was not formed by the Bors glacier, but by the Valsesia glacier. During one of the last expansion phases, the Valsesia glacier became so extensive that it blocked the secondary Bors valley.

This blockage prevented the Bors stream from flowing out, causing its waters to accumulate in a lake. When the Valsesia glacier retreated, the lake’s waters cut through the Fondecco moraine and drained away, emptying the lake and leaving behind the glacio-lacustrine plain visible today, which is the former lake bed.

Glacier fluctuations

Earth, which formed about 4.6 billion years ago, has gone through many different climate phases, some very different from today. Periods of intense cold, the so-called ice ages, when glaciers expanded, alternated with warmer periods, called interglacials, during which glaciers retreated.

The Quaternary, the geological era in which we live, has been especially marked by glaciations, particularly in regions like this one. It is divided into the Pleistocene (from 2.58 million years ago) and the Holocene (from 11,700 years ago to today). The Pleistocene is known for progressive climatic cooling, with four main ice ages: Günz, Mindel, Riss and Würm.

During these glacial periods, alternating with interglacials, glaciers expanded to cover about 45 million square kilometres, roughly one third of the land surface. Great tongues of ice descended from the Alpine massifs, deeply reshaping the landscape. Valsesia, like other Alpine valleys, was carved and widened by the glaciers, while eroded debris was transported downstream and deposited as moraines at the edges of the plains.

About 15,000 years ago, at the end of the last major glacial expansion, the glaciers began to retreat, gradually taking on the extent seen today, in some cases even smaller than at present. Later, between 5,300 and 2,800 years ago, there was a new cooling phase that led to a further glacial expansion. The last significant advance of the glaciers occurred during the “Little Ice Age”, between 1350 and 1850, the largest expansion of the Holocene.

In the past, therefore, Earth’s climate has sometimes been similar to today’s, but the key difference lies in the speed of transitions. Whereas past climatic changes unfolded over thousands of years, today’s warming is happening much more rapidly, making it difficult for many plant and animal species to adapt.

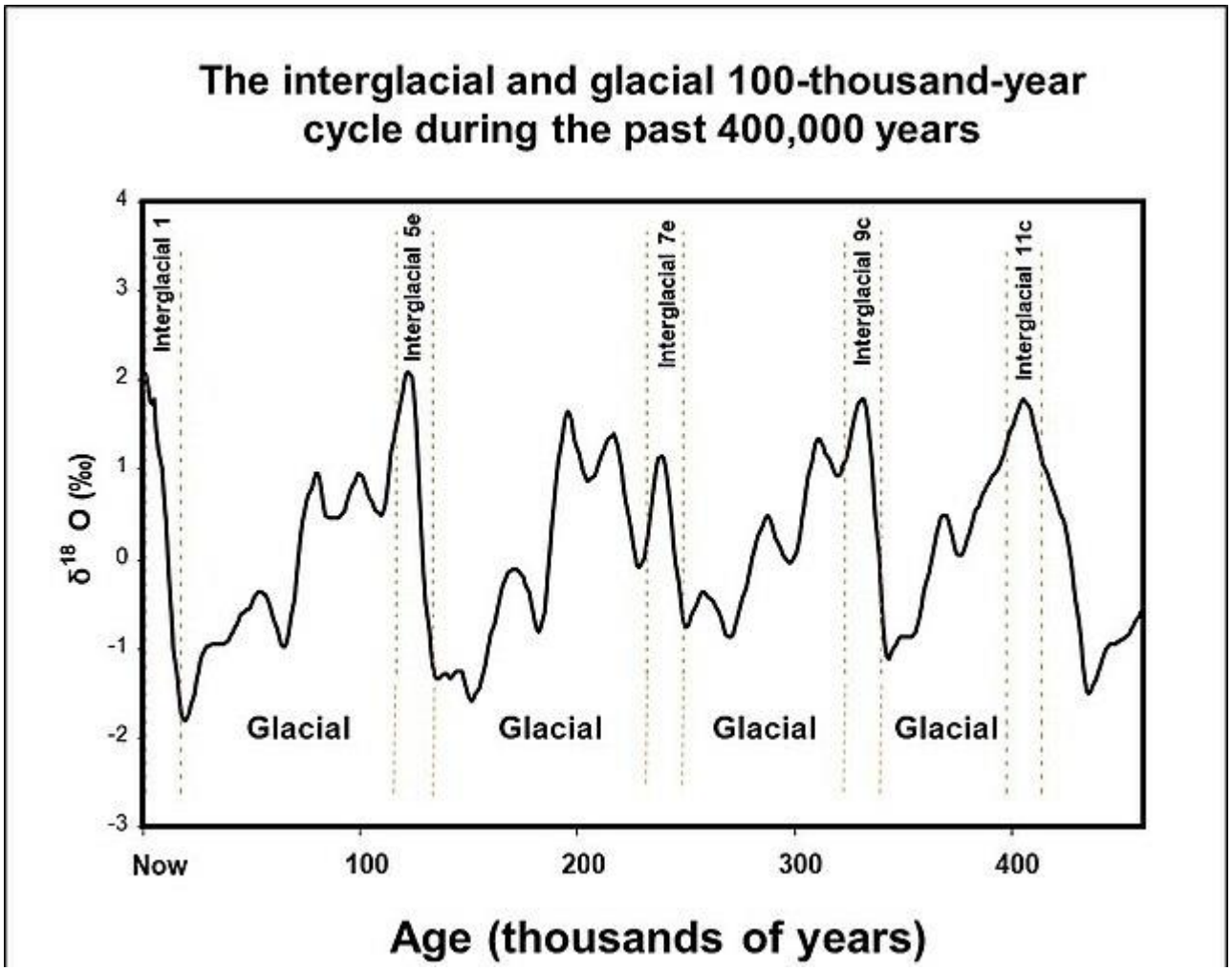

Figure S18 interglacial/glacial cycle illustration. Source: RafizadehTO100P - Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Cyclical_pattern_of_glacial-interglacial_conditions.jpg

Geosites

1.6 San Maurizio Gold mine

The San Maurizio mine is one of the many tunnels dedicated to gold extraction located at the head of the valley. The gold occurrences in the upper valley are the continuation of the productive district of Pestarena–Val Quarazza–Val Quarazzola, forming a complex of vein systems hosted within the Upper Penninic Monte Rosa Unit, the axial part of the Alpine chain.

In Valsesia, the ore body is made up of a series of minor veins and the central Kreas (Alagna) bundle, following an almost constant WNW–ESE orientation. The San Maurizio mineralization consists of one of these so-called minor veins, outcropping for a few hundred metres above the Alpe Bors plateau and on the moraine above Alpe Fundekku. This mine is in good condition, so it is possible to visit the first few metres of the tunnel without excessive precautions; however, in all the mines in the area it is not advisable to go beyond the entrance section without proper guidance and equipment, since they have been abandoned for at least half a century.

As for the metallogenesis of gold, it is necessary to refer more generally to the area usually called the “gold-bearing province of the Western Alps”, which includes the gold occurrences between the

Gran Paradiso Massif and Canton Ticino. It is believed that the deposits within this territory share a common origin.

1.7 Fondecco moraine

The geosite corresponds to the lateral moraine of the Valsesia glacier present in this area during the late glacial period (15,000 to 10,000 years ago). In the Walser language, Fun d'Ekku means "on the moraine." Indeed, the Alpe Fondecco is built on the glacial deposit formed during the "Little Ice Age" (approximately 1300–1850).

Lateral moraines are formed from debris scattered on the glacier's surface, coming from the valley sides; when looking head-on at a glacier tongue, its inverted V shape causes material to accumulate along its edges, creating elongated and raised debris embankments. Due to the glacier's enormous force, the transported and deposited material shows no grain size layering; lateral moraines consist of materials ranging from large boulders to pebbles and sands, varying greatly, and can be angular or striated.

Being a lateral moraine, it is a debris ridge located along the valley sides (once at the glacier's edge) and has an asymmetric cross-section, with the inner side steeper than the outer. This deposit was created during a glacial expansion phase, and its size is larger the more intense the glacial advance was.

1.8 Bors plain

During the late-glacial phase, about 12,000 years ago, the main Valsesians glacier deposited a large lateral moraine cordon, blocking the Bors valley. This moraine deposit is still partially preserved between Alpe Fondecco and Alpe Bors and testifies to how extensive the glacier was at that time. Following climatic changes, the Bors glacier tongue shrank to a cirque glacier, whose melting gave rise to a lake basin. While the lake bottom accumulated sediments, the outlet stream eroded the moraine cordon until breaching it, causing the lake to rapidly empty. This sequence of glacial moraine deposition, cirque glacier retreat, and moraine breaching leading to lake drainage reflects the climatic and geomorphological evolution of the Bors valley area during that period.

Third stage – The alpine orogenesis

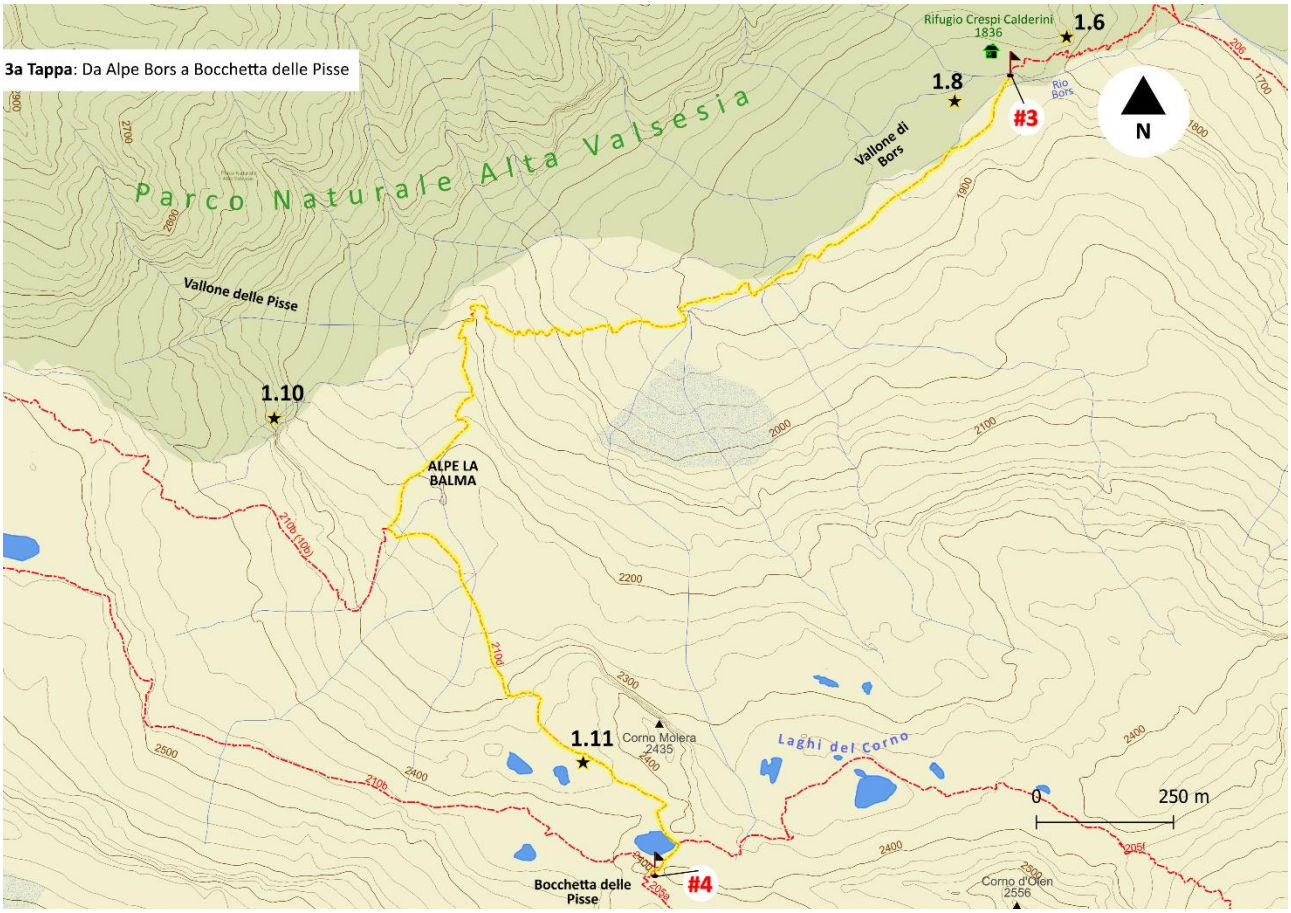

Figure S19 Map of the third stage of the geotrail

General description:

From Alpe Bors to Bocchetta delle Pisse

3.0 km, elevation: +586, -32, 2h

The third stage of the geotrail is one of the most challenging and leads to the first alpine pass of the route. The first half, though at high altitude, is easily walked on a flat meadow. The main difficulties in summer can be the heat, as there is no shade, and in winter, snow might cover the trail markings. After crossing the glacio-lacustrine plain, the path becomes steep but remains a well-marked hiking trail, with the environment becoming more typical of high altitude. Along this stretch, rock outcrops show important tectonic contacts that help reconstruct the geological history of the Alps.

