



## EAGE Toulouse 2025 Conference

### Field trip 4

#### Part 1 : Gold panning in the Salat River

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This half-day will take place **in the Pyrenean foothills**, a particular area of transition, both geological and human, between the Pyrenees high chain and the Aquitaine basin and will be our common thread.

**On the banks of the Salat River, in a meander located** today in the town of Salies du Salat, we will focus on a very particular detrital sedimentary process, the fluvial sedimentation of alluvial plains **with migration and trapping of heavy minerals (and gold?)** associated with detrital, conglomeratic to clays, mainly silicate grains generated **by the erosion of the neighbouring Pyrenees**.

This sedimentary process is marked by **gravity**, which allows the movement of particles from the top to the bottom of the slope, and by **turbulence**, which allows the concomitant transport of mud and heavier, more massive particles. These deposits are the consequence of a complete process from weathering-erosion/transport/deposition profiles that allow the movement from the source to the sedimentation sink over a distance of a few tens of kilometers.

This process illustrates **all the mineral richness of the piedmonts or foothills**, located between the high orogenic chain and the sedimentary basin of the foreland or hinterland, the primary receptacles of the erosion of the chains, whether it is their continental part as here or marine. From Alaska to the Andes, from the Carpathians to the Caucasus, via the Apennines or the Pyrenees in Europe, these geological provinces, marked by sedimentation and then compression and metamorphism, have since the earliest antiquity been the site of countless explorations and exploitations, both for metals or hydrocarbons. They are also located at the borders or interfaces between different peoples: the most emblematic example is of course the Kurdistan region: Persians in the high chain, Kurds in the foothills and Arabs in the Mesopotamian plain.

Therefore, Jack London, a remarkable observer of nature, one of the prospectors of the Yukon gold rush, an unknowing geologist, and author of the wonderful novel "The Call of the Wild" will be our field companion today.

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### 1) Presentation of the region: the small Pyrenees.

The region crossed by the Salat river is part of the Comminges and corresponds to **part of the northern Pyrenean zone** located between the high chain to the south, composed mainly of Paleozoic (and pro parte Proterozoic) series injected at the end of the primary era by granite massifs and **the sub-Pyrenean zone** to the north, which constitutes the southern edge of the Aquitaine basin, a foreland basin corresponding to an enormous central deposit more than 10 km thick formed, mainly, of Cretaceous and Tertiary formations.

The boundary between the Haute Chaine and the northern Pyrenean zone is the FNP (Northern Pyrenean Fault) or better the FNI (Northern Iberian Fault, Biteau and Canerot, 2007) and the boundary with the sub-Pyrenean zone is marked by the FCNP (Northern Pyrenean Thrust Front). In this narrow-elongated east-west band, Triassic, Jurassic and Cretaceous series outcropped and faulted during the Eo-Oligocene, with folds and thrusts, often linked to diapirs of Triassic salt (Keuper) which has largely influenced the local toponymy: Salies, Salat, Salié.... These Tertiary folds are particularly visible in this region of Comminges, in the Plantaurel massif (Ariège) or the Petites Pyrénées (Haute Garonne) as well as much further west, in Chalosse or Bearn. A few major transverse faults, N30° and N160°E, inherited from Hercynian tectonics, complicate the structuring of the northern Pyrenean zone, if it were necessary: this is particularly the case of the mega-regional fault of Toulouse, which even influences the Quaternary deposits and the orientation of river courses. This zone is typical, by its inverse faults and its often asymmetrical folds, spilled to the north or south, of the so-called FTB ensembles, for "*Faults and Thrusts Belts*" (Cramez and Letouzey, 2002) which have always been the site of mining explorations because they allow very varied terranes, older than those of the plain, to outcrop and also O&G exploitation, because they allow the creation of structural traps that are visible either on the surface or in geophysics.

