Tephrostratigraphy of the last 160 ka in Western Limagne (France)

Gérard Vernet, Jean-Paul Raynal, Jean Fain, Didier Miallier, Michèle Montret, Thierry Pilleyre, Serge Sanzelle

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G. VERNET (1), J.P. RAYNAL (1), J. FAIN (2), D. MIALLIER (2),
M. MONTRET (2), T. PILLEYRE (2), S. SANZELLE (2).

(1) Université de Bordeaux 1, Institut du Quaternaire, UMR 9933 CNRS
Avenue des Facultés, 33405 Talence Cedex, France, et GDR 1122 CNRS.
(2) Laboratoire de Physique Corpusculaire, IN2P3 - CNRS
Université Blaise Pascal, 63177 Aubière Cedex, France, et GDR 1122 CNRS.

Abstract : The GEOCLER 1 core extracted from the Clermont crater lake sediments and surface studies made at several localities north of Clermont provided numerous stratigraphic, environmental and chronological data (TL and radiocarbon) which allow us to present a chronostratigraphy of the Limagne for the past 160 ka. 118 ash-falls have been recorded in the crater-lake sediments of the Clermont maar. They demonstrate that a basaltic phreatic activity developed along the western fault-scarp of the Limagne between 160 and 70 ka, after which began the Chaîne des Puys activity. Moreover, several acid eruptions occured between 160 and 40 ka. From Older Dryas to Atlantic, between 15 and 7 ka, fourteen ash-falls occured and in some cases the source volcanoes have been identified. These include Puy de La Nugère, Puy de Dôme, Puy Chopine, Kilian Crater and Puy de Pariou which contribute mainly to the local tephra succession. Prospects for further prehistoric research in volcanic areas are outlined.

Key-words : France, Massif Central, Middle Moutain, Volcanism, Ash-Falls, TL-Dating, Prehistory.

Only a few volcanoes in Western Limagne have been directly dated and the results do not give a realistic picture of eruptive activity in the area. It was thus necessary to establish a good record system at the foot of the Plateau des Dômes to obtain a more precise idea of the regional activity. We chose the Clermont Basin and the Morge Basin.

The following data are preliminary results of mineralogical research which focuses on heavy minerals of volcanic origin in alluviums and tephra (VERNET, 1992). Eruptive markers were tracked in alluviums in the Morge Basin, as well in the calcareous travertines and in the crater-lake sediments from Saint-Hippolyte and Clermont (figure 1). Preserved ash-falls have been characterized by their mineralogy and chemistry. When possible, thermoluminescence age estimates has been obtained (PILLEYRE, 1991).

This work was part of a multidisciplinary project in which physicists, Quaternary geologists and archaeologists collaborated. The research has enabled us to establish the succession of tephras in this area over the past 160 ka. We will consider first the period between 160 and 30 ka approximatively and second, the 15 to 5 ka period.

1 -160 TO 30 Ka.

Within the research area, deposits which are younger than the end of the Monts Dore volcanic activity, around 250 ka (CANTAGREL et BEAUBRON, 1983), but older than isotopic stage 6, do not incorporate any evidence of important volcanic activity. Thermoluminescence dates indicate that 27 volcanoes were active from isotopic stage 6

to 30 Ka (MIALLIER, 1982; GUERIN, 1983; RAYNAL *et al.*, 1984; GOER DE HERVE et al., 1993) and we must consider this as a minimum number.

The Clermont basin formed as a result of several contiguous and quasi-simultaneous maar eruptions. These eruptions were determined by the western Limagne fault system. The Jaude-Salins maar (PELLETIER, 1969; BAUDRY et CAMUS, 1972) (figure 2) erupted during stage 6 according to TL dates obtained on quartz grains extracted from pyroclasts (MIALLIER, 1982; MIALLIER *et al.*, 1983, 1984; RAYNAL et al., 1982, 1985):

Cler TL 23 = 157 ± 22 (Cours Sablon),
Cler TL 27 = 156 ± 22 (Hôtel de Chazerat).