Path description

From Alpe Bors, the paths continues leaving behind the Crespi-Calderini refuge. It heads left following trail 210, crossing the Bors stream, where it passes in front of the chapel-altar erected by the CAI of Ghemme in honor of Blessed Panacea. Continue along the path until you reach the end of the plateau. At this point, leave the Pisse waterfall (Geosite 1.10) on your right—an impressive sight with a drop of about 200 meters—and follow the trail climbing up to the Balma Pass, where

the former cable car station once stood (2206 m). From here, proceed south along trail 210 (10), ignoring trail 210c on the right. The route continues among large fallen boulders, skirting the western side of Corna Molera, then climbs a small gully leading to a little plateau connected to a second glacial cirque, where there is a small lake. After passing the lake, you finally reach Bocchetta delle Pisse (Geosite 1.11) (2396 m). From here, there is an excellent view of the Bors glacier and the Stolemberg summit (Geosite 1.12)..

Short story – The lost valley – Das Verlorne tahl

Figure S20 Illustration of the third tale

Once upon a time, in the region north of Monte Rosa, there was a valley rich with forests and fertile pastures. There, among meadows and woodlands, flowed the clearest water, and the trees were heavy with plums. All the chamois and deer of the neighboring valleys sought refuge there. It was a serene and happy place where rye grew bountifully, and the grass never yellowed. It is said that the glaciers eventually swallowed it, and since then it has been mythologized among the Walser people of Alagna as “The Lost Valley.”

Among Walser hunters, people told stories of this valley — beautiful yet mysterious — said to be unreachable, its location unknown to anyone. Only once every twenty-one years, one of the hunters wandering alone in the mountains was granted the privilege of finding it. Then, the valley would reveal itself in all its beauty, offering fruits and grains, welcoming the hunter with the fairies and sprites that happily inhabited the land. Enchanted by the splendor, the hunters would return to Alagna and describe what they had seen as best they could, but their words sounded so unbelievable that no one ever took them seriously.

The last man to whom the valley revealed itself was, like his predecessors, a hunter from Alagna Valsesia. He did not speak Titschü and would not have called himself a Walser. He was running uphill with his dogs through the Bors ravine, above the Pisse waterfall, pursuing a deer. After hours of chasing, Monte Rosa began to change its face, and the clouds turned threatening. In the blink of

an eye, fog descended upon the hunter and his dogs, who barked in fear. Soaked and frightened, the hunter could not see beyond his nose and wandered through the mountain as if trapped in a dark room. In the mist, he spotted a beam of light to his right, apparently coming from a small cave. Drawn by it, he moved closer; after a few steps, he saw what he never expected — the lush valley revealing itself to him in all its splendor. The air was sweetly silent, the light marvelous. A small stream ran through meadows adorned with scattered red spruces that became denser with altitude until they gave way to gray rock. Deer drank from the stream, slightly curious and utterly unafraid of the hunter's presence. The magical inhabitants of the valley were real too: fairies and sprites from alpine legends shyly watched the visitor, who was reliving the ritual apparition.

But this hunter was different from those before him. Although clearly fascinated by what he saw, he did not seem intent on savoring the moment, showing neither the wonder nor excitement that the fairies and sprites were used to — feelings that once justified the revealing of the secret place. Instead, the hunter pulled out his phone to save his location and take pictures.

When he returned, he told his story to the people of Alagna, who did not believe him, just as they had not believed his predecessors. But this time, he showed them the photos and promised to take them there. He did, and his companions could not contain their cries of amazement when they saw the valley. Nor could they resist the urge to take photos, share the discovery, and make plans to profit from it. They brought in tourism agencies and construction companies, which in turn built a cableway, a large lodge serving as a restaurant, hotel, and spa to host tourists and let them enjoy this unique place. All that commotion disturbed the animals and magical beings that lived there, forcing them to see their home transformed. The deer fled to compete for remote spaces with other creatures. The fairies and sprites, unwilling to live where their presence was no longer welcome, sought refuge higher in the mountains — but, finding nowhere left untouched by man, they vanished.

Thus, the lush valley retained the beauty safeguarded by its surrounding peaks but lost its splendor and uniqueness. And so, the mythical valley of the Walser tales was finally and truly lost..

Figure S21 Illustration of the third tale

Geostop #4 Bocchetta delle Pisse

From this vantage point, one can enjoy a privileged view of the southern face of Monte Rosa, where it is possible to recognize some of the glacial features previously identified, such as moraines, glaciers, and polished rocks. However, this spot is significant for another reason as well: it allows us to go much further back in time, interpreting not only how the Alps and Monte Rosa have been shaped, but also how they were formed.

Figure S22 Landscape at Bocchetta delle Pisse. Credit: MichZ97 – Wikimedia Commons https://commons.wikimedia.org/wiki/File:Bocchetta_delle_pisse.jpg

From this point onward, the rocks and paleo-environments change—that is, the contexts in which these rocks were originally found before reaching their current position are different. This leads us into the concept of geological time and, with some imagination, we must travel back about 60 million years, to the beginning of the Tertiary era.

Up to now, we have moved through a few thousand years, assuming that Earth's geography was similar to today's. But going back millions of years, we must picture a completely different planet. The continents were arranged differently, and the rocks we walk on today were once far away from this place. Fortunately, they still carry traces of their journey, helping us interpret the local geology, which is extremely complex.

If we look at the rocks north of our observation point, we mainly see orthogneiss with large crystals and paragneiss. To the south, instead, we encounter serpentinites and metagabbros. These names, though technical, describe rocks of very different natures, formed under extremely different conditions, even though they are now found side by side. Orthogneiss results from the metamorphism (transformation) of intrusive igneous rocks such as granite, while paragneiss come from sedimentary rocks, such as sandstones or shales, though formed through similar metamorphic processes. In contrast, serpentinites and metagabbros originate from oceanic crust, that is, from an ancient ocean floor.

This helps us understand that the Alps, including the Monte Rosa massif, were formed through the convergence of two tectonic plates: the European and the African. Around 145 million years ago, these plates began to move progressively closer together. Between them lay an ocean—the Tethys—which separated the two continents but no longer exists today due to a process called subduction: the African plate, moving toward the European one, forced the oceanic crust beneath it, gradually closing the Tethys.

During subduction, not all sections of oceanic crust could sink beneath the African continental plate. This caused the accumulation of marine sediments and fragments of oceanic crust along the African margin, forming what is known as an accretionary prism. About 60 million years ago, what remained of the Tethys was precisely this portion of the accretionary prism, which can be imagined as an underwater mountain chain—its peaks occasionally emerging as small islands—trapped between the two continental margins.

It was at that time that the African and European plates collided. More precisely, the European margin subducted beneath both the accretionary prism and the African plate. This convergence caused layers of rock to rise, fold, overlap, and stack upon one another over millions of years, giving rise to the Alpine chain.

To simplify, we can imagine the Alps as a layered cake with all the layers folded over each other: the European plate at the bottom, the African plate at the top, and between them, the accumulated oceanic sediments from millions of years of subduction.

This observation point is therefore crucial, as it reveals part of this history and highlights an important geological boundary. The rocks we have traversed bear witness to the collision between two continents that trapped an entire ocean between them. So, going back 60 million years, we can imagine ourselves walking on the ancient European continent (more precisely on what was then an island, part of the European margin), while we are now entering the ancient ocean floor.

Box alpine orogenesis

The Alpine orogeny is the geological process that gave rise to the Alps, including the Monte Rosa mountain range. This process, which lasted millions of years, began about one hundred million years ago when two large tectonic plates—the African and the Eurasian—started to collide.

Imagine the Earth's crust as a series of enormous rafts floating on an ocean of molten rock. When these rafts (the plates) move and collide, the material between them becomes compressed, deformed, folded, and pushed upward, forming mountains.

This is exactly what happened during the Alpine orogeny: the layers of rock that once lay on the floor of an ancient ocean, called the Tethys Ocean, were uplifted and transformed into mountain chains.

In the case of Monte Rosa, the rocks we see today were once very far from here and in a completely different paleo-environment. In fact, these rocks were once located in a region of the Earth near the equator, which we can imagine as a drifting coastal margin detached from the main continent—somewhat similar to present-day Japan.

During the orogeny, these rocks were buried deep, tens of kilometers beneath the Earth's surface. As the plates collided, the rocks were subjected to enormous pressure and temperature, which caused them to bend, fracture, and sometimes transform through metamorphism.

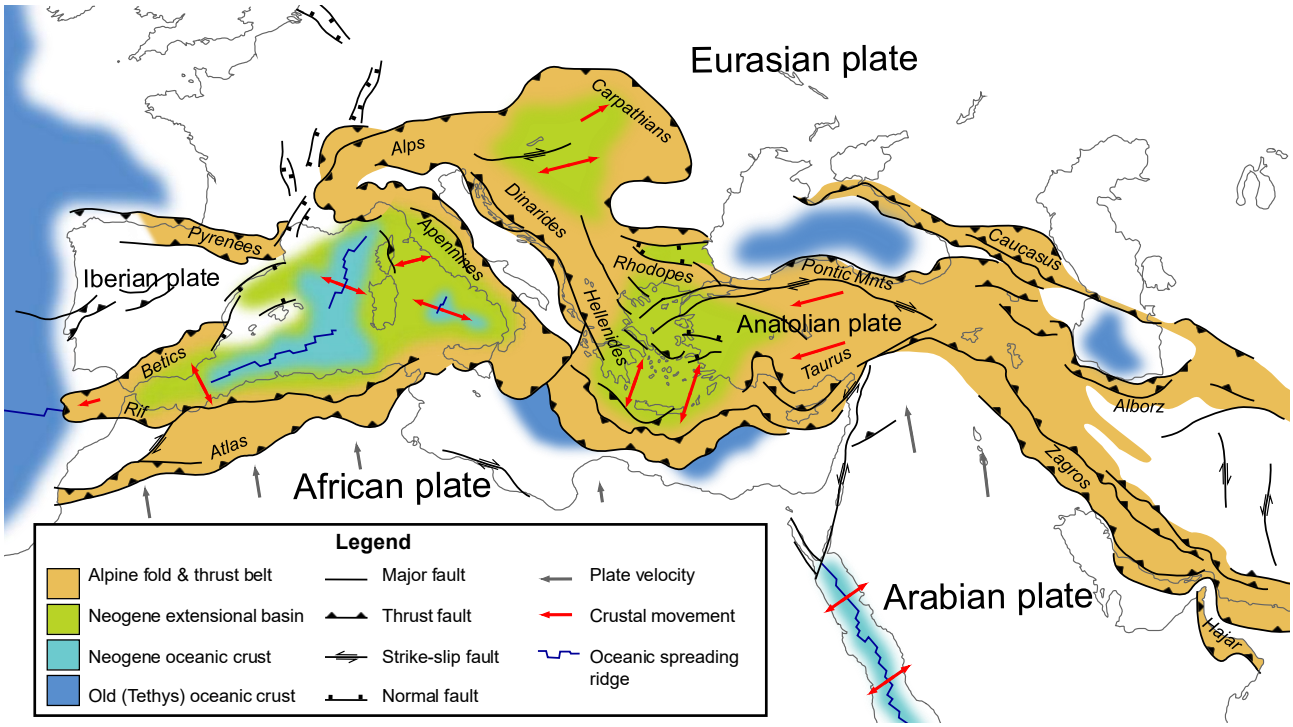

Figure S23 Map with the movement of the plates during the Alpine orogeny illustrated. Source: Woudloper – Wikimedia Commons. https://commons.wikimedia.org/wiki/Category:Alpine_orogeny#/media/File:Tectonic_map_Mediterranean_EN.svg/2

Finally, erosion has shaped the current landscape, revealing the complex geological history hidden in the heart of the Alps. Today, as we look at these mountains, we are reading a story of titanic transformations that continue to shape the landscape around us.

Geosites

1.9 Pisse waterfall

Figure S24 Geosite Pisse waterfall

The geosite is located in the Bors valley, a hanging glacial valley-oriented west–east above the main Sesia Valley. The waters that feed the waterfall come from the meltwater of the Bors Glacier, which once covered the entire valley but has now retreated to a small cirque glacier situated northwest of the geosite, near Punta Giordani.

