

Col du Perthus (France)

Description: The natural analogue of Perthus Pass (near Lodève, Hérault, France) is a site where a basaltic dyke (1.10 m width, 1.7 to 2 My age) intruded an argillite (mudstone) formation of Toarcian age. The argillite has a low water content (3 to 5 %) and consists of clays (40-50 %) (illite, illite-smectite interstratified minerals, muscovite, kaolinite, chlorite), carbonates (calcite, ankerite; 20-30%), quartz (20 %), pyrite. The basalt intrusion caused a transient thermal gradient in the adjacent argillite. The rock is modified mechanically (local induration and fracturation) and chemically (thermal effects, induced dissolution/precipitation of phases). The east and west sides of the dyke display different alteration profiles : the asymmetry in wall rock alteration is assigned to the curved shaped of the basaltic intrusion. Fluid release was favoured on the east side whereas on the west side this apparently did not happen.

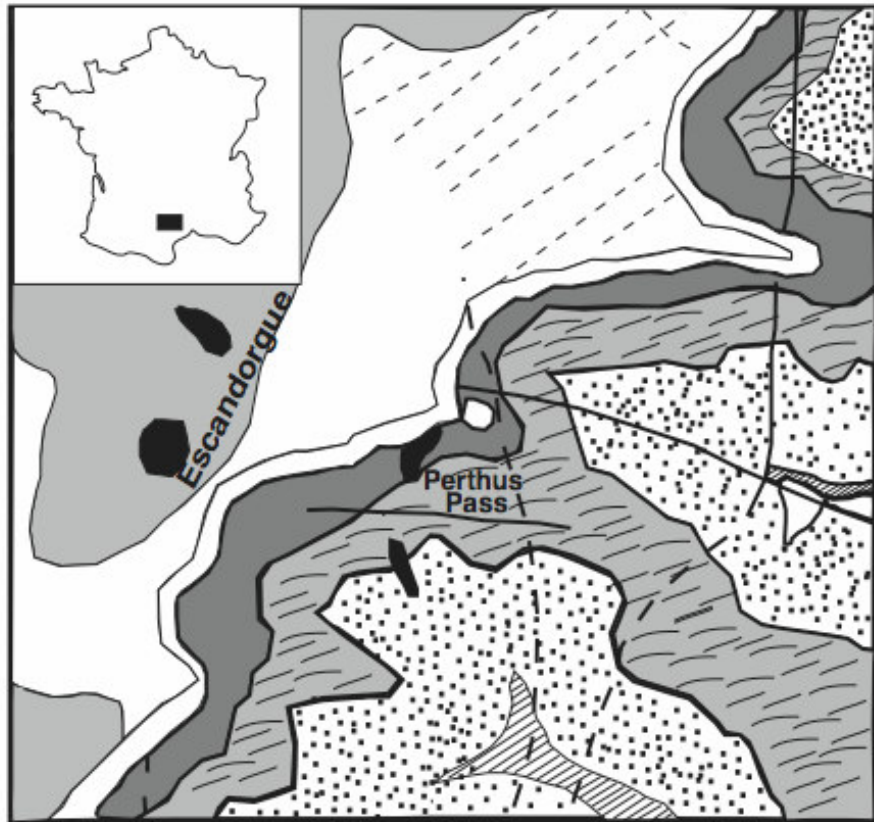
This site was sampled and studied in a EC Project (Pellegrini et al., 1999), grouping the study of three natural analogues of the thermo-hydro-chemical and thermo-hydro-mechanical response : Isle of Skye (U.K.), Perthus Pass and Orciatico (Italy). Further investigations, in particular with the help of isotopic probes, were recently conducted on the Perthus Pass dyke by Techer et al. (2004) (Univ. of Nîmes) ; these works are being presently published.





Main observations conducted on the two wall-rocks show that :