The Aquitaine basin extends over 120000 km<sup>2</sup> but it is the 7000 km<sup>2</sup> of a sub-basin called Adour-Comminges, along the northern edge of the Pyrenees, that will interest us today because of its FTB context. This sub-basin developed in the Lower Cretaceous due to the eastward advance of Iberia (which had separated from Europe between the Permian and the Lower Jurassic), which led to the opening (rifting) of the Bay of Biscay and the creation in its eastern extension (Canerot, 2008), of a succession of very subsident collapse trenches associated with tilted blocks and diapirs. In the Adour-Comminges area, the Albian-Cenomanian series with flysch facies can reach 6000 meters. This type of sedimentation continued until the Campanian during which the phases of compression began, a closing between Iberia and Europe that gave rise to the Pyrenean chain, an orogen that reached its climax in the Upper Eocene. But that relief was quickly eroded and from the Oligocene, the first molasses, major detrital deposits linked to the erosion of the high range, appeared. These deposits of alluvial fans and rivers still continue nowadays and are the first receptacles of all erosion products, in particular heavy minerals.

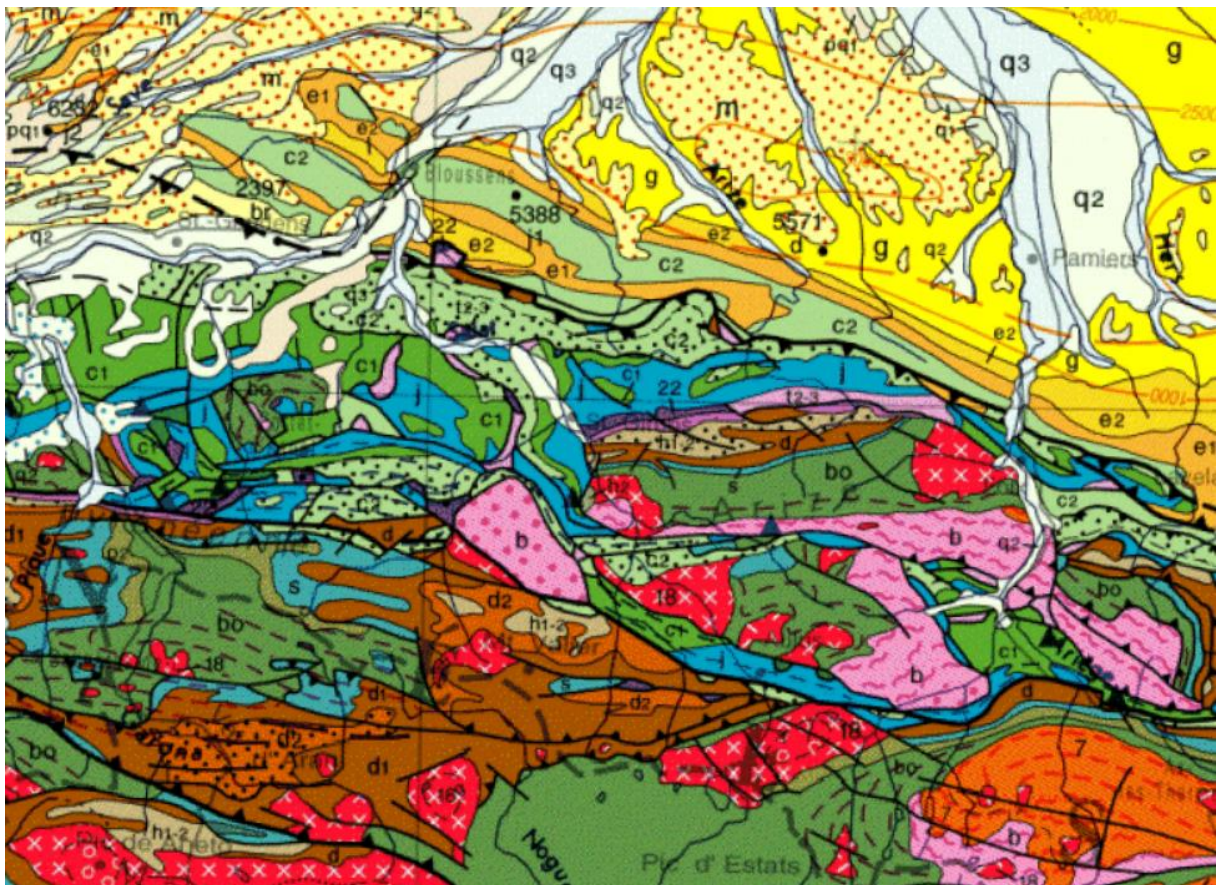
### 2) The SALAT, from the High Pyrenees to the molasse plains: agent of erosion and sedimentation.

