# ITINERARY E

## «from one continent to the other»

### LES HAUDÈRES - VILLA - LA FORCLAZ - FERPÈCLE -

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**Introduction**

In this field trip we shall visit rock exposures between Villa and Ferpècle, diverse rocks will be seen that pertain to several tectonic units (nappes) and that make the passage between the European continent northward (Villa, La Sage) and the African plate to the south (Ferpècle).
This trip crosses the Alpine suture made of rocks of the Alpine ocean that disappeared long ago, between La Forclaz and Seppey.
This trip can be made in one day starting in Les Haudères, either by postal bus or by car. It does not present physical difficulties, but good walking shoes are recommended for the sections by foot. The trip can be completed another day by itinerary A, a 12 km round trip by foot (6 to 7 hours) along the Ferpècle Valley.

■ **Starting point**

All the postal buses departing from Sion stop in Les Haudères where one can take a bus to Villa, La Sage, La Forclaz and in summer up to Ferpècle. See time table at:
http://www.tableaux-horaires.ch/fileadmin/fap_pdf_fields/2013/12.383.pdf
In Les Haudères, go left on the La Sage road just before the bridge on the river Borgne de Ferpècle.

❍ From the first hairpin bend going out of Les Haudères, one can see the typical rocks of this region outcropping along the road, they consist of dark grey calcschists with nodules of white quartz and of greenish rocks, prasinites, formerly basalts or volcanic tuffs of the Alpine ocean. These prasinites can be seen on the main road close to the bus departure in Les Haudères.
Dark schists and green prasinites forming the nappe du Tsaté mark the suture of the Alpine ocean (outcropping over 3 to 4 km along the Ferpècle Valley, from north of La Sage up to the tunnel on the road of Ferpècle). This complex of dark and green schists outcrop all along the road to La Sage.

⇨ Follow the road up to Villa passing through La Sage.

■ **<u>Stop E0</u>: rock outcrop at the playing ground of La Sage**
A small outcrop od whitish dolomites are found at the playing ground, marking the limit between the Alpine ocean to the south and the European margin to the north.

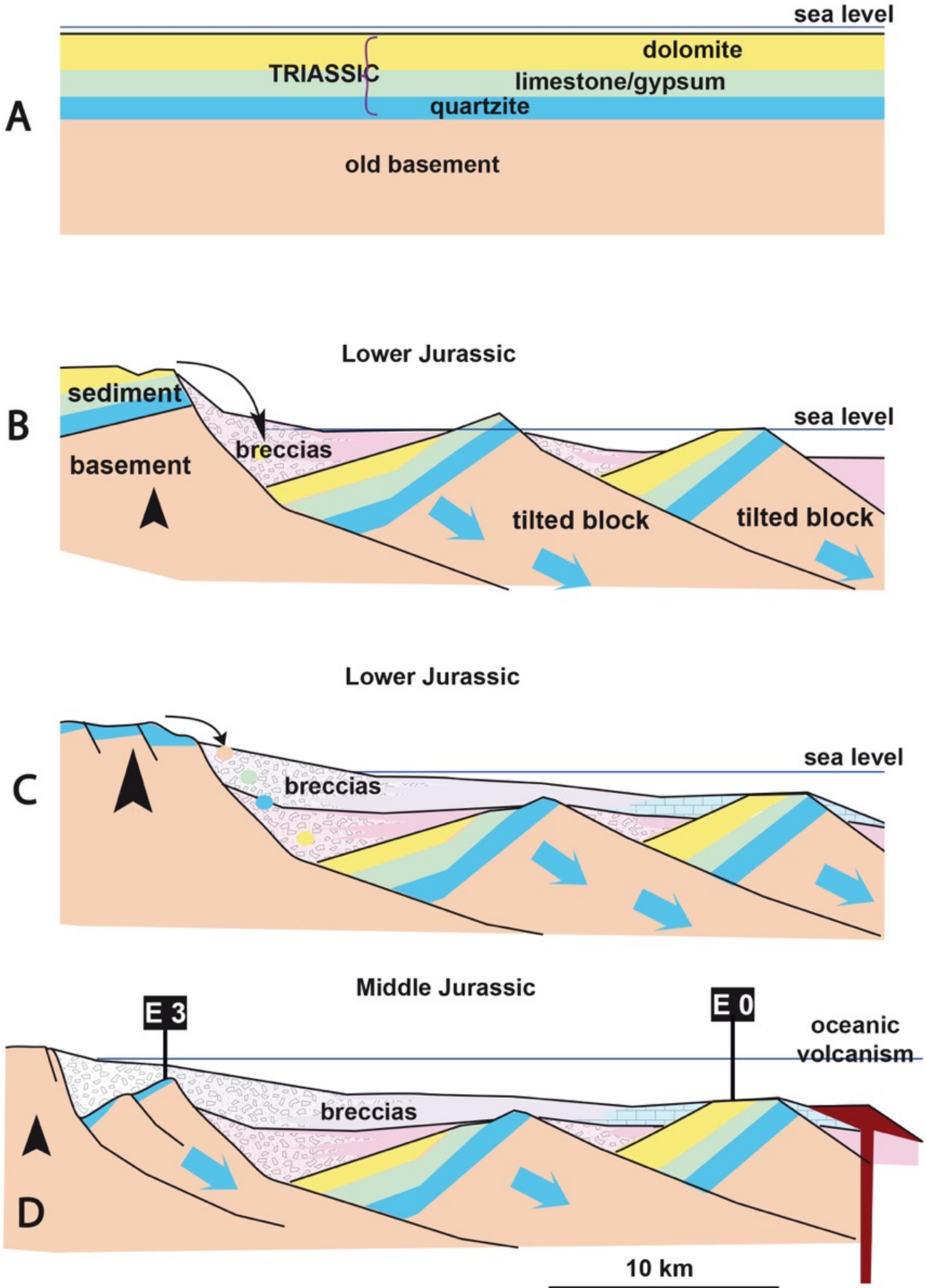
There are several parking spots in Villa, it is better to use the one at the entrance of the village on the left. Go through the village up to the final bus stop, then take a small asphalted road going up to Cotter and that soon passes under a small tunnel.