A huge lacustrine system accumulated in the crater, fed by the water and sediments of the Tiretaine, its major western tributary. The bottom of the lake fill was never reached. Nevertheless, the deposits were recognized in the southeastern part ("Fond de Jaude") where a 86 m long core, named GEOCLER 1, was extracted from the lake sediments in 1986 (RAYNAL, 1987, 1988). We expected a more than 100 m thickness of sediments and thus, a long record for the last 150 millenia. Nevertheless, sedimentological data and absolute dates on tephra beds encountered in the core, clearly indicate that the sedimentation began in the lake before isotopic sub-stage 5e, in agreement with TL dates on the tuff-ring. TL dates have been obtained on thick tephra beds (PILLEYRE, 1991; PILLEYRE *et al.*, 1991):

Cler TL 250 = 126 ± 15 ka at 70 m below the surface,
Cler TL 251a = 88 ± 10 ka, 62 m below the surface (200-315 mm fraction),
Cler TL 251b = 77 ± 9 a, 62 m below the surface (100-200 mm fraction).

In GEOCLER 1 core, 118 ash-falls have been recorded. Three main conclusions can be deduced from this research:

- basaltic phreatic activity developed along the western fault-scarp of the Limagne between 160 and 70 ka,
- the Chaîne des Puys activity began around 70 ka,
- several acid eruptions occured during this period.

Most of these volcanic events have been recorded in less details in the alluviums of the Morge Basin (figure 3).

1.1 - Basaltic activity along the western fault-scarp of the Limagne.

The first major volcanic phase (figure 4) is made up of the Clermont maar eruption and at least 43 ash-falls identified between 86 and 62 m below the surface in the GEOCLER 1 core .

In the GEOCLER 1 core, tephras consist of ash laminites, 1 mm to a few cm thick. They are black, grey or rust-red in colour, and some exhibit blue and vesicular scorias. The major typical mineral is a brown X-shaped twinned automorphic clinopyroxene (figure 4). Green pyroxene and olivine occur in low percentages.

This basaltic volcanism is also recorded in alluviums (phase 3) (figure 3) and a

direct ash-fall has been fossilized in the calcareous travertines at Rouzat.

The eruption of the Saint-Hippolyte maar occured towards the end of this period and is recorded in the alluviums of the Morge basin (phase 4) (figure 3), but not in the GEOCLER 1 core. The typical mineral of this eruption is an automorphic olivine which lacks crystallization easily visible by scanning electron microscopy.

This basaltic eruptive phase along the Western fault-scarp of the Limagne ends approximatively around 70 ka BP.

1.2 - Ancient activity in the Chaîne des Puys.

In the GEOCLER 1 core, between 62 and 28 m below the surface, at least 75 ash-falls have been identified and constitute the second major eruptive phase. Shards of green pyroxene form the major mineral. Brown clinopyroxene is rare. Olivine is abundant and its variations determine several sub-phases. These minerals are associated with fine scorias.

In the alluviums of the Morge basin (phase 5), an important volcanic activity is marked by the abundance of clinopyroxenes and olivines (figure 1).

This eruptive phase, which began around 70 ka ago, is typical of the initial formation of the Chaîne des Puys.

1.3 - Acid eruptions.

No acid tephras has been discovered, but the Fw alluvium from the Morge basin and several layers of the GEOCLER 1 core are rich in acicular green pyroxenes. Microscopic observation shows us that the development of aciculation was syn-magmatic in many cases. Acicular minerals are associated with leucocratic scorias *and probably indicate acid eruptions, the origin of which remains for now unclear but could belong to the latest eruptive phases of the Monts Dore.*

2 - LATE-GLACIAL AND HOLOCENE TEPHRA.

