

# Geological and archeological visit of Geneva

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## Foreword

After the glacial retreat marking the end of the last Würm glaciation, humans settled down in the territories located north of the Alps during the late Paleolithic (Magdalenian culture), some 13'000 years ago. They chose areas with a favorable environment, particularly those crossed by wild animal herds which they hunted for food (reindeers, horses, etc.). Since early times, the Geneva Basin offered favorable conditions for human settlement, as well because of its topography as its climate. In the Neolithic, the existence of the lake and its westernmost bay (the Bay of Geneva) provided favorable conditions for the settlement of the first farmers. Since the Gallic period, the Geneva hill provided a protected and strategic settling place, where the town of Geneva was founded and never stopped to grow until today.

But what are these natural elements from which the city originated, both in the strict and figurative terms, and what has been the human impact on the natural site since its first occupation? This guide tries to answer these questions as well as others associating the natural site, the town and Geneva surroundings. In order to do that, it presents a short introduction about the natural site, its geology and ancient history. The reader is then invited to visit different places within and near the city, and to familiarize himself more thoroughly with the history of the city site and the Canton of Geneva.

In order to better inform interested readers, this guide also refers to complementary documents and additional bibliography about several topics.

*This chapter is largely similar to the following publication (modified and complemented): Walter Wildi 1997: Géographie historique du plan d'eau et des rives du site naturel au site élaboré: 1. Le site naturel de Genève. In: Philippe Broillat (ed.): Les monuments historiques d'art et d'histoire du Canton de Genève, p. 3 - 13. Soc. Hist. De l'Art en Suisse, éd. Wiese SA Bâle.*

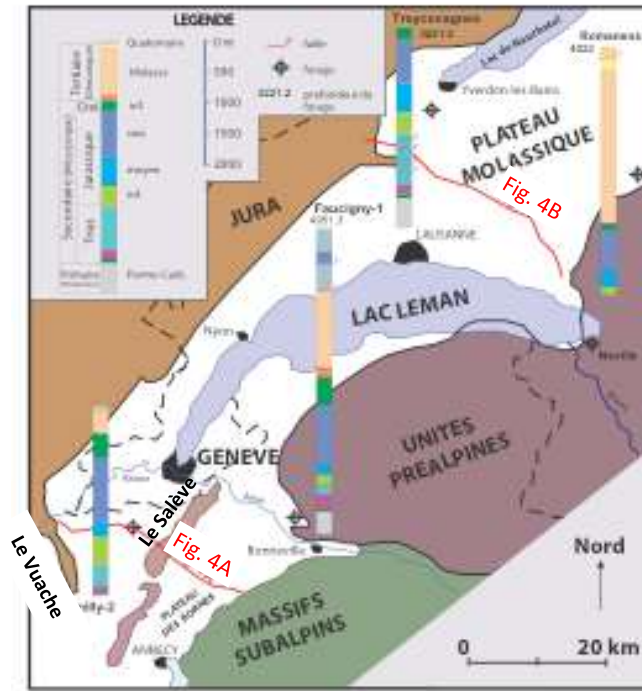
## 1. Introduction

### 1.1.- The natural site

The beginning of the urbanisation coincides with the settling down of the first inhabitants, hunters, fishermen or farmers, but also traders and craftsmen. The outflow area of the lake is particularly interesting for such an urbanisation. It is a zone where one can cross the waters on foot, in a boat, or build a bridge, and where the migration of populations facilitates encounters and trading. Moreover, fishing and lacustrine transport provide interesting economic opportunities. The transition from a small village to a fortified town in order to protect the crossing happened in many other places in those days: in Switzerland, the towns of Constanz, Zürich, Luzern, Thun, Bienne and Geneva provide perfect examples of this situation.

Nevertheless, the building of houses and roads in the outflow zone of the lake may face several problems. Storm waves, lake-level variations, catastrophic and unpredictable flooding events, marshes, a geological substrate often unstable and unsuitable to the construction of buildings were all obstacles to urbanisation. Consequently, the natural sites of towns underwent major transformations and adaptations to human needs, which may sometimes hide their original natural condition.

Geneva, at the western outflow zone of Lake Geneva, is located in a vast topographic depression limited to the north by the Jura Mountain range (reaching an altitude of over 1700 m), and to the south by the Salève Mountain (maximum altitude of 1379 m). This basin is part of the Swiss Plateau and forms its western termination. The Geneva depression is limited to the west by the Vuache Mountain (reaching an altitude of 1105 m), which was uplifted by an important geological lineament linking the Jura to the Salève and subalpine mountain ranges in the area of Annecy (Fig. 1).



**Figure 1:** Schematic map of the geological and tectonic framework of Lake Geneva Basin, with the main geological boreholes and location of geological sections shown in fig. 4 (Gorin et Mascariello 2013, inspiré de Paolacci 2013)

The Geneva Basin, and the Lake Geneva Basin in general, are part of the drainage basin of the Rhône River, which originates in the Canton Valais and contributes for 85% to the water intake of the lake. The present-day water level of Lake Geneva is at 372 m above mean sea level (amsl), whereas the edges of the Geneva Basin, at the foothills of the Jura and Salève mountain ranges, are located at some 500 m amsl.

In Geneva, the average water flow of the Rhône River is of 251 m<sup>3</sup>/sec, and can increase up to 700 m<sup>3</sup>/sec during flooding periods, which are smoothed through the reservoir effect of the lake. The latter is not the case for the Arve River, which drains part of the Mont-Blanc, Platé, Aravis and Bornes massifs. This river is an affluent of the Rhône River, and joins up the latter in the part of Geneva City called «La Jonction» (fig. 2) without having been dammed in any place between its source and Geneva. Its average flow is of 79 m<sup>3</sup>/sec, the maximum flood flow recorded being of 840 m<sup>3</sup>/sec in 1968.

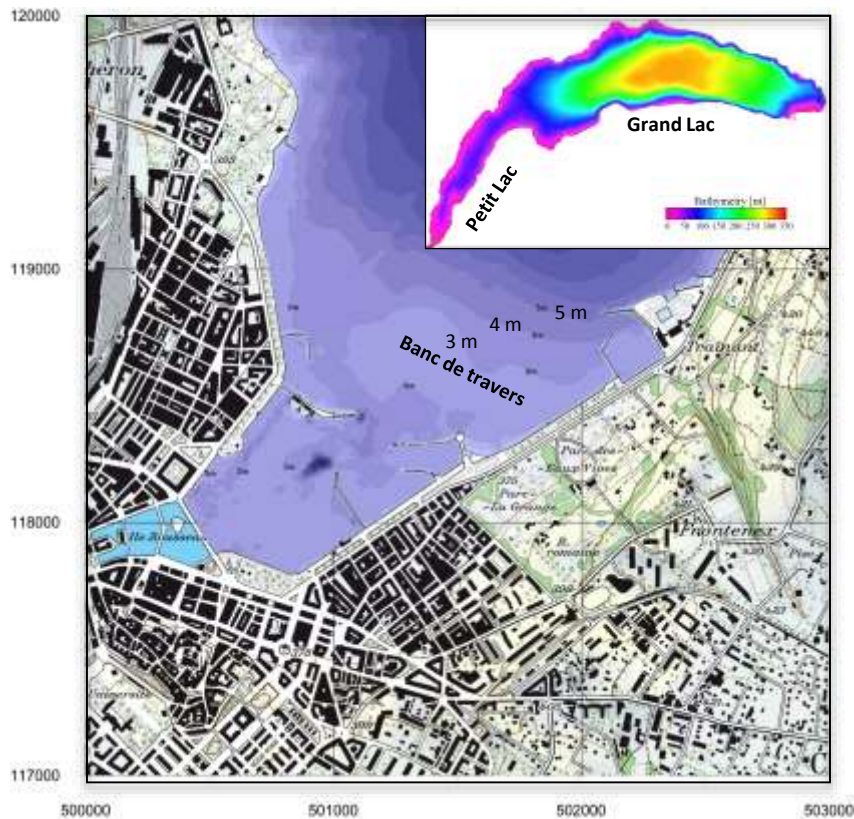


**Figure 2:** Map of Geneva City and its surroundings, 1851 (Collection of the Geneva Centre of iconography N° 39P90). The map shows the situation existing prior to the dismantling of the fortifications surrounding the old part of the city.

The Arve River carries a heavy load of sediments (gravel, sand, silt and mud) which is capable of modifying the landscape in the confluence zone with the Rhône River during flooding periods.

Lake Geneva covers a surface of 582 km<sup>2</sup>, and reaches a total axial length of 72.3 km, a maximum width of 13.8 km and a depth of 309.7 m in its central part. Its volume of 89 km<sup>3</sup> makes it the largest freshwater reservoir in Western Europe. It lies obliquely across the Swiss Plateau between the Alpine front and the Jura mountain range (fig. 1). The ca. 310 m deep basin upstream of Nyon is commonly referred to as the Grand-Lac (fig. 1, 3), whereas the zone comprised between Nyon and Geneva, with depths of less than 70 m (most frequently less than 50 m), correspond to the Petit-Lac.





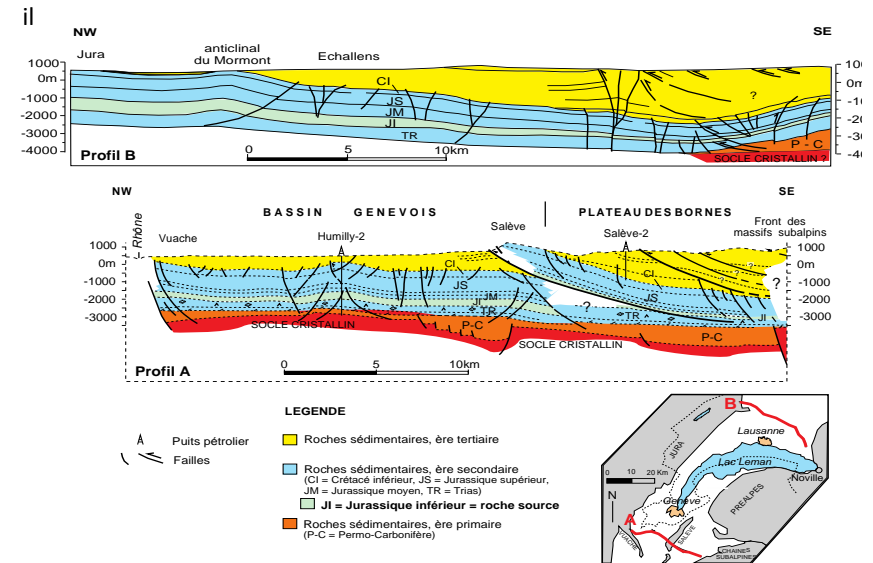
**Figure 3:** Bathymetric map of Lake Geneva and Geneva Bay (Institut F.A. Forel)

The outflow zone comprised between the downstream «Ile Rousseau» and an imaginary upstream cross-line joining up the «Perle du Lac» to the «Port-Noir» is called the Geneva Bay («Rade de Genève»). This imaginary cross-line corresponds physically to a shoal called «Banc de travers» (Fig. 3). It is on this shoal that were located the first coastal villages during the Neolithic and until the end of the Bronze Age (see chapter 1.3)

## 1.2.- Geological history of the Geneva Basin

### From the Alpine sea to the folding of the Jura Mountains

The mountains limiting the Geneva Basin to the north, west and south, i.e. the Jura, Vuache and Salève ranges respectively, correspond to tectonic structures uplifted through folding and thrusting associated with the final phases of the Alpine orogeny some 5 to 10 millions years ago. Nowadays, these movements are still expressed through a relative seismic activity (Figs. 1 and 4).

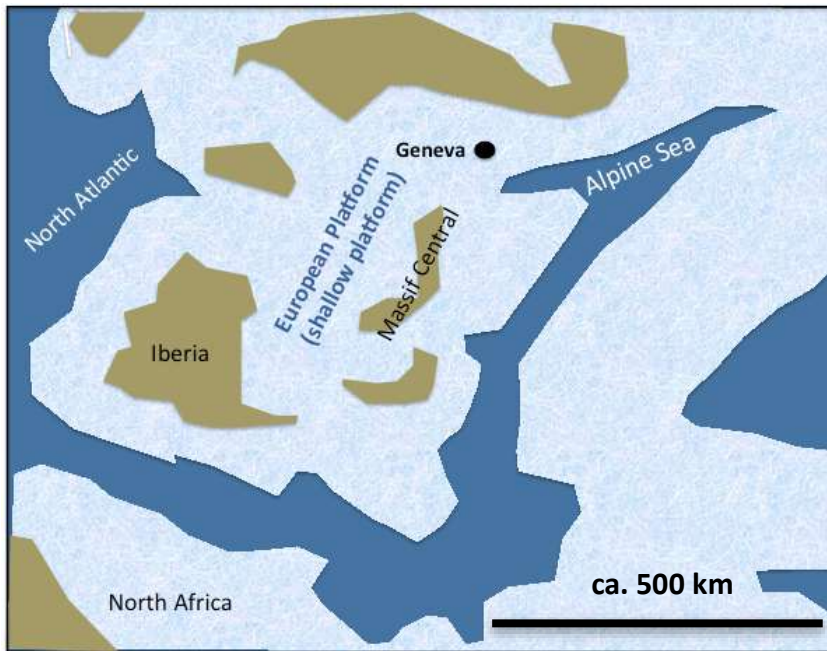


**Figure 4:** Geological cross-sections of Lake Geneva and Geneva basins. See fig. 1 for location of sections (Gorin et Mascariello 2013, modified from Gorin et al. 1993).

<sup>1</sup> The Earth and Environmental Science Section at the University of Geneva houses a seismograph that records earthquakes. The recent records can be consulted at the Rue des Maraîchers 13 (ground floor) during University office hours.

These structures brought to surface the strata of carbonate rocks originally deposited on a marine platform at a water depth ranging from 0 to 100 m, during the Jurassic and Cretaceous (some 145 to 100 millions years ago for the rocks presently visible at surface). This carbonate sedimentation came to a halt some 70 millions years ago, and after that part of the strata was eroded. The carbonate platform was located on the European margin of the Alpine sea, which separated Europe from Africa during the Mesozoic (Fig. 5).

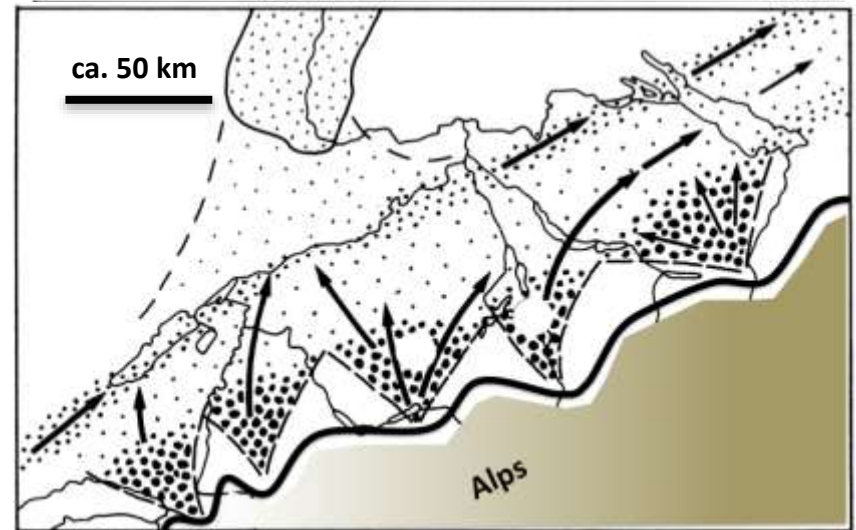
Geological formations of the Jurassic and Cretaceous do not outcrop in the Canton Geneva, but corresponding carbonate rocks play an important role as constructing material (see visits in chapter 2).



**Figure 5 :** Paleogeography of the Alpine sea during the Late Jurassic (about 152 millions years ago): Light blue: marine platform and slope; dark blue: deep seas and oceanic zones; brown: continental zones. At that time the Geneva region was located on the European platform covered by a shallow tropical sea (highly simplifies after <http://cpgeosystems.com/mollglobe.html>)

The **Tertiary Molasse** overlies the carbonate strata of the Cretaceous. It is essentially made of sandstones, marls, intercalations of gypsum and, in the vicinity of the Alps, of conglomerates. The constituents of the latter come from the erosion of the Alps which were being uplifted (Fig. 6). The thickness of the Molasse below the city of Geneva reaches about 1 km. It represents in geological time part of the Oligocene period (approximately 30 to 25 millions years). These deposits were originally deposited over the whole area north and west of the Alpine front, but were subsequently eroded over the Jura and Salève folds. In the Geneva Basin, the Molasse is made of two formations: the « Red Molasse » and the « Grey Molasse ».

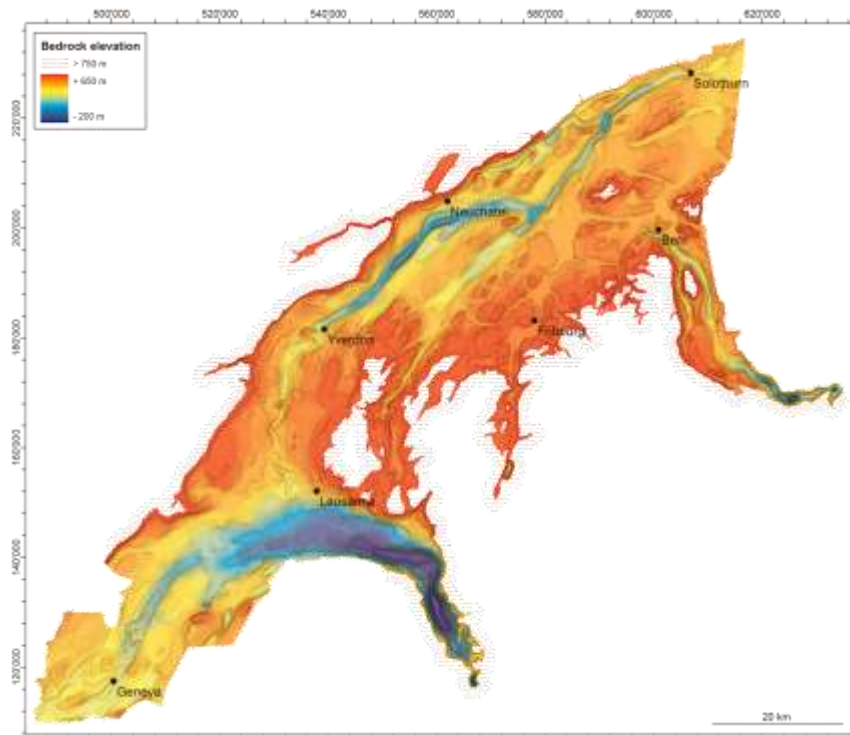
Molasse strata are not outcropping within the area of the Geneva City, but are visible in the small valleys eroded by rivers in the glacial deposits in the countryside surrounding the city. Molasse rocks have been exploited as construction material in the coastal zones on both sides of Lake Geneva until the 18th century, during the winter when the lake level was lower.



**Figure 6:** Paleogeography of the Alpine foreland in the late Oligocene (ca. 30 millions years). Sedimentation of the «Red and Grey Molasse». The Lake Geneva Basin is located within the depositional zone of the Mont Pèlerin fan, where conglomerates, sandstones and marls derived from the erosion of the Alpine range were accumulated. Summits of the latter reached altitudes of over 6'000 m (after Trümpy 1980).

## Glacial ages

The topography of the top of the Molasse bedrock below the Geneva basin, most often covered by more recent deposits, is characterized by SW-NE trending mounds and grooves (fig. 7). West of Geneva City, the deepest grooves reach depths of around 300 to 350 m amsl, whereas the mounds (e.g., that of the Bernex village) are higher than 450 m amsl. In Lake Geneva, the top of the Molasse bedrock dips towards the City of Lausanne and then towards the Alpine front, where it may reach a depth of about 200 m below msl. This topography of the bedrock is essentially the signature of glacial erosion in the Molasse during the Quaternary, particularly during the Pleistocene since two millions years.



**Figure 7:** Topography of the bedrock surface below Pleistocene glacial, lacustrine and fluvial sediments in Western Switzerland (J. Fiore 2007)

The glaciers that covered the Swiss Plateau were sourced from the Alps. A small ice cap was also covering the crest of the Jura Mountains. With temperatures much lower than present-day ones, the glacier accumulation zones reached low altitude areas and glacial tongues temporarily flowed down the Rhône Valley, and eventually extended down to the city of Lyon in France. The signatures that the glacier left in the landscape testify to processes which took place below the ice, on top, at the front and on the flanks of the glacier. The maximum extension of Alpine glaciers during the last glacial age is illustrated in fig. 8.

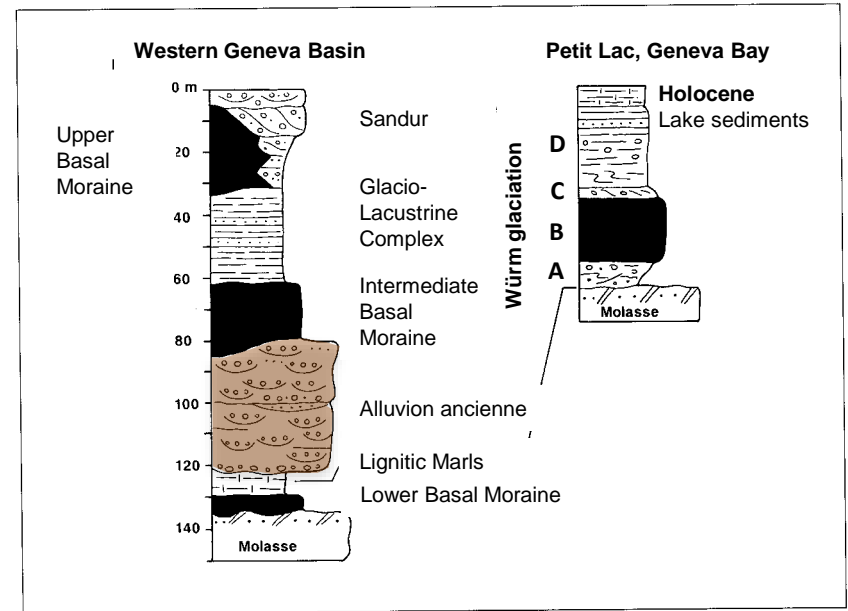


**Figure 8:** Maximal extension of Alpine glaciers during the last glacial age (map by Bini et al. 2009), © 2014 swisstopo (BA14046).