## ■ **<u>Stop E1</u>: rock outcrop**

❍ Going out of the tunnel (1770m, 46°06’31’’_7°30’40‘‘) several marble and calcschist outcrops are found along the right side of the road, (a metamorphic limestone becomes a marble). The marble consists of recrystallised limestone beds locally folded. These beds follow the river forming a structural surface call dip-slope dipping southward between 20 to 40 °. That type of south oriented dip-slope surface is found in many locations along the Val d’Hérens corresponding to the overall nappe structure (see cross-section).

⇨ Going up the road the calcshists facies shows differences with the one of the calcschists of the Tsaté nappe (see stop E7), with the presence of numerous beds of grey marble (1790m, 46°06’37’’_7°30’35‘‘). These beds correspond to deposits of detrital flow on a sub-marine slope, called turbidites. They can be recognised by the presence of graded bedding, mainly when the grains are well visible as it is the case here in some beds of micro-breccias (1792m, 46°06’38‘‘_7°30’34‘‘). The coarser grains are deposited first, they are at the bottom of the beds. This phenomenon permits to defined the bed polarity (the top and the bottom, the tip of the biro shows the top on the photo below), which is very practical when the beds have been strongly folded as in here. The turbidites show that these sedimentary deposits were close to the European continental margin, whereas the Tsaté «série grise» was located further in the ocean, not reached by the turbidites.

NB: these observations give information on the age of the sequence with marble beds. The turbidites were derived from the adjacent continental platform bordering the European continent, this platform disappeared at the end of the Jurassic, drowned after the subsidence (sinking) of the Briançonnais micro-continent. Therefore, these deposits are older than this event, they are of lower to middle Jurassic age.