More locally, it should be noted that the Salat watershed measures about 500 km<sup>2</sup> and is limited to the east by the granite massifs of the Arize and the Trois Seigneurs which culminate at 2200 m and to the south by the high Paleozoic chain, along the Spanish border and then to the west by granite and carbonate peaks transverse to the chain which form the limit with the main basin of the Garonne in which the Salat flows at the confluence of Roquefort sur Garonne. Its main part, central, landlocked, south of St Giron's corresponds to the Couserans region, topped shortly before the border, by the famous Mont Vallier, a landmark and emblem of this region peaking at 2838 m.

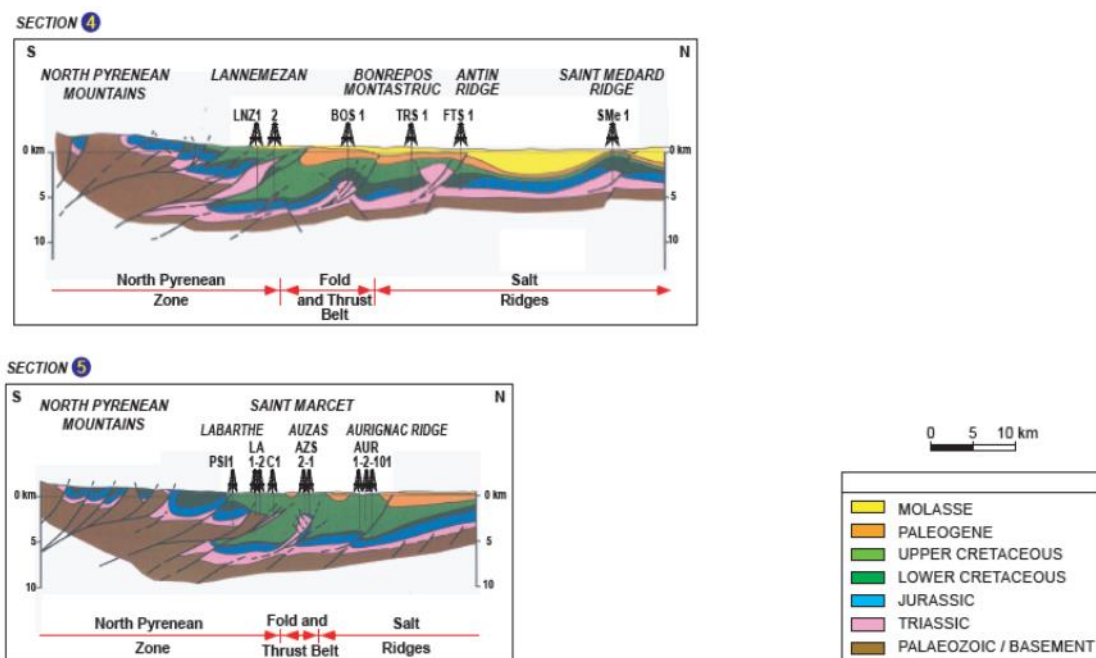
This river, the Salat, therefore, crosses extremely varied geological territories and must, like its main tributaries, make its way through them and its course more than complicated. Along these rivers, we can observe the main direction of flow SE-NW and secondary directions NS and even practically West-East! These variations in flow direction bear witness to an orographic and geological landscape made up of marked changes in lithologies and tectonic directions, in particular transverse accidents inherited from Variscan tectonics. Its catchment area corresponds to:

- To the south-east and center, to crystalline massifs, Variscan calc-alkaline granites (300 Ma) intrusive in the Paleozoic series.
- To the south, the upper Cambrian-Carboniferous high Paleozoic chain and rarer granodioritic intrusions
- To the north, the folded carbonate and molassic ranges of the Petites Pyrenees in an ESE-WNW direction which extend to the west,
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The Salat receives major tributaries: the Garbet on the right bank, the Lez on the left bank swollen by the Bouigane; As a result, the products of erosion are very differentiated, both in size and density, as well as in lithologies or petro-physics, as we will have the opportunity to feel.