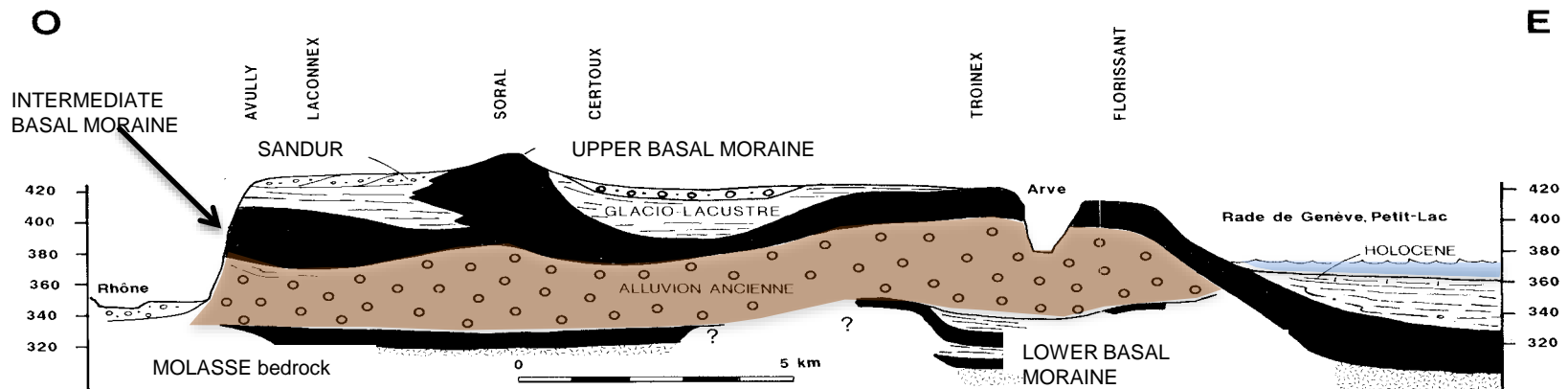


In the Lake Geneva Basin, the first imprints of glaciations are encountered south of Palézieux (Canton Vaud) between Ecoteaux and Maraçon villages at an altitude of 800 m amsl, where deposits of an older lacustrine delta can be observed. This delta can be linked to glacial moraines and lacustrine sediments, part of which is older than the last inversion of the terrestrial magnetic field some 860'000 years ago. The glacial moraines correspond to those of the so-called Günz Glaciation. Up to five glacial advances during the middle and late Pleistocene are documented in the Aubonne Valley near Morges, and in time-equivalent deposits on the southern shore of Lake Geneva related to the Dranse Valley in France. In the vicinity of Geneva, such imprints of older glaciations are encountered in Lake Geneva as deep grooves cut into the Molasse through the Rhône Glacier. These grooves are also known from boreholes in the Geneva Basin (Amberger 1978, Wegmüller et al. 1995, Arn 1984, Brun 2000, Fiore 2007, Fiore et al. 2010, Moscariello et al. 1998, Pugin et al. 1993).

Fig. 9 summarizes the glacial sediment succession in the Bay of Geneva and outside the lake. A synthetic geological cross-section of glacial deposits in the western part of the Geneva Basin is shown in fig. 10. The glacial history of the Geneva Basin is further summarized in fig. 11 and 12.



**Figure 9:** Sedimentary succession from the last glaciation (Würm) until today in the Petit Lac and Geneva Bay, and in the western part of the Geneva Basin (Wildi 1997). Unit A: Gravels et sands sheared by ice; Unit B: basal moraine deposited under the glacier; Unit C: Gravels and sands deposited through the under-glacier torrent at the front of the Rhône Glacier; Unit D: glacio-lacustrine sediments deposited at the front of the retreating glacier.



**Figure 10:** Synthetic geological cross-section of glacial, fluvial and lacustrine deposits in the western part of the Geneva Basin (Wildi 1997).



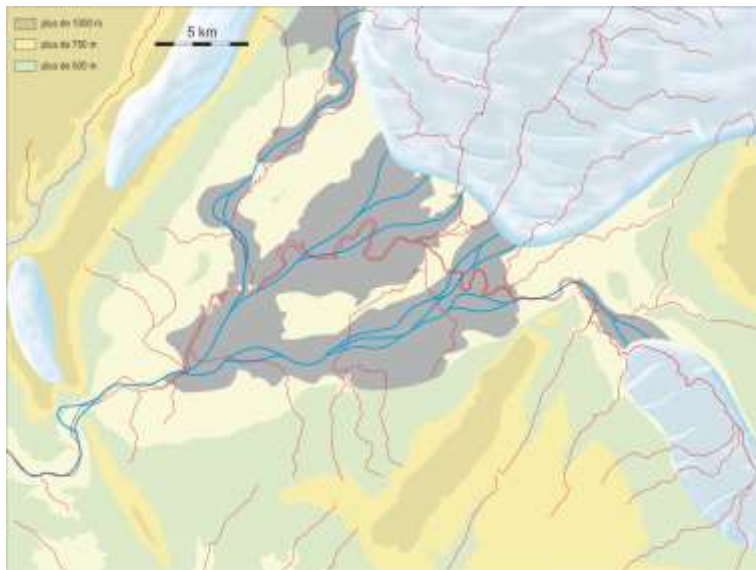
**Figure 11:** Landscapes of the Geneva Basin during the last glacial age. Indicated ages are approximate.



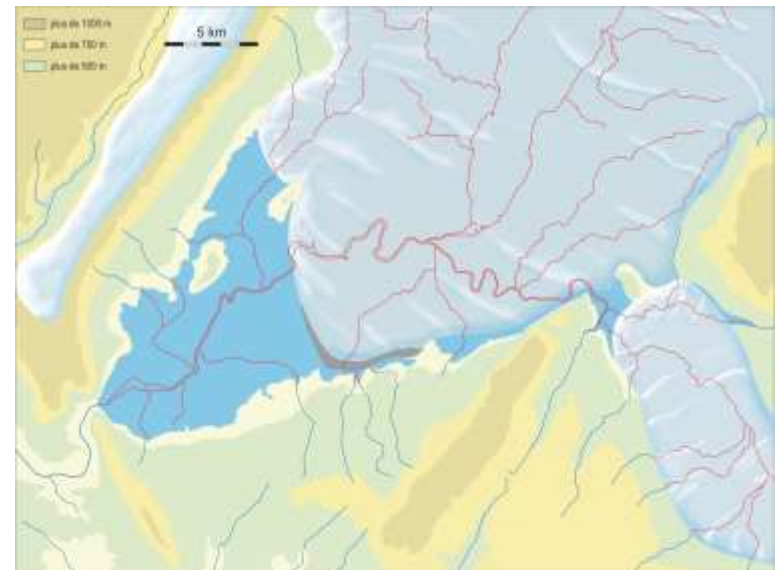
**a)** 70'000 – 60'000 years B.C.? Maximum extension of glaciers during the last glacial age (Lower Basal Moraine).



**c)** Situation around 30'000 years B.C.? Glacial readvance in the Geneva Basin (deposition of the Intermediary Basal Moraine).

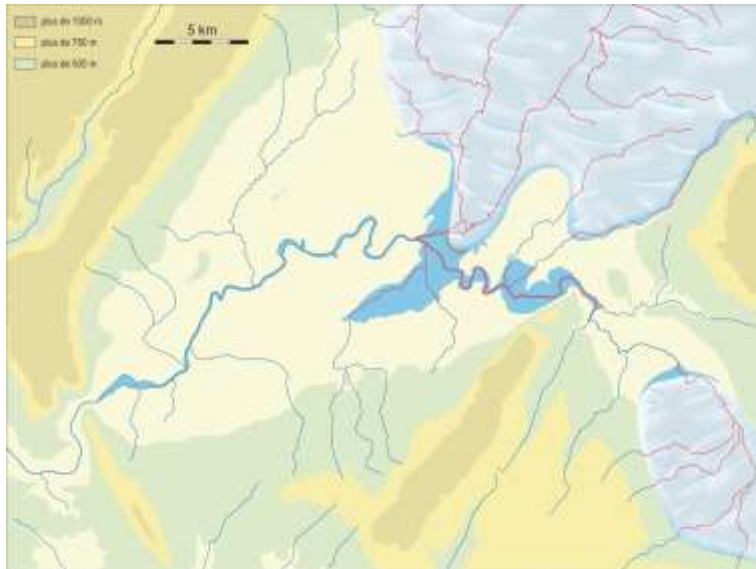


**b)** Situation around 38'000 – 35'000 years B.C.? Deposition of the gravels forming the Alluvion ancienne (alluvial plain in grey).



**d)** Situation around 23'000 years B.C.: Laconnex stage, 470 m lake (deposition of Upper Basal Moraine).

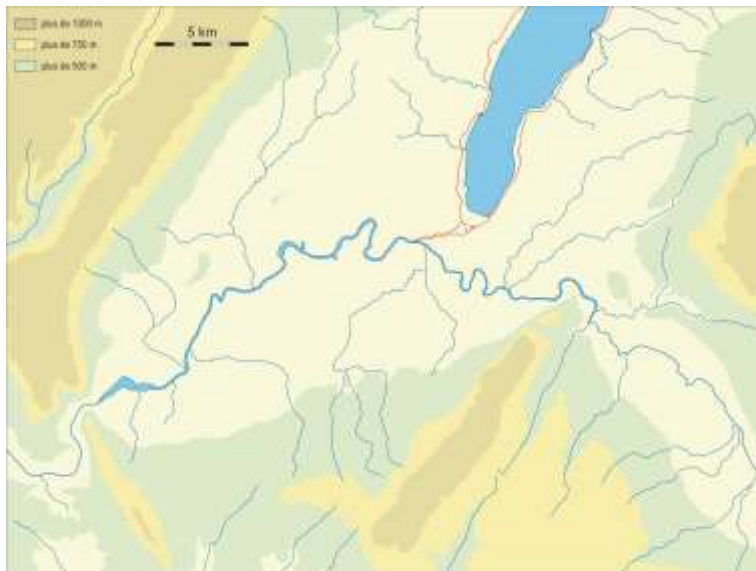
**Figure 12:** Landscapes of the Geneva Basin after the retreat of the glaciers.



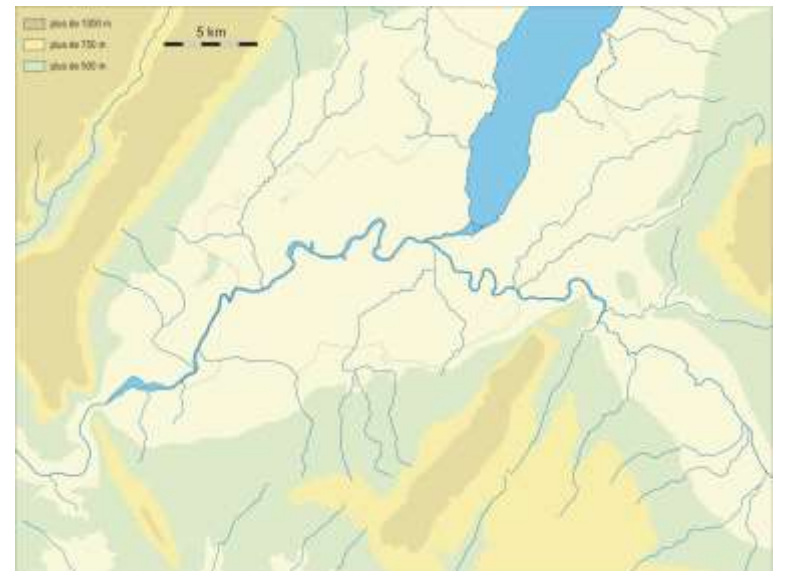
**a)** 20'500 years B.C.: Geneva stage, 405 m lake. Deposition of the glacio-lacustrine Saint-Antoine Delta and the Pierres du Niton.



**c)** Roman times, during a high lake level at 375 m.



**b)** around 1'000 years B.C.: low lake level (< 369 m), period of the prehistoric pile dwellings.



**d)** present-day lake at 372 m.



In the terrestrial part of the Geneva basin, the **Lower Basal Moraine** rests on top of the Molasse bedrock eroded during the older glaciations. This first moraine of the Würmian glaciation corresponds probably to the maximum extension of the Rhône Glacier when it reached the Isère Glacier and eventually the Lyon area (fig. 11a). Lacustrine or marsh deposits (**Lignitic Marls**) locally overlie this moraine and testify to the retreat of the Rhône Glacier up to the Lake Geneva Basin and to the presence of shallow lakes and marshes in the western part of the Lake Geneva Basin.



1. In geology, lands of same composition that can be observed and mapped in the field are « geological formations ». Most often they are named after either their lithology (gravels, marls, limestones), or a place. «*Alluvion ancienne*» is a word used since the 19th century and formally introduced in 1879 by Alphonse Favre. It describes the formation of strongly cemented gravels and sands (conglomerates) forming the cliffs bordering the Arve River (Champel cliffs) and Rhône River (St Jean cliffs). These gravels were deposited during the last glacial age by rivers flowing at the front of the Rhône and Arve glaciers.

**Figure 13:** Outcropping conglomerates and sandstones of the «*Alluvion ancienne*» along the access path to the Bois de la Bâtie (chapter 2, site **Ge 1.2**; height: ca. 2 m).

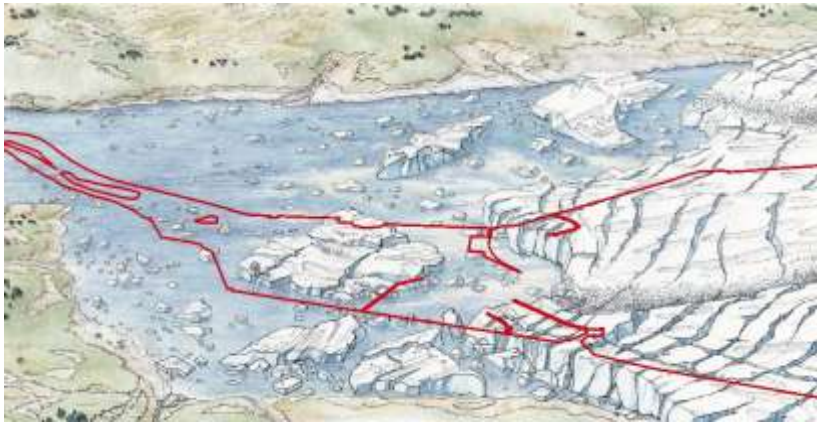
Gravels and sands of the « **Alluvion ancienne**<sup>1</sup> » which overlie the Lignitic

Marls represent the deposits of a large fluvial plain (or *sandur* in the geomorphological terminology) at the front of the Rhône Glacier which was probably located at the level of the Petit-Lac. The river feeding this *sandur* was organized in several channels (braided-stream river) separated through gravel and sand bars (fig. 11b). These sediments outcrop nowadays as carbonate-cemented conglomerates and sandstones in the cliffs bordering the Rhône and Arve rivers (fig. 13).

Following another degradation of the climate, the Rhône Glacier readvanced a last time over the « *Alluvion ancienne* », locally eroding the surface of the gravel terrace and depositing a significant layer of moraines in a large part of the Geneva Basin, called the **Intermediary Basal Moraine** (figs. 9, 10 and 11c). Deglaciation in the Geneva Basin began with a glacier retreat up to Laconnex village (fig. 11d) where a morainic *vallum* was formed (**Upper Basal Moraine**). A lake existed at the front of this *vallum*, being filled by the **Glacio-lacustrine Complex** and the **Sandur** (fig. 11c). Upstream of this Laconnex stage the Intermediary and Upper Basal Moraines can not be distinguished from each other. When the glacier of the Laconnex stage retreated, a new lake formed in the Plaine de l'Aire area (fig. 11d: 400 m lake), progressively filled by fine sediments, grading upwards to peat.

During its phase of melting, the Rhône Glacier stopped for some time at the level of Geneva City. Gravels and sands brought in by the underglacial stream accumulated as a sub-lacustrine delta (**Saint-Antoine Delta**), which forms the relief upon which the city was built. From the Geneva City to the Aire River alluvial plain a new lake was formed (fig. 12a: 405 m lake), which was finally filled by fine sediments, grading upwards into peat deposits.

In the center of the Petit-Lac and Geneva Bay Basin (figs. 9 and 10) the sedimentary succession comprises the deposits of only one glacial cycle. The latter consist of gravels and sands sheared by the movement of the glacier and overlain by a compacted basal moraine and a succession of **Glacio-lacustrine Sediments** deposited during the deglaciation. The «*Pierres du Niton*» are part of this sequence. The discovery of wood fragments in the gravels and sands overlying directly the moraine give an age of around 22'500 years (calibrated age obtained from carbon 14 datation). fig. 12a shows the reconstitution of the Petit-Lac and Geneva Bay deglaciation at that time, with a lake level situated at approximately 405 m ams, and lowering progressively down to 400 m.



**Figure 14:** deglaciation of the Geneva Bay with a lake level at 405 m amsl. Red lines indicate the recent shores of Lake Geneva and Rhône River (drawing by Yves Reymond, in: Gallay 2008 "Des Alpes au Léman".)

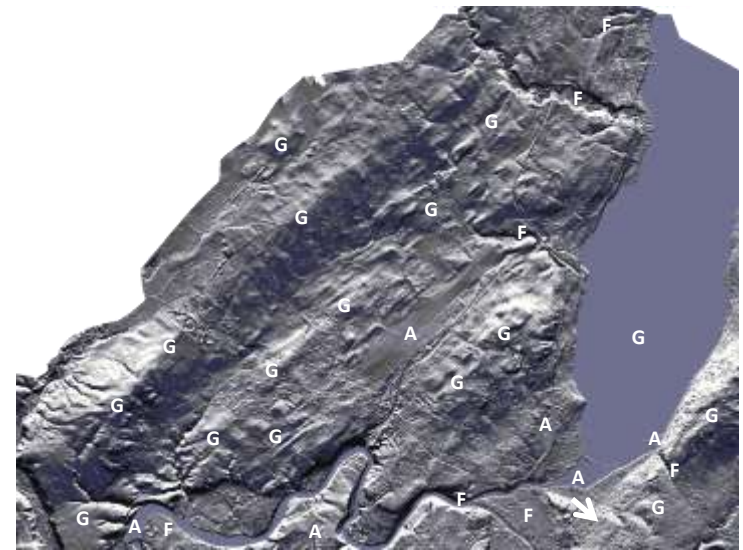
## The Holocene, the Post-glacial period

Whereas the Geneva Basin (outside of the glaciers and lake) was covered at the end of the last glacial age only by a low-diversity flora made of grasses, lichens and mosses, small pioneer trees and flowers were beginning to colonize the ground during the so-called Tardiglacial period. This period ended some 11'000 years ago with a significant climate improvement and passed to the Post-glacial (or Holocene) period. The evolution of the environment at the end of the last glacial age is schematized in fig. 17 using sedimentological indicators in the Petit-Lac and pollen encountered in the sediments. During the Tardiglacial, the level of Lake Geneva continuously dropped to reach a level close to the present-day one approximately 10' 000 years ago. This was the result of the erosion of sills, moraines and other obstacles damming the outlet of the lake. In the Geneva Bay and the Petit-Lac, chalk deposits and fine-grained deposits («muds») rich in organic matter terminate the sedimentary sequence (Moscariello 1996, Fiore 2007, Girardclos et al. 2005).

The lake extension towards the area of La Jonction and Carouge must have

been rapidly filled in by the influx of sediments brought in by the Arve River, thereby transforming the former lake into an alluvial plain. From then on, the Arve River was not anymore flowing into the lake, but directly into the Rhône (visits **Ge 1.1** et **Ge 1.2**). And because the level of the Rhône River bed determined the topographic level of the lake outlet, any plugging of the Rhône River bed through a massive influx of gravels from the Arve River could lead to a lake level rise. By contrast, the base level of the lake outlet was determined by the very cohesive nature of the moraine in the Rhône River bed (see chapter 1.3 concerning observed variations of Lake Geneva level).

The result of glacial, fluvial and lacustrine processes and of human activity which carved the landscape of the Geneva Basin are perfectly illustrated on the digital elevation model of fig. 15.



**Figure 15:** digital elevation model of the northern side of Lake Geneva and Rhône River In Canton Geneva (Fiore 2007). A: human-made morphology (railroad, airport, motorways, lacustrine embankment, dams), G: glacial morphology, most often drumlins (rocks and moraines carved through the ice flow), F: fluvial erosion following the last glacial Age (post-glacial and Holocene).



## Natural risks, tsunamis in Lake Geneva

Geologists or geophysicists will à priori not be very much bothered by the natural risks that might threaten the buildings and inhabitants of the Geneva Basin and City of Geneva. Indeed, this basin presents only a low relief, except for the zones affected by major geological accidents. Nevertheless, some events with a geological or climatic origin can be identified in the history of this region. Among others, it is worth mentioning:

- **Hydrology:** historical floods of the Arve River breaking up bridges have been reported in Haute Savoie and Geneva City in 1404, 1570 (flooding of the Plaine de Plainpalais and backflow of the Arve and Rhône river waters towards the lake), 1733 (destruction of bridges crossing the Arve River), 1852, 1859 and 1888 (flooding of the alluvial plain and backflow of river waters towards the lake; see also visit Ge1). This risk is presently decreased through the human-made channelization of the river (see: <http://www.riviere-arve.org/territoire/inondations-memorables-arve.htm>).