**Reconstruction of part of the European margin between La Sage and Villa**

**the few km of now represented more than 40 km during the Jurassic times!**

■ **<u>Stop E2</u>: rock outcrop**

❍ After some hundred meters, at the level of the last chalet to the left (1825m, 46°06 ' 46 " _ 7°30 ' 23 ') these beds reappear and become massive. We can see some greenish schists too, prasinites, which we also find over the road after the first hairpin bend. Prasinites are often considered as belonging to the Tsaté nappe, and here we could thus put the limit between the Cîmes-Blanches sliver (E3) and the Tsaté nappe, however we also have to envisage that basalt flows were emplaced during the opening of the rift and were part of the sedimentary series of the tilted blocks, which is the case here. The limit Tsaté/Cîmes-Blanches is more likely situated before the small tunnel we just passed. Certain beds present graded bedding, in these avalanches of micro-fragments the classification of grains is sometimes disrupted by the amalgamation of several flows, and in the large avalanches the coarse grains are sometimes in the centre of the bed as in photo below. But we see here that folds exist within these big beds, which makes the reading even more complicated...


prasinites


large grain at the center of the bed

■ **<u>Stop E3</u>: rock outcrop and panorama**

❍ In this first hairpin bend (1835m, 46°06 ' 48 " _ 7°30 ' 19 "), we see appearing under the grey marble another lithology, whitish quartzites, former coastal sands that became sandstones, then quartzites, during the burial of these rocks due to the Alpine folding event (phenomenon of subduction and metamorphism). These quartzites

are representative of the base of the Triassic (250 - 240 My) and the grey marbles of E2 which extend up to here, represent the lower to middle Jurassic (180 in 155 My). Between these two periods, the alpine ocean opened (towards 190-180 My), and a whole part of the Triassic and lower Jurassic is missing due to erosion, or not deposited, during the opening of the ocean. The phenomenon that leads to the opening of the ocean is called rifting (of the rift valley, East-Africa), it is the large-scale fracturing of the whole lithosphere (see figure in stop E-1).
Between the ocean and the continent we find the continental margin, made of tilted blocks of the former rift. During the closure of the ocean, fragments of these blocks are going to be detached from their substratum and incorporated in the accretionary prism. This prism is represented by calcschists and prasinites of the Tsaté nappe, scraped from the bottom of the ocean and accumulated in front of the African plate.
The Triassic quartzites are older than the ocean, therefore they belong to the continent and not to the ocean; massive limestones which are associated to them here represent sediments deposited during the opening of the alpine rift valley. As we have seen, they are represented by calcareous micro-breccias deposited in the form of submarine avalanches. These deposits filled small basins (10 to 20 km wide) between the tilted blocks, every block formed a sort of step, tipped over towards the continent, there were about ten of these big steps between the continent and the ocean. Every step went down some hundred meters, to terminate at the end at the level of the oceanic floor towards -4000 or -5000 m. This zone between the continent and the ocean (continental margin) was a hundred of km wide. Here, between La Forclaz and Evolène, we find the remnants of only three tilted blocks, and the 100 km of the margin have been reduced to a few!
The series of rocks going from the tunnel to the bend represents the Cîmes Blanches unit, folded inside the Tsaté nappe; it is one of the former three tilted blocks of the European margin. This unit becomes thicker on the other side of the valley towards La Meina and the Pic d'Artsinol where we can see important deposit of rift breccias. As these coarse breccias are lacking here we can think that this outcrop was farther away from the source of fragments.

❍ Panorama
In bend of the road we can go until the point of view on the valley (1830m, 46°06 ' 48 " _ 7°30 ' 17 "). Since there, by looking west/northwest, we see the slope over Lana

(Âla, former glacial threshold, see filed trip C, stop 10) which forms the back of the Siviez-Mischabel nappe, the Mt Fort nappe being represented by cliffs below us, over Evolène. We arrive there to the European continent (or Briançonnais domain). At the time of the Jurassic rifting, this piece of continent represented the rift valley shoulder.
NB: it is from this surface of Âla that the sedimentary sequence now forming the Fribourgeoises Prealps was detached.

⇨ We continue the excursion by climbing along the quartzites outcrop, locally the sedimentary contact quartzite/marble (photo) can be observed. We arrive up to both benches where we can sit down to admire the landscape southward

(Dts de Veisivi in the centre, Tsa de l' Ano, Dt Blanche, Dt d' Hérens to the left, Pigne of Arolla to the right, all these summits are in the Dt-Blanche nappe, representing the African plate. Between the two benches (1855m, 46°6 ' 50 " _ 7°30 ' 20 ") there is a small path (light blue marks) northward that reaches to a pathway (1920m, 46°07 ' 11 ' 7°30 ' 21 ') and a few barns (mayens). Over the barn to the right of the two mayens, we have a path which brings us to outcrops of quartzite, forming several tectonic slices.