To the east of the geosite, the valley continues into a glacio-lacustrine plain, at the end of which lies Alpe Bors, an

ancient Walser settlement historically used as a summer pasture.
Beyond the valley, a steep drop marks the ancient confluence of the Bors Glacier with the larger Valsesian Glacier.

The waterfall clearly highlights the steepness of the cliff, which bears witness to the passage of a glacial tongue that shaped this classic example of a hanging glacial valley.

1.10 Bocchetta delle Pisse pass

Bocchetta delle Pisse is a mountain pass located between two side valleys of the Valsesia. Situated near Alagna Valsesia, it offers an excellent panoramic viewpoint to admire the area's geodiversity and to better understand its geomorphological evolution, which has been shaped primarily by glacial processes. From a geological perspective, the geosite is highly significant for interpreting the evolution of the area, as near Bocchetta delle Pisse one can observe the tectonic contact between the large backfold of Monte Rosa and the underlying ophiolites (serpentinites, metagabbros, and metabasites) of the Zermatt–Saas Unit, arranged in a recumbent synformal nappe. The crystalline basement of the Penninic Nappe of Monte Rosa outcrops along the slopes beneath the Cimalegna plateau and on part of the slope below the Bocchetta delle Pisse–Corno d'Olen watershed. The exposed lithotypes include fine-grained gneisses rich in muscovite and sericite; mica schists, often garnet-bearing, with lenses of garnet- and amphibole-bearing pyroxenic rocks; chloromelanitites; and jadeites, interbedded with augen gneiss layers. At Bocchetta delle Pisse, there is also an ancient stone quarry once used to make millstones—a clear example of a geosystem service provided by geodiversity to humanity. In addition, one can observe the Laghi del Corno, high-altitude glacial lakes. Finally, the slope beneath the Bocchetta delle Pisse–Corno d'Olen ridge shows evidence of ancient gravitational phenomena that have shaped its morphology over time.

1.11 Stolemberg

Along the watershed crest connecting Corno del Camoscio (lit.: "Chamois horn") and Stolemberg, it is possible to observe rocks belonging to the Monte Rosa Nappe (the ancient European continental margin) and rocks that once formed part of the ancient Ligure–Piedmont oceanic floor. These rocks are easily distinguishable by their different coloration: the continental rocks (light-colored gneiss and garnet-bearing mica schists) appear lighter, while the rocks from the ancient ocean floor (serpentinites and amphibolites) are darker and form the Corno del Camoscio..

Figure S25 Geosite Stolemberg. Source: Pampuco - Wikimedia Commons. https://short.do/3S_4ii

Forth stage – The seabed

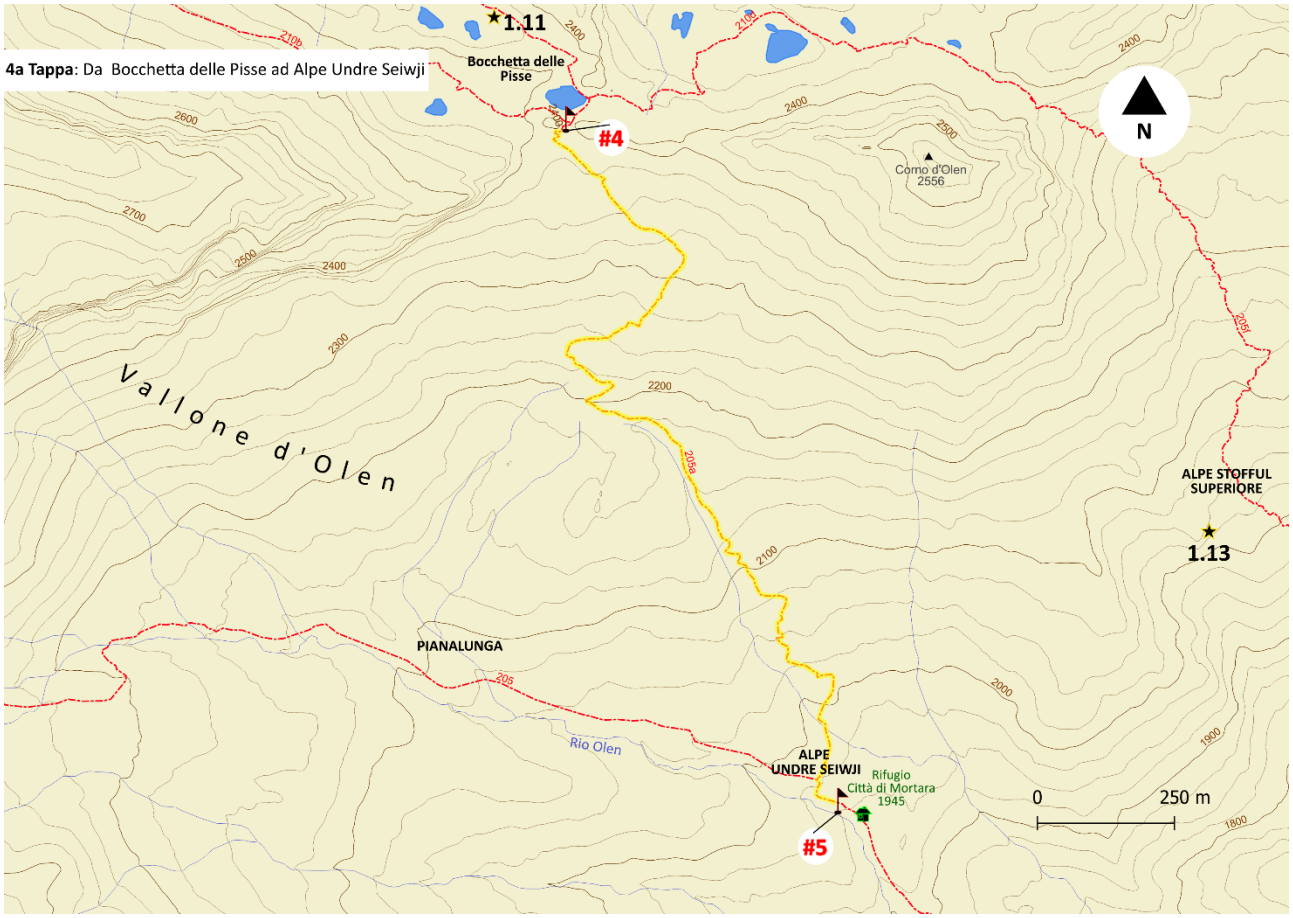

Figure S26 Map of the fourth stage of the geotrail

General description:

From Bocchetta delle Pisse to Alpe Undre Seiwji

2.0 km, elevation +20, -463, 0.40h

After the climb to Bocchetta delle Pisse, the trail becomes easier and descends into the Olen valley through a comfortable, gentle, and wide meadow that is used as a ski slope in winter. At first, the descent is quite steep, but past the halfway point it becomes less so and easier to follow. As we go down, Bocchetta delle Pisse will remain behind us, and we will be able to admire the broad side valley of Olen from above, while on the right we will see the large wall of the glacial step dominated by the Cimalegna plateau.

Path description

The route starts again from Bocchetta delle Pisse (2396 m), following trail number 205. The trail descends along the slope through the pasture, crossing the ski run. It passes Ape Oubre Seiwji (1996 m) and continues on trail 205, which descends to the left and becomes a dirt road. The trail is always exposed to the sun; there are no tall trees, only meadows and some rocky outcrops. The dirt road leads directly to Alpe Undre Seiwji, where the Città di Mortara refuge (1945 m) is located. From here, Alpe Stofful (Geosite 1.13) can be seen in the distance.

Short sotry – The wolf

Once upon a time, there were legends about wolves, bears, and monsters. These tales sprang from the tipsy tales of shepherds or hunters, repeated and exaggerated among friends, and retold by mothers, fathers, and nannies to their children. They spoke of wolves that kidnapped children or young girls who were alone after dusk; of bears that broke down the doors of mountain huts or lurked menacingly outside houses, and of brave men who defeated them; of dark-furred monsters that fled leaving hoofprints after committing some crime. People pretended not to believe these stories, yet part of them still felt their pull. The legends came back to mind during lonely mountain nights or whenever someone dear wandered off alone near dusk. Their charm lingered among the people who still lived alongside the traces left by wolves, bears, and monsters: large footprints on a trail, a clawed paw nailed to a beam as a warning, a decimated pasture, empty milk pails, a missing or wounded child.

The legends continued to terrify, and sometimes frighten, the Walser people of Val Sesia, who prayed that wolves, bears, and monsters would vanish from their lands. Their prayers finally moved the Madonna of Scopello, who heard them and granted their wish: the predators were driven away, and within a few years, they disappeared from the land of the Walser. For many years, there were no sightings of wolves, bears, or monsters. The valley dwellers grew used to not seeing their huge tracks on the paths, even in the most remote areas. They became accustomed to leaving their livestock unguarded in the fields. Some even dared to walk in the dark without tapping their stick, to leave huts unbarred, and to let the milk cool in the open air. The stories of predators were told around the fire, while children laughed and dared each other to spend the night alone in the forest—without any real fear.

After a long time in which the pastures were peaceful and the farmers lived quietly, one of them one day found a few animals killed and torn apart. The news spread quickly across the pastures and reached the village; photos of the incident appeared in the local paper under a sensational headline: “The monster strikes again!” To the farmers’ surprise, the story of a possible wolf, bear, or monster merely stirred curiosity—it did not revive the ancient fears that people had long forgotten. The farmers realized they needed to make their fear urgent and common again, so everyone would work together to drive away whatever threatened their quiet lives. They decided to revive the old legends of wolves, bears, and monsters: they published more photos of the same carcasses in the local newspaper, with different headlines, making them seem like separate events.

The tales of wolves, bears, and man-eating monsters succeeded in rekindling the villagers’ dormant fears. Children faced stricter rules, doors were bolted, and men brushed the dust off their rifles. Around that same time, people told of a charcoal maker who worked in the woods, untouched by the new tide of legends. He was accompanied by a large black dog that followed him as he carried timber and with whom he shared salted meat in the evenings. One day, the charcoal maker left his hut to go down to the village, and when he returned that evening, he found his dog dead at the door.

Figure S27 Illustration of the fourth tale

Geostop #5 Alpe Undre Seiwji

Figure S28 Landscape at Alpe Undre Seiwji. Credit: Wikimedia commons. https://tinyurl.com/yx4a2cdz

Descending from Alpe Bors and reaching this fourth observation point, we notice that the rocks look very different from those in the Bors valley. In fact, along the walls below the Cimalegna plateau and in the area beneath the ridge stretching from Bocchetta delle Pisse to Corno d'Olen, we can still see rock outcrops belonging to what was once the European continent. The rocks visible in these two areas are mainly gneiss—rocks formed primarily from minerals such as muscovite (a type of mica) and sericite—and they underwent metamorphism during the tectonic movements that created the Alps.

Beyond these outcrops, however, the rocks we now see are all of oceanic origin (ophiolites). These rocks contain minerals like glaucophane, garnet, and muscovite, along with smaller amounts of serpentine or serpentinite schists. These rock formations date back more than 145 million years and show that the Alpine orogeny "squeezed" an ancient ocean between the converging European and African plates.

Thus, as we descend the slope, we are literally walking down onto an ancient ocean floor—on the very rocks that once made up the Tethys seabed. From this vantage point, we can observe the effects of metamorphism that transformed these oceanic rocks under the immense heat and pressure generated during the Alpine uplift. For example, from here we can spot Alpe Stofful, where there is a steatite (soapstone) quarry once used extensively by Walser communities for its practical qualities in crafting and daily life.

However, if we could go back in time—before Europe and Africa began moving toward each other—we would see a very different picture. These two continental plates started converging about 145 million years ago, but before that, the movement was exactly the opposite: beginning around 220 million years ago, the European and African plates were slowly drifting apart. As they pulled away, the Earth's crust stretched and thinned until it fractured, creating a new ocean—the Tethys.

As the plates separated, space opened beneath them, allowing the hot and viscous asthenosphere (the upper mantle) to rise through fissures and form a new mid-ocean ridge. When basaltic magma reached the surface and met seawater, it cooled rapidly, solidifying into new oceanic crust. This continuous process caused the ocean to widen over time.

If we could go back roughly 170 million years to the Early Jurassic, we would not see these rocks as they appear today, nor even as described at the previous observation point. We would instead

witness the very moment they were forming, deep beneath the ocean, from magma solidifying as it emerged from the mantle. It is astonishing to observe them now, in such a completely different setting—transformed by the journey that brought them all the way to Monte Rosa..