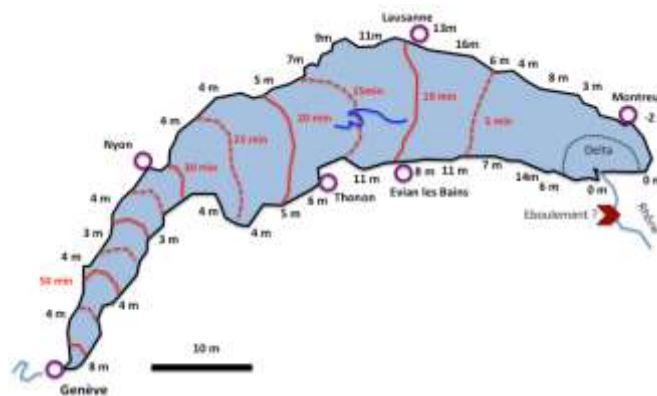
- **Slope instabilities:** these phenomena are observed mainly in erosion reliefs. For instance, large conglomerate blocks of «Alluvion ancienne», encountered at the base of the cliffs formed by this formation, testify to rockfalls occurring more or less regularly in time. Rockfalls from the cliffs in the area of St Jean may even have formed at one stage obstacles to the free flow of the Rhône River waters (visit Ge 3). Moraines may even cause slope

instabilities, not so much in Geneva City, but for example along the reservoir lake of the Verbois Dam, where a large landslide is a major threat on the right shore of the lake, between the village of Peney and the dam.

- **Earthquakes:** the epicenters of earthquakes felt in Geneva City are located in other geological regions, namely in the area of Annecy, along the Vuache Fault, in the Chablais Prealps, in the Jura Mountains or even in Canton Valais. Some important faults, for instance those following the front of the Salève range or those linking the Alpine front to the Jura Mountains are presently inactive, but could well be reactivated one day (Hernandez – Trevethan, 2010).

- **Tsunamis in Lake Geneva:** historical archives tell us that in 563, following the Tauredunum rockfall, the Lake Geneva region was hit by a tsunamil which flooded its shores, destroyed mills and the Geneva bridge, killed men and cattle herds and finally entered the City of Geneva. The study of sediments at the bottom of the Grand-Lac (east of the city of Nyon) reveals

a 1 to 7 m thick gigantic deposit which blankets all of the deep basin bottom and is contemporaneous with the Tauredunum event. It consists of a giant turbidite with a volume of 0.25 km<sup>3</sup>, the movement of which was most probably initiated through the destabilisation of the Rhône delta, following the impact of the rockfall on the subaerial part of the delta. This sediment volume has been used to model the height of the tsunami wave created through the displacement of sediments in the lake. The numerical model shows a wave height of 8 m in the Geneva area and of 13 m in the Lausanne area. This is conformable with historical data which report inflow of water within Geneva City, because in the 6th century, the latter was located on the Old Town hill (fig. 16). These results demonstrate that tsunamis in a lacustrine environment should not be underestimated (Montandon 1925, Kremer et al. 2012). Other tsunamis probably occurred in the Lake Geneva Basin during prehistorical times.



**Figure 16:** simulation of the tsunami wave in Lake Geneva caused by the impact of the Tauredunum rockfall on the subaerial Rhône Delta in the area of Villeneuve. The time of arrival (in minutes) of the first tsunami wave is shown in red, the wave height in metres is indicated in black along the coastline of the lake. The black contour line in the centre of the basin marks the extension of the sediment mass that slid from the delta area, thereby forming an enormous «turbidite» (mudflow).

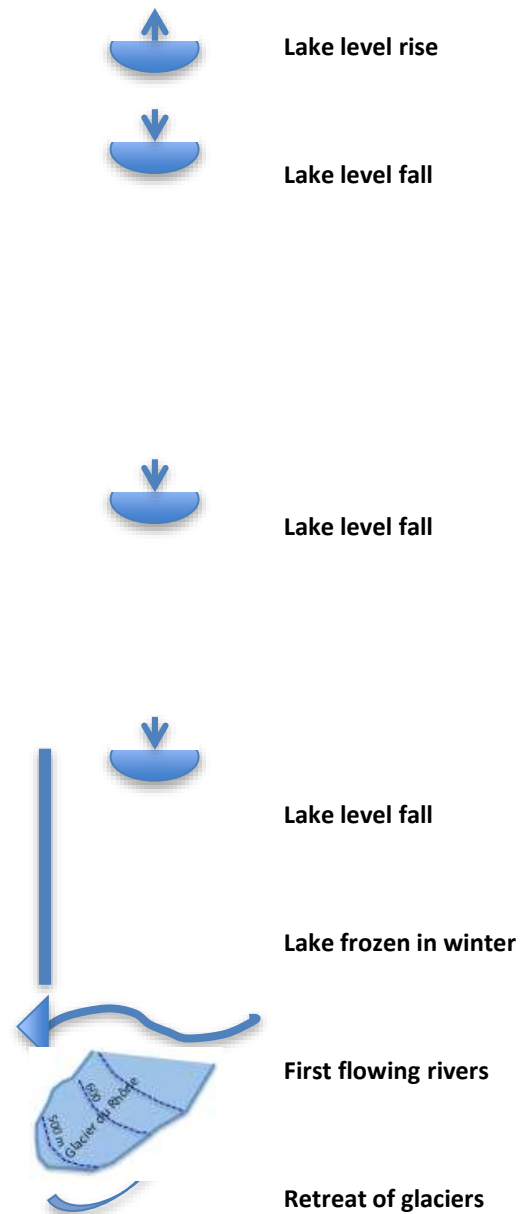
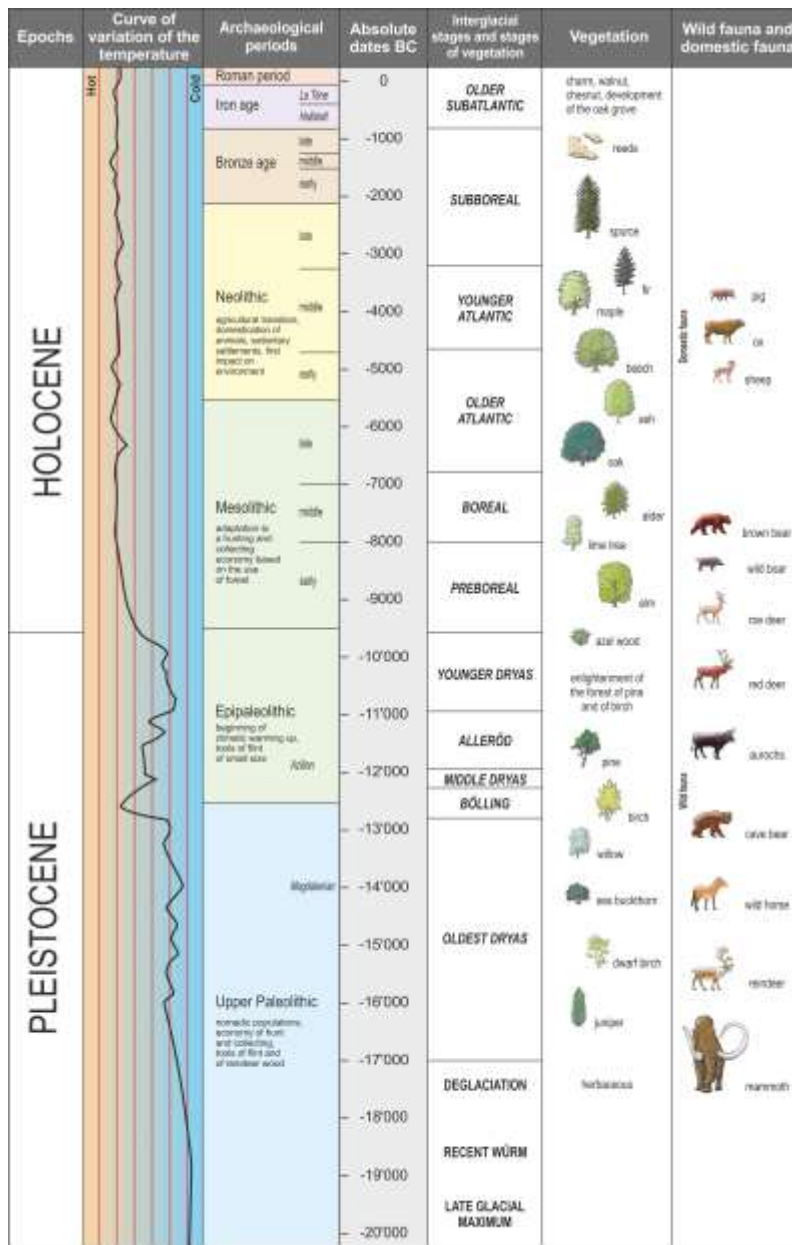


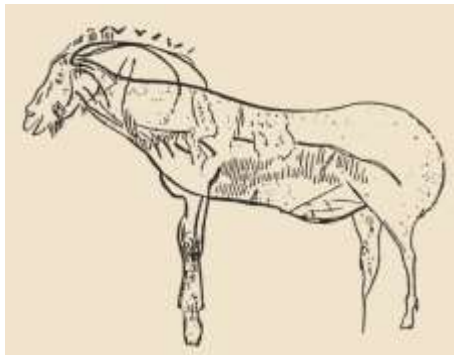
Figure 17: synthetic chart showing the evolution of the environment in Lake Geneva area since the end of the last glacial Age (Corboud 2013, Girardclos 2001)

## 1.3 – Human occupation of the Geneva site

After the final retreat of the glacier from Geneva, the first people to arrive in the area were hunters of reindeers and wild horses. They belong to the Magdalenian culture (Upper Paleolithic). Walking the Rhône Valley upstream from south to north, they followed the game which was itself attracted by the meager herbaceous vegetation of the type growing in a steppe or tundra. The only arboreal species were the juniper tree, the dwarf willow tree and later the dwarf birch tree.

The camp traces of these hunters have been found in shelters beneath blocks of limestone at the foot of the Salève, in the municipality of Etrembières not far from Veyrier. This first human presence dates back to 13'000 years B.C.. These camps were temporary and occupied cyclically or seasonally. The Lake Geneva level was still eight to ten meters higher than at present day. This did not prevent the reindeer hunters to roam the shore of the lake, where water attracted herds of reindeers and wild horses.

The product of the activity of these first «Genevan» people was both modest and very well adapted to their way of life: spear heads made of reindeer horns, scrapers, blades and chisels made of silex, harpoons with remarkably thin barbs. Not forgetting jewelry such as Mediterranean shells or lignite pearls, or everyday objects very nicely decorated.

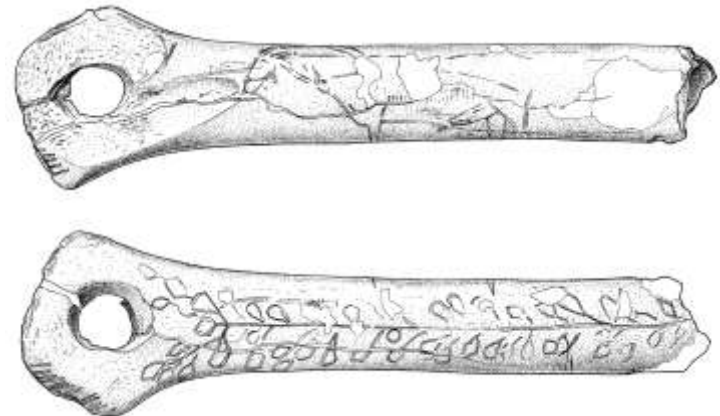


**Figure 18:** the Veyrier site is famous for its pierced sticks made of reindeer horns, probably used to straighten the spear heads. One of these is magnificently decorated with the engraving of an ibex. On the back of the same stick, a vegetal pattern suggests a branch of birch tree.



**Figure 19:** while they were passing through the Geneva Basin, the Magdalenian hunters established their camp underneath large blocks of limestone that had fallen down from the Salève cliffs during the retreat of the glacier.

The most appreciated animal species was the reindeer. Its meat provided food, its skin was used to make clothes and its horns were cut into tools and weapons (drawing by André Houot in: Affolter et al. 2012 «La Haute-Savoie durant la préhistoire»).



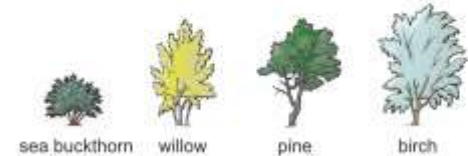
The high density of modern constructions around the lake and ground disturbances undoubtedly erased all traces of human occupation which followed. The climatic warming, which started at around 8500 years B.C., led to an important evolution of the landscape. The sparse arboreal cover was replaced by dense forests where broad-leaved trees dominated, for example the oak tree, the hazel tree, the elm and the lime tree. Cold animal species were replaced by a forest fauna more adapted to this new environment. The prehistoric man also adapted himself, with a still nomadic way of life, but over a smaller territory between plain and middle mountain sites. Lake shores and marshes were popular camp sites. Some of them are known in the Lake Geneva Basin, but unfortunately not in the Geneva area, which is too developed and where the ground has been too much reworked.

A climatic optimum occurred around 5000 years B.C., during which the average temperature was higher than the present-day one. The first farming communities originating from the Mediterranean region settled down on the Swiss plateau and in Valais. They brought with them the agriculture and cattle breeding which had appeared some 3000 years earlier in the Middle East.

Late-glacial vegetation:  
from 17'000 to 13'000 BC



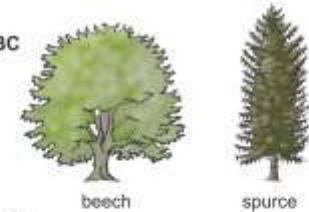
First sparse forest:  
from 13'000 to 9500 BC



Expansion of deciduous forest:  
from 9500 to 4500 BC



Development of beech and spruce,  
human influences: from 4500 to 3500 BC-1000 BC



Deforestation promotes the expansion of the birch,  
alder, hazel and juniper,  
development of the reeds:  
from 3500-1000 BC



**Figure 20:** evolution of the vegetation and of the forest cover between the glacier retreat and 1000 years B.C.. Represented species correspond to those new ones which appeared in relation with the climate and human influence. The others remained, but in smaller proportions (drawings by Yves Reymond).



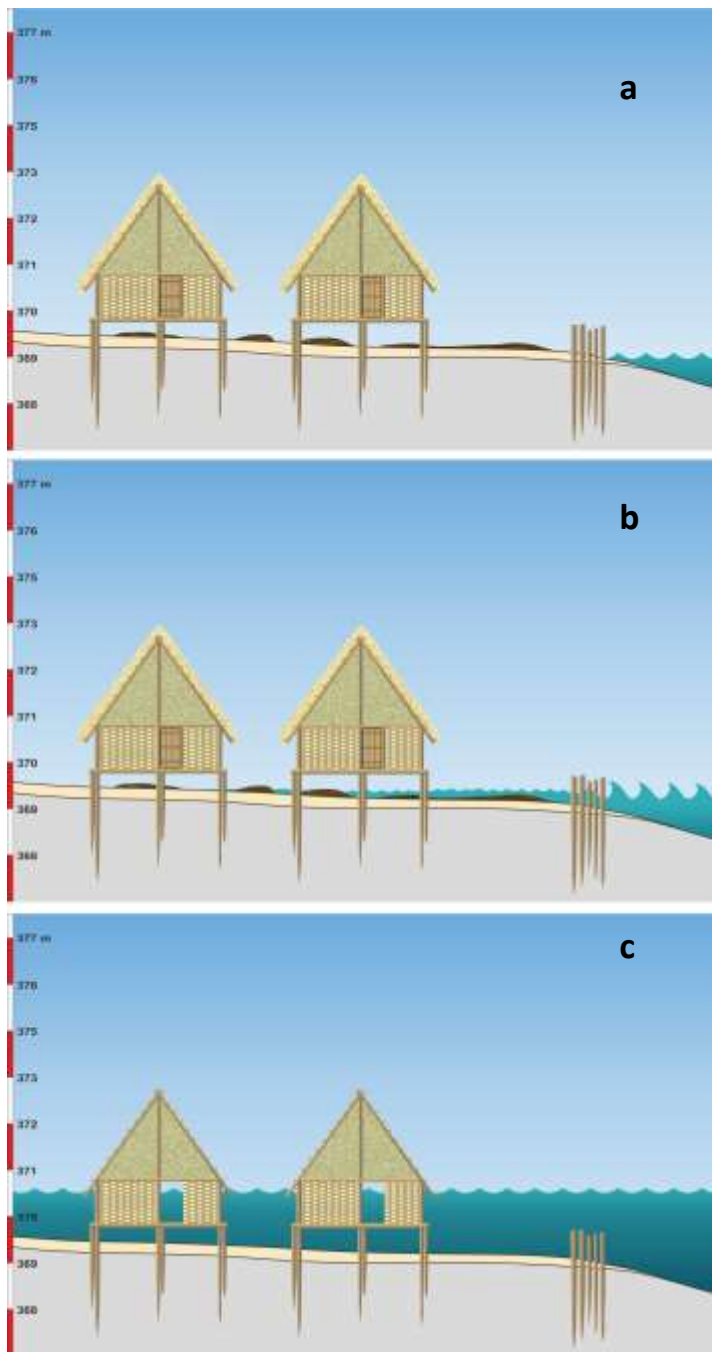
This new way of life coincided with the first impact of man on his environment. Cultivated fields replaced forest cleared thanks to the use of polished stone axes. Villages consisted of wooden houses with cob walls and roofs were covered with cereal thatch or small wooden planks. The occupation of these villages was still reduced to two or three generations of some twenty years each. The depletion of soils close to the settlements forced the inhabitants to periodically move towards new land.

The average level of Lake Geneva at that time was close to the present-day one. Nevertheless, temperature and pluviosity changes induced lake level fluctuations following secular rhythms, reaching a maximum amplitude of up to 9 meters (if one takes also into account seasonal variations).

During periods of relative drought, prehistoric men from the Neolithic and late Bronze Age came closer to the lake and built their villages on the emerged coastal terrace. These settlements are called lakeside settlements or pile dwellings, because their traces are encountered today in the form of thousands of stilts hammered into the soft sediments at the bottom of the lakes, where they formed the foundations of abandoned houses.

**Figure 21:** *abandonment of a village in the late Neolithic (around 3000-2800 years B.C.). Following the depletion of cultivated soils around the village, the village community leaves its village on Lake Geneva shore after having set fire to it. One can distinguish around the village the lacustrine chalk beach partially invaded by grasses and the marshy zone located between the settlement and the first moraine grounds. The latter are marked by rows of willow, viburnum and sea buckthorn bushes. Abandoned fields are partially invaded by vegetation. Most of the community will catch up with a scouting group already settled down in a new location on the lake shore. This group has already built the first houses and cleared new fields in the forest which is still preserved or has gone wild again (drawing by André Houot in: Gallay 2008 «Des Alpes au Léman»).*





**Figure 22 a:** during periods of relative drought, the lake level fell by least two to three meters below its present-day level. Farmers of the Neolithic or Bronze Age took advantage of the coastal zone freed from water to build up their villages and get closer to the lake. Seasonal lake level rises and storms forced them to construct fences acting as wave-breakers (in order to shield the habitations on the lake side) and to raise the floors of the houses to keep them dry.

**b:** several times, during periods of high water level in the summer, the lake level rose by less than a metre and waves were pushed towards the village by the local wind (the «bise»). The wave-breaking fence shielded the constructions onshore and the slightly uplifted floors of the houses prevented them from temporary flooding.

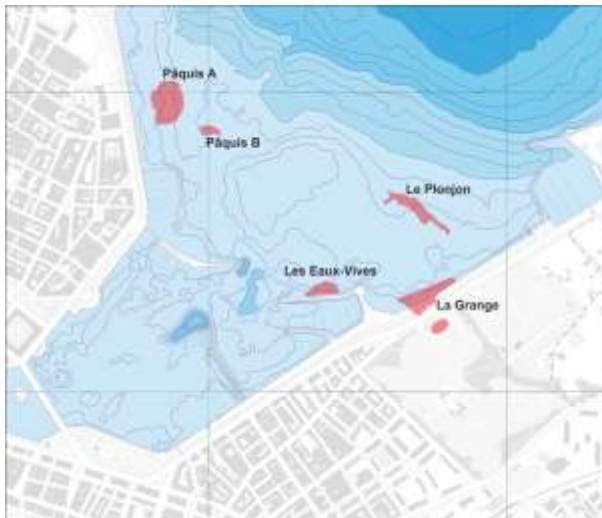
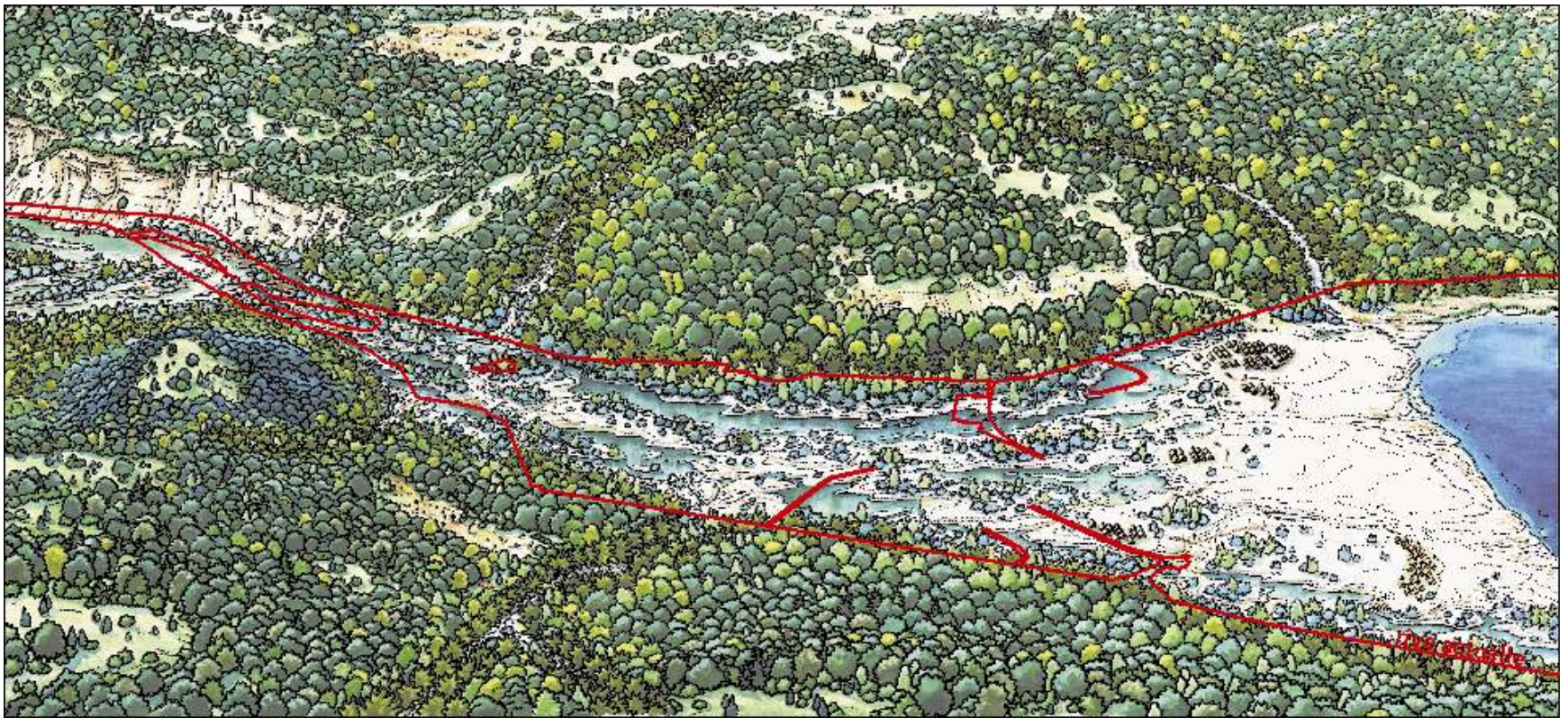
**c:** when the Lake Geneva level rose more and more frequently, house floors were submerged and the lake transgression was too important to permit the continuation of human occupation. Subsequently, the village was abandoned and the constructions were very rapidly destroyed during strong bise storms.

