Geotour France 1: Cantal and the Chaîne des Puys (Auvergne); volcanoes “a la carte”

The Miocene to Holocene “green” volcanoes of France. If someone wants to learn volcanology or simply enjoy an unforgettable natural environment, "this" is the perfect place in Europe.

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Fall and flow pyroclastic deposits in the Puy de Lemptégy, an “open-cast” volcano.

Dates of the visits to the places here presented:

August 7-11, 2008
August 9-13, 2009
August 8-11, 2014

Geotours travelers:

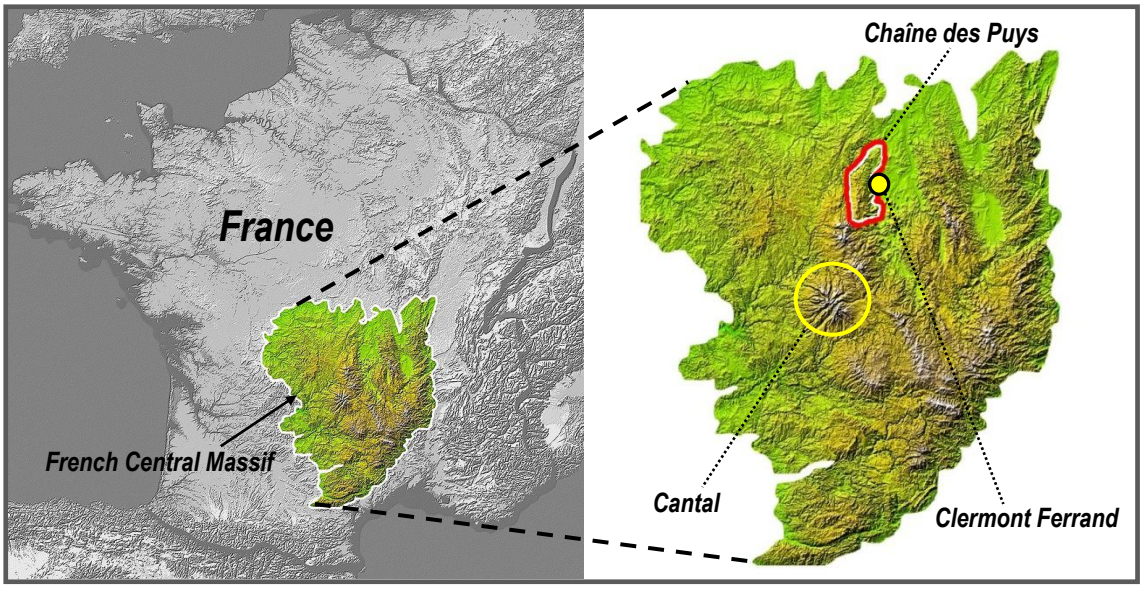
P. Cubas & R. Oyarzun

Aula2puntonet - 2021

Introduction

Our little tribute to Professor Robert Brousse (1929-2010), Auvergnat and geologist, with a superb in-depth knowledge of his region.

For an amazing "volcanic trip" to the heart of France, one must visit and tour the magnificent departments of Cantal and Puy de Dôme. These departments host what it was the largest volcano in Europe and the famous Chaîne des Puys, declared a World Heritage Site by UNESCO. The word *"puy"* (*UK : 'pwi*) comes from the Latin *podium*, and means "height" or "hill" (*Godard, 2013*). Both the Cantal volcano and the Chaîne des Puys are located in the French Central Massif.



The French Central Massif and location of the Chaîne des Puys and Cantal. Images[1,2].

Without even mentioning the geology (*in general*), or the volcanoes (*in particular*), the Auvergne region is internationally recognized for many reasons, its landscapes with impressive peaks, valleys, ravines, forests, lakes, dormant volcanoes (*although as in the Little Prince, by Antoine de Saint-Exupéry: you never know ...*) and so on, its remarkable religious (*Romanesque and Gothic*) and military architectural heritage (*countless castles and fortresses*), and also, why not, for its gastronomy (*after all is France, isn't it?*). To highlight in the latter matter the different cheeses (*such as the Saint-Nectaire*), the wines (*such as the Saint-Pourçain*), some typical dishes (*such as the soupe au fromage or truffade*), and the healthy mineral waters (*such as Volvic, with low content in sodium and nitrates*). Let's say that the region is a palette of colors and flavors in itself.

Gastronomic products of Auvergne. Images[3-5].

There are many cities and charming towns to visit, starting with Clermont-Ferrand (*the capital*), Aurillac, Le Puy-en-Velay, Montluçon, Moulins, Riom, Saint-Nectaire, or Saint-Flour. It is also important to visit (*if you have the time*) the most important sites of the Auvergne heritage, such as the priory of Souvigny, the Orcival basilica, the medieval towns of Charroux, Murat and Salers or the castles of Anjony, Murol and Tournoël.

As if this were not enough, the region also offers to the visitor Vulcania, the "European Volcanism Park"", which is an educational-amusement park with a volcanic theme. Vulcania is located in Saint-Ours-les-Roches, 15 km north-west of Clermont-Ferrand. The project was the brainchild of the internationally famous French volcanologist Maurice Krafft (*who died on Mount Unzen - Japan in 1991*). Krafft and his work had a great impact on the former president of France Valéry Giscard d'Estaing, who promoted the construction of the park while he was president of the Regional Council of Auvergne (*Wikipedia 2021a*).