Tectonics

Tectonics is the process that governs the movements of the Earth's crust, the rigid "skin" that covers our planet. This crust is divided into enormous fragments called tectonic plates, which move slowly over a warmer and more fluid layer of the mantle. Although these movements are imperceptible on a human time scale, they shape the planet over millions of years. The plates can drift apart, collide, or slide past one another, creating phenomena such as mountains, volcanoes, earthquakes, and oceans. It is thanks to tectonics that Earth's landscape is constantly evolving. The edges of the plates are the most dynamic areas, where new rocks form and older ones are destroyed, giving rise to fascinating processes that shape the crust and maintain a perpetual balance in transformation.

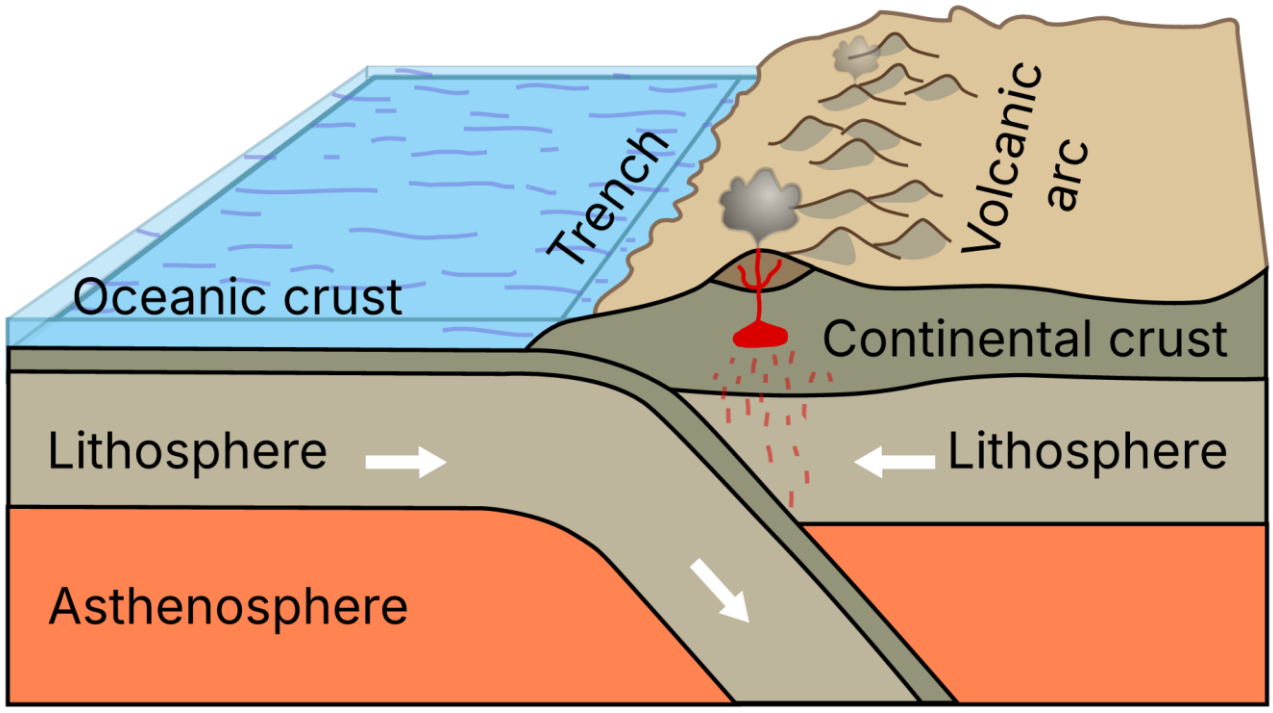

Figure S29 Illustration of tectonic processes. Source: Wikimedia Commons. https://tinyurl.com/2vs5yh22

The oceanic crust—the very one we are walking on—forms where two plates move apart, along mid-ocean ridges. Here, the hot mantle rises toward the surface, partially melts, and produces magma. When this magma cools, it solidifies into new basaltic rocks that make up the oceanic crust. The process is continuous: as new crust forms, the older crust is pushed sideways, driving the expansion of the ocean floor. This movement, known as "seafloor spreading," is one of the fundamental engines of plate tectonics and the starting point for many of the geological transformations of our planet.

Geosites

1.12 Alpe Stofful

Figure S30 Geosite Alpe Stofful

This area contains old, now-abandoned quarries where steatite (soapstone) was once extracted—a symbol of Walser culture and of their deep connection with the land. Soapstone is a rock made up of serpentinite containing talc. The Walser communities made use of these resources, leaving evidence of their traditions and customs, and demonstrating one of the many ways in which geodiversity provided valuable resources for their daily lives.

Fifth stage – approaching Africa

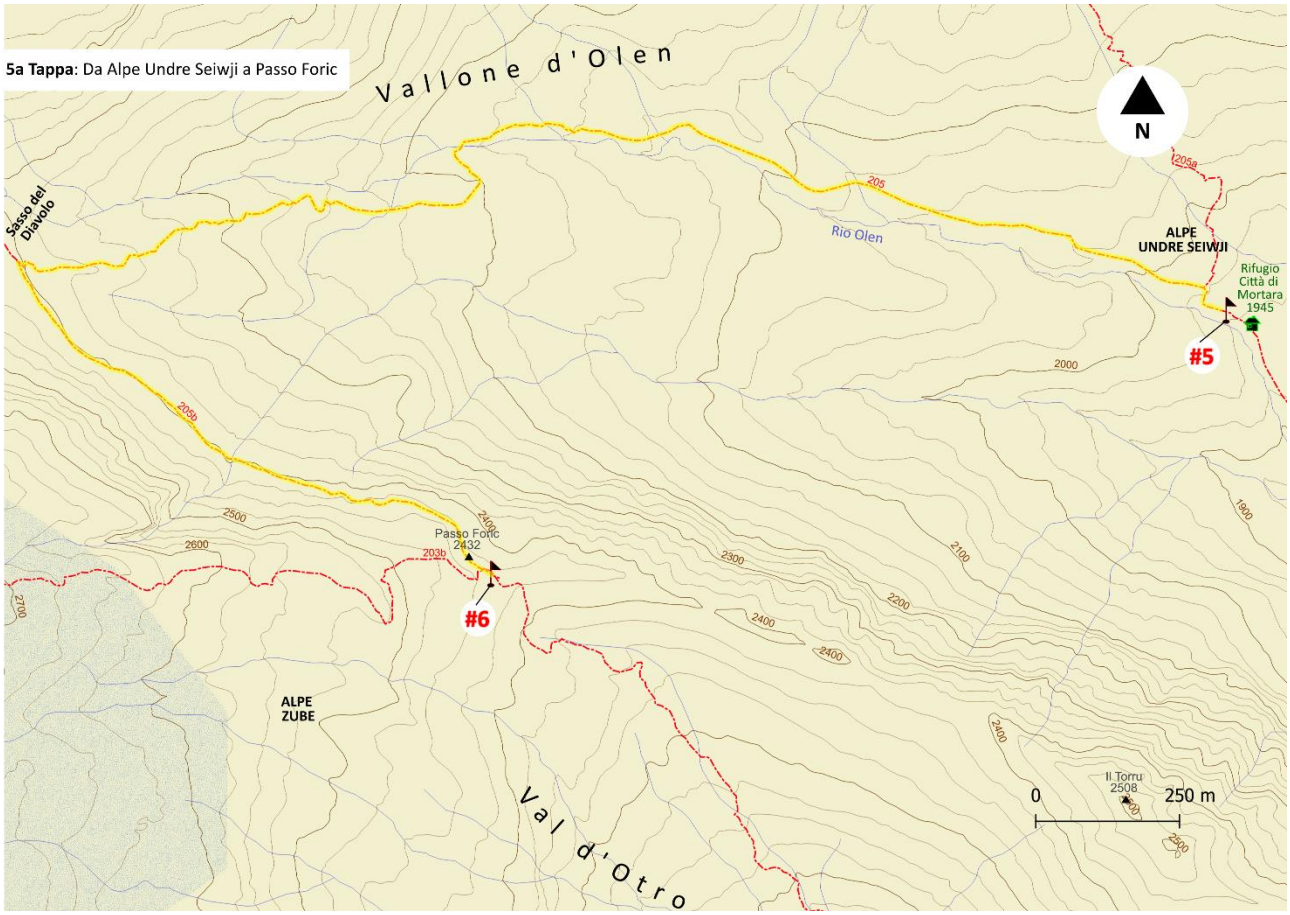

Figure S31 Map of the fifth stage of the geotrail

General description:

From Alpe Undre Seiwji to Foric pass

3.7 km, elevation: +556, -81, 2h

The trail climbs up a secondary valley of the Valsesia, the Val d'Olen, first crossing a gentle area composed mainly of pastures and meadows, and then becoming a narrower but still well-marked and accessible path that ascends the slope up to Foric Pass.

Along this stretch, one can see places of particular significance both for the Walser communities—such as the Sasso del Diavolo (lit.: "Devil's stone") —and for geomorphological and geological history, including the Cimalegna plateau and the oceanic rocks on which we walk.

All of this is set within the cultural Walser trails, surrounded by a dynamic high-mountain environment.

Path description

The trail resumes from Alpe Undre Seiwji (1945 m) and follows path 205. It begins to climb the slope toward Col d'Olen. It is possible to take the mule track along the ski slope, but it is recommended to stay on path 205, which is well marked and offers better views. As the ascent continues, the trail leaves the grassy pastures and enters rocky terrain. After about an hour and a

half of climbing, one reaches a spot just below the large boulder known as the Sasso del Diavolo (2385 m). Here, take the left fork and follow trail marker 205b; if turning right instead, the path leads to the Cimalegna plateau (Geosite 1.14). The route traverses the mountainside, first crossing pastures, then a steep slope, and finally a short rocky section. Caution is advised due to unstable ground. Eventually, the path reaches Foric Pass (2432 m), from which the Otro Glacier (Geosite 1.15) can be seen.

Short story – The Devil's stone– Der Prebet Stai

Figure S32 Illustration of the fifth tale

When the people of Gressoney began building the parish church, the devil grew angry and decided to destroy the worksite before construction could be finished. So he set off toward the Col d'Olen in search of the largest boulder he could find, intending to hurl it down upon Gressoney. He found one and pushed it with all his strength, sending it rolling toward the Passo dei Salati, so the fall would be longer and the impact more disastrous.

Once at the summit, he stopped to rest and, as he imagined with his eyes the path the boulder would take, an angel of the Lord appeared before him and ordered him to leave the stone. Tired and furious, the devil struck the boulder with a fiery fist. The rock then began rolling toward Alagna, down the Olen Valley. Fortunately, it came to stop halfway between the mountain pass and Pianalunga, without striking any living being. The great stone still lies there today, showing on one side the dark, cracked mark left by the devil's punch.

Our modern times offer the devil much more varied and interesting temptations than rolling stones: he now dresses in designer fashion, lives in great cities, and surrounds himself with clever lawyers. Worldly life has long kept the devil away from Monte Rosa.

Over time, the people of Alagna and Gressoney stopped thinking about the boulder and the devil's unfinished project in the Olen Valley. Recently, however, the worldly life has begun to surge back to Monte Rosa in great waves during the ski season. The devil might be tempted, like so many others, by the promises of fun in this "free-ride paradise." And who knows—on an early winter's day, the devil might find himself skiing down the Olen black slope and see, emerging from beneath the thin layer of snow, that same boulder still standing in the valley above the Alagna parking lot, where the windshields wink in the sun.

Figure S33 Illustration of the fifth tale

Geostop #6 Foric pass

Figure S34 Photo from Foric pass. Source: Richard Jones - Flickr

This observation point is particularly significant as it allows us to close the circle and complete our journey through the geological time of Alagna Valsesia.

Crossing Foric Pass, we notice slightly different rocks, similar to what we observed at Bocchetta delle Pisse. This is a tectonic contact between two geological units—both made up of oceanic rocks. In fact, the rocks of Val d'Olen and those of Val d'Otro both originated on the ocean floor, but they differ in how they were deformed during the Alpine orogeny.

In Val d'Olen, the rocks are more metamorphosed, having undergone transformation at greater depths during subduction processes, thus under higher temperatures and pressures. In contrast, in Val d'Otro, the rocks are less metamorphosed; they were displaced and overlain later as a result of tectonic events. For this reason, sedimentary rocks such as calcareous schists and prasinite predominate here.

This contact represents an interaction between different oceanic units within the same tectonic nappe, highlighting the complexity of deformation and metamorphic processes. Looking across the opposite slope of Val d'Otro, we can observe an additional change in the rocks: coarse-grained gneisses with alternating bands of light and dark minerals, and mica schists characterized by their laminated structure and mica content. This indicates the presence of another tectonic contact at the bottom of the Val d'Otro.

Those who have been following the story of Alpine orogeny will recognize this as the contact between the oceanic margin and the African continental margin. In simple terms, the rocks forming the mountains at the southern end of the Val d'Otro were formed more than 200 million years ago and have an African origin.