The water level went on rising regularly and each storm continued to dismantle the horizontal structures of the already wrecked houses, even eroding the vertical stilts. Soon, all pieces of the constructions were scattered by waves, except for those piles firmly hammered into the argillaceous ground (Corboud 2012).

#### The Lake Geneva, an «enclosed sea»?

The Rhône River which stopped flowing in Geneva, the Lake Geneva which was stagnant and the level of which fell down to 5 or 6 meters below the present-day level: impossible to imagine this lake as an «enclosed sea». Nevertheless, up to now, neither archeologists, nor geologists have found a 3 to 4 m deep channel hidden or filled in by sediments broken up by waves, currents or a tsunami, through which the Rhône River would have been able to flow out. Consequently, let's imagine the unthinkable, i.e., that the climate would have been responsible for this situation, keeping in mind the theoretical possibility that a channel might have existed. Anyway, one should not forget that it was not only Lake Geneva that was undergoing low-water conditions, but all of the perialpine lakes, from lakes Neuchâtel, Bienne and Zürich up to Lake Constance and way beyond!





**Figure 23:** Geneva Bay landscape during a period of low lake level (late Bronze Age, around 1000 years B.C.). Forests took up most of the land, with a majority of oak, hazel and beech trees, In areas freed from water, willow trees were colonizing the ground, whereas flooded shores were occupied by reed areas which gave way slightly higher up to a riverside forest of alder and ash trees.

Farmers grew cereal fields on the first terrace overlooking the lake, after having cleared forested areas. Villages were built on the «Banc de Travers», the vast area freed from water and still uncolonized by vegetation (drawing by Yves Reymond in: Gallay 2008 "Des Alpes au Léman").

**Figure 24:** remnants of five coastal settlements occupied between 4000 and 850 years B.C., are preserved in Geneva Bay.



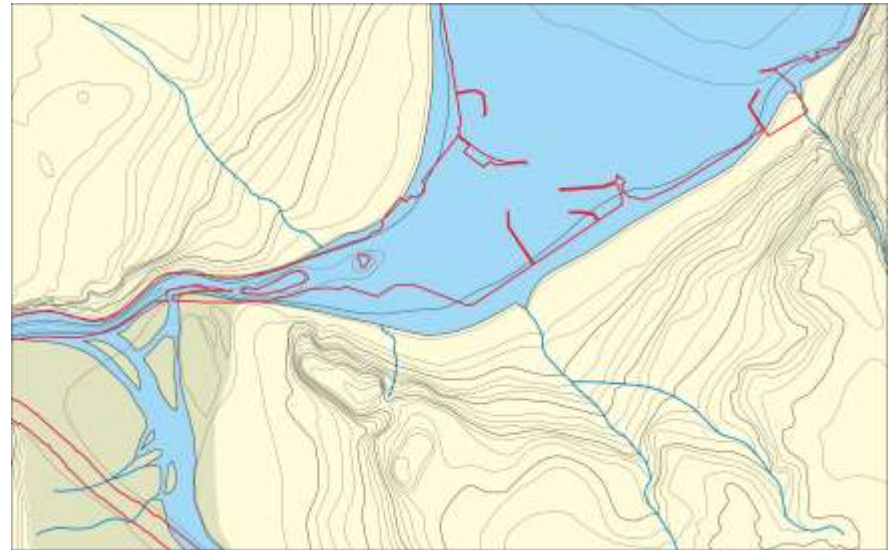
Therefore, during periods of low lake level, the Geneva Bay became a favourite zone for settlements, because of its lack of vegetation and proximity to a permanent water supply. During these periods, Lake Geneva had no westerly outflow and the Arve River waters were the only ones to flow in the Rhône river bed.

There are four cultural phases during which prehistoric farmers built their villages on the emerged shores of the lake: the middle Neolithic (4000 to 3400 years B.C.), the final Neolithic (3200 to 2500 years B.C.), the early Bronze Age (1800 to 1600 years B.C.) and finally the late Bronze Age (1080 to 850 years B.C.). These periods are particularly well known, because their remnants are exceptionally well preserved, particularly the objects made of wood and organic matter.

Between these drier phases, prehistoric inhabitants did not leave the region, but moved up their villages to terraces overlooking the lake. Unfortunately, remnants of their presence in these zones have been only rarely preserved.

Around 850 years B.C., deterioration of the climate led to a water level rise of all lakes north of the Alps. From this time onwards, the Lake Geneva level never fell sufficiently low so as to permit the settlement of the Iron Age populations on its shores. Moreover, during the Roman period, the lake reached a level three meters higher than its present-day average. Such a rise can not be explained through a climatic crisis (increase in rainfall and decrease in temperature), but rather through the formation of a natural dam near the confluence of the Arve and Rhône rivers. The formation of such a temporary dam might also have occurred at other times, caused by the collapse of the cliffs in the area of Saint-Jean, opposite the Bois de la Bâtie hill.

**Figure 26:** Geneva Bay during a low lake level at about 368 to 369 m, i.e., 3 to 4 m lower than the present-day average. A vast zone of sand and clay was accessible to the prehistoric settlers to build their villages, close to the lake shore. The Rhône River was not flowing out of the lake anymore and the Arve River flowed within the Rhône bed.



**Figure 25:** Geneva Bay during a phase during which Lake Geneva had an average level of ca. 372 m. Water on the shores covered a larger area than today.



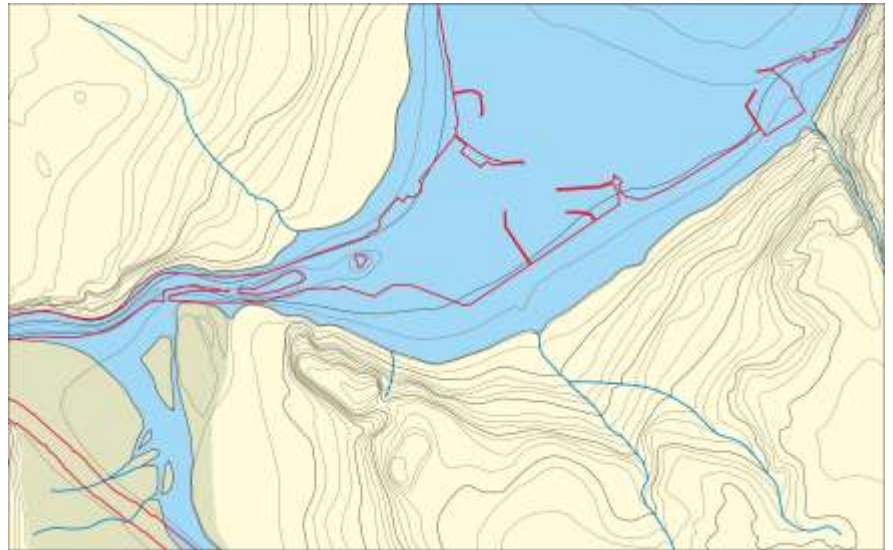


During the Gallic period the Geneva hill was occupied by a Celtic tribe. The settlement was first a small-size village, but then became a fortified camp: around 100 years B.C., this oppidum had solid walls built by the Allobrogs, a tribe integrated within the Roman province of the Narbonnaise. At the foot of the hill, a harbour was built at the present location of the Longemalle Square, just below the Madeleine Church. The lake level was still high and waters covered the area corresponding to the present-day Rues-Basses. In the year 58 B.C., the Helvetians who occupied the Swiss Plateau decided to migrate to southwestern France, to the north of the Gironde Estuary. The general Jules Cesar, in charge of the Narbonnaise Province, did not want this population of some 263'000 people to cross this territory with all their belongings. He moved to Geneva and had the bridge crossing the Rhône River dismantled, because it acted as the only passage way towards the south. Consequently, the Helvetians had to cross the Jura Mountains, but were defeated by the Roman army at Bibracte (Morvan) and forced to go back to the Swiss Plateau under the pressure of Jules Cesar.

Since that date, Geneva and the Swiss Plateau were under the domination of the Roman Empire. The city was called Genua, a name cited by Jules Cesar in his narrative of the Gallic Wars. This marks the transition between prehistory and history

Thanks to its favorable geographical location and commercial harbour, Geneva City experienced a rapid development. Since the 3rd century, at the fall of the Roman Empire, Geneva adopted the Christian religion. A bishopric was founded, which was to take an increasing political weight with the installation of a Prince Bishop since the 8th century. Remnants of the first episcopal group of constructions built between the 3rd and 4th centuries has been discovered beneath Saint-Pierre Cathedral. Its extension was still limited, but it was protected by stonework ramparts.

**Figure 28:** Geneva episcopal group of constructions in the 6th century, viewed from the southeast (drawing by Gérard Deuber, Canton Archeological Service).



**Figure 27:** Geneva Bay during a period of high lake level, 3 meters higher than the present-day average level. The lake reaches the bottom of the Geneva hill, at the location where the Gallic and Roman harbour was located in the 1st century B.C.



From the Early Middle Ages until the Middle Ages, Geneva was enclosed inside its fortifications. The keen interest of its neighbours justified these protective walls.

In 1533 the Prince Bishop had to flee from the city and in 1536 the Reformation was definitely adopted. During the 16th century, the city transformed its system of fortifications by building a network of bastions, which prevented even more strictly the spatial extension of the city. Higher buildings were constructed to accommodate the Protestants who had fled from other European regions where they were persecuted by the Catholics.

From 1350 until around 1850, average temperatures dropped significantly all over Europe. This period is called the «Little Ice Age». Famine affected several low mountain regions.

This long-lasting cooling interval contrasted with the warmer period that predated it around the year 1000 AD and referred to as «Medieval Warm Period». The social and political tensions at the beginning of the 17th century might have been the reasons that encouraged the Duke of Savoy to attack Geneva during the cold night of the 11th to the 12th of December 1602. This aggression was firmly repelled by the Geneva inhabitants and its commemoration led to the traditional yearly celebration of the «Escalade». This war episode highlighted the necessity to have an efficient system of fortifications.



**Figure 29:** map of Geneva and its fortifications between 1750 and 1790 by Nicolas Chalmandrier (Ryhner Collection, Library of Bern University).

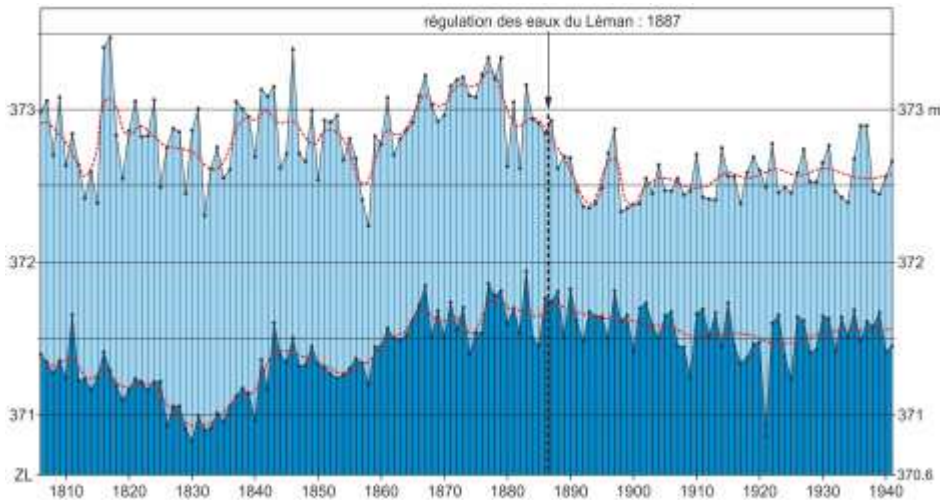


**Figure 30:** view of Geneva from the south around 1642 by Matthieu Merian. In the foreground: the Porte Neuve, which had in the front a drawbridge, a bridge over the moat and a barbican, was constructed in 1565. By cutting the rope of the portcullis closing this door, Isaac Mercier prevented most of the Savoyard troops to enter the city in 1602 (BGE, Geneva Centre of Iconography).



From 1830 onwards, large hotels were built on the northern shore of Geneva Bay. They were popular among the British tourists who enjoyed the Alpine panorama. In the 1850's the need for the city of a military protection had disappeared. The city could demolish its old fortifications and until 1880 extended the urban zone over the area previously occupied by the ramparts. The city was thoroughly transformed, the new living districts built upon the old fortifications constituted the «Fazy Belt», named after the radical politician James Fazy who favoured the opening of the city and its social orientation. This opening also led to the gaining of space on the lake and to the laying out of quays on both shores, where prestigious buildings were constructed which still shape the outline of the bay today.

From the beginning of the 18th century, dams were built in Geneva in the Rhône River to supply water to mills and provide the energy required to operate the numerous workshops located on the river shores. These dams held back the waters and were responsible for the high lake levels. In 1873 the Canton Vaud lodged a complaint to the Federal Court, which led to the so-called «Leman trial» that lasted for nearly ten years. In 1884 this conflict was solved through the signing of a convention between the cantons which defined limits for the variations in water level. The construction of the sluice gates at the «Pont de la Machine» was meant to comply with this convention which was effective since 1887. Since 1995, the Seujet Dam built downstream has replaced the wooden shutters of the old sluice gates.



**Figure 31:** construction in 1885 of the Forces Motrices Building in Geneva. In the background, one can observe the hydraulic wheels which supplied energy to various industrial buildings in Saint-Jean: flour-mill, watchmaker and mechanical workshops. The hydraulic machines meant for providing drinking water to the city were moved from the «Pont de la Machine» to new buildings. The first «Jet d'eau» (water fountain) was meant to lower the pressure of unused water (BGE, Geneva Centre of iconography).

**Figure 32:** evolution of the minimum and maximum annual levels of Lake Geneva between 1806 and 1941. Since 1887 note the effects of the Leman water regulation.



## 2. Site visit

Starting from the geological and archeological history of the Geneva City area described above in the first part of this guide, this second part is devoted to the visit of typical locations corresponding to different geological periods and to the first urbanization. The order in which sites are described follows first an itinerary through the city. Starting from near the City of Carouge, one walks first along the muddy waters of the Arve River and then climbs on the hill of the Bois de la Bâtie. Then, by walking upstream along the Rhône River, one reaches the Lake of Geneva and the visit terminates at the archeological site located underneath the Saint-Pierre Cathedral. The visitor must plan with approximately 3 to 4 hours to carry out this excursion, depending on the time spent at the different sites. This guide comprises the localization (address, location map and Swiss coordinates for GPS localization), description and interpretation of the sites. A detailed city map with zoom and satellite photo can be found on the following website: <http://www.ville-geneve.ch/plan-ville/>

Other sites located outside of the city walk are described after this visit of the Geneva City. Visitors can reach these sites using public transports, except for Site Ge 2, where it is suggested to rent a small rowing or motor boat.

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## Ge 1: Geological visit of the City of Geneva

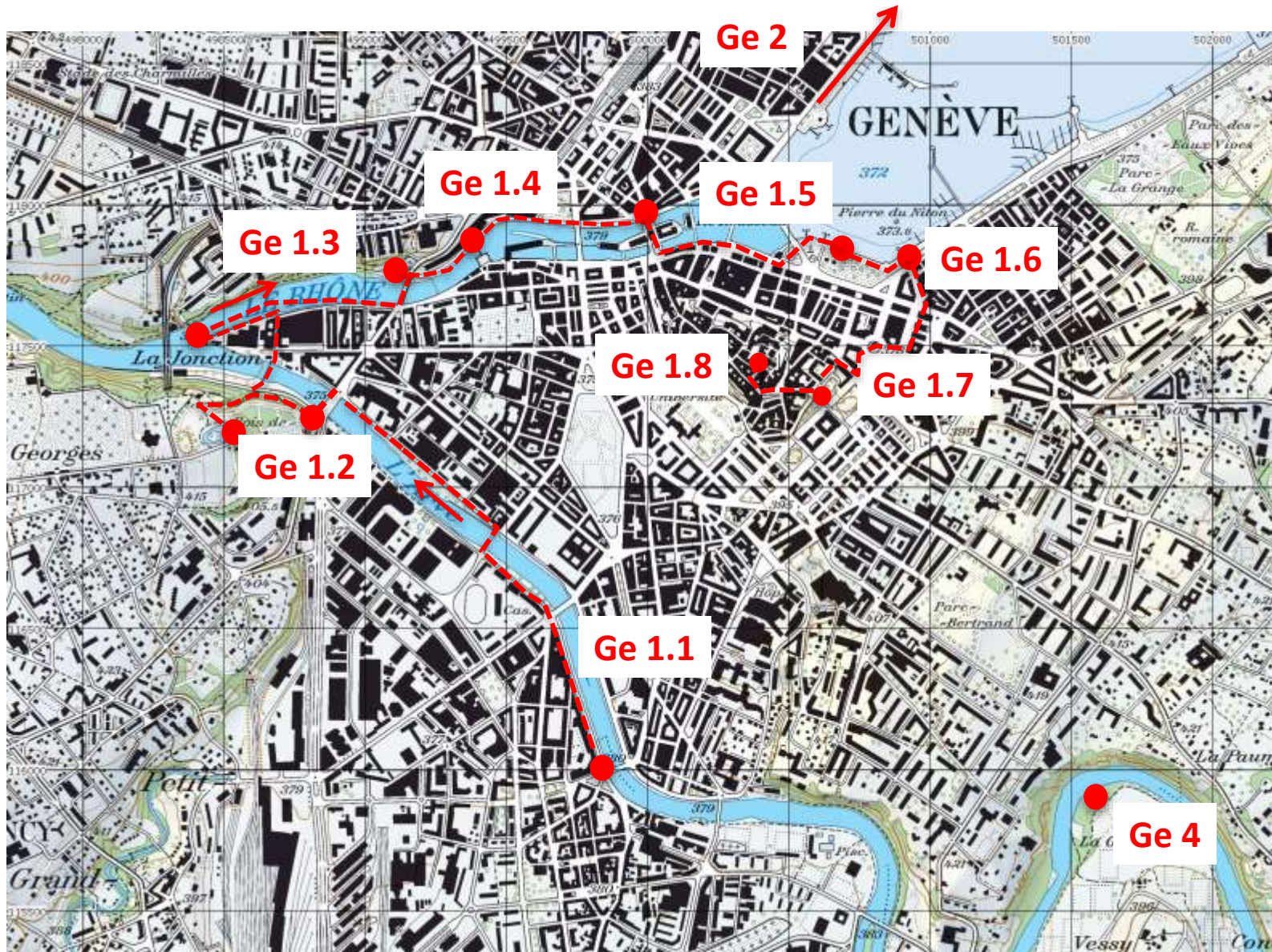
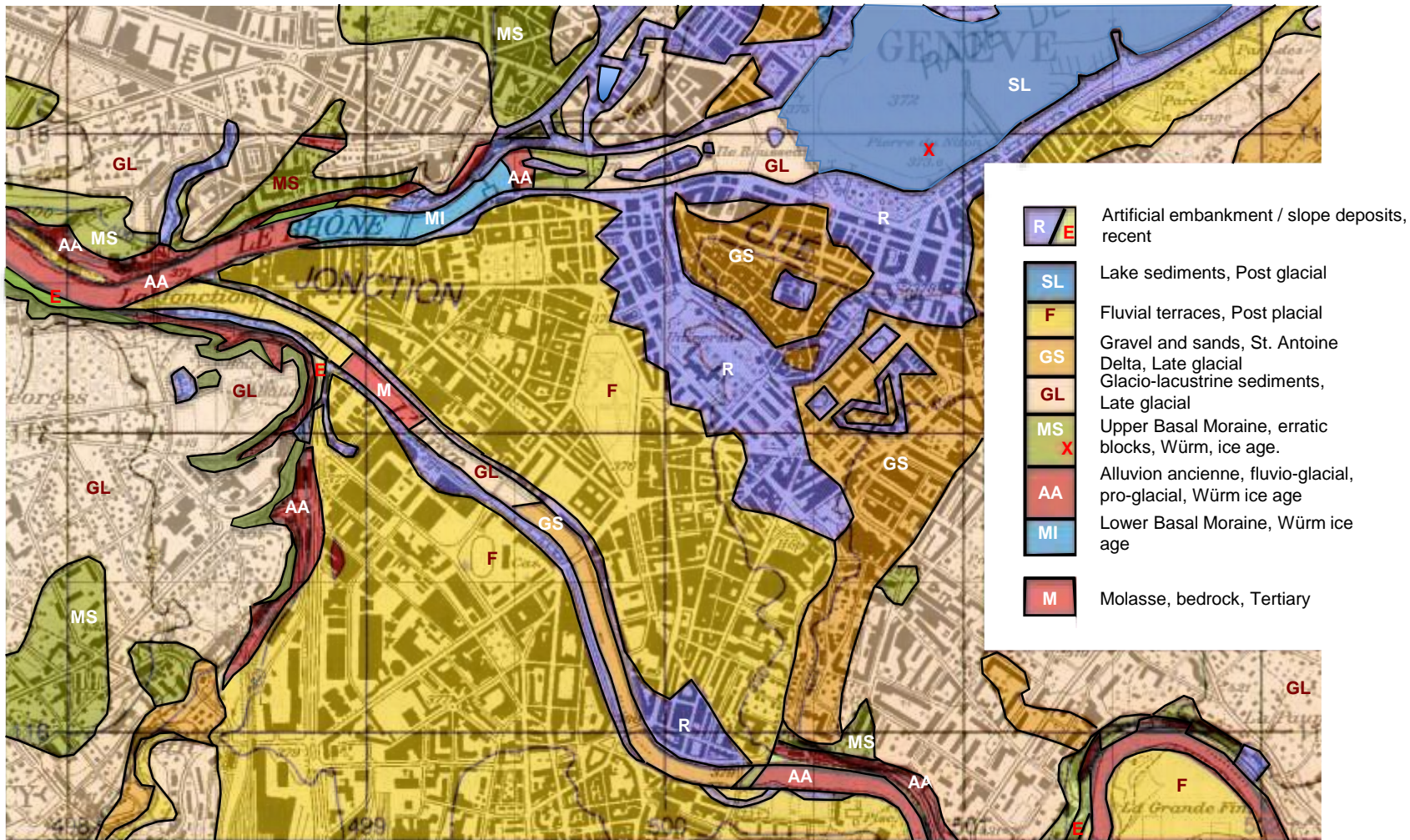


Figure 34: itineraries and map of sites Ge 1, Ge 2 et Ge 4 (Swiss National Map 1:25 '000, sheet Geneva 1301, © 2014 swisstopo (BA14046)).