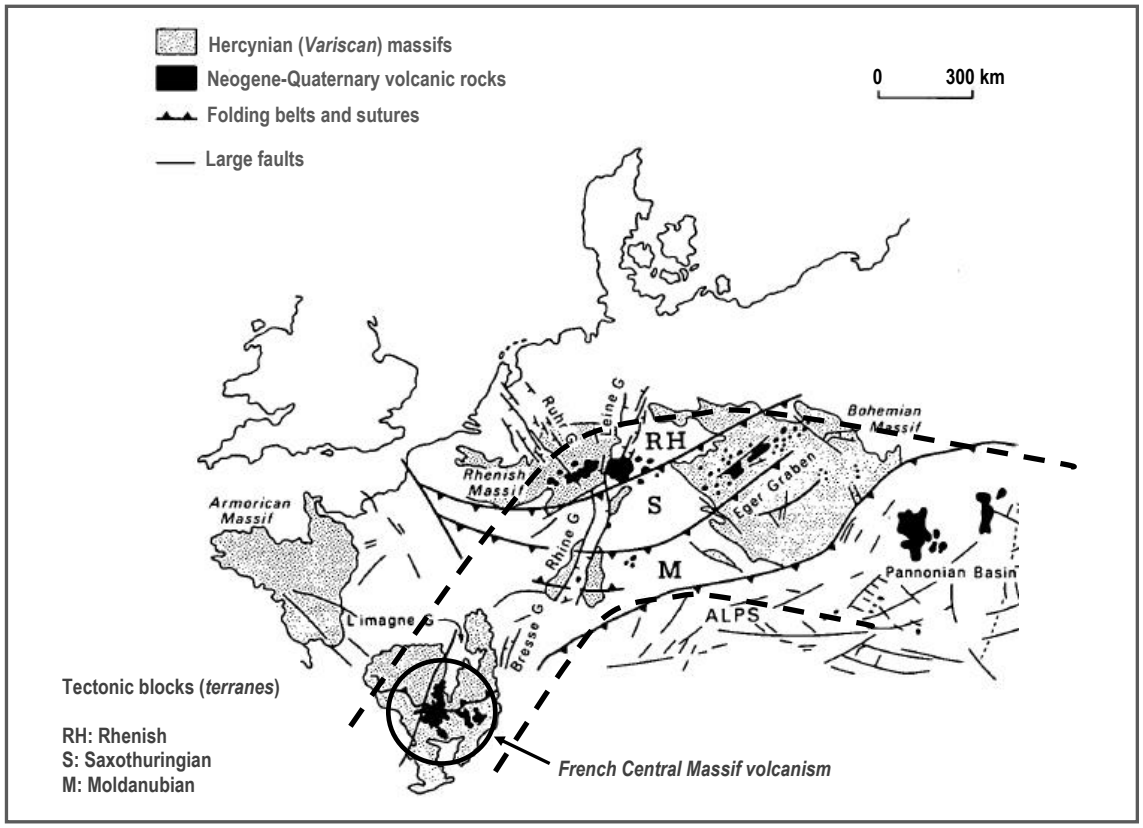
The Gothic cathedral of Clermont-Ferrand (Our Lady of the Assumption of Clermont). Most of its current construction dates from the 13th century. The main originality of the building is the material used: Volvic stone, of the trachyandesite type, which gives it a dark color and whose resistance allowed the erection of very slender pillars (Wikipedia 2021b).

Antique religious urban art in one of the streets of Clermont-Ferrand.

For someone with an interest in volcanoes Auvergne is paradise. In the following pages we will take a trip to a few particularly significant places from a volcanological point of view, in the departments of Cantal and Puy de Dôme. But even if you are not particularly interested in volcanoes, the landscape is beautiful and you will surely enjoy it; in this regard, it doesn't matter if you are on solo travelling, with the family or a group of good friends, the trip will be enriching.

Geology

Auvergne is above all two things: 1) a metamorphic and granitic Hercynian (*Variscan*) basement; and 2) alkaline intraplate (*mafic-intermediate*) volcanism. The whole can be referred to on a large scale as the French Central Massif. This magmatism is part of a pan European alkaline volcanic province of Paleocene-Holocene age that extends from Spain (*e.g. Calatrava, Columbretes, Olot*), passing through France (*French Central Massif: Cantal, Chaîne des Puys*), continuing through Germany (*e.g. Eifel in the Rhine valley*) and up to the Pannonian plain (*several countries*) (*e.g. López-Ruiz et al. 1993; Oyarzun et al. 1997; Wilson & Downes 1991, 2006*).

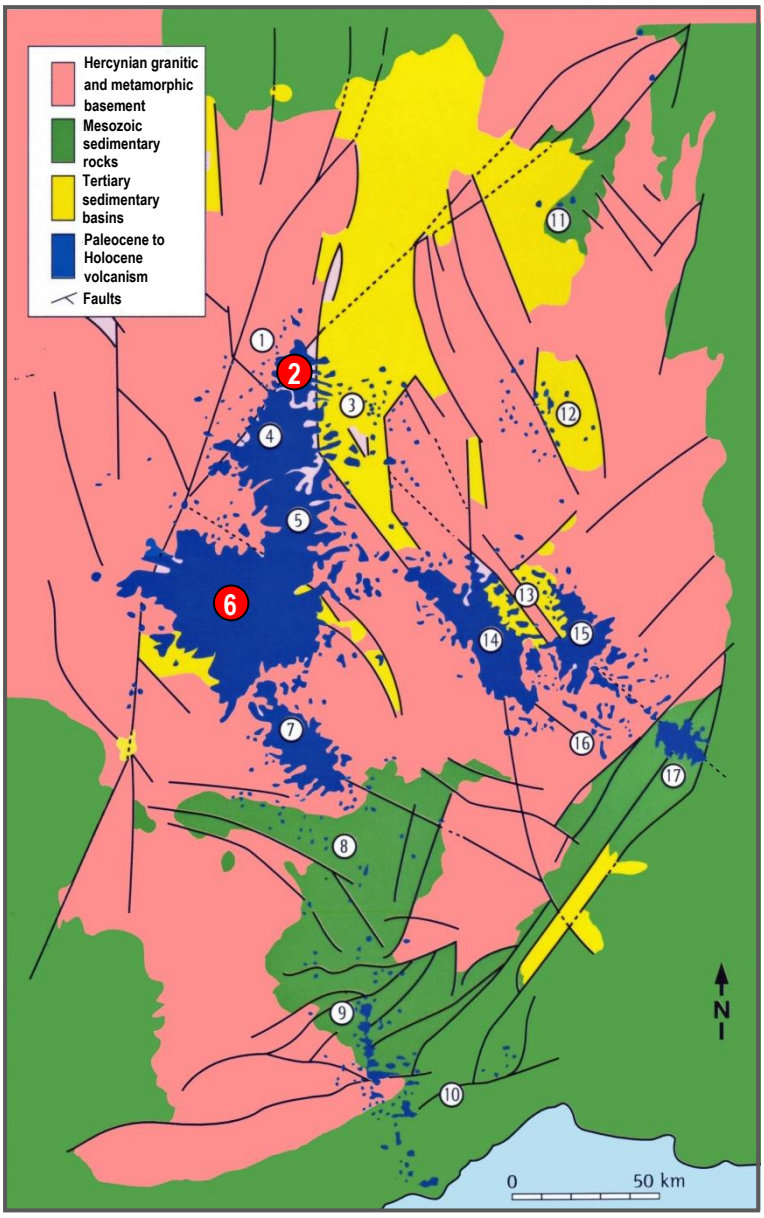


The European alkaline volcanic province (Paleocene-Holocene), dashed line, and position of the French Central Massif and its volcanism (circle); the alkaline basaltic volcanism of Spain (e.g. Calatrava, Columbretes, Olot) is not represented in the image. Adapted from Wilson & Downes (1991).