■ **<u>Stop E4</u>: rock outcrop**

❍ We can see at the bottom of the outcrop a stratigraphical contact between the grey marble on top and the whitish quartzites below (1932m, 46°07 ' 00 " _ 7°30 ' 24 ") (on the photo the top of the branch indicates this contact).

The dark grey elements strongly stretched of the marble are elements of the breccia, and an angular fragment of quartzite is also visible. We have here a breccia deposited directly on the quartzites. It corresponds well to a situation of tilted-block, where the head of the block forms during a few million years an island subjected to erosion (it explain the absence here of several hundred meters of the Triassic sequence), then this island passed under the sea level to be covered by breccias. It also allows to confirm the lower to middle Jurassic age of these breccias.

The quartzites here are strongly deformed and schistose and the quartzite / limestone contact is repeated 4 - 5 m further south. Then about ten metres farther, we have an thrust fault (rather flat fault separating tectonic units) marked by a yellowish zone in hollow on the photo above (called cornieule ). Over the thrust fault we find calcschists. We could consider that this thrust fault represents the limit between the Cîmes-Blanches nappe and that of the Mont-Fort, but it can be a thrust fault inside the Cîmes-Blanches too. These nappes being very similar it is a question difficult to answer... However the deformation is more important here than at the level of the upper quartzite seen towards the two benches and than we find again farther south (1945m, 46°06 ' 58 " _ 7°30 ' 26 ") along the trail, the main tectonic contact is certainly in between.

⇨ By following the path rising to Mayens de Cotter, we find the grey marble locally with breccias and beautiful folds. These folds as those seen in E1 are folded towards the N-NE, as the whole nappe structure. Before the ascent to the mayens, go down towards the hairpin bend of the road.

❍ In passing, the famous Neolithic stones with cupules sculptured in a grey marble (1980m, 46°06 ' 59 " _ 7°30 ' 26 ") can be seen.

⇨ From there, we can reach La Sage by the road or by the path which starts in the next bend in the descent.

⇨ On returning to the parking lot, you can set off now on foot by the route des Méijonneutes (1725m, 46°06 ' 21 " _ 7°31 ' 48 ") in order to reach E5 and E6 stops. These stops allow to see the remnants of another tilted-block representing the Frilihorn nappe. These remnants are few and a real work of detective was needed to find them because they are enclosed in schists and prasinites of the Tsaté nappe. They form on this side of the valley a small strip of outcrops going from Les Haudères (Molignon) until the Sasseneire, on the other side of the valley they raise up towards La Giètty and La Niva (excu C stops 8-9)

■ **<u>Stop E5</u>: rock outcrop**

⇨ On the route des Méijonneutes we arrive at a crossroads, take route du Prélet which brings to a hairpin bend (1805m, 46°06 ' 06 " _ 7°31 ' 07 ").

❍ We have here a white marble outcrop associated with grey marble. In the ravine at the foot the cliff, we note the presence of quartzite and yellow dolomite that indicate the Triassic, thus these are not rocks of the ocean like those of the Tsaté nappe that surround them. It is again, as in the previous outcrops ( E2-3-4), remnants of a tilted-blocks which was even farther in the ocean. The presence of white marble (corresponding to very pure limestones at first) is an indication of this former situation, because it shows that the sedimentation was without contribution of detritus from the continent. We speak about pelagic sedimentation in this case, the former white limestone being essentially made by calcareous micro-shells from the sea plankton. Its age is likely Upper Jurassic.


⇨ Leave the Route du Prélet and continue southward by the Route des Méijonneutes that cuts the torrent of La Sage (1790m, 46°06 ' 07 " _ 7°31 ' 09 ").

❍ In the torrent we can see a block of white and grey marble, continuing we find siliceous calcschists a little bit different from those of the Tsaté nappe, and in which the stream has cut a small gorge.