**Figure 35:** simplified geological map of Geneva City (geology: modified after Wildi 1993; data: Geotechnical map of Geneva; topography: Swiss National Map 1:25'000, sheet Geneva 1301, © 2014 swisstopo (BA14046).



## ***Ge 1.1 (1): The Arve River: an Alpine river and its alluvial plain***

*Localization:* from the Octroi Square (coordinates : 499 800/115 980, tramway no. 12 stop «Armes» in Carouge) to the Saint-Georges Bridge (coordinates: 498 910/117 350).

*Web:* <http://www.fgsp.ch/Rivieres/Arve/Arve.htm> (detailed descriptions, history, constructions, nature), <http://www.hydrodaten.admin.ch/fr/> (Arve River flows).

*Itinerary:* from the Armes Square towards the Arve River up to the Octroi Square, then one follows the river downstream up to the new Hans Wilsdorf Bridge, and then, on the right bank, up to the Saint Georges Bridge (at the base of the Bois de la Bâtie hill).

The Arve is an Alpine river. Its average flow, at the hydrographical station of the Bout du Monde (upstream of Geneva City), is of 78 m<sup>3</sup>/sec. From December till January or February, a large part of the water is retained as snow in the Mont Blanc Massif. In periods of low waters, the river flow drops below 20 m<sup>3</sup>/sec, with a minimum at around 10 m<sup>3</sup>/sec, and from Carouge to the Hans Wilsdorf Bridge downstream the bedrock made of pebbles and rocks becomes visible (fig. a). This river bed and the embankments on both sides of the river result from containment and correction works carried out at the end of the 19th century, in particular after the 1888 flood which reached a record flow rate of 1136 m<sup>3</sup>/sec (fig. b). Other floods took place on 14th April 1970, 1st July 1974 and 22nd-23rd May 1980. The river presents an essentially snowmelt-dominated regime with pronounced floods in the spring, but also after summer thunderstorms or autumn rains. During the summer, the melting of glaciers contributes significantly to the river flow. The river is often loaded with sands and silts, which originate either from glacial erosion in the summer (« glacial milk » of grey colour), or from soil erosion (brown colour). A large part of these sediments are deposited within the reservoir lake of Verbois, the dam being located 8km downstream of Geneva City. The influence of the dam can be observed up to the upstream side of the Saint-Georges Bridge, i.e. between the latter bridge and the Hans Wilsdorf Bridge. On the right bank of the Arve River, small terraces of fine-grained sandy sediments indicate the water level reached by the annual floods. Centennial floods infill completely the man-made contained channel, whereas millennial floods may flood the areas of Geneva City and the City of Carouge located on the fluvial terrace of the Arve River.



**Figure a:** rocky bed of the Arve River upstream of the Hans Wilsdorf Bridge. On the right bank of the river one can observe the narrow sandy terrace resulting from the annual floods. Photo taken in autumn 2013 with a river flow of 38 m<sup>3</sup>/sec.

**Figure b:** upstream view of the Quai Ernest-Ansermet embankment, on the right bank of the Arve River. This man-made construction protects the areas of Plainpalais et La Jonction from centennial and millennial floods.



## Ge 1.1 (2): The Arve River: an Alpine river and its alluvial plain

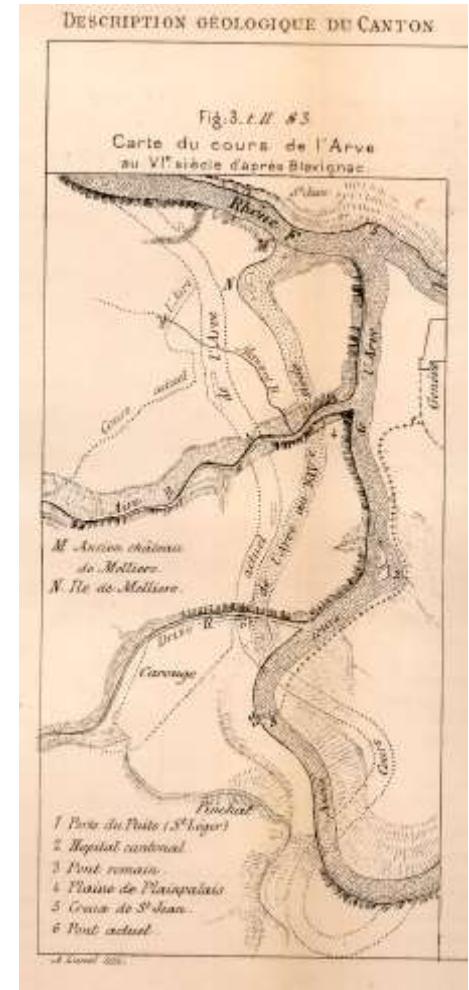
At the end of the last glacial age, since some 22' 500 years before present (calibrated C-14 age), the Arve River has progressively filled the lake located between the Geneva Old City hill, the relief of the Bois de la Bâtie and that of the Saint-Jean area. The City of Carouge and the districts of Les Acacias, Plainpalais and La Jonction in Geneva City are located on the alluvial terrace of the river. The river flows either on the glacio-lacustrine silts (fig. c), or on its own gravelly terrace, or on Molasse outcrops that can be seen in the river bed (during low level periods) upstream of the Saint-Georges bridge (see geological map in fig. 17).

**Figure c:** geological cross-section of the Arve River fluvial terrace in Les Acacias (Alphonse Favre 1879, plate III). In the vicinity of the river, the terrace is made only of Arve gravels. Towards the edges of the terrace (area of La Praille), paludal silts (marsh deposits) and slope silts brought down from the Lancy Plateau are overlying the gravels of the fluvial terrace. Underneath the Arve gravels, at a few meters depth, one can observe black-coloured silts and fine-grained sands deposited after the glacial retreat in the «pro-glacial» lake (i.e., located at the front of the glacier). This lake was constrained by the relief of the Bois de la Bâtie, the Rhône River gorge being not yet present at that time.

**Figure d:** «Map of the Arve River course in the 6th century after Blavignac» (Alphonse Favre 1879, Plate I). This figure shows the migration of the Arve River channel over its alluvial plain through time. The river channel would have migrated since Roman times from the base of the Geneva Old City hill towards the other end of the Plaine de Plainpalais, at the base of the Bois de la Bâtie relief.



c



d

### Gold washing: gold diggers in the Geneva rivers

Alpine granitic rocks contain gold in small quantities. Nevertheless, it is not in these rocks that one goes to look for it, but in their weathered and eroded products. Indeed, gold is present as small flakes in the sands deposited by the rivers draining the Alpine massifs, as well as in the sand deposits and moraines from the last glacial age. Gold is characterized by its high density, i.e.,  $19.3 \text{ g/cm}^3$  («19.3 density»), with respect to the  $2.7 \text{ g/cm}^3$  of the continental crust, granitic rocks and gneisses of the Alps. Because of this large difference in density, gold flakes can be separated from the sands through a washing process: one places two to three handfuls of sand in a special hollow pan, that looks like a Chinese «wok». The gold digger (or «gold panner») adds water from the river, makes it swirl in the pan and overflow to get rid of the sand. When the amount of sand is reduced, one might have the chance to see gold flakes shining at the bottom of the pan.

A little bit of history (simplified after <http://www.riviere-arve.org/usages/orpailage-sur-arve.htm>)<sup>1</sup>:

- 1397: first mention of a gold panner concession given by the feudal lord of Gex.
- 15th century: in 1471 four gold panners had a concession granted by the Duke of Savoy to exploit the gold sands of the Arve River at the level of the Aïre islands near Geneva.
- In 1477 a licence was granted to 12 gold diggers for a sum of 12 pounds per year.
- In 1651, following a large flood, Pierre Amyrant was authorized to start a gold digging business on a large scale in the Arve River from Conches down to the confluence with the Rhône River, but this undertaking failed and the lease was terminated in 1658.
- In 1682 Mr. Jean Frezely asks the Council of the Geneva Republic for permission to dig the Arve River alluvial deposits and put up smelting works in order to transform gold flakes into ingots.
- Near the middle of the 18th century, a strong decline in gold washing is observed in the region as well as in the whole of Europe.
- The last gold panners of the Arve River disappeared around 1900: their work brings in at that time three to four francs a day.

Nowadays, gold washing in the Canton Geneva rivers requires a permit. The latter can be obtained only for the months of May, June and September (<http://ge.ch/nature/formulaires/activites-de-loisirs-en-riviere-ou-dans-des-sites-protoges-hors-foret>). For an initiation to gold washing we recommend the following address: <http://www.thierrybasset.ch>.

1 Reference: J.J. Pittard 1936: La Recherche de l'or dans la région de Genève. Société générale d'imprimerie.



*Demonstration of gold washing during the «Nuit de la science» 2012*



## ***Ge 1.2 (1): The Bois de la Bâtie: the «Alluvion ancienne», deposits of an older, pro-glacial alluvial plain overlain by the Upper Basal Moraine of the Rhône Glacier***

*Localization:* bus/tramway stop «Jonction» of the bus/tramway TPG lines 2, 4, 11, 14, 19, D; start from the Saint Georges Bridge, left bank (coordinates : 498 830/117 270) to the wildlife park of the Bois de la Bâtie, (coordinates: 498 450/117 160).

*Itinerary:* cross the Saint Georges Bridge and take the pedestrian/bike path going up towards the Saint Georges Cemetery. At the Café de la Tour turn left towards the wildlife park.

The steeply dipping slope linking the plateau of the Bois de la Bâtie to the Arve River bank is the result of erosion. The framework of the slope, with occasional cliffs outcropping, is made of the ' «Alluvion ancienne» conglomerates. At the bottom of these cliffs one finds fallen rocks, made of pebbles from the conglomerates, as well as rock slides from the conglomerate (fig. a). About halfway up the slope, the path crosses the conglomerate cliff (fig. b and c).

**Figure a (right):** rock falls and small rock slide (g) between the «Alluvion ancienne» cliff (a) and the path



**Figure b (left):** strongly cemented conglomerate and sand. The calcareous ( $\text{CaCO}_3$ ) cement is precipitated from interstitial waters.



**Figure c:** cliff of «Alluvion ancienne» conglomerates by the path.

The conglomerate is made of more or less rounded pebbles, the size of which varies from 1 to 15 cm. The conglomerate forms 1 to about 3 m thick bars, which may thin out and disappear laterally. Dm-thick sandy intervals are intercalated between the bars.

***Ge 1.2 (2): The Bois de la Bâtie: the «Alluvion ancienne», deposits of an older, pro-glacial alluvial plain overlain by the Upper Basal Moraine of the Rhône Glacier***

Maître et Vergain (1992) have dated precipitation phases of the conglomerate calcareous cement, using the carbon 14 method. They found a maximum age older than 35'000 years. It is evident that the age of the formation of the «Alluvion ancienne» and that of the first cementation dates back to a period between two glacial advances, i.e., between the formation of the Lower Basal Moraine and the Intermediary or Upper Basal Moraine, during the second part of the last glaciation (Würm). The last cementation phase is postdates this glaciation.



***Figure d, e:*** braided river downstream of the Mont Miné Glacier (Valais). Source of the river (above) and alluvial plain (left). The different channels of the river are shallow and separated by sedimentary bars made of gravels with large pebbles. During periods of high waters (snow melting), the alluvial plain is covered by water and sands are deposited on top of the sedimentary bars.

The «Alluvion ancienne» corresponds to deposits of a braided river downstream of the Rhône Glacier. At the time of deposition the glacier was located in the area of Chêne-Bourg, upstream of Geneva City.



## ***Ge 1.2 (3): The Bois de la Bâtie: the «Alluvion ancienne», deposits of an older, pro-glacial alluvial plain overlain by the Upper Basal Moraine of the Rhône Glacier***

Walking up the path towards the Saint Georges Cemetery, a change of slope marks the top of the « Alluvion ancienne » cliff. Below the leaves along the path, one can observe a clayey and sandy matrix incorporating rounded pebbles and blocks (fig. f and g). These deposits are called « argiles à blocs » (« clays with blocks ») in the Geneva terminology. They correspond to the merged Intermediary and Upper Basal moraines which cover the Bois de la Bâtie Plateau and the whole Saint Georges and Lancy Plateau.



**Figure f:** Upper Basal Moraine in the stream upstream of the Nant-Manant footbridge (Bois de la Bâtie, coord. 498 550/116 930). Rounded pebbles have rolled in the glacial torrent before being incorporated into the moraine clayey and sandy matrix. The composition of the pebbles allows the tracing of their origin to the Alps. In the photo, dark green coloured pebbles come from the Zermatt – Saas Fee Zone in Valais. The surface of some pebbles was scratched through the friction with other rock fragments at the base of the moving glacier.

This moraine has a very low permeability. Consequently it retains rain water and forms an ideal bed for the pond of the wildlife park (fig. h).

This glacial formation may often be masked through some centimeter- to decimeter-thick lacustrine clays and silts, deposited in a lake during the glacier retreat.

Basal moraines form at the base of glaciers, where the latter release the fine «abraded» material and blocks pulled out through the movement of the glacier on the rocky bed. Fig. i shows an example of such a moraine formed underneath an Alpine glacier. Usually, the fine material of basal moraines on the Swiss Plateau contains less pebbles and sands, and more clays and silts, than shown in this example.



**Figure g :** landslide in the Upper Basal Moraine downstream of the Nant-Manant footbridge (photo taken from coord. 498 560/116 930).



**Ge 1.2 (4): The Bois de la Bâtie: the «Alluvion ancienne», deposits of an older, pro-glacial alluvial plain overlain by the Upper Basal Moraine of the Rhône Glacier**



**Figure h:** pond in the wildlife park of the Bois de la Bâtie. This pond rests on top of the impermeable Upper Basal Moraine.



**Figure i:** basal moraine in formation at the base of the Mont Miné Glacier (Val d'Hérens, Valais). The moraine is made of silt, sand, pebbles and blocks without any hydraulic sorting (through water flow) .

## ***Ge 1.3 (1): From the Jonction, where the Rhône and Arve rivers meet the reservoir lake of the Verbois Dam, to the «Prieuré de Saint-Jean», where the Upper Basal Moraine of the Rhône Glacier passes underneath the Rhône River and Lake Geneva***

*Localization:* from the «Pointe de la Jonction» (coordinates: 498 390/117 500 ) to the ruins of the «Prieuré Saint-Jean» (coordinates: 499 150/117 800).

*Itinerary:* walk down from the Bois de la Bâtie towards the Arve River and cross it using the La Jonction footbridge; walk to the Rhône River bank and then downstream up to the Pointe de la Jonction. Then walk upstream the Rhône River and cross it using the Sous-Terre Bridge and enter the small park on the right bank where the ruins of the « Prieuré de Saint-Jean » are located.

Where it flows out of Lake Geneva, the Rhône River carries only little suspended solid material, and this mainly during windstorms from the east (wind called the «Bise») when waves rework lacustrine sediments in the Geneva Bay. Consequently, downstream from Geneva City, most of the sedimentary load in the Rhône River comes from the Arve River. It is either reworked soil material or sands and silts originating from the glacial abrasion in the Mont Blanc Massif (fig. a). By contrast, only little gravel is



**Figure a:** confluence of the Rhône (left) and Arve rivers (right) at the « Pointe de la Jonction ». On this photo the Arve River is in flood following heavy rains and carries an important load of sediments coming from soil erosion. On the right handside the relief of the Bois de la Bâtie, and on the left handside the cliffs and area of Saint-Jean (photo: Jean-Luc Loizeau).

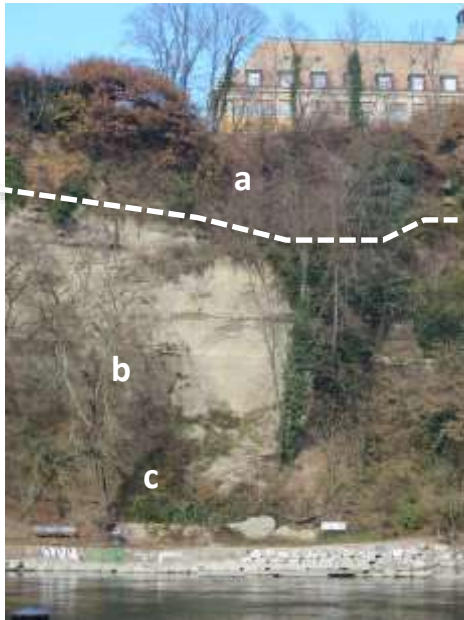
Transported by the Arve River nowadays, because this resource has been used as construction material until very recently in Haute Savoie (France). This exploitation stopped following the signature of a « river contract » in 1995, and one can expect the return of gravels up to La Jonction in the forthcoming years.

**Figure b:** old fan of the Arve alluvial plain towards the Rhône River and erosive edge of the Saint-Jean cliffs (red dashed line). For reference, see fig. d of the **Ge 1** itinerary.



From the « Pointe de la Jonction, one walks upstream on the left bank of the Rhône River. One goes alongside the old front of the Arve alluvial plain towards the Rhône River, where the Arve River was in the past pouring out gravels in the Rhône River bed and was pushing it progressively towards the Saint-Jean cliffs (fig. b). Large conglomerate blocks and fallen rocks at the foot of the Saint Jean cliffs (fig. c) testify to the active erosion of these cliffs. Through time, the infill of Arve gravels and rockfalls from the Saint-Jean cliffs may have led to the elevation of the Rhône River bed, and subsequently to an elevation of Lake Geneva level caused by the position of this sill.

**Ge 1.3 (2): From the Jonction, where the Rhône and Arve rivers meet the reservoir lake of the Verbois Dam, to the «Prieuré de Saint-Jean», where the Upper Basal Moraine of the Rhône Glacier passes underneath the Rhône River and Lake Geneva**



**Figure c:** Saint-Jean cliffs: a) Upper Basal Moraine, b) «Alluvion ancienne», c) fallen rocks and blocks

The Upper Basal Moraine, which forms the upper part of the Saint Jean cliffs becomes topographically lower and lower upstream of La Jonction and near the Pont Sous-Terre, passes underneath the Quai de Seujet and the river (fig. c). The basal contact of the moraine is erosive resulting from glacial abrasion. This lowering of the moraine below the Rhône River bedrock and then below Lake Geneva can also be observed on the geological map (fig. 17).



**Figure d:** Pont Sous-Terre and Prieuré de Saint Jean, the contact between the Upper Basal Moraine and the Alluvion ancienne plunges underneath the Quai du Seujet. a) Upper Basal Moraine, b) Alluvion ancienne, c) Prieuré de Saint Jean.



## Ge 1.4 (1): Dam and sluice gates of the Seujet: control of Lake Geneva level and electricity production

Localization: right bank of Rhône River (coordinates: 499 400/117 850 ).

Itinerary: from the Prieuré de Saint Jean pass underneath the Sous-Terre Bridge et walk upstream along the Rhône River (right bank).

The level of Lake Geneva is controlled since 1884, following the convention signed by the cantons of Vaud, Valais and Geneva. This agreement was meant to control and stabilize the level of Lake Geneva throughout the year. In the spring, the level is temporarily lowered to create the volume needed for the intake of melting waters from the Alps. According to this agreement, Geneva is in charge of keeping the lake level within a specific range, using a specific regulation device (fig. a).

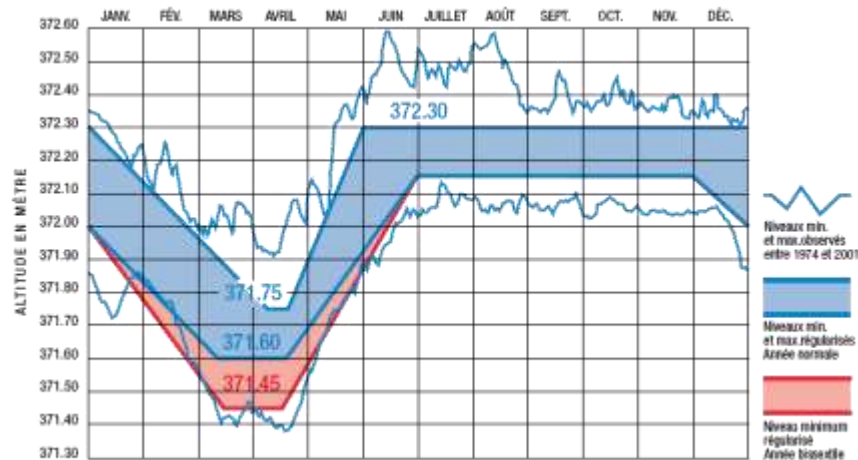


Figure a: regulation of Lake Geneva level by the Services Industriels de Genève ([www.geneve.ch/nature](http://www.geneve.ch/nature))

The first regulation installation was that of the La Machine Bridge, located 800 m upstream of the Seujet site. A set of wood shutters fixed to the bridge allowed the manual regulation of the Rhône River, and consequently of the lake level. This device was used until the construction of the Seujet Dam in 1995.