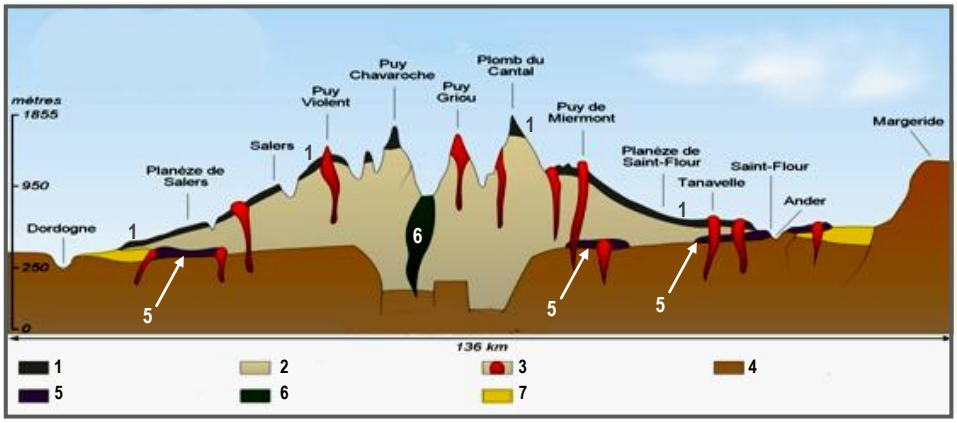
This Cenozoic volcanism developed in various sectors of the French Central Massif (*Cattermole 2001; Nehlig 2007; Godard 2013*) and here we will briefly describe two of these: Cantal and the Chaîne des Puys.

The "Cantalian" volcanic past

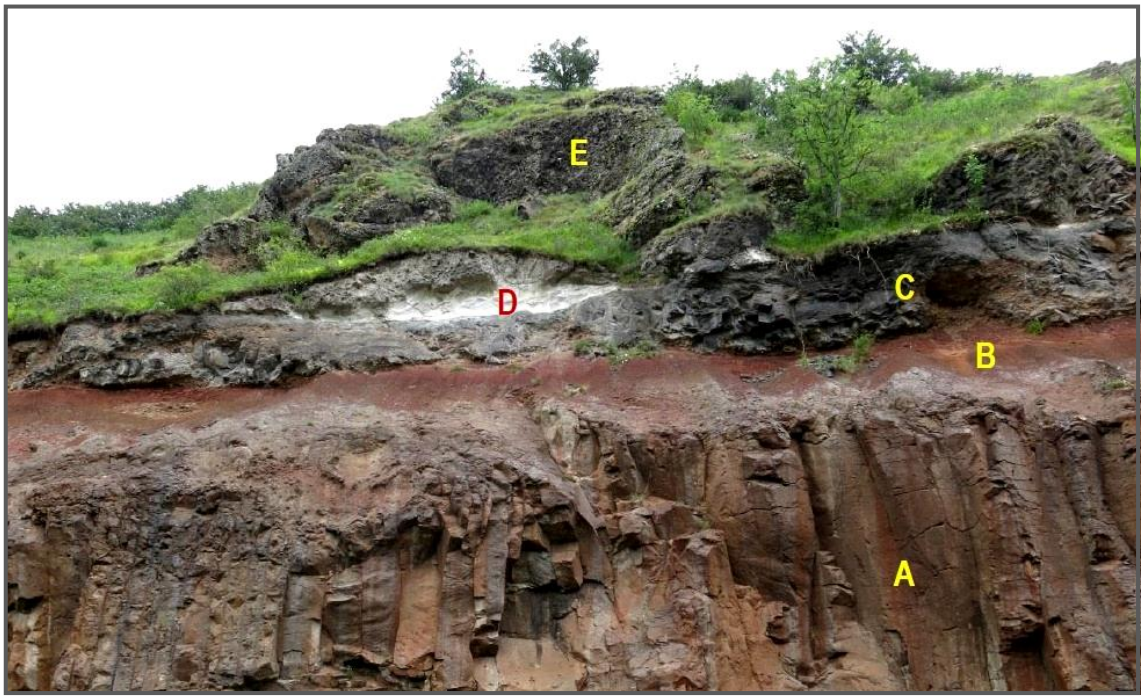
In the heart of the French Central Massif, a volcanism that we will here refer as "Cantalian", developed shortly before, during and after the formation and destruction of the mega volcano of Cantal. The age of this volcanism ranges from 13 to 3 million years and it gave rise mainly to alkaline basalts, trachytes and phonolites, lava flows and domes, with innumerable pyroclastic episodes and the formation of debris flows.



*The Paleocene-Holocene volcanism (dark blue) and its geological setting. 1: Chaîne de la Sioule; **2: Chaîne des Puys**; 3: Limagne; 4: Monts Dore; 5: Cézalier; **6: Cantal**; 7: Aubrac; 8: Causses; 9: Escandorgue; 10: Bas-Languedoc; 11: Bourgogne; 12: Forez; 13: Bassin du Puy et Emblavés; 14: Devés; 15: Velay Oriental; 16: Bas-Vivarais; 17: Coiron. Adaptada de Godard (2013).*



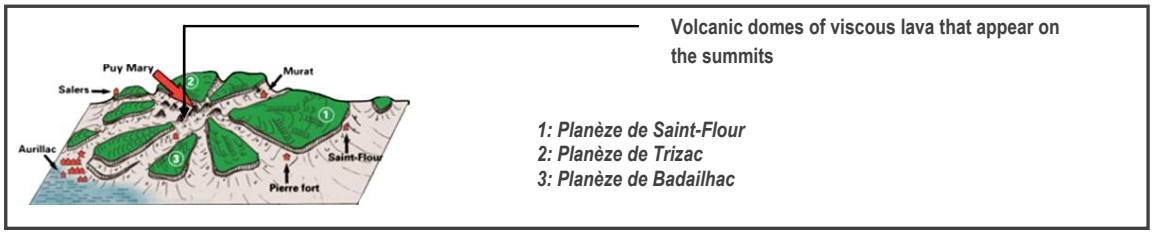
Schematic, vertically exaggerated WNW geological section of the Cantal volcano (image[6]). 1: Basalts; 2: Agglomerates, ignimbrites; 3: Volcanic chimneys; 4: Hercynian basement: 5: First phase lava flows; 6: Feeder neck of the volcano; 7: Tertiary sediments.