Tracing the history of the Alpine orogeny, caused by the convergence of the European and African plates that compressed the oceanic floor, we have first encountered the European plate, then "slid" over the oceanic floor, and can now see rocks of African origin. This place is extraordinary because, within just a few kilometers, it contains the entire geological history of the Alps.

These rocks, having traveled thousands of kilometers over millions of years, collided, folded, overlapped, and stacked upon one another, eventually coming to rest here, allowing us to retrace their geological story simply by walking through the landscape.

It is astonishing to be able to observe, within such a limited space, rocks belonging to two different continents and an ocean. This makes the site essential for reconstructing past events and interpreting the geological landscape.

But there is an important question: we have imagined the Alps as a layered cake, with Africa on top, the ocean in the middle, and Europe at the base. So why can we see all three units here, not one on top of the other? The answer lies in erosion.

Over the last few million years—and continuing today—the uplift of the Alps has been constantly counteracted by erosion caused by heat, cold, wind, rain, landslides, and glaciers, which have removed vast amounts of material. As a result, in the highest areas, the African material has been eroded away, exposing the underlying oceanic rocks. These, too, have been worn down, revealing the rocks of the European plate beneath, as occurs in the Monte Rosa massif.

The Bors Glacier

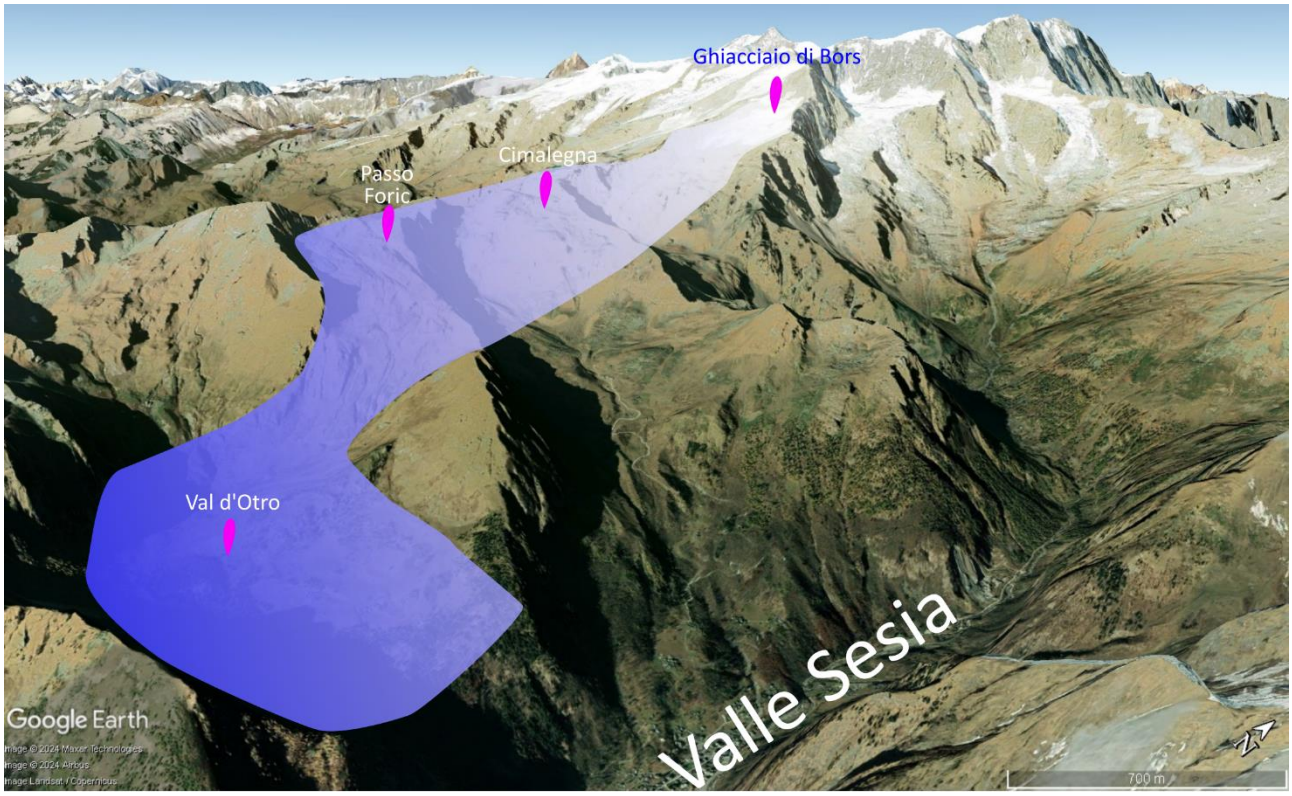

Figure S35 Graphic reconstruction of Bors glacier

The Bors Glacier, now confined to the high altitudes of the Monte Rosa massif, tells an extraordinary geological story that takes us back to the penultimate glacial era.

During that time, the glacier extended far beyond its current limits, crossing Foric Pass and descending along the Otro Valley. There, its ice masses merged with the much larger Sesia Glacier—an immense glacial system that once dominated the entire region.

Careful observation from Foric Pass reveals an interesting geographical alignment between the Bors Glacier, the Cimalegna plateau, and the saddle of the pass itself. This alignment, still clearly visible today, suggests that the glacier once occupied all three areas, linking them in a single flow of ice.

Subsequent erosion sculpted the present-day landscape, carving out the valleys that now separate these areas. These valleys formed along structurally weak zones in the Earth's crust, such as faults, which facilitated the erosive action of ice and water.

Geosites

1.13 Cimalegna Plateau

Figure S36 Geosite Cimalegna plateau

Cimalegna is a high-altitude glacial plateau that was once heavily shaped by intense glacial activity, as evidenced by the glacial forms and deposits still visible in the area. It is currently surrounded and overlooked by other glaciers, although these are steadily retreating.

The geosite is highly representative of the high-mountain environments of the Northwestern Alps, as winter snow persists here for a period of between five and eight months. This creates conditions typical of nival environments, including characteristic landforms, soils at various stages of evolution, and specific plant species—though the grassy cover across the area is very sparse.

The site also bears visible traces of current climate change, with increasingly frequent exposure of rocky outcrops caused by the melting of glaciers and perennial snowfields. The plateau furthermore played a crucial role in medical research in the early 20th century, with the inauguration of the A. Mosso Institute of Human Physiology in 1907.

Today, the geosite is seasonally influenced by human activities associated with winter sports (the "Monterosa Ski" area) and serves as a connection between Valsesia and the Lys Valley. The Cimalegna Plateau geosite is also part of the "Cimalegna Glaciological and Pedological Trail," a geotourism route designed to highlight the glacial landforms and distinctive soil-forming processes of the cold, high-altitude environment.

Sixth stage – The Walser people

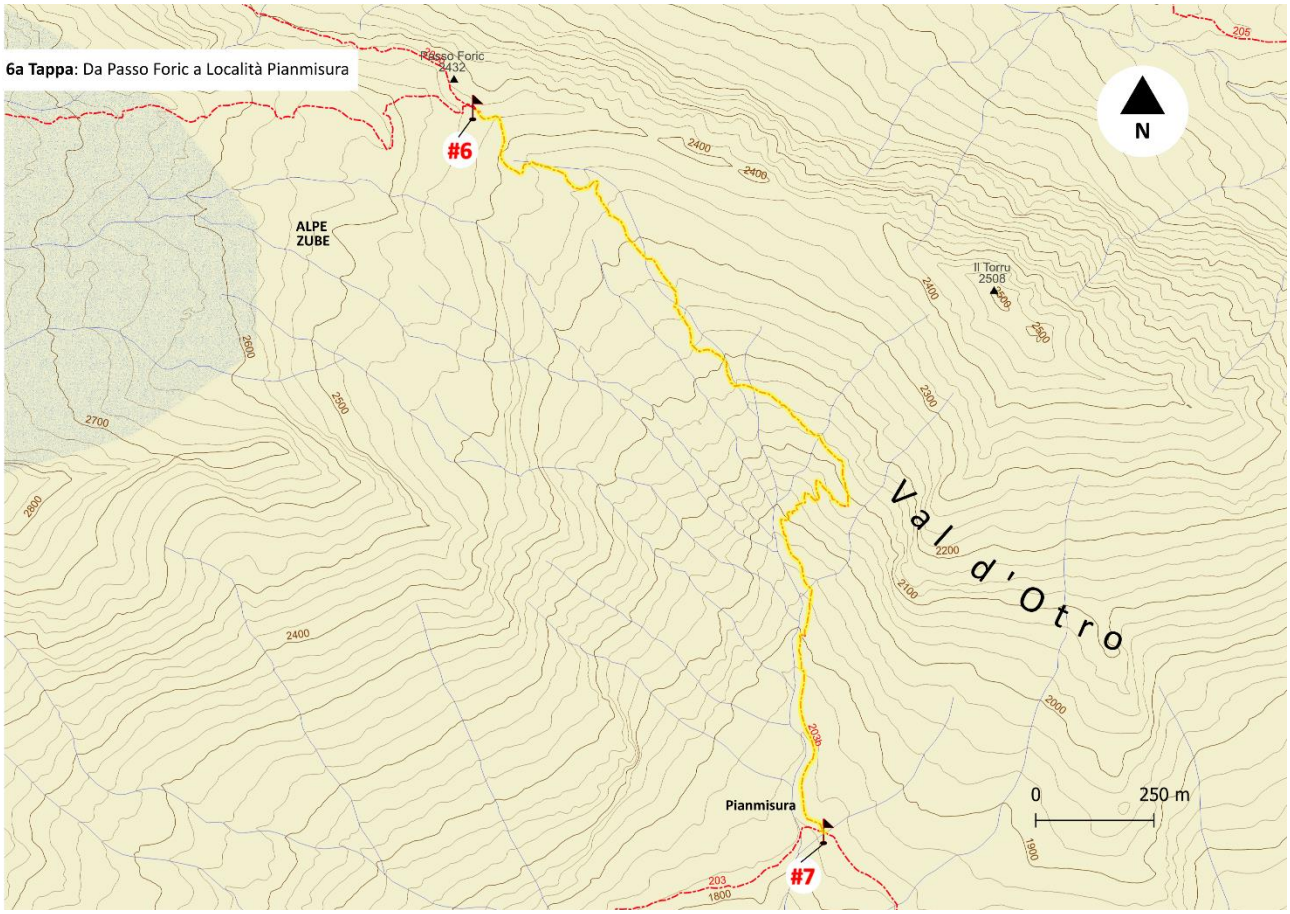

Figure S37 Map of the sixth stage of the geotrail

General description:

From Foric pass to Pianmisura

2.4km, elevation: +51, -661, 1h20

The trail winds along a fairly steep path with switchbacks, always well marked and easy to follow. From the high altitude of Foric Pass, the route descends toward Alpe Pianmisura, offering an elevated view of the Otro Glacier and the secondary glacial valley of Otro.

This section of the trail gradually introduces us to the world of the Walser people, the native community that still inhabits these places.

Path description

From Foric Pass (2432 m), the route continues south, descending along trail 203b and leaving Zube Pass behind. At first, the trail crosses a few gentle ridges, then descends in a series of switchbacks along a path that is, in places, eroded, until reaching Pianmisura Grande (1848 m).

From there, the descent continues following the Foric Stream. The trail then turns left onto path 203, passing below the Ravelli bivouac (2505 m) and arriving at the alpine pasture of Pianmisura Piccola (1835 m).

Short sotry – The wild man - Das Wilte Mandiè

Figure S38 Illustration of the sixth tale

Once upon a time there was an old man of such a wild nature that he lived all alone, even in the heart of winter, in a place of the Otro Alps called die Saccu. Every day he went down to the Otro stream with his little bucket to fetch water. Then he would slowly climb the path back up, setting the bucket down from time to time to blow on his fingers, for the cold was intense in that place where no ray of sunlight ever reached in winter.

One day, during one of those pauses, the figure of a man appeared before him.

“Good morning,” said the stranger in a dry voice. “Why do you live all alone in this desolate place? The village must have truly wearied you, to make you prefer this spot where you must go down to the stream each day at the risk of freezing along the way. Listen, my good old man, to the proposal I offer you: promise me your soul when you are at the end of your life, and I will soften the climate of this valley a little. All of the Otro Alps would become wonderfully fertile land, where wheat and even vines could grow.”

According to the legend, at these words the wild man made the sign of the cross, and his tempter vanished. The old man remained living in die Saccu, enduring the winter cold; on the Otro Alps, only rye and potatoes continued to grow. The Walser taught their children that the wild man is solitary but lives in harmony with nature, and therefore he should not be regarded with hostility.