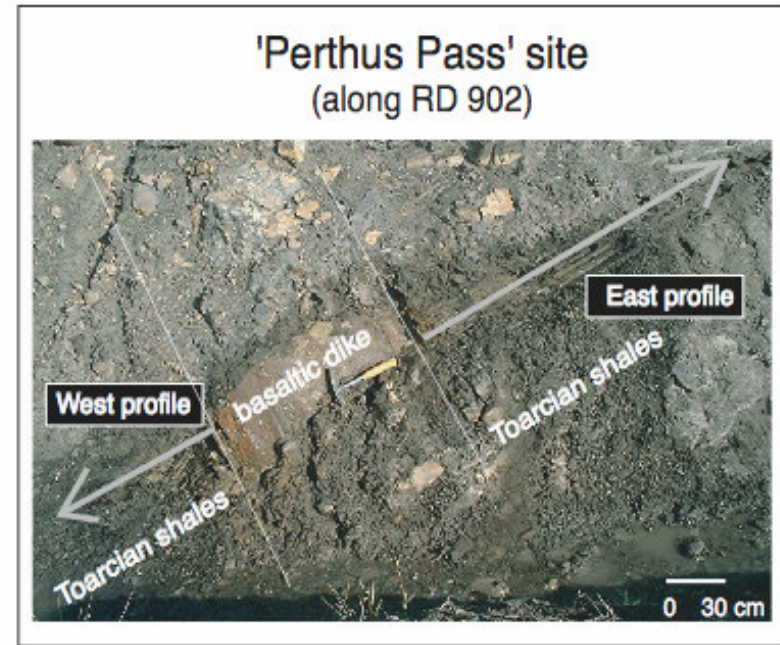
- the mudstone undergoes important textural changes near the dyke and becomes stiff and compact ($x < 0.1$ m). Shrinkage of the heated mudstone has produced fractures; these fractures are often filled with secondary calcite, presumably precipitated from migrating fluids.
- detection of high temperature secondary phases locally in the contact zone ($x < 0.1$ m) : diopside, albite, probable wollastonite
- a marked decrease in calcite occurs near the basalt dike ($x < 0.3$ m) ; ankerite is also lost for $x < 1.20$ m.
- kaolinite decreases markedly for $0.45 \text{ m} < x < 0.70$ m and disappears for $x < 0.45$ m.
- clay minerals show significant evolutions close to the dyke ($x < 0.50$ m on the west wall). The illite/smectite mixed-layer minerals evolve towards more illitic compositions. A smectitic phase (probable saponite) forms in the vicinity of the basaltic intrusion. This is corroborated by a 2-fold increase of the C.E.C. of the material.

Paleotemperature determinations were conducted using 2 methods: vitrinite reflectance and illite crystallinity index. The background temperature is around 100 °C, consistent with a burial depth of the Toarcian argillite in the range 3 to 4 km. Illite crystallinity index shows a temperature increase up to about 140 °C at less than 1 m of the dyke, whereas vitrinite reflectance accounts for a higher temperature (200-250 °C) on a 1 m broad zone. Models suggest that the duration of the high temperature event is probably very short, in the order of 1 to 10 years. Recent measurements were conducted using the K-Ar system and computing apparent K-Ar ages (Capon, 2001; Techer et al. 2004). They confirm that the thermal effect was much more spread out on the east side of the dyke (~2 m) than on the west side (~0.3 m) with temperatures values ranging around 200 °C next to the dyke and less than 150 °C above 90 cm.

The extent of changes having affected surrounding groundwaters and water/rock exchanges are not easy to trace and some attempts have been recently done by using Sr isotopes (Capon, 2001; Techer et al., 2004). They suggest that recent fluid circulation, possibly driven by the Dogger limestone aquifer, occurred in the thermally disturbed argillite near the dyke and is responsible of the basaltic dyke margin alteration.



-  Basaltique flows and intrusions
-  Bathonian- Bajocian : dolomites and limestones
-  Toarcian : shales
-  Sinemurian : biodetritic limestones
-  Hettangian : dolomitic limestones
-  Rhetian : limestones



45% Clays
I/S 60-45%
Kaolinite 15-20%,
Chlorite 10%
 15-20% Calcite; 5-10% Dolomite
 20% Quartz
 <5% Siderite, Pyrite

From Techer et al., 2004

Relevance: The argillite/mudstone rocktypes are relevant in several countries (e.g. France, Switzerland, Japan, Germany) as possible host rocks for geological waste repositories. The thermal impact exerted by high level waste packages is expected to increase locally the host rock temperature from initially 30 °C to the range from 80 to 150 °C.

Position(s) in the matrix tables: Near Field Rock, EDZ, CDZ, integrity of the rock, impact on migration and retention in the near field,

Limitations: The thermal perturbation caused by a thin dyke may be seen as a very short temperature spike ; this is quite different of what is expected in the vicinity of hot radioactive canisters : 300 to 1000 years heat production followed by a slow decrease of heat generation. This might impact significantly the geochemical pathways and the kinetic control of the transformations, in particular for clay phases. In addition, dykes often release water whereas in a waste disposal, the heat source will not be accompanied by a water input.

However, the duration of the thermal imprint linked to the basaltic magma emplacement corresponds to the first step of the temperature increase in a deep geological storage: the maximum temperature is reached in the first ten years, then it is maintained during a few years before decreasing over a time scale of hundreds of years (Poinsot, 1997).

Quantitative information: Mostly qualitative information with semi-quantitative checks :

- tests of heat transfer models
- extent of illitisation of I/S minerals

Uncertainties: Alterations having occurred after the dyke has cooled down, due to preferential groundwater pathways in the modified argillite or due to surface weathering
Fluid circulation along the dyke/argillite interface

Time-scale: The duration if the thermal perturbation is in the range 1 to 10 years.

PA/safety case applications: Gives some guidance to evaluate the maximum allowable temperature (MAT) in the host rock (mudstone). Above 150 °C, important mineralogical and textural transformations are expected.

Communication applications: None known.

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Added value comments: None suggested.

Potential follow-up work: Work in progress using isotope probes (Techer et al.)

Keywords: Near-field, mudrock, claystone, EDZ, CDZ, THM, THC, diffusion, heat, clay, dissolution, precipitation,

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