Cantal pre-volcano basalts (basalts of the first phase) with columnar jointing (A), a red paleo soil (B), another volcanic level (C), white ash (D) and breccias (E). These rocks were formed about 9-7 Ma ago and are in part prior to the formation of the great volcanic edifice of Cantal (8.5 to 7 Ma). Road cut; N122 road from Saint-Flour to Aurillac, near Murat. This route that describes an arc takes us into the Cantal volcano on its southern flank. More information: see Nehlig (2007).

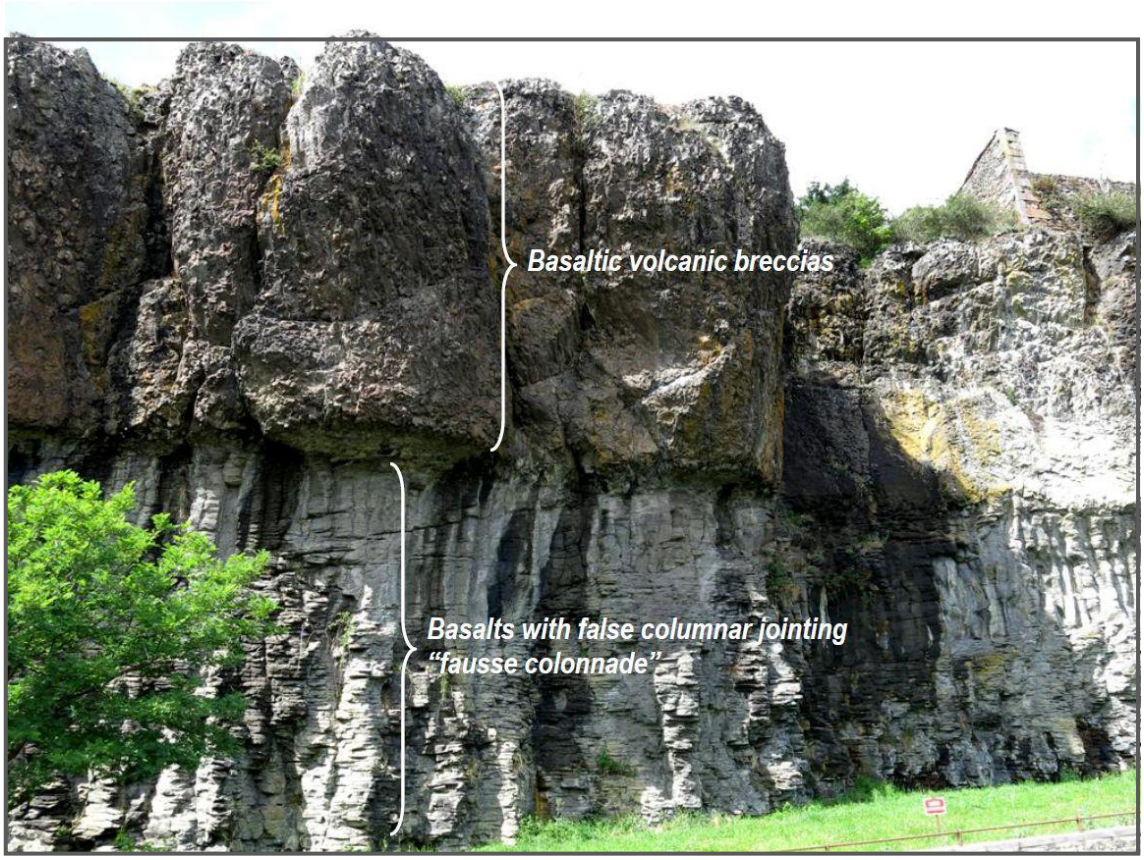
The trachytic dome of Chazes (A) cutting violet monolithological breccias (B) and being in turn cut by a basaltic dyke (C). The contact between A and B is blurred by the effect of a small fault zone (D) that has crushed the rock. Road cut on the N122 road from Saint-Flour to Aurillac, near Saint-Jacques-des-Blats. More information: see Nehlig (2007).

The Cantal stratovolcano (*now extinct*) is the largest in Europe. Its base is approximately circular with a diameter of between 50 and 70 km. Its highest point is the Plomb du Cantal (*1855 masl*). There are about 20 valleys in the massif, radiating from the center and cutting the basaltic plateau into triangular pieces known as *planèzes* (*Wikipedia 2021c*).



Main valleys and planèzes around the Cantal volcano (image[7]).

The Puy Mary, a trachytic dome cutting sub-horizontal older basalts (arrows). Image[8].



Saint-Flour is built on a planèze of Miocene (8.8 ± 0.5 Ma) basaltic volcanic rocks and the access road to the town allows you to see the upper volcanic sequence, with false columnar basalts and breccias. The columns have a somewhat poor development and in French they are known as "fausse colonnade" (false columns). This is due to the high porosity of the basalt that does not allow a sharp formation of the prisms.