For the period between 15 and 7 ka (Older Dryas to Atlantic), numerous volcanoes were active in the Chaîne des Puys and neighbouring areas. Strombolian phases built numerous cones and poured out long lava flows which disorganized the drainage pattern. Trachytic and trachyandesitic maar eruptions occured (Kilian, Nugère, Pariou, Pavin). Plinian eruptions were followed by trachytic plugs and dome erection (Puy-de-Dôme, Sarcouy, Chopine...). Tephra columns and plumes reached 20 km into the atmosphere and spread over wide areas aided by wind (GOER DE HERVE *et al*, 1991). Some volcanoes have been directly TL dated :

- Puy de Côme, 15900 ± 1500 and11600 ± 830 (GUERIN, 1983).
- Puy de Lassolas, 15700 ± 1700 (GUERIN, 1983).
- Puy de Tartaret, 13700 ± 1600 (PILLEYRE *et al.*, 1992).
- Puy de Gorce, 13200 ± 1300 (GUERIN, 1983).
- Puy de Barme, 11900 ± 1200 (GUERIN, 1983).

- Puy de la Nugère lava flow, 10900 ± 1200 (GUERIN, 1983).
- Puy de Dôme, 10800 ± 1100, 9300 ± 1100 (FAIN *et al.* , 1986, 1991).
- Puy de Pariou lava flow, 8180 ± 810 (GUERIN, 1983).
- Puy de la Vache, 8100 ± 800 (HUXTABLE *et al.,* 1978), 9150 ± 550 et 8820 ± 870 (GUERIN, 1983), 9130 ± 720 (MONTRET *et al.*, 1992).
- Puy de Montchal,7560 ± 770 BP (GUERIN, 1983).

In the research area, 11 new ash-falls have been recognized. Their chemical and petrographic characters have been analysed and are presented here according to the international classification (LE BAS M.J. *et al*, 1986) (table 1, figure 5) and for some of them, the volcano has been identified (VERNET, 1992). Some of them have been TL dated (PILLEYRE, 1991). These new data complete those previously obtained in peat-bogs and lakes (BASTIN *et al.*, 1990 ; BAUDRY et CAMUS, 1972; CAMUS, 1975 ; GUENET, 1986 ; JUVIGNE, 1987, 1992, 1993 ; JUVIGNE et GILOT, 1986 ; JUVIGNE et GEWELT, 1987 ; JUVIGNE *et al*, 1987, 1992 ; ETLICHER *et al*, 1987 ; MARAMBAT, 1986, 1991). They consist of 5 new ash-falls in the Morge basin and 6 new ash-falls in the Clermont basin.

2.1 - The Morge basin.

From the oldest to the youngest, the identified tephra are :

- Cellule Tephra : Basaltic trachyandesite (Mugearite). The main mineral is green clinopyroxene in shards. Palynological results indicate an Older Dryas age . The source volcano is probably the *Puy de La Nugère*. (VERNET and PAQUEREAU, 1986, 1991; VERNET *et al.*, 1990).

- Les Roches Tephra : Trachyandesite (Benmoreite). The main minerals are brown hornblendes and clinopyroxenes. A radiocarbon accelerator age estimate of 12010 ± 150 BP (Gif TAN 91102), has been obtained on wood fragments collected among the ash-fall (Bølling-Dryas II boundary). The source volcano may be the *Puy de La Nugère.* This tephra has been recognized in an *archaeological context* in a rockshelter, at the top of the Magdalenian sequence at Enval (Puy-de-Dôme) (VERNET, 1991, 1992).

- La Moutade Tephra : Basaltic trachyandesite (Shoshonite). The main mineral is brown hornblende. A radiocarbon age estimate of 11360 ± 130 BP (Ly 3733), has been obtained on the surrounding peat and 13700 ± 1700 (Cler TL 110) by TL on quartz grains in the ash-fall. Palynology on the peaty layer indicates the Alleröd. The source volcano is the *Puy de La Nugère* (VERNET and PAQUEREAU, 1986, 1991; VERNET *et al.*, 1990 ; JUVIGNE *et al*, 1992).

- Gimeaux Tephra (upper) : Trachyandesite (Benmoreite). Green clinopyroxene is the main mineral. The age is Late-glacial *sensu lato* and the source volcano is unknown (VERNET, 1991).