**Figure 1** - Extract geological map. Northern Pyrenean zone- BRGM-<https://infoterre.brgm.fr/viewer>



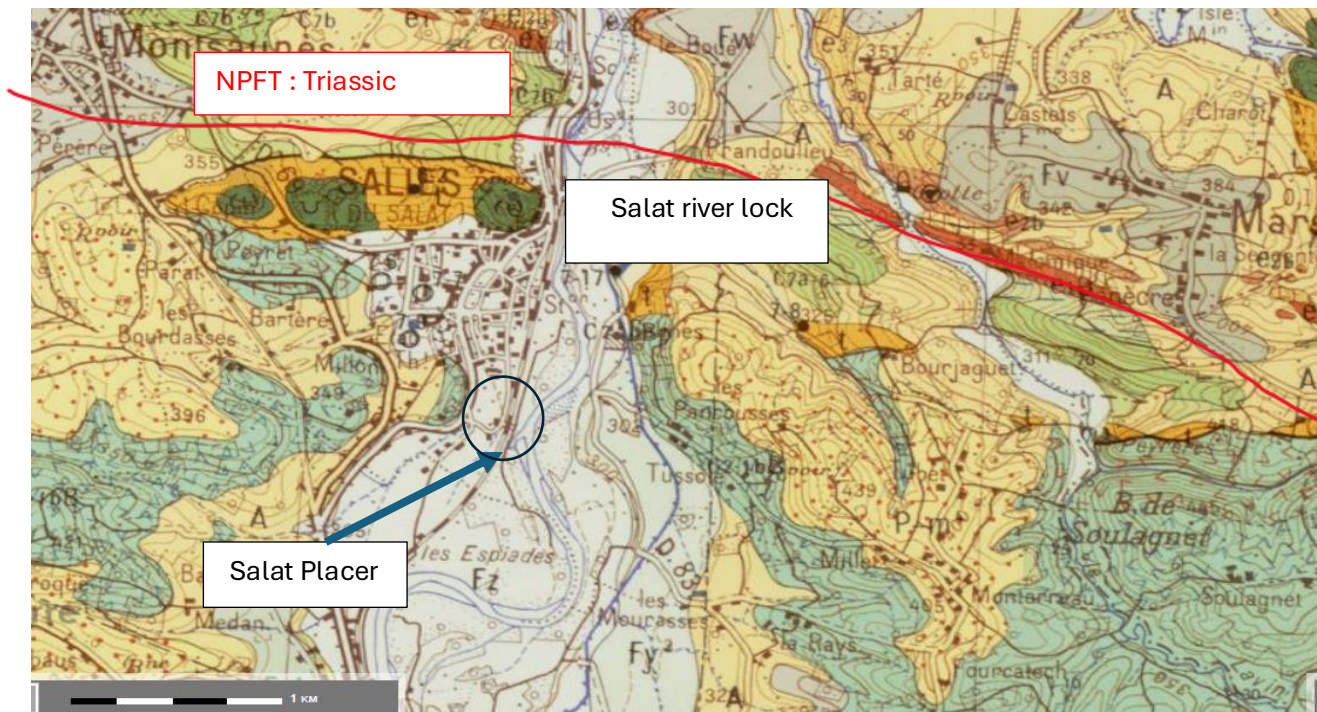
**Figure 2** - Structural sections of the northern Pyrenean border, Biteau JJ et al. (2006).

### 3) In search of nuggets in the footsteps of Jack London: the placer of Salies du Salat

To find gold at the bottom of your pan, it is not enough to force yourself to wash the alluvium of a gold-bearing stream, **you also must know where to look**. Because of their density, the gold and heavy minerals carried by the current are deposited and concentrated in specific places called **alluvial placers** (from the Spanish word placer i.e. pleasure). It is from these places that the alluvium to be washed must be taken. The river classifies, according to their density and size, the materials it moves and deposits. Nature thus prepares the work of the gold miners by naturally concentrating the heavy minerals in the alluvial placers. But this type of alluvial prospect (which will be defined as a sedimentary volume capable of containing the ore sought) is only a detrital, secondary, derivative of a primary deposit located upstream that we will call "source-rock".

The placer(s) of Salies du Salat are located according to the geological map of St Gaudens (1/50000 th) in a part of the valley oriented South-North, immediately south of the FCNP marked by a small cluse thanks to the crossing of hard Triassic rocks (ophites: gabbros of Norian to Hettangian age), and quite close to Triassic diapiric points (see satellite photo and photo, below) rich in evaporites that gave rise to thermal springs and the pleonastic name of... Salies du Salat where salt extraction has been carried out since Roman times.