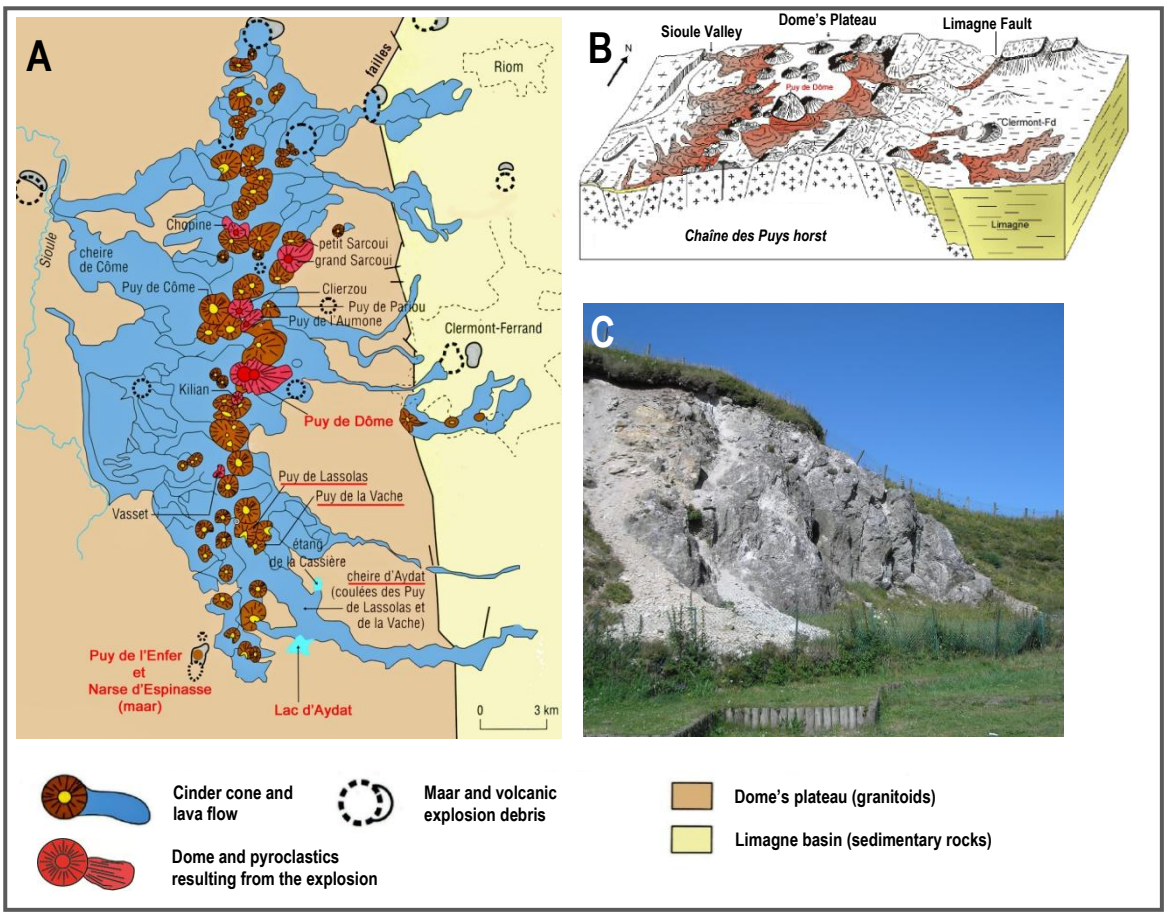
There are two great car tours that allow visiting the sites described here. We recommend staying in Saint-Flour, a beautiful city located on the edge of a planèze with wonderful views and a magnificent architectural and religious heritage. The routes are: 1) From Saint-Flour to Aurillac on the N122 road (*95 km*); and 2) From Saint-Flour to Neussargues-Moissac, on the D679 road and from there to Massiac, on the N122 road (*46 km in total*). We also recommend, if you want to better appreciate the geology, the guide by P. Nehlig (*2007*). These are just two ideas, because there is much, much more to see.

Views from the edge of a basaltic planèze: Saint-Flour

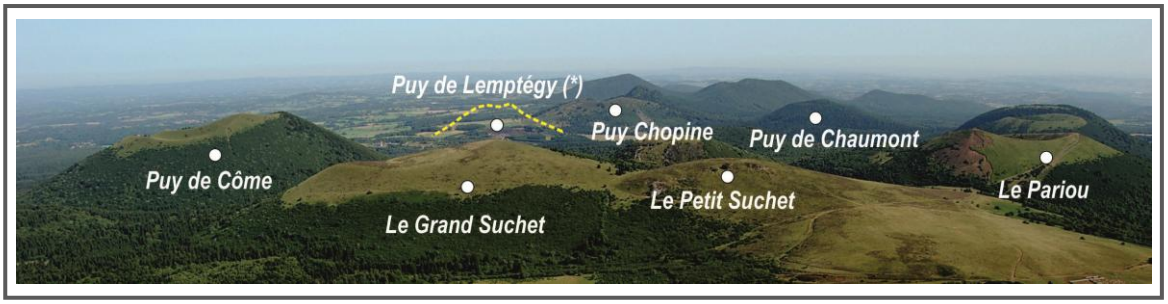
The ubiquitous basalts at Saint-Flour: arch of vesicular basalts.

The Chaîne des Puys

Towards the north of Cantal, and west of Clermont-Ferrand, a younger volcanism developed. Volcanic activity began about 156,000 years ago, although it lacked continuity, with four main periods (*Godard 2013*): 1) between 95,000 and 90,000 years, 2) between 75,000 and 70,000 years, 3) between 45,000 and 30,000 years, and finally 4) between 13,500 and 7,000 years. According to the same author, the chain includes a myriad of volcanic devices, arranged in a north-south axis; One of the main characteristics of the chain is that it is formed by monogenetic cones independent of each other, they are small in size, and generally visible in the landscape.



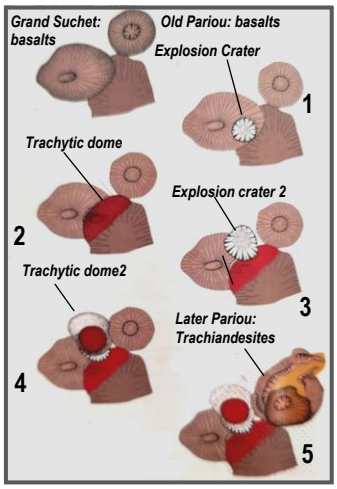
The Chaîne des Puys. A) Simplified geological map; B) Block diagram; C) Outcrop of trachytes near the summit of Puy-de-Dôme. A and B: Adapted from Godard (2013).



View towards the north from the top of the Puy de Dôme, showing some of the main volcanoes and domes. (*): The Puy de Lemptégy as it might have been before erosion and open-cast mining (yellow dashed line); today the site stands out for its educational value: the only volcano on Earth allowing an inside out visit.

Although simple in appearance, the geology of these volcanic and subvolcanic edifices is anything but. For example, let's analyze the history of two nearby volcanoes, the Grand Suchet and Le Pariou, or we should rather say the “old” Pariou. It is important to make this distinction since both the Grand Suchet and the old Le Pariou originally had a basaltic composition. The system evolved as follows (*Boivin et al. 2009*):

1. An explosion crater forms on the eastern slope of the Grand Suchet cone that will give rise to Petit Suchet.
2. In this same sector, the emplacement of a trachytic dome takes place.
3. The story does not end here as a new explosion crater forms, this time between the Grand Suchet and the old Pariou.
4. This is followed by the placement of a trachytic dome in the explosion crater.
5. Lastly, volcanism is renewed in Le Pariou, but this time with trachiandesites.



Volcanic evolution of the Grand Suchet and Pariou volcanoes. Adapted from Boivin (2009).

The closeness between the volcanic cones and domes in the Chaîne des Puys has allowed the pyroclasts ejected by one to cover others, thus generating a complex array of overlapping layers from different volcanic sources. On top of this complexity we must add the variety of lithological and structural types. For example if we only consider the volcanoes and domes that appear in the panoramic image on the previous page the following types can be recognized (*e.g. Camus & de Goër de Herve 1999; Boivin et al. 2009*)

- Trachytic domes: Puy de Dôme, Le Petit Souchet, Puy Chopine.
- Basaltic strombolian cones: Le Grand Suchet, Puy Chaumont, “old” Pariou.
- Trachybasaltic strombolian cones: Puy de Lemptégy 1
- Trachyandesitic strombolian cones: Puy de Côme, “later” Pariou, Puy de Lemptégy 2.