- Rouzat Tephra (upper) : Basaltic trachyandesite (Shoshonite). The main mineral is a green pyroxene in shards. The age is Holocene *sensu lato* and the source volcano is unknown (VERNET, 1992).

2.2 - The Clermont basin.

From the oldest to the youngest, the identified tephras are :

- CF1, Creux-Rouge Tephra : Trachyandesite. The main mineral is brown clinopyroxene. The age is Late Glacial *lato sensu* and the source volcano is *either the ancient Puy de Pariou or the Puy de la Nugère* (RAYNAL *et al.*, 1979).

- CF2, Descartes Street Tephra : Basaltic trachyandesite (Shoshonite). The main minerals are green clinopyroxene and brown hornblende. A TL age estimate of 8700 ± 900 (Cler 114) has been obtained on quartz grains, and palynology suggests an age on the Pre-Boreal / Boreal boundary (VIVENT, unpublished). The source volcano is *either the former Puy de Pariou or the Puy de la Nugère* (RAYNAL *et al.*, 1989).

- CF3, Montjuzet Street Tephra : Trachybasalt (boundary potassic trachybasalte/Hawaïte). The main minerals are green clinopyroxene and olivine. Palynology suggests a Boreal age (VIVENT, unpublished). The source volcano is unknown. In thin section (figure 6), this tephra shows three parts (VERNET, 1992):

- at the bottom, a thin reddish blast deposit of a phreatomagmatic eruption.
- in the middle, a mixture of phreatomagmatic (black compact scorias) and magmatic (highly vesicular scorias) products and of red scorias reworked from a former cone.
- at the top, 90% of vesicular scorias larger than 2 mm belonging to a strombolian plume ash-fall.

- CF4, Blanzat Street Tephra (lower) : Basaltic trachyandesite (Shoshonite). The main minerals are clinopyroxene and olivine. Palynology suggests a Boreal age (VIVENT, unpublished). The source volcano is unknown.

- CF5, Sous-les-Vignes Street Tephra : Rhyolite. The main minerals are green clinopyroxene, zircon and brown hornblende. Palynology suggests an age around the Boreal/Atlantic boundary (VIVENT, unpublished). The source volcano is doubtless the *Kilian Crater* : lack of sphene excludes the Puy Chopine (BENTOR, 1955) and the stratigraphic position excludes the Puy de Dôme. *This is the first acid tephra of the Chaîne des Puys identified in the Limagne* (VERNET, 1992). A wide dispersal of trachytic tephra from the Chaîne des Puys (Vasset or Kilian) during the Boreal has recently been proposed (JUVIGNE, 1991, 1992).

- CF6, Blanzat Street Tephra (upper) : Trachyandesite. The main minerals are clinopyroxenes. Palynology suggests an age on the Boreal/Atlantic boundary (VIVENT, unpublished). The source volcano is doubtless the *Puy de Pariou*, and this tephra relates particularly to the main lava flow episode in the history of this volcano (CAMUS, com. pers.).

Late-Glacial and Holocene volcanism is concentrated in a small area but the dispersal of its products is sometimes much wider. The isochronic implications of this are of great interest in prehistoric research

3 - CONCLUSIONS.

Regional research carried out in a small area has produced results which add precision to our knowledge of volcanic activity in the Chaîne des Puys during the past 160 Ka. It demonstrates that the Limagne d'Auvergne has frequently been covered with tephra

falls. Thus, human settlements had to face this reality and this has been evoked several times in former papers (Daugas et Raynal, 1989, 1991 a and b; Raynal et Daugas, 1984, 1991; Raynal et Sanzelle, 1989).

Let us take for example the Magdalenian site located in a rockshelter at Enval (Puy-de-Dôme) where the last occupation layer is overlain by a tephra which forms the top of the stratigraphic sequence. This has been identified as Les Roches Tephra, emitted around 12 Ka BP by the Puy de la Nugère. Was volcanism the cause of the site falling into disuse ?