**Figure 3-** Salies du Salt Geological Map-- BRGM-<https://infoterre.brgm.fr/viewer>



**Figure 4:** satellite view of 13/05/2025. Source: GOOGLE Earth.

The existence, due to the presence of hard Triassic soils associated with diapiric rises, leads to the existence of a small cluse on the Salat marked by rapids (see photo) and a calmer reach upstream which allow the deposit of alluvium in the place that we will explore.





**Photo 1** place it from Salies de Salt upstream of the rapid. Photo: 12-05-2025- Credit: Marc Blaizot

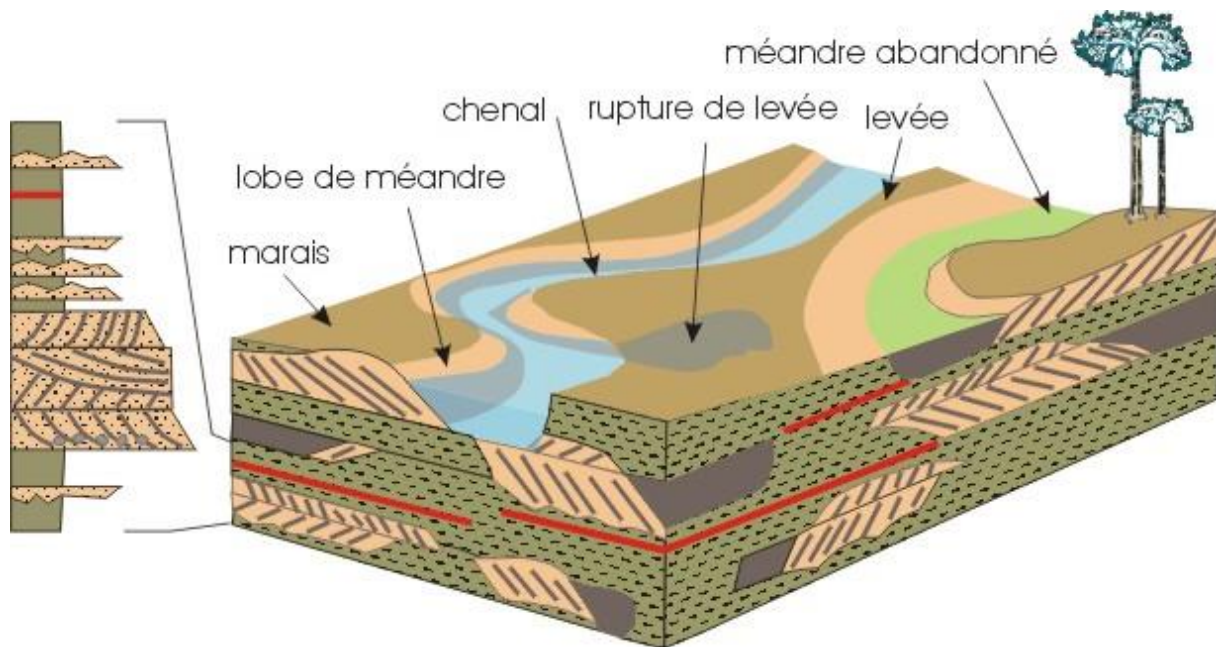
### 3a-What is a placer?

The current moves the alluvium by classifying it; the heavy minerals do not circulate over the entire width of the bed; they follow a narrow channel, often called, in America, **the "gold line"**. Narrow passages exacerbate this phenomenon. In the case of meanders, this channel generally follows "the rope". In a straight line, it is the shape of the riverbed that determines the path taken by the nuggets and gold flakes. During floods, the path of heavy minerals changes according to the flow rate and the configuration of the area crossed. When a slowing of the current occurs, the alluvium is deposited according to its density and volume. The density of gold being 19.33 and that of pebbles and sands between 2 and 3, gold is deposited at the same time as **gravels much larger than it**. Thus, in a meander bar, the deposits are generally classified from upstream to downstream and from bottom to top, in the following way: just above the hard bed-rock, a series of large pebbles, associated with heavy minerals and sometimes gold in nuggets-then gravels resting on coarse sands, with heavy minerals and fine gold flakes and finally fine silts, generally sterile and clays.

During floods, the areas of passage and especially of deposits of heavy minerals are found uncovered on the banks of the river. It's time for the gold miner to start his exhausting work!