This is without counting the maars that were formed by the development of explosion craters (*at present many harbor lakes*) and compositionally diverse dikes. Closer examples of maar, in Spain, can be visited in the volcanic area of Campo de Calatrava (*Ciudad Real*), which is on a smaller scale equivalent to what happened in the Chaîne des Puys.

There are three sites that are almost mandatory to visit in the Chaîne des Puys:

- The Puy de Lemptégy.
- The Puy-de-Dóme
- Vulcania

We will deal the last two separately since they are more of a “geological tourist attraction” (*essential in any case*) than “hard geology”. It could be argued that the Puy de Lemptégy is also a

tourist attraction (*you have to pay an entrance fee to access the site*) but the geological display provided by “an open-cast volcano” results in a “unique” and solid didactic field experience.

The Puy de Lemptégy: an open-cast volcano

What transforms the Puy de Lemptégy into a unique geological experience is its mining past for the exploitation of pozzolans. For once, an open pit mining operation has had a positive result that has allowed to examine a typical Strombolian cinder cone “from the inside”, and in turn, study the influence of neighboring volcanoes in the construction of the site.

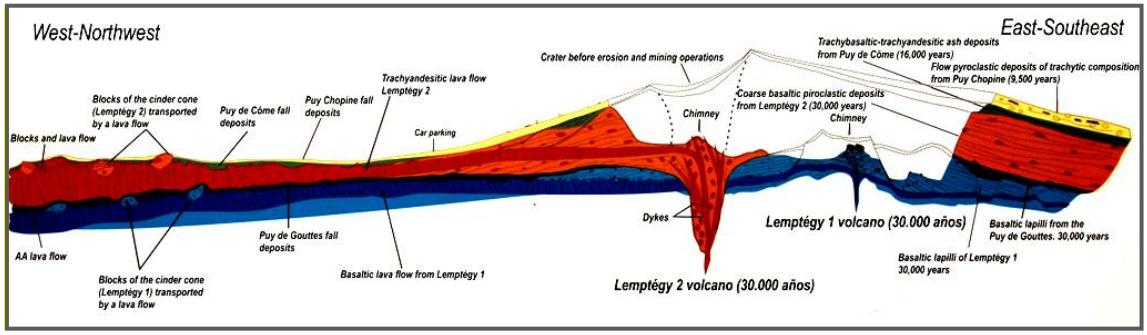
The term pozzolana comes from Pozzuoli, an Italian port on the outskirts of Naples. This puzzolana is an ash tuff of phonolitic composition, emitted during a cataclysmic eruption 14,000 years ago (*Lavina 1999*). The composition of this rock gives it the property of self-hardening in the presence of water. It is the pozzolanic reaction that corresponds to a combination of silica + alumina + heat + water that transforms pozzolana in a “natural concrete” (*Lavina 1999*) and as such it was used in Roman times. Mining operations at the Puy de Lemptégy began in 1946 and continued without major modifications until 1993, the year in which a last mining permit was granted for 15 years, requiring (*in any case*) the progressive transformation of the place into a site of educational interest (*Lavina 1999*).

The Lemptégy pozzolan quarry as it is seen today. The visitors can move freely along the enabled sections. You can visit the site alone or in a group, with or without a guide. There are many excellent explanatory panels.

Delcamp et al. (*2014*) add the following: starting in the 1980’s, the extraction was carried out with the advice of volcanologists to preserve the shallow magmatic conduit system and the three-dimensional Lemptégy stratigraphy. Detailed mapping made it possible to distinguish key stratigraphic units and reconstruct the building volcanic phases. The emplacement and evolution of the shallow conduit system was thus revealed.

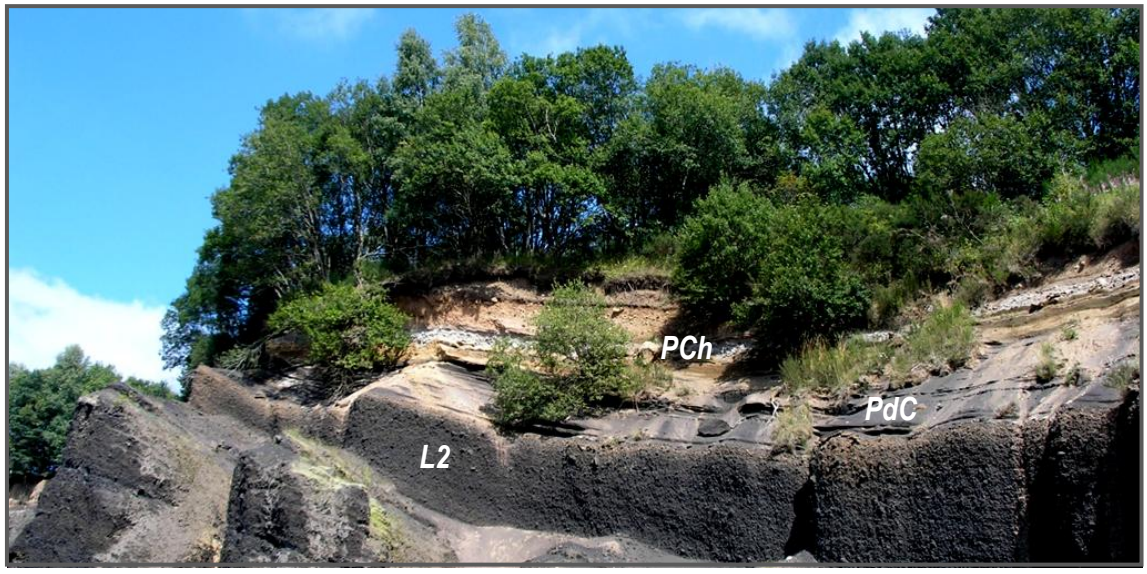
The same authors indicate that the growth of the monogenetic lapilli cone included two temporally well separated eruptions with closely spaced independent chimneys. The activity included Hawaiian, Strombolian and Vulcanian explosions, lava effusion, formation of a crypto dome and domes, partial collapse, formation of satellite chimneys, eruptive pauses, and the emplacement of intrusions with subsequent uplift. The cone shape, structure, and hence local stress field, conduit system, and thermal state were continually changing, which in turn influenced the eruptive style and arrangement. The morphology of the magmatic conduit system and microtectonic structures revealed the local stress field and changes in the direction of the magmatic flow.