⇨ Then the track goes up the hill rapidly and we reach another north-south path (close to 1860m of altitude). Take this path northward, returning towards the stream.

■ **<u>Stop E6</u>: rock outcrop**

❍ Having crossed the stream, we find a beautiful outcrop of greenish prasinite rather massive (metabasalt), which represents a former lava flow characteristic of the Tsaté nappe and which erupted on the oceanic floor 160 Ma ago.

⇨ Follow the hillside path that returns to the Route du Prélet; in the next hairpin bend in the ascending direction, come down again by the path to the left which returns to the parking lot.

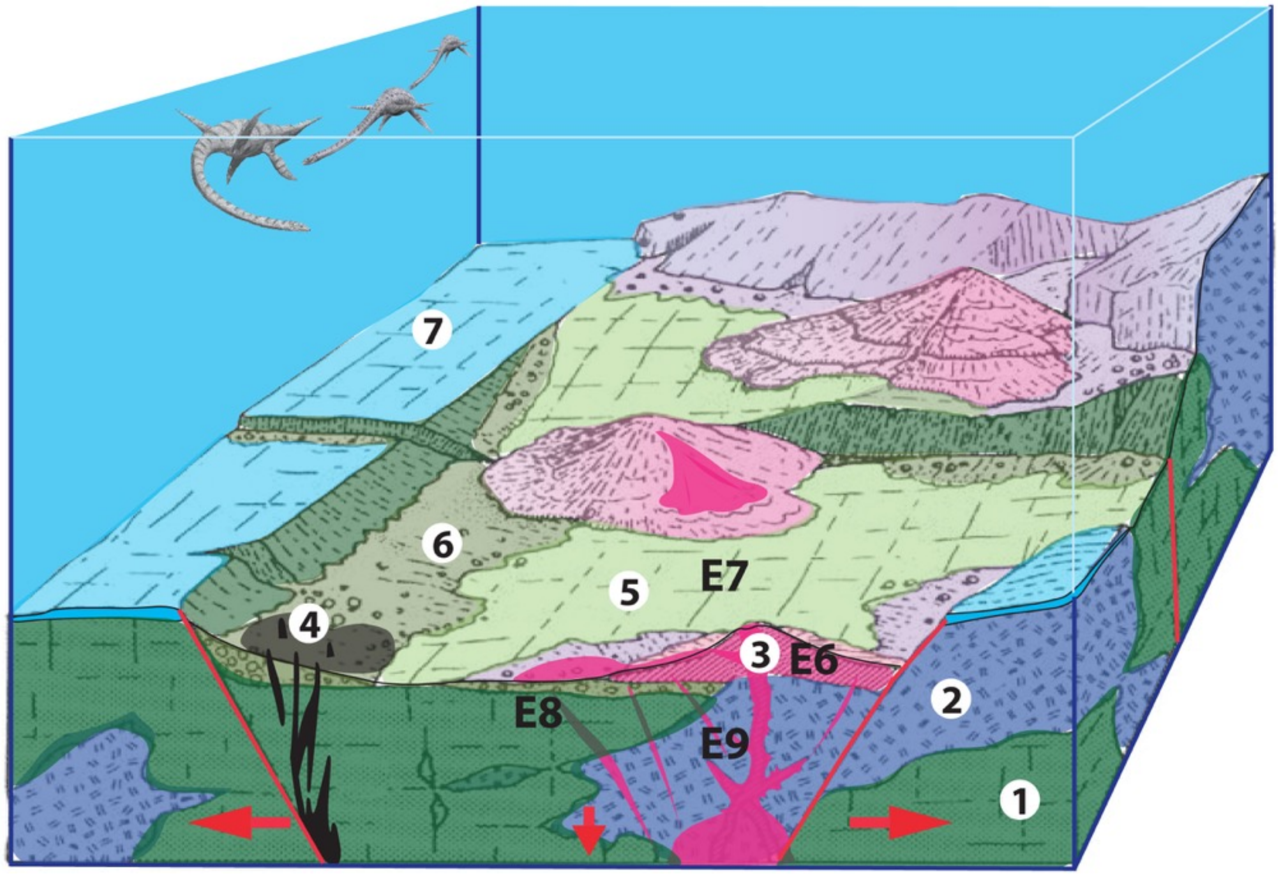
⇨ Take back the road descending towards La Sage, take to the left at the exit of the village direction La Forclaz-Ferpècle.
In La Forclaz one can join the field trip A (dotted line route on the map). Park then at the entrance of the village and go to the old village to the right.
❍ Under the chapel, there is a beautiful outcrop of prasinites (meta-tuffs).
⇨ A path in between the houses goes down to field trip A itinerary (crossing under La Forclaz, 1686m, 46°04'60"_7°31'11'), it allows to go to Ferpècle by foot avoiding the road. On the way one passes through a small pierre ollaire (soapstone) mine (stop A3, 46°04' 52"_7°31'15"), then to the small village of Seppec (stop A5).