### 3b- River sedimentation

Channels are present in many types of environments: alluvial, but also coastal and underwater. Some characteristics of meandering river systems include:



**Figure 5.** Diagram of a meandering fluvial system and example of a filling sequence. The lateral levees bordering the channel develop following the decrease in the speed of the current near the bank. Sand in beige, clay and silt in green, peat in grey and paleosols in red. Source: Boulvain F., 2018-University of Liège.

Alluvial placers are quite mobile, often displaced or remobilized by floods. The piedmont areas, at the end of the high relief, such as in the Salies area and upstream of the rapids, are particularly sought after because of the overall slowing of the current, and a less marked orographic profile. But looking at a topographic map or a satellite photo to define a good prospect would be too simple. Some more local parameters are also to be looked for and make all the art of the prospector. The vegetation flooded by a flood works like a carpet and constitutes an excellent trap holding heavy minerals and gold, hence the name, beyond Greek mythology, of the "Golden Fleece" given to the sheepskins used to recover nuggets; these plants, their roots, the sands they retain must be taken and washed carefully in the pan. Fine roots, moss, carpets of grass are very promising... of gold.

### 3c - In search of the parent rock

Mineralogically, gold is mainly native, trapped in quartz gangue or in sulphides, pyrite ( $\text{FeS}_2$ ) **and especially mispickel** (arsenopyrite  $\text{FeAsS}$ ). The destruction of quartz by erosion, particularly in the Pyrenees by freeze/thaw phenomena, releases the gold particles and allows them to migrate towards alluvial placers.

#### Identity sheet: Gold

Colour: bright yellow

Very dense: 19.3

Unalterable to water and air

Very ductile: 1g of gold can give a 3 km long wire!

Atomic number: 79 (protons); Atomic weight: 197

Clarke (mean crustal content): 0.005 g/t or 5 ppm

The origin of the Salat gold is clearly detrital, but several "source-rocks" or primary deposit candidates are possible upstream; they are provided to us either by historical testimonies or by



geology, archaeology and even toponymy. The latter shows upstream of St Girons and on a tributary, the Bouigane, the following localities: Argein, Aucazein, Augistrou, Orgibet, Augirein... all gold-based roots, no need to do a long etymological study...

## Quelques villages le long de la Bouigane



*Photo 2. Some emblematic names of the Bouigane valley, a tributary of the Salat in the Couserans area. Photo credit: Blaizot Marc., August 2018.*

Mining archaeology and the numerous research in the Pyrenees chain from the Basque Country to Roussillon, carried out by Béatrice Cauuet (University of Toulouse, UMR TRACES) also demonstrate the existence of Gallic works, more certainly Roman. Besides Roma had long coveted the "Gallia aurifera", one of the reasons for its conquest by Julius Caesar in 52 BC.