Contrary to what is usually assumed, the internal architecture, stratigraphy and evolution of the Lemptégy volcano show just how complex a monogenetic volcano can be.

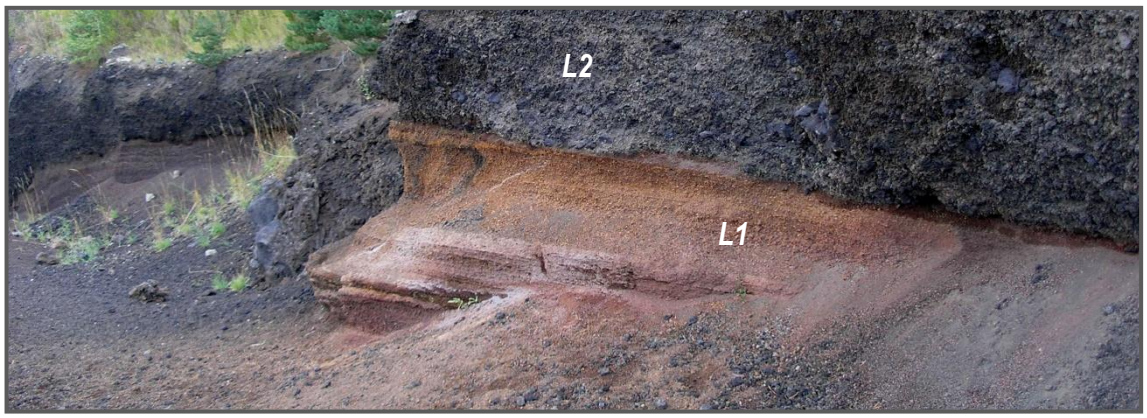


Main geological features of the Lemptégy volcanic complex. See the existence of "2 volcanoes in one", compositionally different, but on the same site (Lemptégy 1 and 2). Adapted from Camus & de Goër de Herve (1999).

There are several volcanic features that are worth observing in detail during the visit, such as the superposition of pyroclastic layers from different eruptions and different volcanoes, the chimney of Lemptégy 2 and its radial dykes, and the size of volcanic bombs from Lemptégy 1.



Inside Lemptégy (and the following images). Coarse fall deposits from Lemptégy 2 (L2) (30,000 years), gray ash from Puy de Côme (PdC) (16,000 years) and pyroclastic flow deposits from Puy Chopine (PCh) (9,500 years).



Fall deposits (lapilli and coarser materials) from Lemptégy volcanoes 1 and 2 (L1 - L2).

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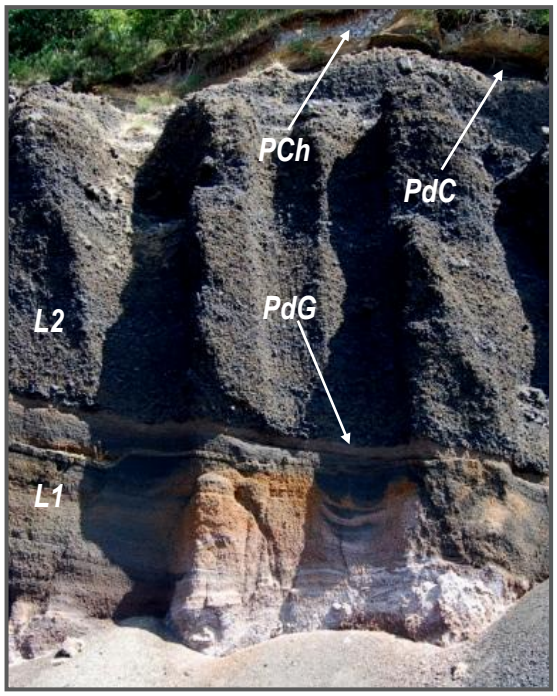
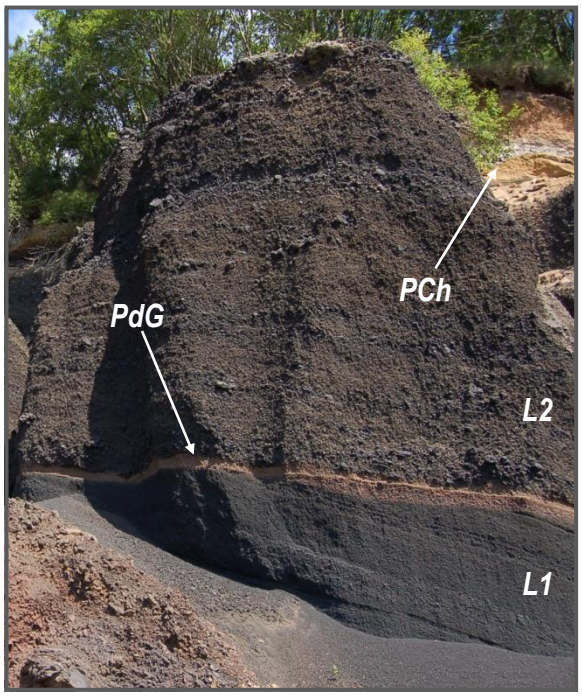
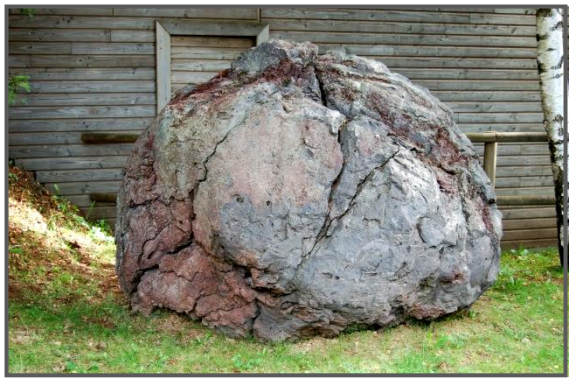
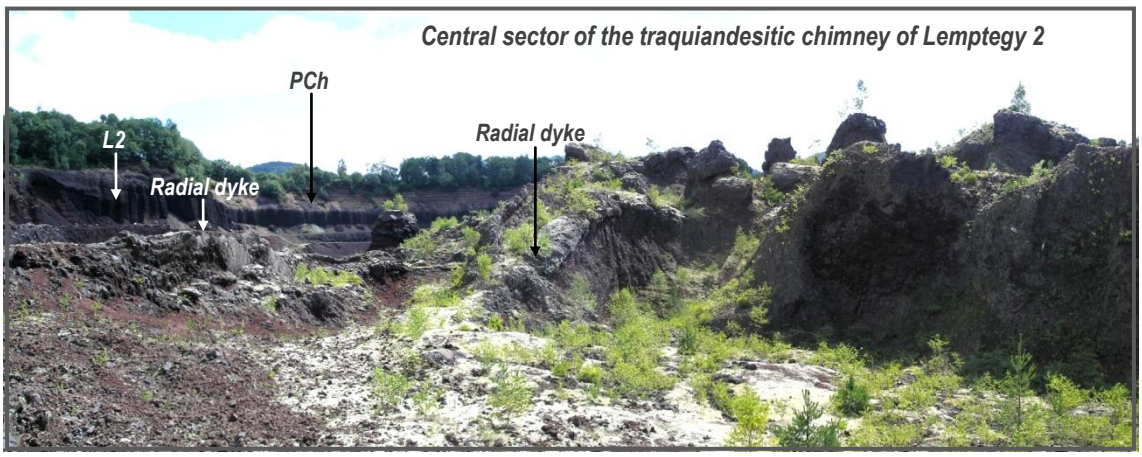