■ **<u>Stop E7</u>: rock outcrop**

❍ On the road to Ferpècle going out of La Forclaz we arrive at an outcrop of grey calcschists (1697m, 46°04 ' 45 " _ 7°31 ' 34 "), typical of the " série grise ", which composes the largest part of the Tsaté nappe. We see nodules of white quartz there, the quartz is accompanied with a little bit of yellowish, sometimes dissolved calcite forming voids in the quartz.

The calcschists were made from a calcareous mud deposited at the bottom of the ocean. The limestone came from the plankton (calcareous micro-algea), the clay and the fine particles of quartz came from the continent, taken by the currents. These sediments were brought at great depth by the subduction of the European plate under the African one, in front of which they accumulated in the accretionary prism. The pressure as well as the increasing temperature with depth, triggered the circulation of hot fluids in these sediments charged with silica (quartz) or calcium carbonate (calcite). These fluids circulated through cracks or faults where they precipitated when going up to the surface, forming veins of quartz and calcite.
Subduction continuing, these sediments were brought at depth several times, and again washed by the hot fluids. At the same time they were deformed, folded and with the heat the clay was transformed into mica, what gives now this shiny and slaty appearance to these rocks (we often speak about glossy schists – schistes lustrés), the limestone re-crystallised giving this grey mass made of small crystals, the rock becomes then a calcschist. Veins were also broken in fragments, forming kinds of white nodules.

NB: quartz can be recognised from calcite by the following tests, the quartz scratches steel, calcite not, calcite reacts (by making bubbles) to dissolved hydrochloric acid at 10 % (it works also with the durgol), quartz does not react




On this diagram, stops E-6 to E-9 are located on a reconstructed Jurassic mid-ocean ridge.

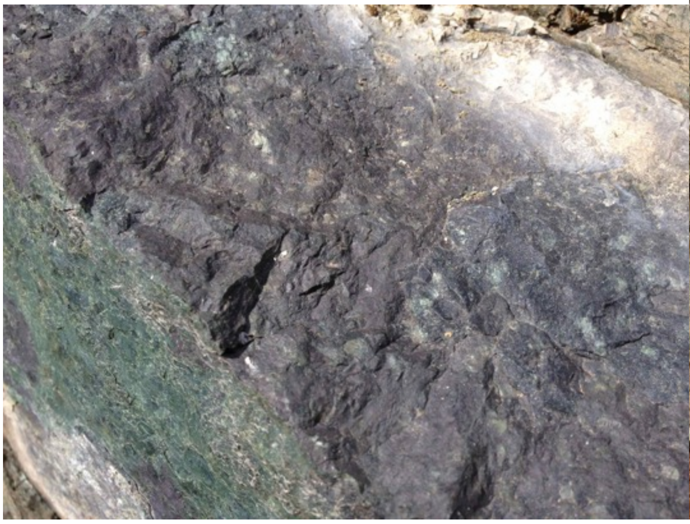
This ridge was made of peridotites (1) brought back to the surface during the processus of rifting, and transformed into serpentinites. Gabbros (2) represent former magmatic chambers from which lava was expelled to the surface as basaltic flows often made of pillow-lava (3). Hydrothermal activity was represented by black-smokers (4), associated to mineralisations (copper, manganese).
The fracture of the lithosphere created faults escarpments marked by the deposition of breccias (6) made of fragments of peridotite, gabbro and basalt. In the central graben volcanic tufs (layered prasinites) (5) were deposited together with muddy sediments (calcschist). On promontories, pure limestones can be found (7).