Nowadays, the Seujet installations provide the following services (fig. c) and d):

- Regulation of Lake Geneva level according to the 1884 convention.
- Local production of electricity (3 turbines).
- Flow regulation of the Rhône River towards the hydroelectric plant of Verbois and regulation of electricity production.
- A sluice permitting the passage of boats between the lake and the river.
- Fish ladder

Figure b: the La Machine Bridge at the time when the Lake Geneva regulation was carried out through metal shutters underneath the bridge. This device, totalling 39 larch-wood shutters was constructed in 1887 (photo: view from the Belair Island, 1988).

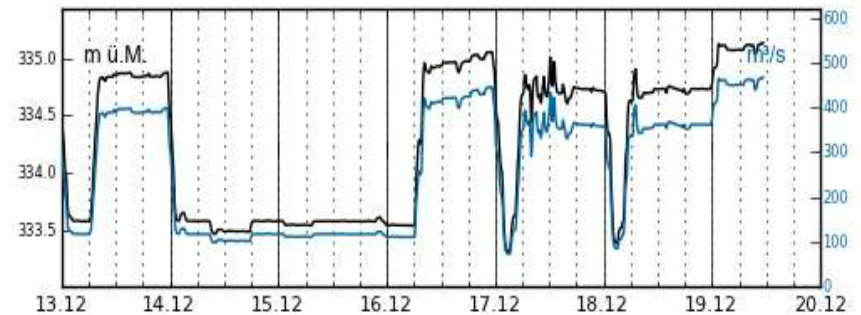


## Ge 1.4 (2): Dam and sluice of the Seujet: control of Lake Geneva level and electricity production



**Figure c:** dam and sluice of the Seujet, downstream view from the left bank of the Rhône River; a) sluice, b) gates regulating the river flow and Lake Geneva level, c) turbines.

Owing to the Seujet plant, Lake Geneva is presently being used as a reservoir lake through the hydroelectric plant of Verbois. Indeed, during hours of high electricity consumption, the Services Industriels de Genève open the gates at the Seujet, which leads to a high electricity production at the Verbois plant, 8 km downstream (essentially during working days). By contrast, during weekends and nights, the river flow is considerably reduced at the Seujet (fig. d). Nevertheless, the contribution of the Arve River flow to the Rhône River can not be regulated with this installation. The production capacity of the Seujet plant is of 5.6 MW, and that of the Verbois Dam of 100 MW ([www.sig-ge.ch](http://www.sig-ge.ch)).



**Figure d:** measure of the Rhône River flow at Chancy (place called « Aux Rippes ») downstream of Geneva City. The strong flow variations are caused by the flow regulation at the Seujet.

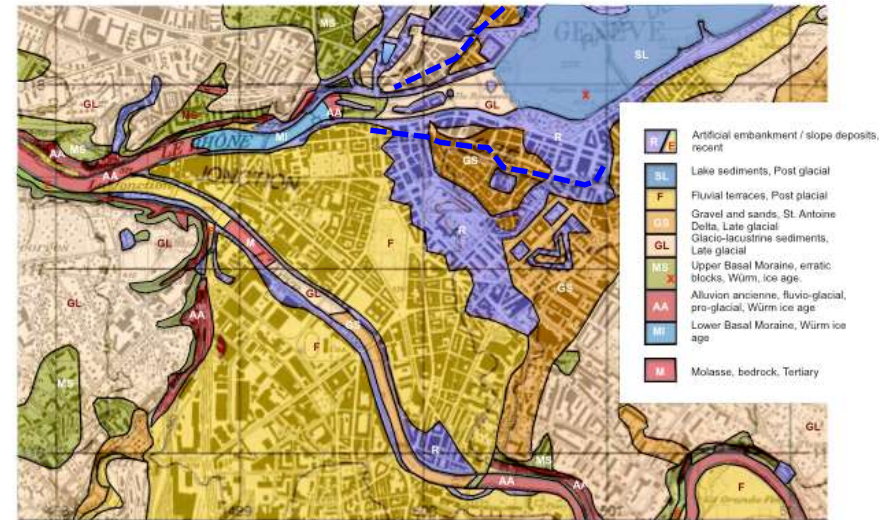
## Ge 1.5 (1): From the Pont de l'Île to the Jardin Anglais: the old shores of Lake Geneva

*Localization and itinerary:* the walk starts at the Pont de l'Île which links the two banks of the Rhône River (coordinates: 500 000/117 950). From there, one walks upstream towards the Jardin Anglais, on the left (southern) shore of Lake Geneva (coordinates: 500 650/117 850).

In the «History of Geneva» Alfred Dufour wrote: “The first time that the name of Geneva appears in historical records is in the writings of one of the most famous Roman historians and politicians, Jules Cesar. Indeed, Cesar, who at the same time presents a striking portrait of the Helvetians at the beginning of his «Commentaries on the Gallic Wars» (De Bello Gallico) in 52 B.C., indicates that the only bridge linking the Helvetian land with that of the Gauls is located where the Rhône River flows out of Lake Geneva. Informed of the Helvetian project to settle down in this area, he reached Geneva to block the way to them”. This « place where the Rhône River flows out of Lake Geneva » did not correspond to the present-day termination of the lake at the level of the Mont Blanc Bridge, but was located downstream by the Belair Island, as shown in the landscape reconstitution in fig. a) for the so-called Atlantic Period. At that time, the lake level was located at an altitude of approximately 372 m amsl, close to the current level. This can be explained on one hand by



**Figure a:** Reconstitution of the outlet of Lake Geneva during the Atlantic period (3800 till 7500 years before present time (drawing by Yves Reymond from the prehistoric archeology division of the Institut Forel).



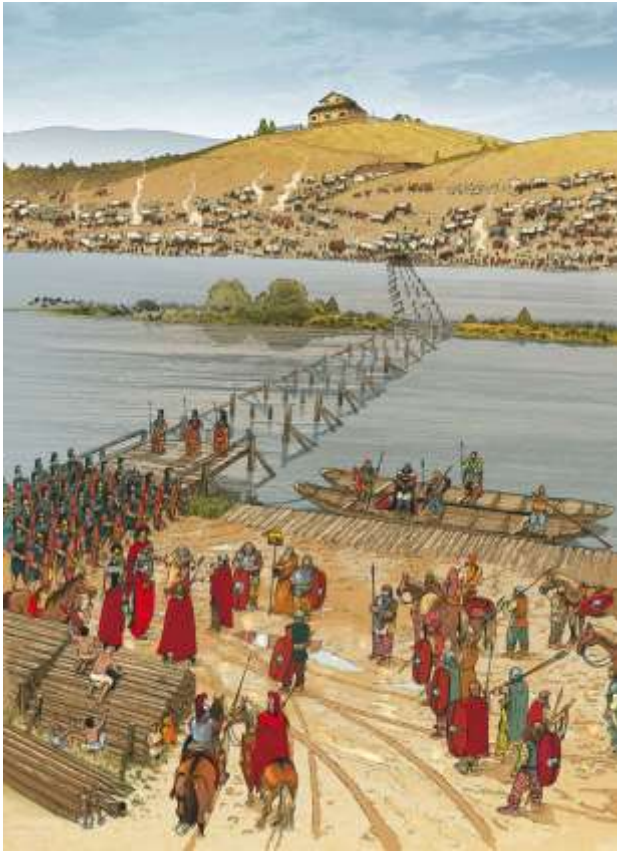
**Figure b:** geological map; in blue, the approximate shoreline of Lake Geneva during the Roman period.

the drop in lake level since that time, and on the other hand by the backfilling of the lake (fig. b). Most of the present-day buildings located on the left bank, between the Rues Basses and Rue du Rhône and the river, lie upon this backfill. An antique harbour has been discovered in the Rues Basses during roadworks (coord. 501.540/117.580, alt. 375 m). This backfilling of the lake really started in the 18th century and went on until about 1880, in particular with the construction of the embankments on the right and left shores and with the backfill of the Jardin Anglais.



## Ge 1.5 (2): From the Pont de l'Île to the Jardin Anglais: the old shores of Lake Geneva

As illustrated in fig. b), the islands located in the middle of the Rhône River are made of clayey and sandy terrains with blocks, interpreted as Upper Basal Moraine of the last glacial age. This material was certainly particularly favorable for the driving of piles during the construction of bridges (fig. c).



**Figure c:** deconstruction of the bridge of Bel-Air by Jules Cesar, to prevent the Helvetii to cross (58 BC, (drawing André Houot in: Gallay 2008 "Des Alpes au Léman")).

As far as the historical description of the evolution of this part of town and that of the lake termination, we refer the reader to the book edited by Ph. Broillet, éd. 1997: Les monuments d'art et d'histoire du Canton de Genève; la Genève sur l'eau. Société d'histoire de l'art en Suisse, Wiese, Bâle

### The La Machine Bridge and supply of running water to the City

A visitor should not pass by the La Machine Bridge without knowing that this name refers to the emplacement of the installations used for pumping the waters of the Lake, respectively of the Rhône River. In their book entitled «Trois siècles d'eau genevoise», G. Duc, A. Frei et O. Perroux (2009) present the following main phases of running water supply to the City of Geneva (slightly modified text):

- 1st to 3rd century: water supply to the city through an aqueduct from a source at the base of the Voirons Mountain (France).
- Middle Ages: supply through private and public wells (see visit Ge 1.8) and some sources.
- 1708 : installation of a first hydraulic pump on the river banks by the engineer Joseph Abeille, originally to supply water to 7 public fountains (fig. d).
- Through time the pumping capacity will be increased from 250 to 700 liters/minute and the installation will supply up to 24 public fountains.
- 1843 : The engineer Jean-Marie Cordier installs a new machine in the original building of the present-day La Machine Bridge (fig. e).
- A hydraulic machine is then instilled in the Rhône River bed, in the original building of the present-day La Machine Bridge (capacity : 16' 000 l/min).
- 1880 : Installation of a hydraulic steam machine.
- 1886 : Construction of the hydraulic plant of the Coulouvrenière, supplying 40 to 50' 000 l/min of water under pressure.
- Years 1920-1930: installation of the first pumping stations on the lake shores and in the water table of the Geneva countryside.
- 1950's : the lake water quality degrades and Geneva builds its first filtering plant (Prieuré). At the same time, major investments are made for the construction of a network of main sewers and purification plants (STEP) in the whole canton.

**Ge 1.5 (3): From the Pont de l'Île to the Jardin Anglais: the old shores of Lake Geneva**



**Figure d:** fountain of the Bourg de Four Square, built in 1817 et and supplied at the time through the running water pumped at the La Machine Bridge.



**Figure e:** La Machine Bridge, where the running water pumps were installed in 1843.

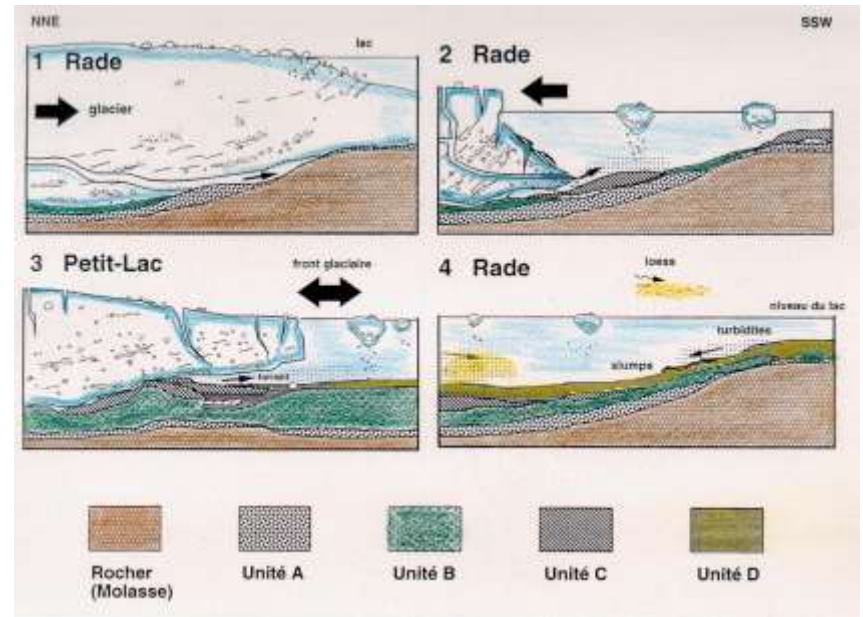
## Ge 1.6 (1): Geneva Bay at the end of the last glacial age

*Localization* : at the pontoon of the Neptune boat, opposite the Pierres du Niton (coordinates: 500 950/117 830).

The Geneva Bay marks the transition from the Geneva Lake to the Rhône River. Its present depth of less than 3 m (fig. 3 of chapter 1.1) is noticeable particularly during windstorms from the northeast (the so-called « Bise » wind), from autumn till spring, when the waves rework the fine sediments and make the waters turbid. Before the backfill and construction of the embankments in the 19th century, the bay shores had a low-angular, continuous slope.

The geology of the Bay is particularly known thanks to the boreholes carried out during the 1980's for a project of bridge construction (which was never achieved). In the centre of the basin, a single glacial sequence is in direct contact with the Molasse bedrock (fig. 9). This sequence dates back to the last advance of the Rhône Glacier (fig. a, units A et B). When deglaciation started 22'500 years ago, gravels and sands of Unit C and then fine sediments of Unit D released by the glacier were deposited. This formation of glacio-lacustrine sediments contains pebbles and blocks that were transported on top of icebergs and then dropped at the bottom of the lake (« drop stones »).

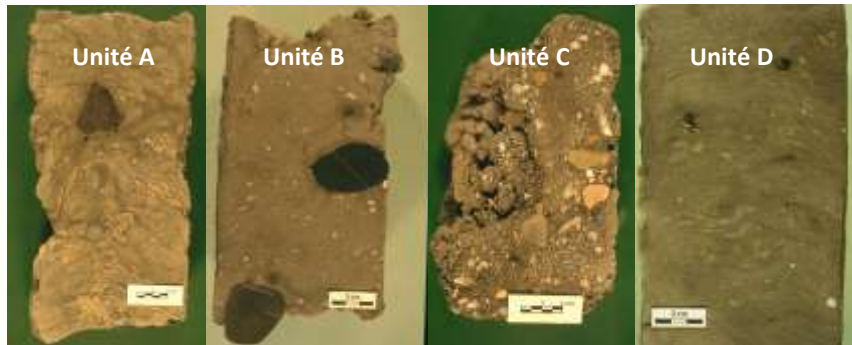
The Pierres du Niton (fig. c), visible upstream of the Jardin Anglais on the left shore of the Bay, are the best examples of such dropped blocks which are visible above the lake surface. These two blocks made of porphyric granite are respectively 4.3 and 3.5 m high and come from the eastern part of the Mont Blanc Massif. A bronze geodesic marker was fixed in 1837 on the highest one, at an altitude of 376.6 by G.H. Dufour. This point had been chosen as an altitude marker for the elaboration of the first national topographic map at 1:100'000 scale. In 1902, Switzerland deciding to use the precision levelling of bordering countries (France), the block lost altitude, which was calculated at 373.6 m above the mean level of the Mediterranean Sea established at the Marseille maregraph (Deriaz 1958).



**Figure a:** scenario of glacial advance and retreat explaining the genesis of the sedimentary sequence observed in the centre of the Geneva Bay and Petit-Lac (Moscardiello 1996). Unit A: gravels and sands sheared by the moving glacier; Unit B: basal moraine deposited below the glacier; Unit C: gravels and sands brought in by the sub-glacial stream at the front of the Rhône Glacier; Unit D: deposition of glacio-lacustrine sediments at the front of the retreating glacier. Sediment samples from the four units are shown in fig. b.



## Ge 1.6 (2): Geneva Bay at the end of the last glacial age



**Figure b:** samples representing the four sedimentary units of fig. a. They show parts of cores taken during the geotechnical investigation campaign carried out in the framework of a bridge construction project in the Geneva Bay (taken from Moscariello 1996). The wooden debris which yielded a Carbon-14 age of 22'500 years (calibrated age) come from Unit C)

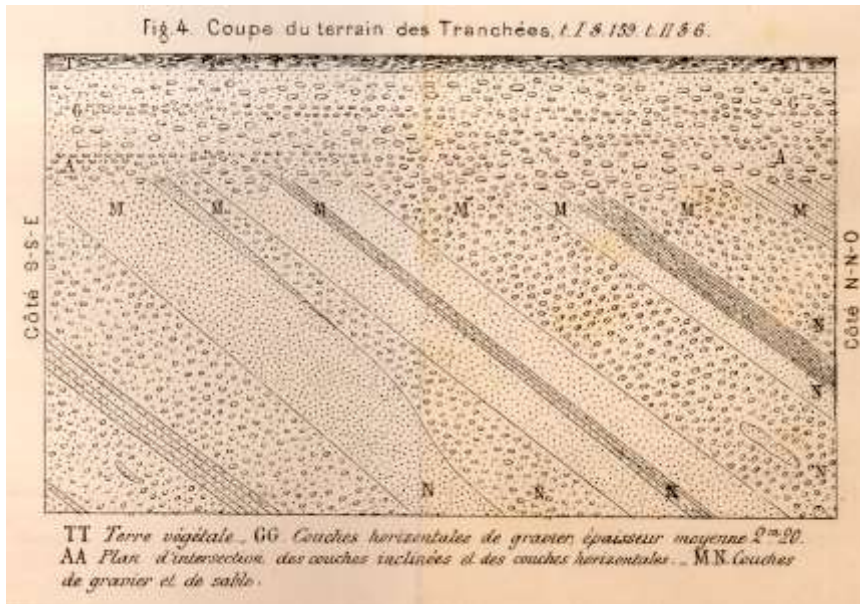


**Figure c:** Pierres du Niton viewed from the pontoon of the La Neptune boat.

## Ge 1.7: The glacio-lacustrine Saint-Antoine Delta

Localization : Promenade Saint-Antoine (coordinates 500 620/117 300).

In the middle of the 19th century, the City of Geneva decided to build ring avenues, in order to concentrate the traffic around the old city. The digging out of parts of the hill upon which the old town is located led to the creation of the Boulevard Jaques Dalcroze and Boulevard Helvétique. We owe to Alphonse Favre a most valuable geological drawing illustrating the geological arrangement of sediments along the flanks of these trenches (fig. a). This drawing shows an alternation of gravel and sand layers steeply dipping towards the north-northwest. Some layers display packages of broken-up sediments and traces of post-depositional erosion. A 2.2 m thick horizontal layer overlies the dipping sediments.



**Figure a:** outcrop of the Saint-Antoine Delta mapped by A. Favre (1879, fig. 4 ).

This sequence was again discovered during the construction of the Saint-Antoine parking (fig. b); nevertheless, the outcrops were much less spectacular.



**Figure b:** Saint-Antoine Promenade and parking viewed from the bridge crossing the Boulevard Jaques Dalcroze. The construction of the parking has unearthed old fortifications of the town and the Saint-Antoine Delta.

The presence of this delta poses a problem. Indeed, fine glacio-lacustrine sediments (silts and sands) have been discovered through boreholes underneath the deltaic sequence. Consequently, the glacier had already retreated from this location, before readvancing up to the location of the city and depositing this delta by means of its sub-glacial stream. Similar sediments are found laterally in the Champel area (fig. 35).

## ***Ge 1.8 (1): Saint-Pierre Cathedral: archeological site and stones used for the construction of Geneva Old Town***

*Localization* : from the Promenade Saint-Antoine take the Rue des Chaudronniers down to the Bourg de Four Square and then take the Rue de l' Hôtel de Ville. The first street to the right will take you to the La Taconnerie Square and Saint-Pierre Cathedral (coordinates: 500 400/117 400).

The Saint-Pierre Cathedral, as it stands now, was built in gothic style between the 12th and 15th centuries, with a portal dating from the 18th century. The basement of the building hosts an archeological site where one can visit the remnants of old religious constructions built up at this location since the 4th century A.C. One can also observe the contact between the geological substrate (the glacio-lacustrine delta) and the cultural layers. It is recommended to use the audio-guide available at the entrance of the site, in order to benefit from the explanations during the visit. Opening hours and other informations can be obtained on the website [www.site-archeologique.ch](http://www.site-archeologique.ch).



**Figure a:** old drinking water well in the archeological site beneath the Saint-Pierre Cathedral. From mid-19th century and the construction of the Boulevard Helvétique and Boulevard des Tranchés the water table does not reach anymore the wells in the old city..

The cathedral itself and the other buildings surrounding the cathedral square give an idea of the construction material used to build up the old city of Geneva. This material consists essentially of two types of natural stones:

- On one hand, white-coloured limestones often displaying fine zig-zag lines called « stylolites » (dilution sutures of the limestone). Locally, one may also encounter limestones with traces of burrowing organisms, which are called « calcaires vermiculés » by the geologists . All these rocks date back to the Late Jurassic (or Malm, about 155 to 145 million years ago) and come mainly from quarries located at the foot of the Jura Mountains, where they outcrop as massive or stratified limestones. The latter are quite resistant to weathering and ground humidity. Consequently, they have been used for the basement of buildings, cornerstones and towers (fig. b et c).



**Figure b:** Saint Pierre Cathedral, towers built with white-coloured limestone and nave with Molasse sandstones.



## **Ge 1.8 (2): Saint-Pierre Cathedral: archeological site and stones used for the construction of Geneva Old Town**



**Figure c:** base of a column at the cathedral entrance; white-coloured limestone referred to as « vermiculé » (see darker specks), with numerous stylolites (fine, zig-zag shaped dilution sutures).