The legend has never been disproven: no one cultivates wheat or vines on the Otro Alps. Yet the freezing days of winter have grown fewer each year. The blanket of snow that gathers in die Saccu arrives later and turns to mud earlier with every passing season. In Gattinara, the cultivation of Nebbiolo grapes thrives and continues to expand. The terraced vineyards of Gressoney now cling to the eastern slopes of Monte Rosa and reach altitudes that were once beyond their limit.

Figure S39 Illustration of the sixth tale

Geostop #7 Alpe Pianmisura

Figure S40 Photo of Alpe Pianmisura

At this point in our journey, we can say that we have learned to interpret the geological landscape of Alagna Valsesia. We have understood that its rocks were formed in vastly different and faraway environments, millions of years ago. They were later deformed during the stages that led to the Alpine orogeny and, finally, sculpted by the erosion produced by geomorphological agents.

Now, let's step into our time machine and move forward to a period when the geological and geomorphological conditions were similar to those of today: the 13th century, about 600 years ago. Six hundred years is a very short time in geological terms—along our route, we have seen that some of these rocks are hundreds of millions of years old. Nevertheless, the surrounding environment was slightly different, because in the 13th century, here at Alpe Pianmisura, one of the greatest agents of landscape change had not yet arrived: humanity.

In the 13th century, the Otro Valley was populated by a unique community: the Walser. The Walser originated from Saxony, in northern Europe. From the 4th century onward, they began migrating southward, likely driven by climatic pressure but also by their social structure, which required the younger sons of a family to leave in search of new lands to settle. Over the centuries, the Walser reached the valleys of Monte Rosa and, crossing the Alpine passes, colonized the southern valleys.

The oldest Walser village in Valsesia is Rima, founded around the mid-1200s by a group of twelve families who had emigrated from the Valais (Switzerland). In Alagna, the Walser arrived toward the end of the 13th century, coming from Gressoney and founding their first settlement in Pedemonte. From there, they moved up into the Otro Valley.

Around 1250, Europe's population began to grow rapidly, tripling by 1350 compared to the year 1000. This created an urgent need for new agricultural land, sparking a vast effort of land clearing that transformed Europe's landscape. For the feudal lords of the Alpine valleys, the Walser communities—mountain people skilled at clearing stony ground and turning wild lands into meadows and fields—became a valuable resource.

Likely due to their northern origins, the Walser were particularly adept at adapting to harsh high-mountain environments. They were the only people capable of settling successfully in the cold, elevated climates of the Monte Rosa area. From the late 1200s to the early 1400s, numerous

records—especially from the Diocese of Novara—mention colonists of “Alemannic” or “Teutonic” origin in several Monte Rosa valleys, such as Saas, Zermatt, Formazza, Anzasca, Alagna, Gressoney, and Ayas.

Thanks to the Walser’s work, many areas around Monte Rosa, including Alagna, became permanent settlements surrounded by cultivated lands. These villages, often founded at high elevations, also developed as strategic points along transalpine routes, taking advantage of important mountain passes.

According to historical documents, the Walser who settled new territories enjoyed a special legal status that guaranteed them perpetual use of the lands they cleared, through an arrangement known as “hereditary lease,” a typical feature of medieval law. It was under this system that they established their settlements here in the Otro Valley during the 13th century.

Before their arrival, the environment must have looked far wilder and more forested. Once granted the perpetual use of these lands, the Walser, equipped with their remarkable ability to adapt to the mountain environment, cleared the forests and reclaimed the land, creating a landscape of fields and pastures much like the one we see today.

Walsers’ processions

The Walser communities of Alagna Valsesia, descendants of settlers of Alemannic origin, wrote a unique chapter in Alpine history — one made of migrations, adaptation, and traditions. Around the 12th century, these people, perhaps coming from Saxony, began migrating from the Swiss canton of Valais toward new lands, driven by the search for pastures and survival opportunities. They crossed harsh mountain passes and settled in remote, high-altitude areas that were difficult to inhabit, such as the valleys around Monte Rosa, including Valsesia. There, they shaped the landscape and developed a culture deeply connected to the mountains.

Their migrations were not just historical events, but a continuous cycle tied to herding and Alpine pastoralism. During the summer months, Walser families would move with their livestock to higher pastures, living in Alpine huts. When autumn arrived, they returned to the valley bringing with them the fruits of their labor — cheese, butter, and stories from life in the high mountains. This cyclical movement marked the rhythm of community life and strengthened the ties between families and their land.

Today, these migrations are celebrated through traditions and festivals that keep their memory alive. One of the most significant reenactments is the “Rosario Fiorito” (“Flowered Rosary”), a ceremony that recalls the thanksgiving processions held upon returning from the Alpine pastures. During this day, local communities gather to celebrate their devotion and spiritual bond with the mountains, decorating churches with flowers and retracing the paths that once marked the herds’ return to the valley. These celebrations are not only a tribute to the past but also an opportunity to rediscover the Walser heritage — one of resilience, ingenuity, and a deep connection with nature. Through festivals and reenactments, today’s generations can relive and understand the meaning of

those long journeys, which were not merely physical movements, but moments of transformation and communal identity.

Geositi

1.15 Valle d'Otro (Villaggi Walser)

Figure S41 Geosite Valle d'Otro

The land on which the settlements stand is what remains of a glacial terrace, formed first by the glacier's depositional action and later by erosion, both during and after the glacier's retreat. Just as the Otro stream is today a tributary of the Sesia River, the glacier of the Val d'Otro was once a tributary of the Sesia Glacier. In a complex glacial system such as that of Valsesia, erosion acts with varying intensity depending on the energy developed by each moving ice mass. In this case, it is evident that, since the Otro Glacier was smaller than the main one, the profile of the Valsesia lies at a significantly lower elevation than that of the lateral valley.

Between the main valley and the secondary one, a threshold was thus formed — a step that suspends the tributary valley. After the glaciers retreated, fluvial erosion caused the connection between the two valleys to occur through deep gorges carved directly into the rock, as seen in the d'Otro plunge pool, which can be easily observed by following a marked detour along the trail. The asymmetrical profile of the lower and middle sections of the Otro valley developed as a result of deep gravitational slope deformation (DGSD) affecting the slope from Feglierec to Pianmisura. This process caused instability and local rock detachment from the upper parts, a fragmentation of the rock masses accompanied by surface stretching in the middle section, and a consequent bulging in the lower portion of the valley.

Seventh stage – Man-nature relationship

Figure S42 Map of the seventh stage of the geotrail

General description:

From Pianmisura to In D'Follu

1.5km, elevation +57, -175, 0h30

The route of this stage follows a gentle downhill slope across the ancient Walser hamlets, which since the Middle Ages have shaped this glacial terrace through their settlement, sometimes living in conditions of extreme cold. As we descend the Val d'Otro, we will see vast pastures and a glacial terrace that, thanks to its favorable sunlight exposure, made possible the cultivation of rye and, above all, the creation of the ancient Walser villages — among the best preserved (and still inhabited) in the entire Alpine region.

Path description

Starting again from Pianmisura Piccola (1835 m), continue along the marked trail no. 203. The path crosses the pastures with a very gentle descent, and keeping the valley floor on your right, you reach a junction. Turning right leads to Alpe Gender, while our trail continues to the left, still following the 203 markers, and reaches Scarpia (Zar Schkorpiu, 1730 m). Following the trail, you pass through the hamlet and then, going straight ahead, you also pass Im Dorf (1710 m), while on the left you can observe a deep gravitational slope deformation that characterizes the Val d'Otro (Geosite 1.16). After about 15 minutes, you reach the church of In D'Follu (1664 m).

Short story – The signs in the ice

Figure S43 Illustration of the seventh tale

The Walser people had a profound ability to interpret destiny through everyday life events. They knew, for example, that the imminence of death is signaled by hearing dripping water when there is no rain, hearing the fox howl, hearing knocks at the door or seeing it open wide without any physical presence, or seeing small whirlwinds lifting hay or snow without wind. Extraordinary events are foretold by celestial phenomena, such as eclipses or the northern lights; the latter was seen in Valsesia during World War II and was believed to presage its end. Ordinary events are instead predicted by the patterns formed by ice crystals: these allow one to foresee the profession a child will have, as the crystals take the shapes of the tools of the trade he will use as an adult. According to tradition, on New Year's Eve, a child's parents place a bowl of water outside the window. In the morning, the family retrieves the bowl and examines the frozen surface. A story is remembered in Scarpia of a boy whose ice crystals unexpectedly did not show a hoe, like the one his father had left months earlier at the end of summer. Instead, the crystals showed a backpack and boots; recognizing them, the boy understood he was destined to leave the community and explore new territories.

The Walser lived in close-knit communities that sometimes split; smaller groups with a strong spirit of adventure left the original community and crossed alpine passes in search of new lands to colonize. Once settled, they collectively reclaimed the area and built houses and alpine pastures. Just as the founders of his community had done centuries before, when the time came, the boy said goodbye to his family and, turning his back on his home, set off down the valley.

He walked to Romagnano and stopped to ask for water at a gas station. A couple in a car nearby, curious about the cut of his mezzalana outfit, approached to ask where he was headed. He told them his destination was a new home, yet to be found or built. One of the men, a foreman in the local yarn factory, offered him a job and lodging. The young man did not accept immediately but waited a night and looked for a frozen puddle in the shadiest spots. There he thought he saw a spinning wheel; so he accepted the job and settled in Romagnano. Years passed, and when the time came for the man's children to ask the crystals what their future work tools would be, to everyone's surprise, one child's New Year's Eve bowl showed the grandfather's hoe.

When the time came, the boy returned to his grandfather’s village, now changed but not completely forgotten. The houses his father had seen built showed signs of age and had their shutters closed. The few remaining inhabitants moved with the dignity of guardians of ancient stories. When the boy presented himself in the village center, he was met with curiosity and a touch of suspicion.

However, when he began to speak of his desire to return to mountain life, his fellow villagers' eyes lit up. His intention awakened a long-dormant sense of belonging and redemption. Inspired by this renewed fervor, the boy proposed to organize a festival to revive the traditions of his people. He thought first of the bread festival, which the Walser made in October using rye flour and potato puree, fruits of the labor of men like his grandfather. "We must celebrate who we are," he said passionately. "Let's invite the young people who have left to come back, to rediscover their roots and share their experiences." The news spread quickly and, surprisingly, many answered the call. During the bread festival, the village filled with colors, sounds, and the smell of freshly baked bread. The young people brought their modern stories, weaving them together with Walser legends.

Figure S44 Illustration of the seventh tale

Geostop #8 Follu village (In D'Follu)

Figure S45 Photo of In D'Follu village

The Val d'Otro, the place where we now stand, was colonized by the Walser people who came from Alagna, themselves originally from Gressoney. As early as 1306, the valley was permanently inhabited, with settlements independent from Alagna. From a geomorphological point of view, this is a hanging valley, like the Bors Valley and the Val d'Olen, and it lies transversely to the main valley. The glacier was the main agent shaping this valley, but unlike the others, here the valley is much wider. This suggests that it was not only the Otro Glacier that carved it, but also the Bors Glacier, which during the penultimate ice age (about 130,000 years ago) crossed Cimalegna and the Foric Pass, entering Val d'Otro and shaping it before flowing into the large Valsesian glacier.

This geomorphological configuration gives the valley good sunlight exposure and an almost flat terrain. The Walser knew how to take advantage of the environment to build a landscape that respected nature while meeting their needs. Val d'Otro is considered the prettiest and most archaic of the Valsesian valleys. In 1924, Luigi Ravelli described it as a place exuding a special charm — a gentle, pastoral poetry combined with a sense of solemn peace. Although this landscape may seem peaceful and untouched, for the Walser it was a place of daily life. They built their hamlets here, which were inhabited year-round for a long time.

In particular, the hamlet of In D'Follu, where we are now, was the main settlement of the valley and hosted the primary school (destroyed by an avalanche) and a chapel dedicated to Our Lady of the Snows, built in the 1500s. The houses were positioned where the ground is flattest, and the terraces still visible today bear witness to high-altitude cultivation. In Im Dorf, there was the community bread oven — a gathering place for residents, where the traditional Walser bread baking took place.

Another communal feature, showing how the Walser had to adapt to the geomorphological dangers of the area, were the avalanche barriers. The hamlets were located in places naturally protected from avalanches, but where that was not possible, the Walser built stone barriers. In Scarpia, for example, you can still see stone spurs covered with earth that split the avalanches to protect the upper houses. The lower ones, in turn, were shielded by stone walls, in some cases rounded in

shape. This type of avalanche-protection method is interesting because it is deeply local and functional, but it also serves as a reference point when viewing the hamlets from above. The indigenous techniques of avalanche risk protection have been recognized by UNESCO as Intangible Cultural Heritage.