⇨ Between stops E7 and E8 the small path going down to Seppey (Seppec) leads to itinerary A.

■ **<u>Stop E8</u>: rock outcrop**

❍ A little farther, at the level of the bus stop Seppey (1690m, 46°04 ' 41 " _ 7°31 ' 40 "), and of a barn to the left of the road, we arrive at an outcrop of layered yellowish to greenish altered prasinites (former submarine volcanic tuffs). Then, 50 m farther (46°04 ' 39 " _ 7°31 ' 41 "), we enter a series of outcrops of serpentinite, a first outcrop is found just before the road goes down, the second at the bottom of the slope on both sides of the stream.

Serpentinites are former rock of the Earth mantle grouped under the label of peridotites. They are magmatic ultramafic rocks (or ultra-basic) constituted by large crystals of olivine (peridot) and pyroxene, on this photo the crystalline texture is still visible in the dark part. The largest part of the original crystals is now replaced by serpentine (where from the name serpentinite).



The serpentine takes diverse aspects, along numerous cracks and fractures that characterise these rocks, the mineral aligned itself form sorts of coarse gleaming fibres, of green tint. These fibres can be even more transformed to give asbestos or talc.
The transformation of peridotites already begins during their uplift in the mid-oceanic ridges, because of the circulation of very hot water, this is accompanied by an increase of volume that explains that these rocks are highly fractured. During the subduction they can be again transformed by the circulation of fluid and heat.
⇨ At the level of the stream (1673m, 46°04 " 31 ' 7°31 ' 54 ") the path to the right returns on the itinerary A that we can take on the way up towards A6 or on the way down towards A10, (the crossing is in 1660m, 46°04 ' 29 " _ 7°31 ' 53 ").

■ **<u>Stop E9</u>: rock outcrop**

❍ At the level of the bus stop Pra Flori (1700m), begins an outcrop of gabbros quite altered with a yellow patina with rust. In some rare places we can again see the crystalline texture of the gabbro (46°04 ' 24 " _ 7°32 ' 12 "; photo). At first, these basic crystalline rocks contain olivine and pyroxene (as peridotites) and also plagioclase and amphibole. The metamorphism of gabbros can transform them into different types of rocks depending on the conditions of pressure or temperature, when the pressure becomes very high eclogite can be formed.

Here the metamorphism produced mainly a hydrothermal alteration with formation of actinote (clear colour) and chlorite (dark colour). As for peridotites, transformation of gabbros already started within the mid-ocean ridge and continued during their subduction. These gabbros represent the magmatic chambers that formed under the mid-ocean ridge, giving basalt flows at the surface. These magmatic chambers were situated several kilometres under the oceanic floor. Thus the series serpentinite (peridotite ), meta - gabbro, prasinite (meta basalts), represents the oceanic floor, we call this series «ophiolite». The outcrops between the stop E7 and E9 thus represent a cross-section through the oceanic lithosphere of the alpine ocean. The rusty colour of these rocks (gabbros, peridotites) at the surface is due to the presence of iron, formerly in the form of magnetite.

⇨ continuing the road we can see that the gabbros are more and more altered and slaty because we approach the Dent-Blanche nappe and a major thrust fault in the Alps, the former limit between the European and African plates