We believe that this sort of research has important implication for prehistory in volcanic areas, especially in the French Massif Central (RAYNAL et DAUGAS, 1989 ; RAYNAL et al, 1994). Mineralogy enables tephra beds to be distinguished in archaeological sequences and can help to set up isochronic comparisons. This will allow better evaluation of the impact of volcanism on human behaviour and thus provide a key to understanding regional settlements pattern and environmental exploitation strategies.

In conclusion, everyone can appreciate the potential of Western Limagne for tephra studies. Nevertheless, the ancient Chaîne des Puys remains badly known and insufficient research has been carried out on its acid eruptions. We hope that these preliminary investigations may be developped further in future.

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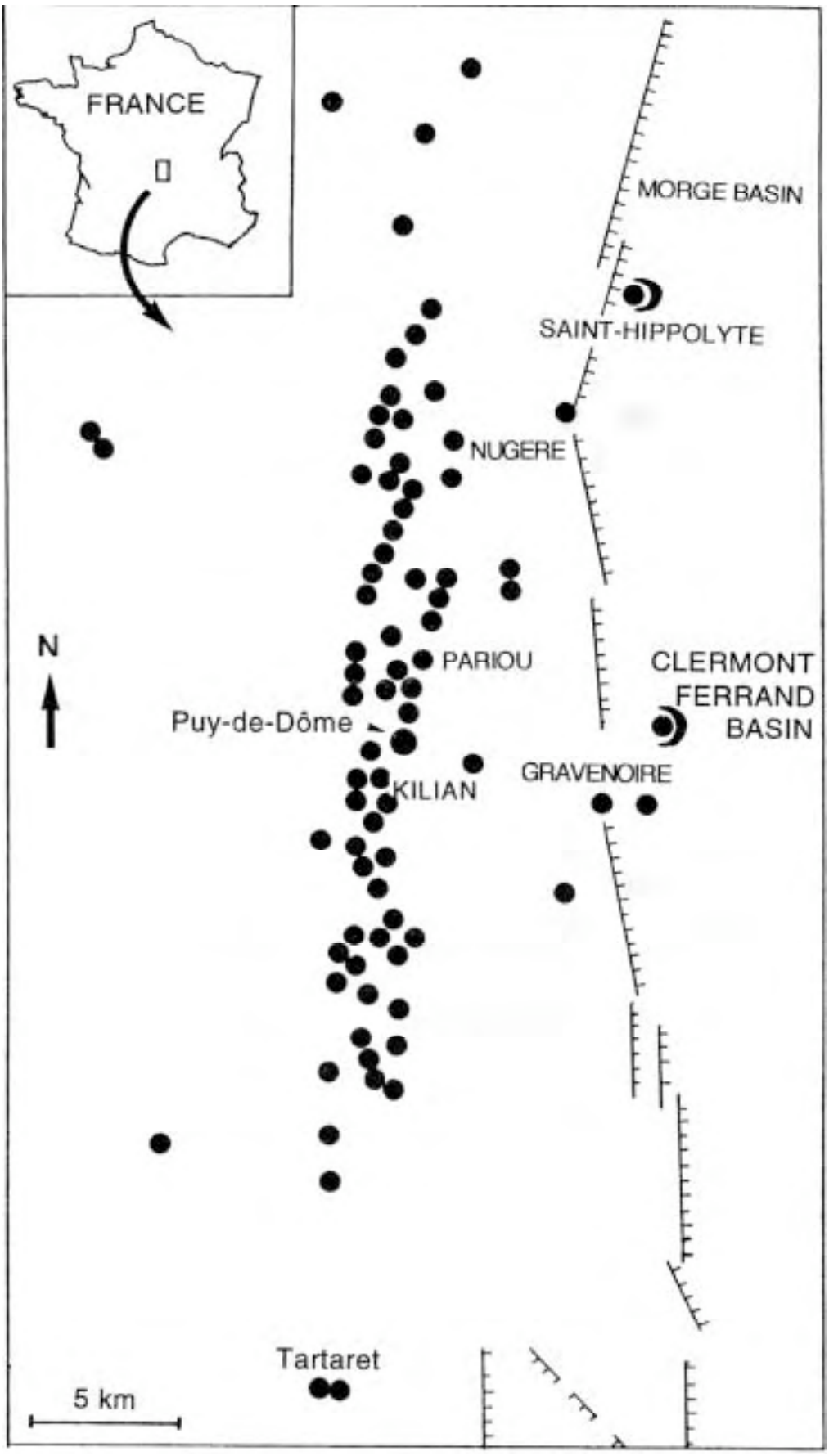