- On the other hand, red or grey to greenish sandstones. Most of them come from old sub-lacustrine quarries (see visit Ge 11) exploited at the time during the winter (low-water periods of Lake Geneva), then brought to the city on barges during summer. These sandstones of the Red Molasse date back to the Oligocene period (about 30 million years ago). They were deposited in meandering river channels in the Alpine foreland. Red traces may indicate the presence of organic matter which is at present completely oxidized. The lenticular shape of the sedimentary structures give an idea of the dimension of the river channels at the time of sedimentation.



**Figure d:** Saint Pierre Cathedral; Red Molasse fluvial sandstones displaying lenticular sedimentary features.

Molasse sandstones are used essentially as «infill» building material. It is a rock that is easily weathered, in particular because of its poor calcareous cementation that makes it poorly resistant to acid rains.

## ***Ge 2: Sub-lacustrine quarries of the Old Geneva in Chambésy***

*Localization et itinerary* : take TPG bus N° 28 up to the Botanical Garden, or TPG tramway N° 15 from the Cornavin train station up to the Les Nations Square. Walk down the Avenue de la Paix up to the Route de Lausanne and follow the latter in the direction of Lausanne. The pits of the quarry are located 300 m upstream of the Reposoir Beach, off the Chinese Embassy. The perimeter is marked through buoys (coordinates: 500'750 / 121'039). For a proper visualisation, a small boat with little draught is needed.

These quarries were dug in the Red Molasse sandstones of Geneva. The thickness of this formation in the Geneva area varies between 250 and 1000 m. Its lithology, sedimentary structures, fauna and flora point to deposits of a flood plain, the latter being crossed by a set of fluvial meandering channels. It dates back to the geological stage of the « late Chattian », about 30 million years ago (see Decrouez 2012).

These quarries have been exploited from the end of the Middle Ages until the 18th century. The extracted blocks were used to build part of Saint-Pierre Cathedral, the western front of the Town Hall and several houses around the Bourg-de-Four Square.

For the extraction, the quarrymen isolated the zone to be exploited by means of "batardeaux" (the holes used to fix the batardeaux are still visible around the pits). Once the zone had been isolated, the quarrymen drew the water in order to be able to work. They sawed terraced pits, some of



**Figure a:** Buildings made of Red Molasse sandstones in the Cathedral Square



**Figure b:** sub-lacustrine quarries in Chambésy as observed in Google-Earth

them reaching a depth of ca. 3 m. Then they sawed the blocks down to the required dimensions. The extraction pits are separated one from the other through molasse walls upon which lied the batardeaux. In several pits, « staircases » were cut ([www.plongeplo.ch/wiki/index.php/Le\\_Reposoir](http://www.plongeplo.ch/wiki/index.php/Le_Reposoir)). The cut stones were then transported to the city by means of barges.

Onshore, Molasse quarries were also exploited in the perimeter of the Botanical Garden. These outcrops are not anymore accessible today.

## Ge 3 (1): From the Mon Repos Park to the Longemalle Square: variations of lake levels, villages of the Bronze Age and Roman colonization

Localization and itinerary: with the TPG bus N° 1 or 25, or with the Mouette N° 4 (boat) at stop/wharf De-Chataubriand. Get close to the lake, at the level of a small beach north of the wharf (point A).



Look towards the Pâquis lighthouse. You are well positioned to imagine the stretch of water in front of you as being a vast sandy and argillaceous zone with locally some willow groves. This was the landscape that the prehistoric farmers were gazing at in the Neolithic or the Bronze Age, during periods of low lake levels. The lake level was some 3 to 4 metres lower than the present-day one. You can use the draughted reconstitution (fig. b), to locate the two pile dwellings villages of Pâquis A and B, which were occupied in the late Bronze Age, between 1067 and 960 years BC. Then continue with the visit following the lake shore towards point B.

Figure a, itinerary 3: from the lacustrine villages to the Romans. (Swiss national Map 1:25'000, sheet Geneva 1301, © 2014 swisstopo (BA14046)).





**Figure b:** imaginary reconstitution of the Pâquis coastal villages during the late Bronze Age, around 1000 years B.C.  
Viewed from the Parc Mon-Repos towards the Bains des Pâquis  
(drawing by Yves Reymond).

**Ge 3 (2): From the Mon Repos Park to the Longemalle Square: variations of lake levels , villages of the Bronze Age and Roman colonization (continues)**

**Figure c:** the Geneva Bay in 1444, view from the northern shore : «The miracle fishing» by Konrad Witz  
Photo, Art and History Museum of Geneva.





### ***Ge 3 (3): From the Mon Repos Park to the Longemalle Square: variations of lake levels , villages of the Bronze Age and Roman colonization***

Stop a little before you reach the Pâquis Bath jetty (point B). Looking towards the Pâquis lighthouse (built in 1894 and classified as historical monument), you can imagine the last remnants of the prehistoric occupation in the Geneva Bay. These remnants were still visible between 1881 and 1921. At present, no more archeological remnants remain downstream of the Pâquis and Eaux-Vives jetties. Some rare stilts are still trying to withstand the current along the Eaux-Vives jetty.

From the Pâquis rotunda (point C), one can easily observe the two «Pierres du Niton» (Niton stones), the only survivors of a large number of blocks cluttering the bay and the southern shore of the lake in the 19th century. The Pierre du Niton which is the furthest away from the bay shore bears a bronze marker that was embedded in 1820. It acted for a long time as an altitude marker for the levelling of Switzerland, in particular for the Dufour Map, carried out from 1848 till 1864.

Continue your walk up to the Mont-Blanc Bridge. Before crossing it (point D), look at the view of the Prealps and Alps. In a clear day one can admire the Mont-Blanc. This point of view was highly appreciated by the English tourists residing in the grand hotels of the northern shore. This was a must in the «Grand Tour» of the wealthy elite passing through Geneva.

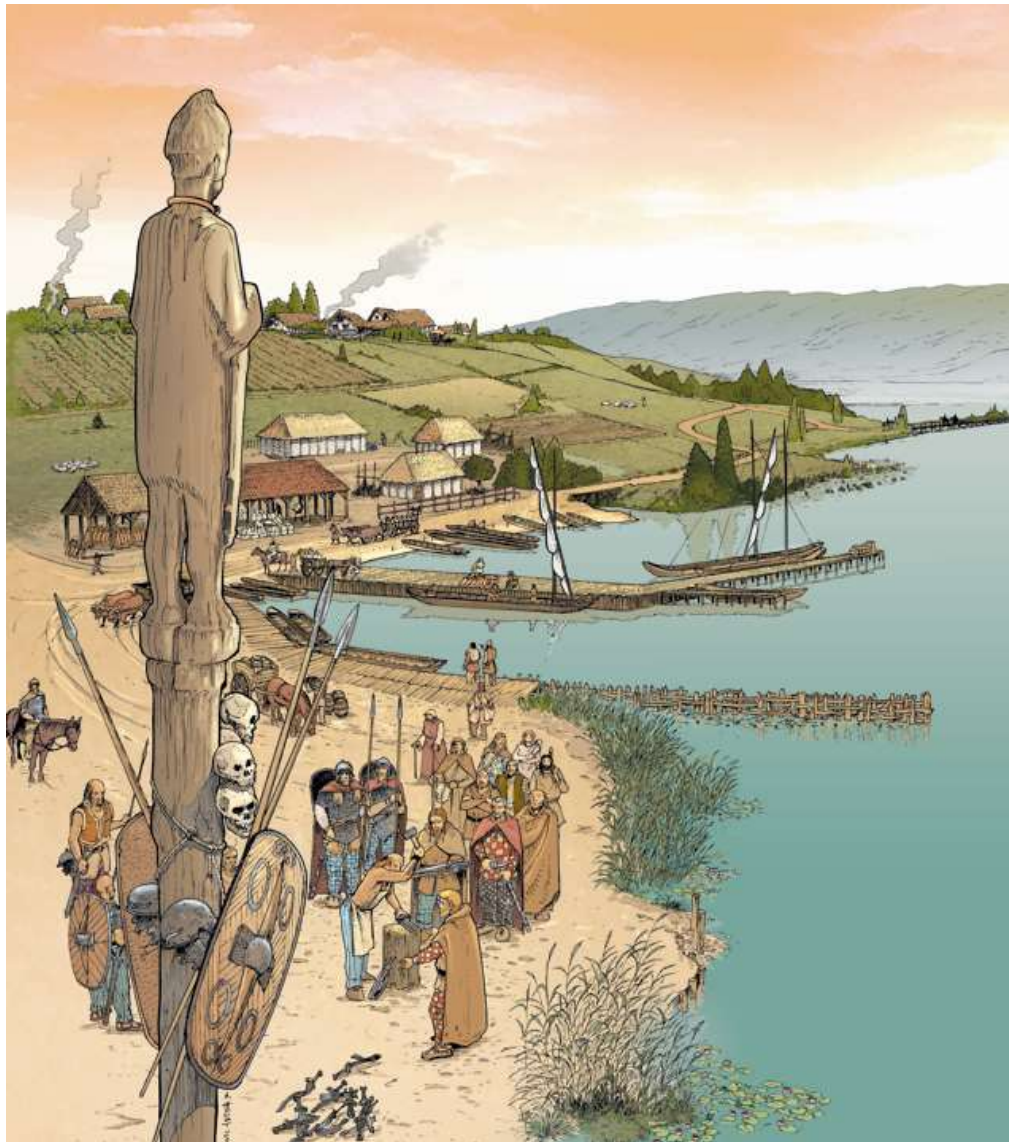
This panorama owes also its fame to the altarpiece of the Basel artist Konrad Witz (see previous page). It was the first realistic topographic representation of a landscape painted in 1444. In the foreground, one observes in the water evidences of clay digging for a tile factory. To the far left one notices the trace of the «Nant de Trainant», a stream draining the waters of the Frontenex plateau. Behind the Christ, a line of wooden piles sticks out of the water. This was probably designed to prevent the small boats to get to the shore. Piles from this line, made of oak wood, have been dated back to the autumn-winter of the years 1298/1299 AD.



***Figure d:*** the sluice gates of the Machine Bridge viewed from downstream of the bridge, between 1888 and 1898 (BGE, Genva Centre of iconography).



### **Ge 3 (4): From the Mon Repos Park to the Longemalle Square: variations of lake levels , villages of the Bronze Age and Roman colonization**



**Figure e:** reconstitution of the first Geneva harbour around 120 till 80 years B.C. (drawing by André Houot in: Gallay 2008 «Des Alpes au Léman»).

Now look downstream to the other side of the bridge. Passed the Bergues Bridge and the Rousseau Island, a white majestic building catches the eye: the building of the «Pont de la Machine» (point E). First built in 1709 to house the hydraulic machine designed to pump the Rhône waters to feed the city fountains, it was transformed in 1885 to support the sluice gates designed to regulate the Lake Geneva level, following the famous «Leman trial».

Now you cross the Mont-Blanc Bridge to reach the southern shore of the Geneva Bay. Walk on up to the Longemalle Square which you will cross. Stop between a cigar and a toy shop (point F). You are standing precisely at the location of the first Geneva harbour built around 120 to 80 years B.C.

The Gallic harbour was built by the Celtic tribe of the Allobrogs who was allied to the Romans. The altitude of the jetty points to a lake level situated at more than 374.6 m, i.e., more than two metres above the present-day average level. An oak wood statue was discovered nearby. It represents a warrior who had become a hero or a divinity. This statue was dated through dendrochronology as being post-100 years B.C. The figure wears a short tunic with a hood or maybe a helmet. He wears a gold torc around his neck. The remains of defeated enemy warriors (spears, shields, sacrificed heads) are hanging at the bottom of the statue

Around 47 years A.C. the harbour is completely rebuilt, this time with a dike made of stones and wooden beams stretching over more than 200 metres. The oppidum of Geneva is now in Roman hands. We are leaving prehistory to enter history.

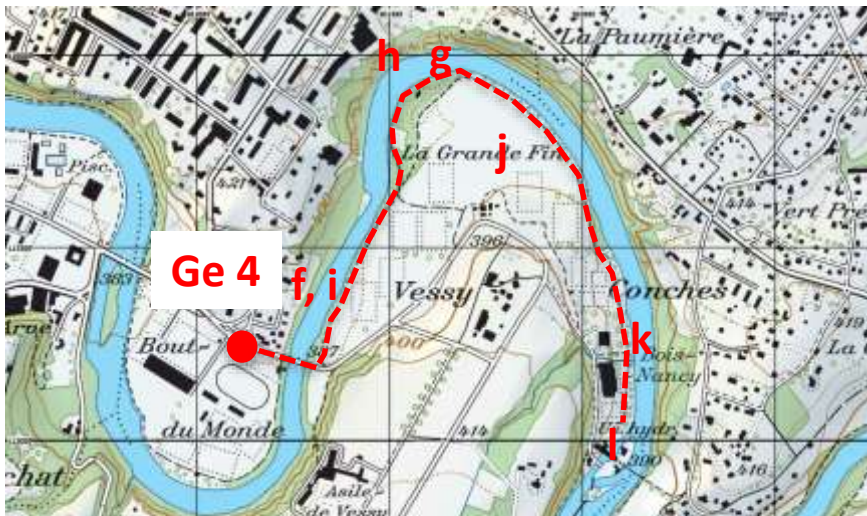
## Ge 4 (1): Vessy: the water table supplying drinking water to the City of Geneva

*localization et itinerary* : take Bus TPG N° 11 from the Jardin Botanique or Carouge up to the Bout du Monde (coordinates: 501 025/115 310), then by foot walking upstream along the left bank of the Arve River. The visit starts at some 1500 m upstream of the Bout du Monde, at the dam of the Vessy plant.

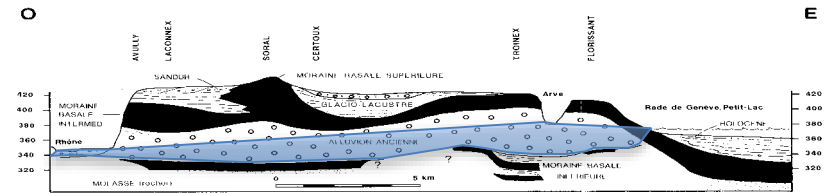
The Services Industriels de Genève are the main suppliers of drinking water in the canton. 80% of the water distributed in the network come from the pumping in Lake Geneva, whereas 20% are provided by a water table called «Nappe du Genevois» .



**Figure a:** main water tables exploited by the Services Industriels of Canton Geneva. Yellow circle: zone of artificial feeding at Vessy; blue squares: main pumping stations. Arrows: flow direction of the «Nappe du Genevois» (figure: Service de géologie, sol et déchets, Canton de Genève).



This water table originates in the Arve River valley, upstream of Geneva City (fig. a), where the river crosses the Alluvion ancienne and partly infiltrates the gravels of this formation. Following the Alluvion ancienne formation, the water table then flows on one hand northwards towards Lake Geneva, and on the other hand westwards, where it meets the Rhône River near the village of Chancy (fig. a and b). All along its course, the «Nappe du Genevois» is shielded from pollution through the clayey-silty deposits of the overlying basal moraines and lacustrine deposits. Its intensive exploitation provoked a significant decrease of its

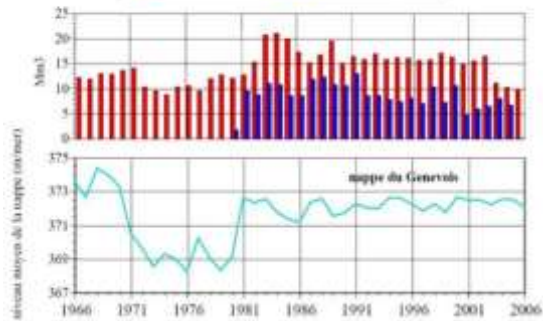


**Figure c:** synthetic geological cross-section from Lake Geneva to the Arve Valley and the Rhône Valley at Chancy (see fig. 10 above), and the «Nappe du Genevois» water table.

level in the 1970's (fig. c). This led Canton Geneva to build an important installation of artificial feeding (fig. d). Because this corresponds to one of the most important uses of a georesource in Canton Geneva, we hereby propose a visit, either within the framework of an independent excursion in the field, or within the framework of a guided visit (<http://ge.ch/geologie/eaux-souterraines/les-nappes-principales-du-domaine-public/la-nappe-du-genevois/realimentation-de-vessy>).

<- **Figure b:** itinerary of the visit. Points f to l correspond to the location of the figure below (Swiss National Map 1:25'000, sheet Geneva 1301, © 2014 swisstopo (BA14046)).

## Ge 4 (2): Vessy: the water table supplying drinking water to the City of Geneva



**Figure d:** pumping, artificial feeding and evolution of the level of the Nappe du Genevois at Vessy from 1966 till 2006. Red: pumping; blue: artificial feeding (De los Cobos 2012).

Fig. (d) shows a map where are located the different installations used for the artificial feeding, from the water intake at the old hydroelectric plant at Vessy, to a water treatment plant, where the Arve water is decanted and filtered (sand filters), and finally distributed into a large network of infiltration drains. The infiltration terrain is located on a low gravelly terrace of the Arve River, dating back to the late and post-glacial period. At this location, the river is presently eroding and digs its natural bed in the large Vessy meander. On its right bank, the Arve River is destabilizing the slope made of moraine and Alluvion ancienne, at the foot of the Champel area and of the high university residential building. Inside the meander, in the forest bordering the infiltration area, gravels and sands form an unstable point bar.



**Figure e:** installations of the artificial feeding of the Nappe du Genevois at Vessy: (1) water intake (pumping in the Arve River); (2) pipe towards the treatment plant (340 m long); (3) treatment plant; (4) pipe towards the area of artificial feeding (700 m long); (5) area of artificial feeding (underground drains, 5000 m long (De los Cobos 2012).

Therefore, the walk along the river allows an overview of the technical installation of artificial feeding, as well as the visit of a beautiful natural site.



## Ge 4 (3): Vessy: the water table supplying drinking water to the City of Geneva

**Figure f:** natural infiltration zone into the Alluvion ancienne (view from point i).



**Figure g:** point bar in the Arve meander at the foot of the Champel cliff (501 490/ 115 815).



**Figure j:** fountain for the distribution of water and infiltration terrace between the Vessy sport grounds and the Arve meander (coord. 501 725/115 790).



**Figure h:** landslide in the Upper Basal Moraine forming the Champel cliff. View from 501 650/ 115 955.

**Figure i:** torrential fluvial deposits with up to 50 cm in diameter blocks, below the terrace where the Vessy sport grounds are located, just opposite the tower of the «Cité universitaire». Their age is probably late glacial (coord. 501 475/ 115 585).



**Figure k:** plant for the treatment of waters taken from the Arve River prior to re-infiltration (view from 502 110/ 115 260).



**Figure l:** Vessy hydroelectric plant; site of water taking from the Arve River (view from 502 005/ 114 920).

## Ge 5 (1): Allondon River and Roulave Stream: from a Jura-sourced torrent to traces of bitumen in the Molasse

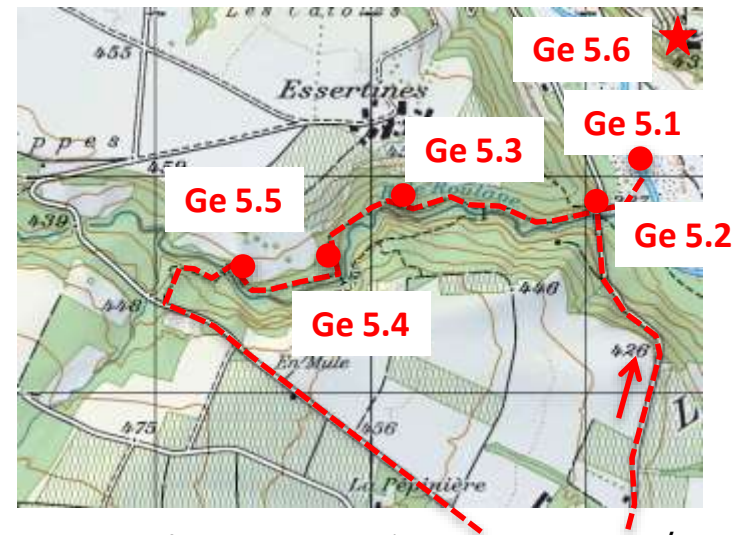
**Localization and itinerary:** the starting point is the Dardagny Town Hall (castle in the centre of the village). To get to Dardagny, a pedestrian path connects the CFF train station in La Plaine to the village of Dardagny; the walk takes about 30 minutes. For possible connections using Geneva Public Transports, one shall refer to the relevant website ([www.tpg.ch](http://www.tpg.ch)). If using a private vehicle, park on the parking lot of the multi-purpose hall. The walk follows to a large extent the naturalist path of the «Vallon de la Roulave» (Roulave Valley; geotope n° 060 Ge of SC NAT). The visit lasts 2 to 2h½ hours, it follows partly tarmac roads and (for the walk up the Roulave Valley) natural paths which are often humid, muddy and slippery (fig. a and b). From the Dardagny Castle, follow the pedestrian path (yellow signposts) towards the «Chapelle de Malval». Crossing first the moraine plateau and the vineyards, the road then goes steeply down with severe undulations (because of landslides) down to the bridge over the Roulave Stream (fig. c).

**The Allondon River:** it is known through its «Vauclusian» source (karst) at the foot of the Jura (Naz-Dessus hamlet). It is fed through the rain or snow falling on the high ridge of the Jura Mountains, where the highest summits reach altitudes of over 1700 m. The river flow shows very strong variations, similar to those of an Alpine torrent. The «River index card» edited by the Environmental department of the Canton (DIA 2003) indicates a low water flow of 0.5 m<sup>3</sup>/second and a high water

(flood) of 85 m<sup>3</sup>/second (10 year flow) or of 150 m<sup>3</sup>/second (100 year flow at the place called «Les Granges», one kilometre downstream from our observation point). In the zones where the river is not canalized (by blocks or dikes), i.e., downstream of a transect through the Essertines hamlet, this flow variability is expressed through a «braided stream» bed characterized by several channels separated by sedimentary bars. These channels can migrate laterally considerably over time. Fig. d, e and f illustrate this situation in views from point **Ge 5.2** (small dike, coord. 488 515/117 930).