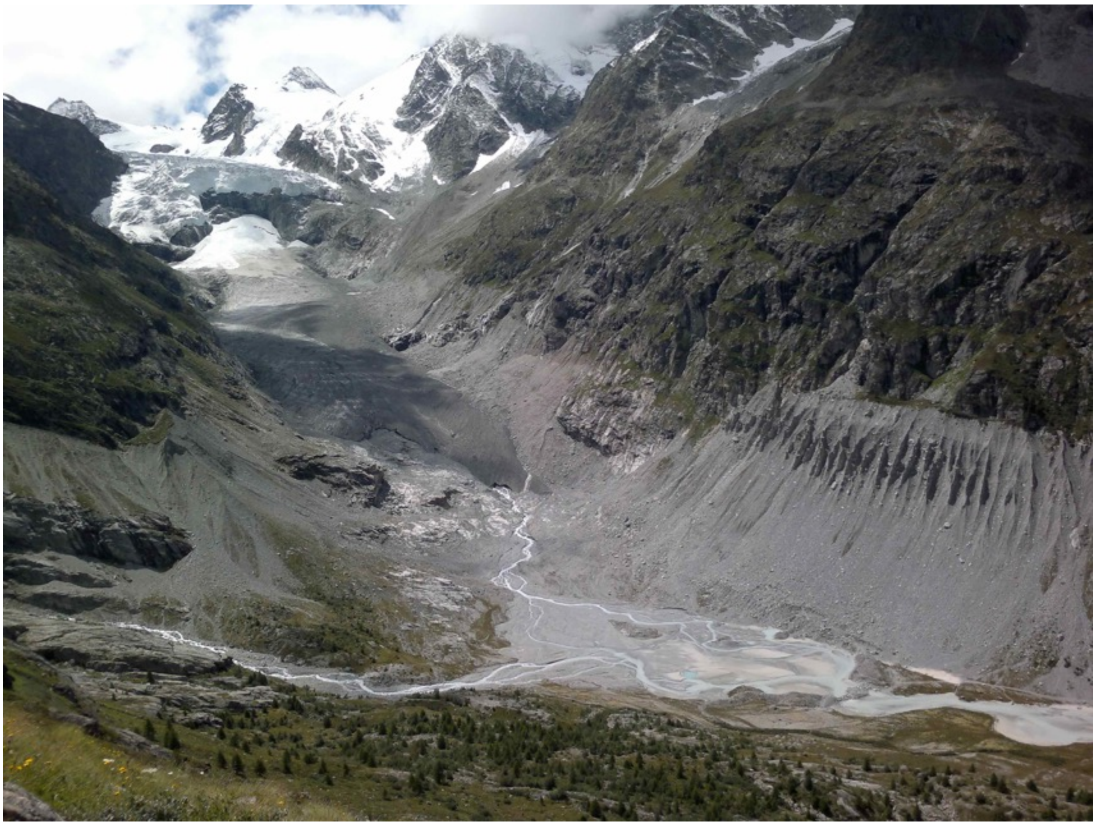
## ■ <u>Stop E-10</u>: rock outcrop

❍ At the level of the tunnel (1720m) we enter the Dent-Blanche nappe characterized by the presence of gneiss. Gneisses present white eyes made of feldspar (we speak about eyed-gneiss or augen-gneiss, photo coin for scale) surrounded with smaller crystals of greyish quartz and with white mica and chlorite forming greenish layers. These layers underline the deformation and the stretching of the rock, it is thus a metamorphic rock which originally was a granite, a magmatic rock formed of quartz, feldspar and mica and which represents former magmatic chambers in a continental environment (whereas gabbros are magmatic chamber in an oceanic or rift environment). Lavas emplaced at the surface from a granite are rhyolites.

These Permian granites of the Dt-Blanche intruded older Palaeozoic rocks (photo on the left). These rocks could be older granites or metamorphic rocks or sedimentary rocks, but they were all (re-) metamorphosed and deformed and are not easy to distinguish of each other. This explains that we can meet many variations in the aspect of rocks forming the Dt-Blanche nappe, including very different rocks such as metagabbros (they form the Mount Collon for example). These gabbros were also intruded in the Permian era, during the opening of rift valleys related to the collapse of the Carboniferous cordillera.

Here in the entrance of the tunnel, gneisses are very deformed breaking into slabs, marking well the major limit between the two plates.

NB: this over-thrusting limit was transformed into a normal fault during the exhumation of the rocks of the suture (rocks from E7 to E9, these were at more than 30 km of depth); rocks situated over this fault are less metamorphic than those situated under, while in an overthrust it is generally the opposite.



⇨ From the tunnel we can continue on foot or by car up to the parking lot then go to stops A8 (46°03 ' 17 " _ 7°33 ' 02 ") and A9 (1960m, 46°3 ' 0 " _ 7°33 ' 11 ") to observe the effects of the last glacial advance of 19th century, as well as the very fast retreat of the glaciers since around thirty years ago.