In the 16th century, with the onset of the Little Ice Age, the climate became harsher and the population began to move to lower altitudes, using the houses in Val d'Otro only as summer alpine pastures. In the 19th and 20th centuries, March 19th (St. Joseph's Day) was considered a special date, when people would clear the mule track of snow and, a few days later, ascend to the Otro hamlets, where they stayed until Christmas Eve. These elements show how, despite coming from afar, the Walser managed to adapt to all aspects of local life — from religion to changing climate, to relations with local populations.

However, beyond preserving legends and traditions, what they have always maintained is their language. The Walser, in fact, represented and still represent a linguistic minority, speaking the language of their ancestors: the Titschu, an ancient German dialect. Even while integrating and adapting to any environmental and social context, they have always preserved their traditions, recognizing themselves most strongly through their language — their truest and most powerful distinguishing trait.

The Walser house

Figure S46 Photo of a Walser house in Val d'Otro

The Walser house is one of the most representative examples of Alpine architecture, designed to ingeniously respond to the challenges of life in high mountain environments. This structure was not merely a dwelling but a true microcosm where family, animals, and daily activities coexisted in perfect harmony with the surrounding environment. The Walser houses, found in places such as Alagna Valsesia, are notable for their combination of local materials: stone and wood. The stone base ensured stability, insulation from the cold, and protection from ground moisture. Above this base rose the wooden structure, usually made of larch or fir — abundant, durable materials capable of withstanding the harsh Alpine climate.

The interior layout was equally functional. The ground floor housed the stable, where the livestock were kept during winter; their body heat helped to warm the upper floors. The first floor was reserved for the family, with small, simply furnished, yet cozy rooms. The attic served as a granary and storage space for hay, essential for feeding the animals during the cold season. Externally, Walser houses are characterized by projecting wooden balconies, often decorated with carvings and

flowers during the warmer months. These balconies had a practical purpose: drying hay, storing tools, and spreading out harvested grains.

The roof, generally a double-pitched one covered with *piode* (slabs of local stone), was designed to withstand heavy snow loads, ensuring the structure's stability and longevity. These houses were not isolated but formed part of small Walser villages, where each home was strategically placed to make the best use of sunlight and minimize avalanche risk. This layout promoted community life, with shared spaces used for collective activities such as dairy processing or the construction of new buildings.

The Walser houses, with their sturdy simplicity and their ability to combine dwelling, stable, and storage in one functional unit, embody the ingenuity and adaptability of a community that managed to thrive in an environment both beautiful and severe. Even today, these structures stand as symbols of resilience and harmony with the mountains, and many have been restored to preserve this unique cultural heritage.

Geosites

1.15 Valle d'Otro (DGSD)

Figure S47 Geosite Valle d'Otro (DGSD)

Some time ago, about one-third of Alagna's population lived in Otro. The well-sunned and sheltered slopes allowed for more fertile harvests. The inhabitants of these hamlets stayed in the villages from March until Christmas Eve, whereas today only a few houses are occupied during the summer months. The Walser settlers established themselves in this valley at the beginning of the 14th century, coming from Gressoney, during what is called the "second migration," although it is more accurate to speak of a single, long migration toward the Italian valleys, carried out by numerous small groups over a span of two hundred years.

The avalanche barriers of Scarpia are a perfect example of how this population managed to coexist with the hardships of mountain life, making full use of its resources while never disturbing its natural balance. Indeed, it is this feeling of balance and serenity that the Otro terrace conveys to visitors. A visit to Cima Mutta, on the opposite side of the valley but reachable only from the Val Vogna (a two-hour walk), is well worth the effort—both for the view of the surrounding peaks and for the opportunity to look down upon the Val d'Otro. Just as when studying an aerial photograph or using a flight simulator, from here it is easy to recognize the forms that define the valley's geomorphology and the full extent of the Walser settlements, stretching from Feglierec to Pianmisura.

Eight stage – Im Land

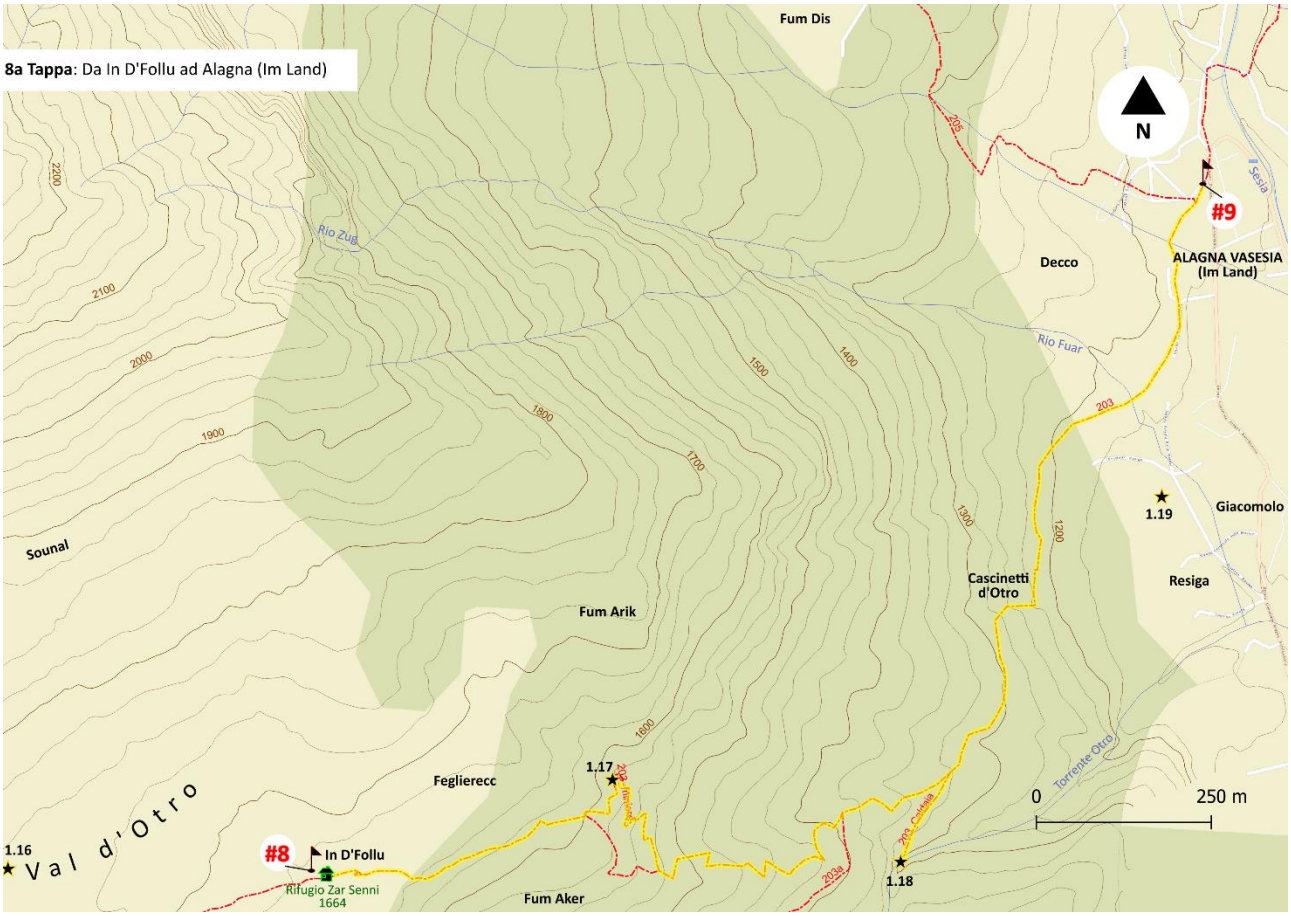

Figure S48 Map of the eighth stage of the geotrail

General description:

From In D'Follu to Alagna Valsesia (Im Land)

2.8km, elevation +57, -573, 1h

This section of the trail takes us through the final descent of the Geotrail and gradually leads us toward the end of our journey. After having walked across and observed the ancient European paleocontinent, a paleo-ocean, and the African paleocontinent, we now head toward our final destination: Alagna Valsesia. To reach it, we must descend through the forest one last glacial step, a formation that bears witness to the confluence of the Val d'Otro glacier with the great Valsesian glacier.

Path description

After In D'Follu (1664 m), continue descending along mule track 203, retracing one of the main Walser migration paths. Shortly after, the trail enters the forest and becomes steeper as it prepares to descend the glacial step. A series of switchbacks lead us to the manganese mine (Geosite 1.17) (1575 m) and then to a chapel. Continuing downward, you reach a fork (1420 m): the road to the right leads to the Tailli lakes, while our trail turns left, continuing down toward Alagna. The path becomes easier, with hairpin turns under a fir forest whose roots often form natural steps. At 1325 m, a new fork to the right leads via a short trail to the Caldaia d'Otro (Geosite 1.18). Returning, the

descent continues rapidly with a succession of steps offering a beautiful view of the Alagna settlement. Continuing along trail 203, you will cross the ancient hamlet of Alagna, Riale Superiore (Im Oubre Grobe), passing Resiga (Zar Sogu) on the right, with the Pulfer Stain (Geosite 1.19), until reaching the fountain of the hamlet Pedelegno (Zar Chilchu) (1191 m).

Short story –Water

Figure S49 Illustration of the eighth tale

In the hamlet of Rusa, in the upper part of the settlement, before the woods that cover the slopes of the mountain where the Alpe Buràcchi is located, there still exists the Cà 'd Mirëtt. Once it was a beautiful house, enriched by a fresh and good fountain that sprang directly from the adjacent ground. One day, unfortunately, a little girl fell into the fountain and drowned. Her mother, stricken with grief, cursed the fountain.

The Camproso region once had many fountains flowing high up, at the top of the meadows. One day, a woman carrying a bucket of milk slipped due to the wet ground and spilled the milk. From her lips came a curse directed at the water: “va 'n fund a l'érta” (go to the bottom of the slope).

The water gladly served the Walser, who had always shown it respect, but it realized that in this situation it had not done them proper service; therefore, it obeyed the woman's words. From then on, little by little, the fountains of Camproso and that of Cà 'd Mirëtt dried up until they became completely unusable. New fountains appeared lower down in their respective valleys, where the water thought it would better serve the Walser.

Also, in the hamlet of Dorf, a new fountain with two basins appeared. The water from the Dorf fountain was said to be scarce in rainy periods and abundant during droughts. Over the years, however, fewer and fewer people came to the Dorf fountain. The water no longer saw the people filling their buckets and doing laundry; instead, visitors were more often hikers who praised its freshness and filled their bottles. The water doubted that its service was still essential in that village.

So, it began to flow into the Sesia river and descended to the valley, observing the contemporary world. During its journey to Alagna, the water stopped near a hotel with a crowded terrace where children played and adults relaxed. It felt the joy and vitality of those people and understood that its flow could bring happiness and health; it offered them a beneficial pool, turning that terrace

into a spa and the hotel into a resort. From the chatter of the resort guests, it learned that their holidays were ruined due to insufficient snow on Monte Rosa for skiing.

The water then offered itself to the Alagna community in the form of reservoirs, which technicians used for the artificial snow cannons. The water continued down the Sesia, encountering the lowland farms that diverted the river to flood the rice fields. The water felt fulfilled to be useful to these men and, as it did in Dorf, during droughts it did everything it could to serve them, melting glaciers and rising from underground aquifers.

Figure S50 Illustration of the eighth tale

Geostop #9 Alagna Valsesia

We have arrived at Alagna, and specifically at the hamlet of Pedelegno (Zar Chilchu). In fact, what we today call Alagna was originally not a single town but a series of different hamlets. On the way here, we have seen some of the central hamlets, while continuing we will see the ancient ones. Pedelegno (il cui nome deriva da Pè d'Alagna) represents the second hamlet nucleus founded after Pedemonte. Here, the houses, still built according to the architettura vernacolare dei Walser despite the arrival of new constructions, overlook the old road, which followed a small canal that supplied water to mills and fountains. This viewpoint projects us into the daily life of the Walser and, once again, shows how the construction of houses first, and villages later, was functional both to inhabiting a place with a harsh climate and to carrying out the typical community life of this population.

Arriving at Alagna, as was customary, the Walser settlers founded the first hamlets at the foot of the hanging valleys (Pè d'Alagna, Pè d'Olen, Pè d'Otro, Pè de Monte), and only later built the others. Moving forward along the trail, we can also see the work of the Walser in adapting this place to their needs and making it habitable. At the forest's edge, there are terraces now colonized by young forest trees, which testify to the agricultural use of these terraces until the last century, again demonstrating the great clearing work of this Alpine community.