Fall deposits (lapilli and coarser materials) from Lemptégy volcanoes 1 and 2 (L1 - L2), ashes from Puy de Gouttes (PdG) (30,000 years) and Puy de Côme (PdC) (16,000 years) and pyroclastic flow deposits (ignimbrite) from Puy Chopine (PCh) (9,500 years). The coloration changes in L1 (left) could be deuteric in origin.



Volcanic bombs from Lemptégy 1.



The Lemptégy 2 chimney and trachiandesitic radial dyke system. L2: Lemptégy 2 coarser fall deposits (30,000 years); PCh: pyroclastic flow deposits of the Puy Chopine (9,500 years).

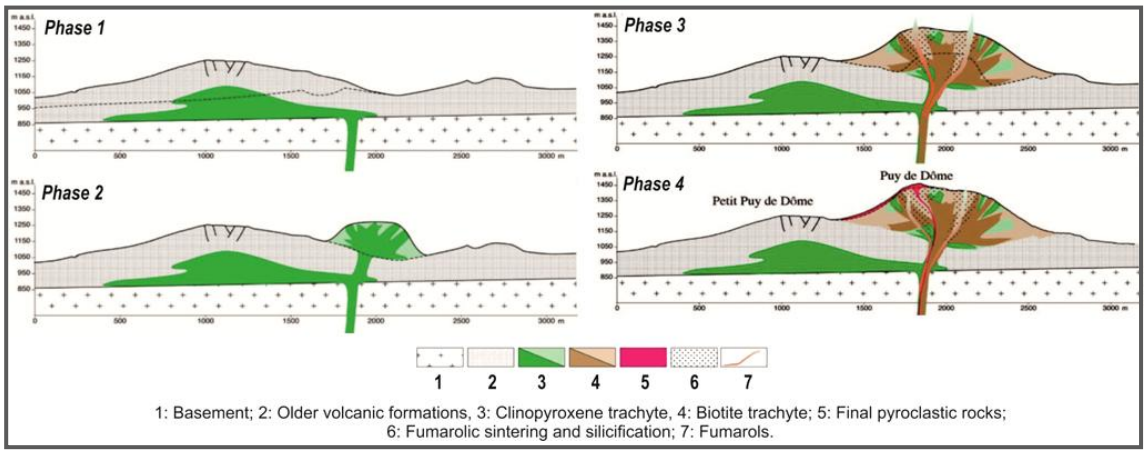
Puy de Dôme: the flagship of the Chaîne des Puys

The Puy de Dôme has been one of these iconic sites in France for ages. The Gallo-Romans installed on its top a temple dedicated to Mercury in the 1st or 2nd century, which is now under restoration. The importance of the temple far exceeded the limits of the territory of Auvergne. It was abandoned around the 3rd or 4th century and rediscovered in 1872 during the construction of a meteorological observatory (*Wikipedia 2021d*). Nowadays the Puy de Dôme is the flagship of the Chaîne des Puys and at its top there is an interpretation center, the archeological site of the temple to Mercury, a gift shop, and a restaurant. Due to the large influx of public, nowadays it is not allowed to go up by car, and the ascent is done in a modern tram expressly commissioned for this work. You may also do it by foot if you feel like, and there is well developed system of trails around the summit (*Alexander 2018*). Last but not least, you can also see and inspect the outcrops of trachyte near the summit of Puy de Dôme.

The Puy-de-Dôme (imagen[9]).

The Puy de Dôme is the most notorious volcanic edifice in the Chaîne des Puys. It is a complex dome of trachytic composition *ca.* 11,000 years old. The volcanic process has been traditionally

interpreted as the result of the single emplacement of a trachytic dome. However, a recent and comprehensive study (*Deniel et al. 2020*) reveals that the case can be more complex, as the process would have developed over four distinct phases: 1) the intrusion of a magma body of clinopyroxene trachyte emplaced as a cryptodome; 2) the emplacement of a first trachytic dome by successive intrusions; 3) the emplacement of the main dome of biotite trachyte by successive intrusions, breaking the first dome and embedding the resulting blocks during continuous growth; and 4) explosive activity, corresponding to the eruption of less differentiated magmas, which resulted in a strong ash emission that covered the eastern flank of Puy de Dôme.



Evolution of the Puy de Dôme magmatic system (adapted from Deniel et al. 2020). NNE-SSW sections.

Part of the trachytic dome complex of the Puy-de-Dôme, near the top.

Vulcania: entertaining science

Vulcania is one of those theme parks, which should not be missed, especially because calling it "theme park" sounds more like childish fun and little more. On the contrary, Vulcania is an excellent gateway to the world of volcanoes both for children and adults with no specific training in geology. We are talking about a first-rate didactic resource, which at the same time is fun, a duality that is difficult to achieve. By the way, geologists will enjoy it too.

Aerial view of Vulcania. Don't be misled, this is just the tip of the iceberg, as the facilities are underground, although no one will really notice it. Image[10].

In the words of its administrators (*Vulcania 2021*), the site consists of an amusement park that allows everyone to better understand how volcanoes and our planet work. Bringing science to life through discovery and emotion while remaining true to its educational ambition, this is the challenge for Vulcania. This aim modified the site in form and spirit, with a new articulation between attraction and knowledge, between emotion and knowledge. Young and old can gather around enriching attractions and workshops.

A film in Vulcania "The Awakening of the Giants of Auvergne" (Le Réveil des Géants d'Auvergne) (Vulcania 2021).

A last tip, Vulcania is just a few minutes away by car from the Puy de Lemptégy, thus both sites can be easily visited the same day. Book your visit to Vulcania in advance to avoid long lines during the summer season.

References:

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