Fault evolution and fluid circulation in the Great Geneva Basin (Jura fold-and-thrust belt, France & Switzerland)

Cardello G.L.*, Lupi M.*, Makhloufi Y.*, Do Couto D.*, Clerc N.*, Moscariello A.*, Sartori M.* & Meyer M**

* Section des sciences de la Terre et de l'environnement, Université de Genève, Rue des Maraîchers 13, CH-1205 Genève (luca.cardello@unige.ch)
** Services Industriels de Genève (SIG)

The Canton of Geneva is exploring the opportunity to exploit geothermal energy in the Great Geneva Basin (GGB). The GGB is an Oligo-Miocene siliciclastic basin tightened between the Alps and the southern Jura fold-and-thrust belt. The outcropping relieves represent good field analogues of buried faulted structures identified after seismo-stratigraphic analysis. In this frame, we review the regional tectonics to:

(1) understand the present-day structural setting with a special focus on fault properties and;

(2) assess preferential paths for fluid flow.

Hereby, we present new field observations, kinematic analysis, and petrographic determination of the deformation processes. Field and geophysical evidences confirmed that the Molasse siliciclastic deposits progressively seal the growing anticlines constituted of Mesozoic carbonates. Those are shaped by a set of fore- and back-thrusts usually having little veining association.

Structural analysis indicates that syn-kinematic mineralisations and pressure-solution planes occur far from the thrust zones, concentrating on the strike-slip faults. In relation to the presence of shale-rich interlayers, bed-to-bed flexural slip is the main mechanism accompanying shortening. Locally, a consistent transition from less to well-developed en échelon fracture sets can be recognised. The study of their arrangement leads to a regional fault-evolution model. The coalescence of mode-I veins is associated with larger amount of accumulated displacement. This is the result of strain localisation and fluid circulation that created progressively longer and mature faults. Some of these faults acted as proper tear-faults that can reach a few kilometers in fault length. They can be distinguished on the base of: orientation, amount of displacement, spacing and fault fabric. Preliminary data highlight the occurrence of two main transversal fault-sets, showing veining and mineralisation.

The first set (1) strikes NNW-SSE. It has fault length up to 60 km in map view, cutting the whole Mesozoic-Cenozoic cover, and possibly also the Quaternary deposits (i.e., Vuache fault system). Most notably, it is associated with brittle-ductile transition textures and crack-and-seal carbonate mineralization. This fabric was probably inherited during the exhumation (in the order of a few km). The Vuache fault later evolved into brittle faulting that is traced by shallow earthquakes (i.e. less than 5 km deep) reaching a local magnitude as high as ML 5.3. This involves change in fluid-flow regime (i.e., Epagny earthquake in 1996; Gratier et al. 2013).

The second set (2) is constituted by W/NW-striking 10 km long tear-faults. Those are associated in places with up to few meters thick calcitic and brecciated polyphase mineralisations. Such faults are most likely confined at the upper thrust sheets and limited to the Meso-Cenozoic formations although we track the continuity of some of them up to the surface.
In addition, as visible on the Digital Elevation Model and satellite images, smaller size (up to 4 km fault length) N-S and NE-striking faults are associated with dry and tightly spaced (5-10 cm) open joints. Those are possibly good candidates for recent activity and water infiltration. Uprising fluids occur too, as indicated by natural geothermal upwelling (e.g. Divonne-les-Bains) being, vertical fracture connectivity enhanced at strike-slip fault intersection.

In conclusion, our obervations show that:
1) on the outcropping relieves, WNW- and NNE-striking systems are vein-rich and therefore “wet” whereas N- and NE-striking systems are “dry”;
2) within the buried structures, similarly oriented fault-zones act as conduits that may have opposite fluid-flow directivity depending on the structural position;
3) from a dynamic point of view, most of the faults are coherent with the present day stress regime orientation;
4) at a regional scale, the kinematics of the fault systems may have evolved during time with the indentation of the Jura arc.

REFERENCES

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