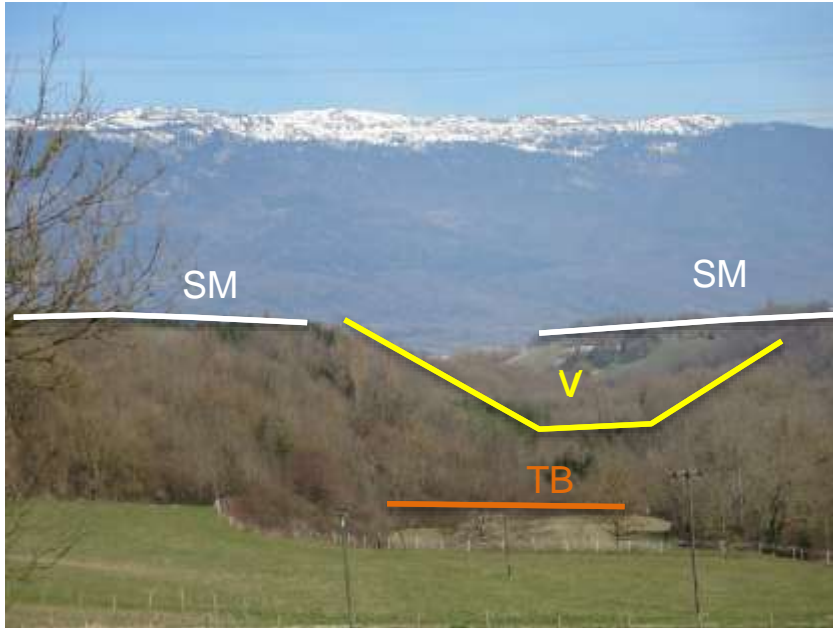
**Figure a:** itinerary of the visit (Swiss National Map 1:25'000, sheet Chancy 1300, © 2014 swisstopo (BA14046)).



**Figure b:** location of observation points (Swiss national Map 1:25'000, sheet Chancy 1300, © 2014 swisstopo (BA14046)).



## Ge 5 (2): Allondon River and Roulave Stream: from a Jura-sourced torrent to traces of bitumen in the Molasse



**Figure c:** view from the south of the low Allondon Valley (coord. 489 380/ 115 990) towards the Jura ridge (the «Recullet» summit on the left handside, the «Crêt de la Neige» summit on the right handside). The moraine surfaces (**SM**) with their «drumlin»-shaped reliefs (elongated mounds made of moraine or bedrock and formed below the glacier) date back to the glacial recurrence some 30'000 years ago (fig. 11 c). The relief of the valley (**V**) is erosive and later than this recurrence (Geneva Stage, fig. 12 a): from top to bottom the erosion profile cuts: the Intermediary Basal Moraine, the «Alluvion ancienne» and the Molasse. The «Baillets Terrace» (**TB**) corresponds to the highest levels of fluvial terraces at that time. They look down on the present-day Allondon river bed by up to 10 m (low valley) and are made of gravels and sands brought in by the Rhône Glacier or eroded from the «Alluvion ancienne» outcrops. At the location of profile V, the Geneva electricity company (Services Industriels de Genève) had planned the construction of a hydroelectric dam in 1938-39.



**Figure d** (on the left handside): braided stream and meandering river (meander reactivated by works, situation in March 2014). During high waters, the whole plain is flooded.

**Figure e** (on the right handside): flood channel (C, on the left handside, out of the water) and main channel (or low water channel E, on the right handside). River flow: 4.5 m<sup>3</sup>/second.



**Figure f:** erosion of the «Baillets Terrace» on the left bank of the Allondon River, downstream of observation point **Ge 5.2**. The cliff is approximately 5 m high.

Channels and sedimentary bars can migrate from one season to the other, or from one year to the other. The conditions shown in fig. d, e and f correspond to those in March 2014. At observation point **Ge 5.1** (fig. b) the Allondon River feeds its water table through infiltration. A few hundreds of metres downstream, conditions are reversed and the water table exfiltrates into the river.



## ***Ge 5 (3): Allondon River and Roulave Stream: from a Jura-sourced torrent to traces of bitumen in the Molasse***

**Walk up the Roulave Valley:** the walk starts at point **Ge 5.1** (bridge on the Malval road, coord. 488 515/117 915).

Some twenty metres north of the bridge, one can observe in the slope on the right handside a small cliff made of the strongly cemented conglomerate of the Alluvion ancienne (fig. g, see also visit **Ge 1.2**). The latter cliff together with the Molasse cliffs form the steep-slope reliefs in the valley.



**Figure g:** conglomerate of the Alluvion ancienne at point **Ge 5.1**.

While following the footpath up the valley, one notices large erratic blocks made essentially of various gneisses and granites from the Valais Alps. Some 100 metres from the starting point, the path goes over a small cliff made of Molasse green sandstones, which also outcrop in the river bed. Then one crosses a zone of wild forest disrupted by landslides on the right (south) bank of the river.

At point **Ge 5.3** (coord. 488 100/117 915, explanatory sign) one can observe a small cliff made of green and multicoloured, marly to argillaceous Molasse. It is finely bedded with some small sandstone beds (fig. h et g). These deposits were formed between 27 to 30 millions of years ago in an alluvial plain, probably during floods.



**Figures i, j:** small cliff (approx. 3-4 m high) of marly and argillaceous Molasse in the meander of the Roulave River at point **Ge 5.3**.

When one gets to a fork in the path (coord. 487 900/117 860), take left following the signpost «Grottes». The explanation site **Ge 5.3** (coord. 487 920/117 800) is located opposite a sandstone cliff of Red Molasse. The latter is made of different parts and has a cumulated height of some 20 m. Three galleries of some 2 m in diameter have been dug in the cliff to look for bitumen impregnating the sandstone (see boxed text on next page). In March 2014, none of the three galleries was accessible because of block and tree falls and landslides.

Molasse sandstones are essentially made of quartz, feldspath and mica. They are poorly cemented and weathering is important. Some zones are more strongly cemented by a calcareous cement and form prominent stronger beds. The bitumen impregnates sandstones in an irregular way, these impregnated zones forming sorts of «nests» or «lenses».

Sedimentary structures (fig. k) correspond to the infill of meandering river channels. The apparent width of these channels could reach or be over 10 m, with a depth in the order of one metre. Some smaller structures are also visible.

## ***Ge 5 (4): Allondon River and Roulave Stream: from a Jura-sourced torrent to traces of bitumen in the Molasse***



**Figure k:** sandstone cliff in the Molasse and gallery for the exploration of bitumen, opposite the observation point. The ca. 2 m wide gallery was not accessible in March 2014 because of rock falls.

The base of this Molasse has been dated in the stratigraphical column as «Lower Chattian» (approx. 28 millions of years old) thanks to the discovery of small remnants of rodents, in particular teeth.

### **Looking for petroleum in the Roulave Valley and Canton Geneva**

As explained in the explanatory signs at site **Ge 5.4**, «the bituminous sandstones have been prospected since a long time, they are already mentioned in 1770 by H.B. de Saussure. The first attempts to exploit them in the area date back to 1826, the digging of galleries in the Roulave Valley began around 1845, and phases of production and abandonment went on until 1894. During the two world wars, the exploitation was reinitiated with the digging of wells and deep galleries. Probably a total of several tens of tons of viscous bitumen was extracted. It was used to asphalt some streets in the City of Geneva, lubricate carriage wheels, caulk boats or for medical purposes » (see also H. Lagotala 1935).

Where does this bitumen come from? It corresponds to the migration up to the surface of crude oil produced by a source rock located underneath the Geneva Basin at a depth of about 3'000 m below the surface in Lower Jurassic rocks (approx. 180 millions years; see fig. 4 in introductory part). Because of the increase in temperature and pressure, the source rock reached its thermal «maturity» and «expulsed» crude oil that «migrated» upwards because of gravity (indeed sedimentary rocks are impregnated by water and crude oil is lighter). If this migrating oil does not meet an impermeable rock that can form a petroleum trap and block the upward migration of the oil, the latter will reach the surface and impregnate the rocks outcropping at surface and form oil seeps. Volatile components will evaporate and light components be biodegraded by bacteria, leaving only the heavy components which form the bitumen.

This petroleum system has obviously an economic interest in case the oil can be trapped in subsurface rocks to form an oil field. For example, the oil of producing oil fields in the Paris Basin (Val de Marne, east of Paris) comes from the same source rock which also underlies the Paris Basin. At the beginning of the 1980's, the company BP France drilled a series of shallow wells around the Canton Geneva in the Gex area to test for potential oil fields. They found some viscous oil, but such accumulations were not considered as economic at the time. In the Geneva Canton, an exploration licence has been granted to the company Tethys Oil at the beginning of the 2000's, but so far no well has been drilled.

## Ge 5 (5): Allondon River and Roulave Stream: from a Jura-sourced torrent to traces of bitumen in the Molasse

When following the footpath towards Dardagny from point **Ge 5.4**, one crosses a large landslide in the Intermediary Basal Moraine. This landslide has been moving since many years; it is reactivated and accelerates during humid periods and sometimes slows down during periods of drought (fig. l – o).

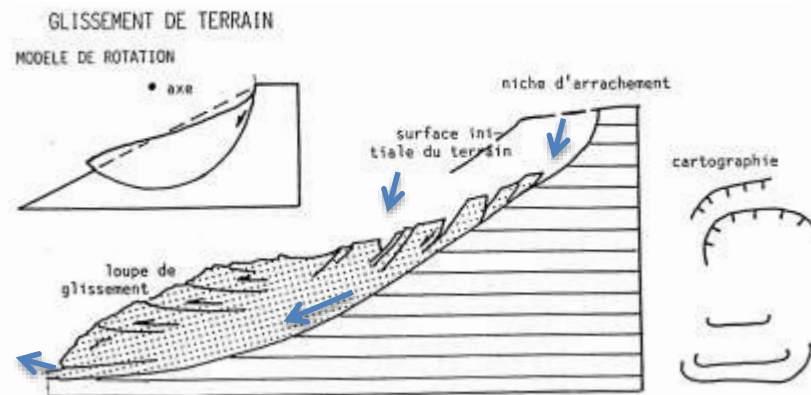


**Figure l** (on the left handside): the path connecting point **Ge 5.4** to **Ge 5.5** crosses the flank of a landslide. The humid zone testifies to the seeping of water.

**Figure m** (on the right handside): scar left by the landslide, where the moraine is exposed.



**Figure n**: fissures in the ground along the footpath. This marks the beginning of a new landslide.



**Figure o**: formation of a landslide (in blue: water circulation).

Two galleries (or «caves») in the Molasse are accessible at observation point **Ge 5.5** (coord. 487 680/117 760). Bitumen is concentrated in fine-grained sandstone lenses associated with marly intercalations (fig. p and q).

### References:

- Collectif d' auteurs 1990: Sentier naturaliste. Vallon de la Roulavaz (Dardagny). Série documentaire 27 des Conservatoire et jardin botaniques de la Ville de Genève. 1990. 89p.
- Lagotala, H. 1935. les gîtes bitumineux de Dardagny (Genève). Le Globe, Mém., Genève.
- Schroeder, J.W. 1958. Géologie du Pays de Genève. Le Globe 97.
- Feuille de l'Atlas géologique de la Suisse au 1:25'000, Feuille Dardagny, Vernier, Chancy, Bernex, Feuille 12, No. 1300.



## ***Ge 5 (6): Allondon River and Roulave Stream: from a Jura-sourced torrent to traces of bitumen in the Molasse***



**Figure p** (on the left handside):  
gallery in the Molasse at point **Ge 5.5**.

**Figure q** (below): bitumen  
impregnation (in black) within the  
Molasse inside the gallery.



**Figure r:** from point **Ge 5.5** one  
crosses the stream (fig. r) and walks  
up towards the road linking  
Dardagny village to Essertines  
hamlet (coord. 487 520/117 700).

### **Postscriptum**

This geological and archeological guide of Geneva tells the recent history of the Earth and landscapes upon which the first inhabitants settled down in Geneva, as if we were present at the time and as the story of a chronicler. But this impression is evidently deceiving. Indeed, geologists and archeologists work in reality like scientific police to reconstruct the story of the crime: they collect informations about the sites, date and hour of the crime. Then they compare and correlate what happened in the different sites under inquiry. These informations are compared with other stories that have or would have taken place somewhere else or at another time. All this is finally assembled in a more or less convincing scenario.

Whereas hard work has been carried out to reconstruct the true prehistory of Geneva, we must keep in mind that this scientific «truth» will last as long as no new discovery is made which will contradict or correct the previously established facts. Therefore, this guide is intended to be modified in the future with respect to new discoveries and investigations, and let's hope it will never be terminated.

This guide benefited from the thorough read-through by Jean-Claude Lalou (Vaumarcuse) and Alexandra Baeriswyl (Institut F.A. Forel). Katia Loizeau took care of loading it on the website of the Institut Forel. We are very grateful to them!

## References

- Affolter, J. A., Argant, J., Castel, J.C. et al. 2012: La Haute-Savoie durant la préhistoire, 40 000 - 5 500 av. J.-C. Collection d'Ouvrage Culture74/8. 128 p.
- Amberger, G. 1978: Contribution à l'étude du Quaternaire de la région lémanique: Résultats de quelques sondages profonds exécutés à Genève. *Eclogae geol. Helv.* 71/1, 193-206.
- Arn, R. 1984: Contribution à l'étude stratigraphique du Pléistocène de la région lémanique. Thèse Fac. Scie. Univ. Lausanne.
- Blavoux, B. 1988: L'occupation de la cuvette lémanique par le glacier du Rhône au cours du Würm. *Bull. AFEQ* 2/3, 69-79.
- Broillet, Ph., éd. 1997: Les monuments d'art et d'histoire du Canton de Genève; la Genève sur l'eau. Société d'histoire de l'art en Suisse, Wiese, Bâle, 455 p.
- Brun A. 2000: Révision des données polliniques dans le Pléistocène du Bas-Chablais (Haute-Savoie) : implications chronostratigraphiques et pluralité des glaciations [Reconsideration of the pollen data in the Pleistocene of the Bas-Chablais. (Haute-Savoie): chronostratigraphic implications and plurality of glaciations]. In: *Quaternaire - Volume 11 - Numéro 1 – 2000*, 41-51.
- Collectif d'auteurs 1990: Sentier naturaliste. Vallon de la Roulavaz (Dardagny). Conservatoire et jardin botaniques de la Ville de Genève, 89 p.
- Corboud, P. 2012: L'archéologie lémanique un siècle après F.A. Forel. *Arch. Scie.*, 237 – 248.
- Coutterand, S. 2010: Etude géomorphologique des flux glaciaires dans les Alpes nord-occidentales au Pléistocène récent. Thèse Univ. Savoie, Chambéry, 471 p.
- Decrouez, D. 2012: Carrières sous-lacustres (Prégny-Chambésy, GE). *Géotope suisse n° 304 (GE)*. ScNat, Berne.
- De los Cobos, G. 2012: L'eau sans frontières. Quarante ans d'une gestion partagée de la nappe d'eau souterraine du Genevois. Slatkine, Genève, 200p.
- Dériaz, E. 1958: Cartographie actuelle du canton de Genève. *Le Globe*, *Mém. Soc. Géogr. Genève*, t. XCVII, 15-36.
- DIA 2003: L'Allondon; fiche rivière n° 1, 3<sup>ème</sup> édition. Département de l'agriculture, de l'intérieur et de l'environnement, Genève.
- Duc, G., Frei, A. & O. Perroux 2008: Eau, gaz, électricité, Histoire des énergies à Genève du XVIII<sup>ème</sup> siècle à nos jours. Ed. Infolio, Gollion, 2008.
- Dufour, A. 2001: Histoire de Genève. 3<sup>ème</sup> édition. « Que sais-je? » PUF, Paris, 128 p.
- Favre, A. 1879: Description géologique du Canton de Genève. A. Cherbuliez & Co, Genève.
- Forel, F.A. 1892: Le Léman: Monographie limnologique. F. Rouge, Lausanne (réédité par Slatkine, Genève 1969).
- Fiore, J. 2007: Quaternary subglacial processes in Switzerland: Geomorphology of the Plateau and seismic stratigraphy of Western Lake Geneva. *Terre et environnement* 69, 169 pages. ISBN 2-940153-68-X. Cyberthèse.
- Fiore, J., Girardclos, S., Pugin, A., Gorin, G. & W. Wildi 2010: Würm deglaciation of western Lake Geneva (Switzerland) based on seismic stratigraphy. *Quat. Scie. Reviews* 30, 377-393.
- Fuchs, M. 2008: Integration of ground-penetrating radar, high-resolution seismic and stratigraphic methods in limnogeology: Holocene examples from western Swiss lake deposits. *Terre et environnement* 77, 254 p. ISBN 2-940153-76-0
- Gallay, A. (ed.) 2008: Des Alpes au Léman: Images de la Préhistoire. Gollion: Ed. Infolio.
- Girardclos, S. 2001: Sismostratigraphie et structure sédimentaire en 3D d'un bassin lacustre, du retrait glaciaire a nos jours (Lac Léman, Suisse). In: *Terre et Environnement*, vol. 33. Université de Genève, Switzerland, 182 pp.
- Girardclos, S., Fiore, J., Rachoud-Schneider, A.M., Baster, I. & W. Wildi 2005: Petit-Lac (western Lake Geneva) environmental and climate history from deglaciation to present: a synthesis. *Boreas* 34, 417-433.
- Gorin, G.E. & A. Moscariello 2013: Léman et gaz de schiste : un souci infondé. *Lémaniques*, *Bull. assoc. Sauvegarde du Léman*, sept 2013, 2-6. 61

Gorin, G.E., Signer, C. & G. Amberger 1993: Structural configuration of the western Swiss Molasse Basin as defined by reflection seismic data. *Eclogae geol. Helv.* 86, 693 - 716.

Hernandez Trevethan, M. 2010: Scénarios de risques sismiques dans la région urbaine de Genève. Thèse Univ. Genève. Cyber-thèse <http://archive-ouverte.unige.ch/unige:16943>.

Jäckli, H. 1970: La Suisse durant la dernière période glaciaire. Atlas de la Suisse, planche 6.

Kremer, K., Simpson, G., Girardclos, S. 2012: Giant Lake Geneva tsunami in AD 563 *Nat. Geosci.* 5, 756-757.

Lagotata, H. 1935: Les gîtes bitumineux de Dardagny (Genève). *Le Globe, Mém., Genève.*

Maystre, D. H. & J. Vergain. 1992. Les dépôts glaciaires et proglaciaires dans la partie occidentale du Bassin genevois: genèse et chronologie. *Eclogae geol. Helv.*, 85, 169-194.

Monjuvent, G. & G. Nicoud 1988: Interprétation de la déglaciation rhodanienne au Würm, des moraines «internes» à la cuvette lémanique. *Bull. Assoc. Fr. Etude Quat.* 2/3, 129-140

Montandon F. 1925. Les éboulements de la Dent du Midi et du Grammont (examen critique de la question du Tauredunum). Extrait des Mémoires du Globe, tome LXIV, Genève: 35-91.

Moscariello, A. 1996: Quaternary Geology of the Geneva Bay: sedimentary record, palaeoclimatic and palaeoenvironmental reconstruction since the Last Glacial Cycle. *Terre et Environnement, Univ. Genève* 4, 230 p.

Moscariello, A., Pugin, A., Wildi, W., Beck, Ch., Chapron, E., De Batist, M., Girardclos, S., Ivy Ochs, S., Rachoud- Schneider, A.-M., Signer, C. & T. van Clauwenberghe 1998: Déglaciation würmienne dans des conditions lacustres à la terminaison occidentale du bassin lémanique (Suisse occidentale et France). *Eclogae geol. Helv.* 91, 185 -201.

Paolacci, S. 2013: Seismic Facies and Structural Configuration of the Western Alpine Molasse Basin and its Substratum (France and Switzerland). Thèse Univ. Genève.

Pittard, J.J. 1936: La Recherche de l'or dans la région de Genève. Société générale d'imprimerie.

Pugin, A., Bezat, E., Weidmann, M. & W. Wildi. 1993: Le bassin d'Ecoteaux (Vaud, Suisse): Témoin de trois cycles glaciaires quaternaires. *Eclogae geol. Helv.*, 86/2:343 – 354

Schroeder, J.W. 1958: Géologie du Pays de Genève. *Le Globe* 97.

Sesiano J., Schnyder C., Proz P.-A., Gnos E. and Schaltegger U. 2011: Les Pierres du Niton revisitées : soubassement, minéralogie, datation et origine. *Archives Des Sciences* 64: 81-90.

Trümpy, R. 1980: *Geology of Switzerland: a Guide Book. Part A: An outline of the Geology of Switzerland.* Schweiz. Geol. Komm. Wepf & Co. Publishers. Basel, New York.

Wegmüller, S., Amberger, G. & J.P. Vernet 1995: La formation de Montfleury près de Genève: Etude palynologique et sédimentologique d'une séquence du Pléistocène moyen. *Eclogae geol. Helv.* 88/3: 595-614.

Wildi, W. 1997: Le site naturel de Genève, pp. 3 -13. In: *Les Monuments d'Art et d'Histoire du Canton de Genève* (Ph. Broillet, ed.). Soc. Hist. de l'Art, Berne.

### **Cartes géologiques**

Feuilles de l'Atlas géologique de la Suisse au 1:25'000:

- Coppet, feuille 46, CN 1281
- Dardagny, Vernier, Chancy, Bernex, Feuille 12, CN 1300
- Genève, Feuille 46, CN 1301

### **Géoportail du Canton de Genève**

<http://ge.ch/geologie/>

### **Université de Genève, Section des sciences de la Terre et de l'environnement**

<http://cms.unige.ch/sciences/terre/>

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<https://www.ville-ge.ch/mhng/>

### **Randonnées géologiques**

<http://www.thierrybasset.ch>