Figure 1: Sketch map of the Chaîne des Puys (GOER DE HERVE *et al*., 1991) with main localities studied. Black dots represent cones and domes, black dots with crescent respresent maars.

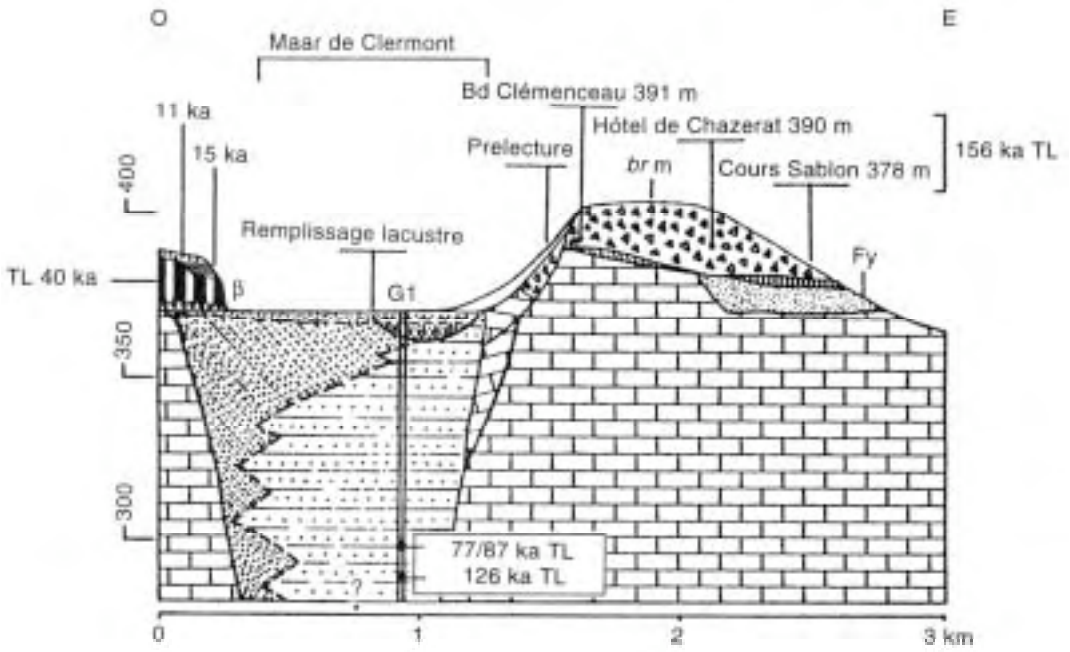

Figure 2: Clermont maar. Stratigraphic schema and dates. G1 : GEOCLER 1 core.

PHASES	Sardon Chamberon Morge alluviums	VOLCANIC SIGNALS INTENSITY 30% 90%	CHRONOLOGY
I	Fv Sardon Fv Chamberon (layer 6 Saulnat) Fw1 Sardon	Brown clinopyroxene + Hornblende Green clinopyroxene.	Correlation with Fw Allier 0,2 Ma
II	Fv Chamberon (layer 2 Saulnat) Fv Morge	Brown clinopyroxene and some green acicular clinopyroxenes	
III	Fw Morge	Green acicular clinopyroxene	
IV	Fw2 Sardon Fv Chamberon Vol. Fw Morge Vol.	Clinopyroxene and Olivine	Eruption of Saint-Hippolyte maar 90 Ka
V	Fw Chamberon	Brown clinopyroxene	Beginning of Chaîne des Puys activity 70 to 60 ka
VI	Fx, Fy, Fz, Sardon and Chamberon Fx, K, Morge	Clinopyroxene, Olivine, Hornblende Direct ash-falls	Chaîne des Puys Late-Glacial and Holocene activity 11 - 8 Ka

Figure 3: Volcanic minerals in the alluviums of the Morge Basin (after VERNET, 1992).