Moreover, the houses, built with local materials (both stone and larch wood), find perfect harmony with the surrounding landscape. The Walser community was rooted in the territory, demonstrating the ability to exploit its resources while living in sustainable balance for centuries. Despite their strong bond with their land, with globalization's advent, even the Walser experienced a common phenomenon for mountain regions: emigration. Often men left searching for fortune and wealth, and if they succeeded, they became benefactors of their home village, once again showing the strong connection to their territory.

An example is the square where we are now, dedicated to "Michele Necer", an emigrant from Alagna who became an important benefactor. The fountain was also designed by Necer, and this viewpoint was chosen also for this reason — it symbolizes the Walser's strong bond with their territory and somehow summarizes and encloses our journey. In fact, the fountain has three water jets, representing the three valleys and the respective streams of Alagna: Sesia, Olen e Otro. This is precisely the path of our journey through the geological time of this extraordinary place.

The *Titschü* language

The Titschü language, an Alemannic dialect of Germanic origin, represents one of the most distinctive aspects of the cultural heritage of the Walser people of Alagna Valsesia. This language was once the everyday speech of the Walser communities, tied not only to communication but also to the oral transmission of traditions, legends, and the practical knowledge needed for life in the mountains.

Today, Alagna is a single village, but in the past it was known as Im Land, a territory made up of numerous independent hamlets, each with its own identity and community organization. Each

hamlet—such as Pedemonte, Ronco, or Riva—was connected both physically through paths and culturally through the shared language, which strengthened the sense of belonging to one unified Walser community.

Titschü was the glue of this alpine microcosm, used to pass down stories of life in the high mountains, techniques of herding and farming, and even community laws that governed the management of pastures and resources. Like many minority languages, Titschü gradually declined over time due to modernization and migration to the cities. However, in recent years, important efforts have been made to preserve it.

Courses, events, and cultural projects aim to keep the language alive, not only as a means of communication but also as an element of identity that tells the story and resilience of the Walser community. An example of how the Titschü language survives through time can be found in certain traditional celebrations that bridge past and present. These festivals not only recall the ancient seasonal migrations and alpine work but also feature songs, prayers, and stories in Titschü, maintaining a living connection to Alagna's deep roots.

The linguistic and cultural heritage of the Walser people is not merely a historical curiosity but a living treasure that invites new generations to rediscover the value of dialogue with their land and with the stories it holds.

Geosites

1.16 The manganese mines

Figure S51 Geosite The manganese mines

Manganese (Mn) deposits are found in the Piedmont Zone of the Calcschists with Greenstones, occurring as nodular or lenticular aggregates. They are located within layers—sometimes up to several tens of meters thick—of micaceous or chloritic quartzites, interbedded within calcschists and prasinite rocks. The lenses of manganese-bearing minerals follow the schistosity of the surrounding rocks and are often stretched and flattened, sometimes reduced to centimeter-thick sheets.

The mineralizations in Feglierec may consist either of a single mineral (for example, hematite) or of several associated minerals forming multicolored bands, which, however, are not visible on the surface because manganese oxidizes upon contact with oxygen. The manganese metal content ranges from a few percent to peaks of about 20%.

The origin of these deposits is attributed to sedimentary rocks known as cherts, among which radiolarites are likely present. These are siliceous rocks formed from the shells of radiolarians—amoeboid protozoa that make up part of the plankton. During the Late Jurassic, these rocks were

deposited on the bottom of the Piedmont Basin, alternating with volcanic deposits produced by oceanic ridges.

In correspondence with fractures and/or ridge zones, a hydrothermal flow developed. Enriched with sulfur (sulfides), silicon, copper, iron, and manganese, it passed from a state of extremely high temperature (hundreds of degrees) to the near-freezing temperature of the ocean floor. This process caused the formation of black smokers and the immediate precipitation of most of the transported minerals, which built the characteristic black chimneys of the ocean floor. Others, including manganese, due to their higher solubility, remained in solution longer and precipitated very slowly—at a rate of centimeters per million years—far from the fluid's exit points.

The manganese contained within the siliceous deposits was later affected by Alpine metamorphism and the associated deformation phases. However, since these deposits did not undergo remobilization, they have preserved their full significance as paleogeographic and metallogenic markers.

1.17 Otro plunge pool

It is a system made up of three elements: the gorge that channels the water from above, the waterfall about 40 meters high, and the sub-circular cavity at the base of the waterfall, known as the actual "cauldron" (fig. 2). Like the Caldaie del Sesia, the Otro cauldron and its adjoining gorge have a glacial origin. They consist, in fact, of a gorge and a large sub-circular cavity formed in the past by subglacial waters that flowed between the base of the glacier and the underlying rock.

Figure S52 Geosite Otro plunge pool

These waters, carrying a substantial load of sediments, had a strong erosive effect on the bedrock; when they encountered zones of lesser compactness and resistance, they exerted even greater abrasive and cavitation effects due to their swirling motion. Later, the surface waters of the Otro stream further deepened and shaped the pre-existing landforms.

1.18 Pulfer Stain

A large boulder originating from a landslide in the 1700s. The interior of the boulder was hollowed out to create a room used for storing explosive powder intended for use in the area's mines. Today, the boulder serves as a rock climbing training site for the Alagna Mountain Guides Corps.

Nineth stage – Conclusion

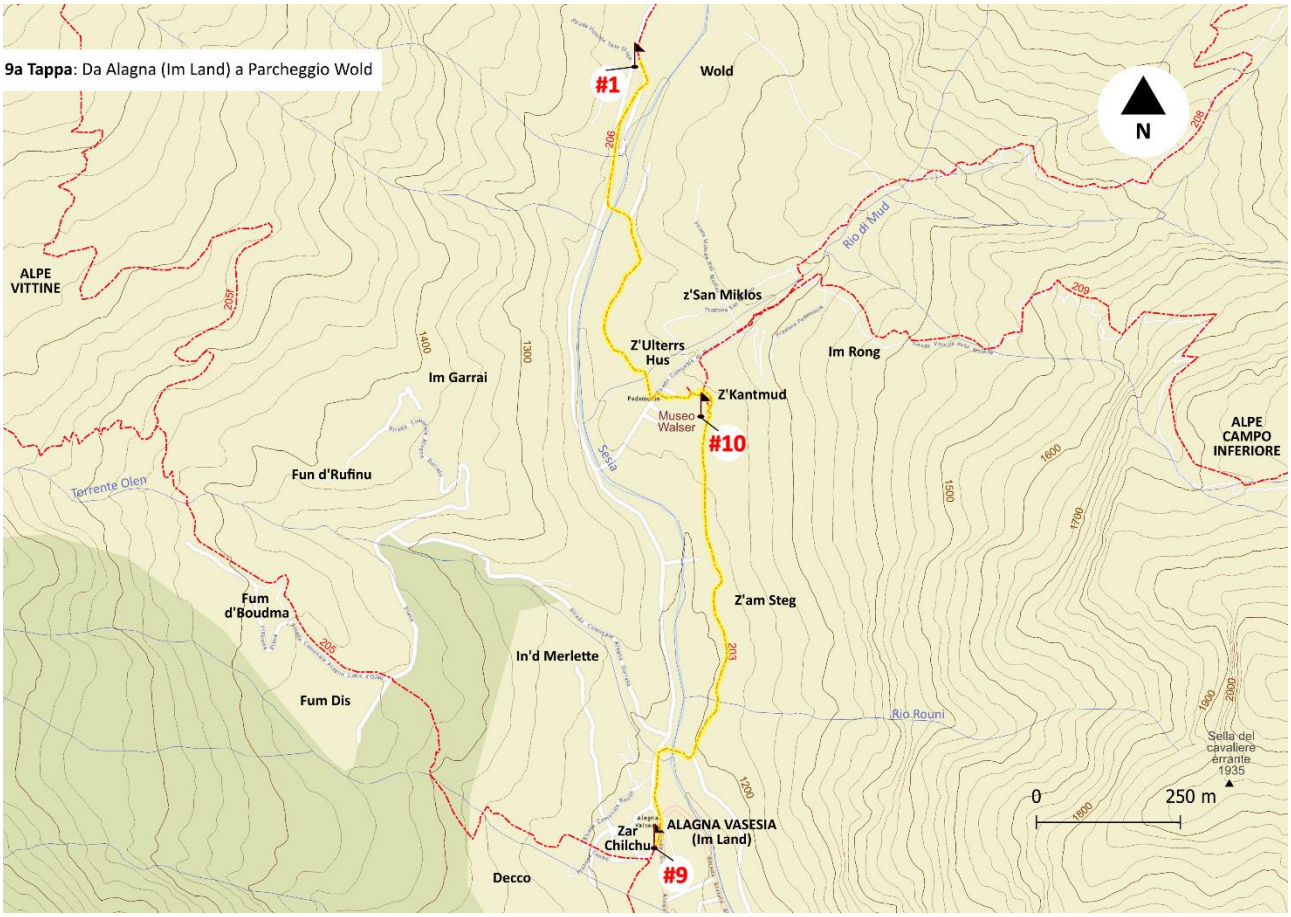

Figure S53 Map of the nineth stage of the geotrail

General description:

From Alagna Valsesia (Im Land) to Wold parking site

1.3km, elevation +128, -44, 0h50

In the final stage of our route, the geotrail leads us along alternating stretches of road and path, allowing us to sum up what we have seen and to observe Alagna Valsesia—through its various hamlets—as it lives today and interacts with the surrounding environment.

Path description

The final stage begins in Pedelegno and continues northward, passing Piazza Regina Margherita (probably built over the first Walser necropolis) and Piazza Grober. Following the road that runs alongside the parish church, the route passes Piazza degli Alberghi and, shortly after, turns right, crossing a small pedestrian bridge over the Sesia River. From here, signs indicate the path leading to the hamlets on the river's left bank.

The trail continues across the Rio Rouni, through patches of young woodland and meadows at the foot of a slope broken by agricultural terraces. It then enters the hamlets of Ponte first and Pedemonte next, where the Walser Museum is located. From there, the route continues across a bridge over the Rio Mud, passes through the hamlet of San Nicolao, and proceeds straight across a

meadow to descend gently onto an earthen bridge that crosses the Sesia River once again. Turning right, after a few meters you reach the Wold parking area, completing the loop..

Geostop #10 The Walser museum

Pedemonte is the first Walser hamlet of Alagna Valsesia in order of foundation. The first settlers established themselves here, and their presence is still strongly felt today. The path opens into a small square, in front of a spring-water fountain with two monolithic basins, each bearing a date: 1540 and 1557. The houses surrounding this small square are in perfect Walser style, built according to vernacular architecture, with larch-wood frameworks set close together to retain warmth and allow passage through semi-enclosed corridors outside the houses, providing protection from heavy snowfall. This building method was developed especially during the Little Ice Age.

On the fountain, a bronze figure of the Walser symbol—the eagle—can also be seen. The main feature of the square is the Walser Museum: a perfectly preserved Walser house dating back to 1628, now set up as a museum that illustrates how daily life unfolded within these traditional homes.

Just outside the small settlement stands the oratory dedicated to Saint Nicholas, built here after a flood in 1757 destroyed the previous one located beyond the Rio Mud. Saint Nicholas is a deeply cherished figure among the Walser: even today, his feast on December 6 is celebrated by baking bread throughout the day and night, producing loaves that Walser families keep to feed themselves through the year.

A final message

The Geotrail we have followed offers a deep insight into the relationship between the natural environment and the human communities that have inhabited it, particularly the Walser people. Through the observation of geomorphological landscapes—shaped by natural forces such as glaciers—and the study of rocks that preserve the memory of millions of years of geological processes, we have embarked on a journey through time, discovering a land in constant transformation.

This landscape is the result of an encounter between a complex geological setting and human ingenuity, which allowed communities to take root and thrive in an extreme environment. The Walser community is a perfect example of how adaptation has been essential for survival and progress. They did not merely endure natural conditions but managed to transform the land according to their needs—building villages, fields, and systems to protect against avalanches—while always maintaining a balanced and respectful relationship with nature. In this sense, their pragmatic and respectful approach to the environment carries a message that is more relevant than ever: sustainable coexistence between humans and nature is only possible when based on a deep understanding of, and respect for, the limits and opportunities offered by the land.

At the same time, the Geotrail reveals the geomorphological and geological history of this region, which condenses millions of years of Earth's history into just a few kilometers. Rocks that were once distant and distinct are now brought together in a unique story of transformation. This history encourages us to view the landscape as something alive and ever-changing, reminding us that what we see today is only a snapshot of a much broader and more complex process. Looking back through time allows us to grasp the beauty of this extraordinary evolution.

Traveling through these valleys has taught us to look at the landscape with new eyes, recognizing it not only as a geological heritage but also as a cultural one. It is the outcome of millions of years of natural transformation and centuries of adaptation by communities that, through ingenuity and resilience, have made this extreme environment their home. Even today, they continue to embody a living presence in the area through their language, traditions, and culture.