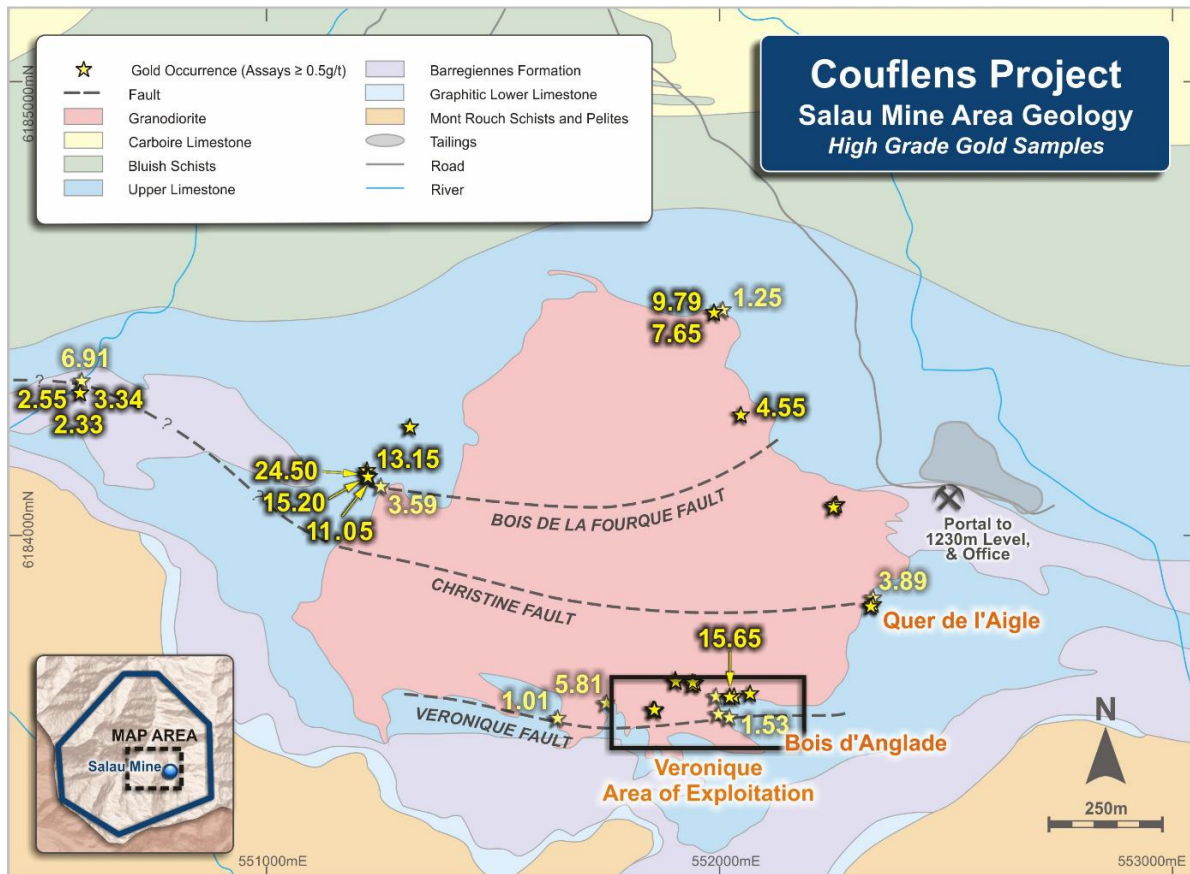
The main types of gold deposits outside of detrital rocks, the "source rocks" are as follows (Vic G and Tourlière B., 2006):

- the Archean** (Canada East, Western Australia, Brazil), Proterozoic, and **Hercynian (Africa-Europe)**, and Tertiary (USA, Chile) belts, which often correspond to quartz-rich veins **associated with massive sulphides** (lead, zinc, iron) of volcanic origin (Canada, Australia, Sweden) and intersected with tectonic deformation corridors (De Souza and Matthieu, 2018). The south-west Couserans zone (Mines of Bentaillou) could be attached to it.

- porphyry-type granites** associated with copper, with low gold contents, but of very large dimensions: USA, Canada, Peru, Chile, Papua New Guinea (Beaudoin, 2018).

- **skarns** (contact metamorphism between granites and carbonates). These skarns are well known in the upper Salt Valley near Salau. This skarn was discovered and exploited for tungsten in the 1950s and 1980s, but new data (Thomas Poitrenaud's thesis, 2018) reveal quite staggering gold grades (**up to 25 g/t!** Testard J., 2018).





**Figure 6.** Salau-Couflens zone: Contents *e*; after Poitrenaud T. published in Testard J. (2018).

In the case of the Salat watershed, we could therefore mention the three types of "source rocks", but more certainly type 3. It should be noted, however, that the source rock has not been formally recognized despite frequent research, but in very difficult conditions (cliffs, high mountains, cold).

The world production of gold is about 2500 t/year. Since the dawn of time (Bronze Age), 130,000 t are said to have been extracted (see Geochroniques, 2002) of which 100,000 t still remain today (jewelry, coins), testimony to the great quality of gold: its resilience due to its unalterable nature, a well-known guarantee of eternal love.

#### 4) Conclusions

Petroleum system and gold system: many similarities, beyond the sometimes very similar sedimentation, in the search for gold or ...black gold. In the end, it is the same triptych that the petroleum or mining geologist must reconstitute **mature source rock/migration/trapping**. It is this process that allows scientific and reasoned prospecting, even if very often, it is the trap (the deposit!) that is found first, without even knowing the nature, quality and location of the source rock! Even if this could well, in both cases, be the Holy Grail! Find the primary gold vein and find the hydrocarbons, known as unconventional, shale oil and gas (in the case of hydrocarbons)! **It is above all and finally the same state of mind: the pleasure of research or better: The search for pleasure (or the placer)!**



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