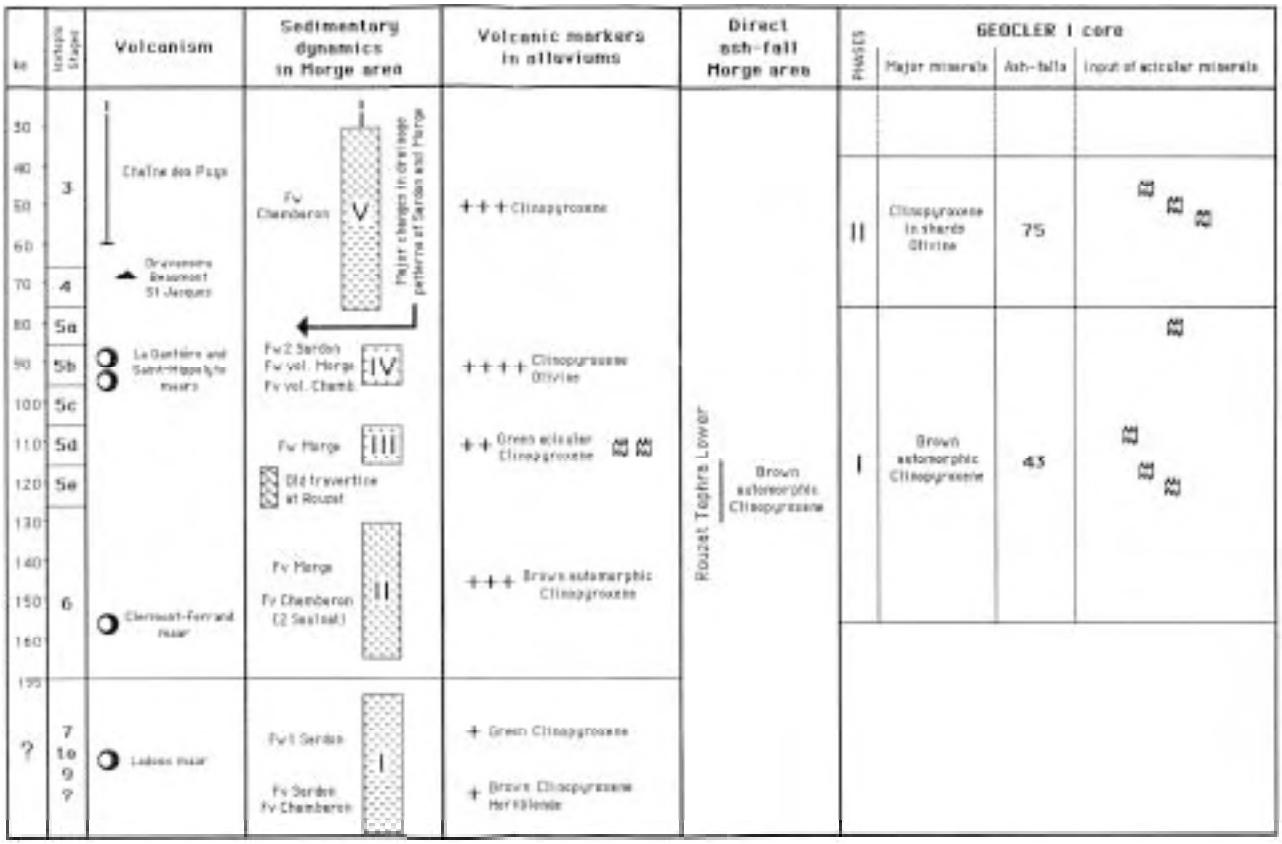

Figure 4: Tephrostratigraphy and dynamics in North-Western Limagne between 300 and 30 ka (after VERNET, 1992).

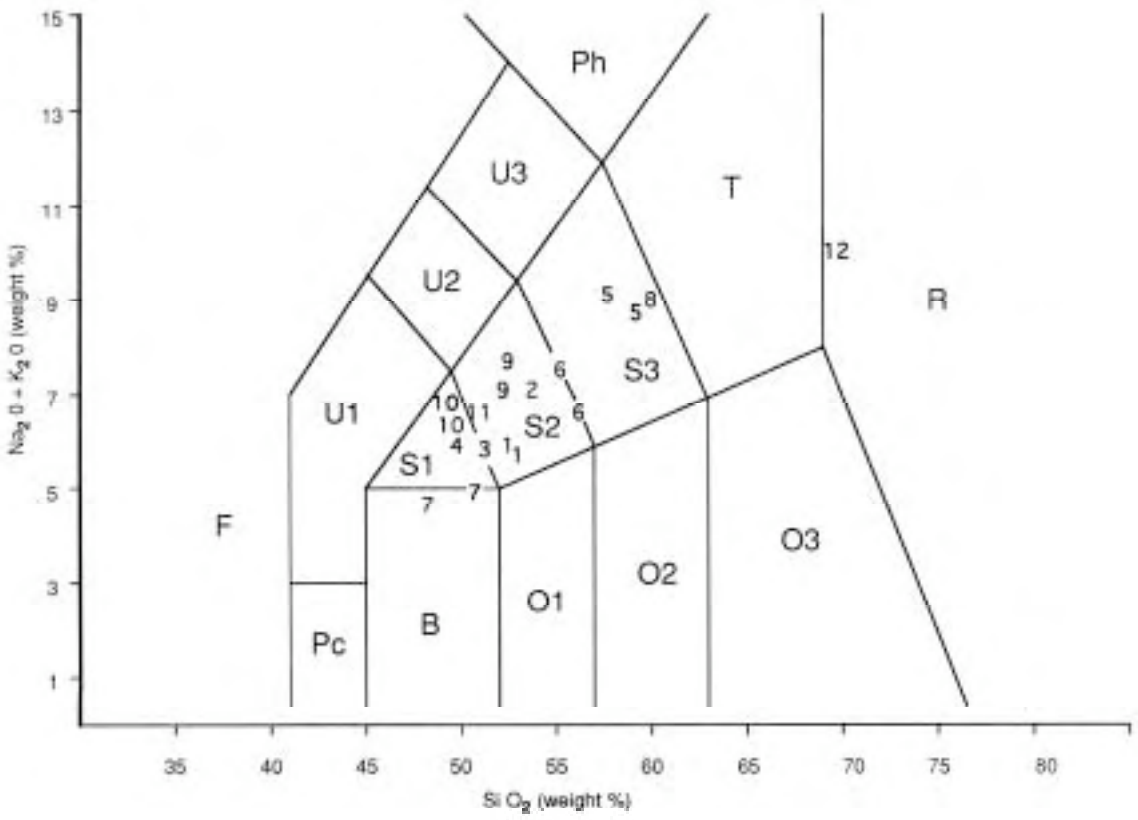

Figure 5: Chemical composition of identified tephra in SiO2/Na20+K2O (weight%) diagram (LE BAS *et al.*, 1985).1 : La Moutade Tephra (2 samples). 2 : Cellule Tephra. 3 : Rouzat Upper Tephra. 4 : Rouzat Lower Tephra. 5 : Gimeaux Upper Tephra (2 samples). 6 : Les Roches Tephra. 7 : Saint-Hippolyte Tephra (2 samples). 8 : CF1 Tephra . 9 : CF2 Tephra (2 samples). 10 : CF3 Tephra (2 samples). 11 : CF4 Tephra . 12 : CF5 Tephra.

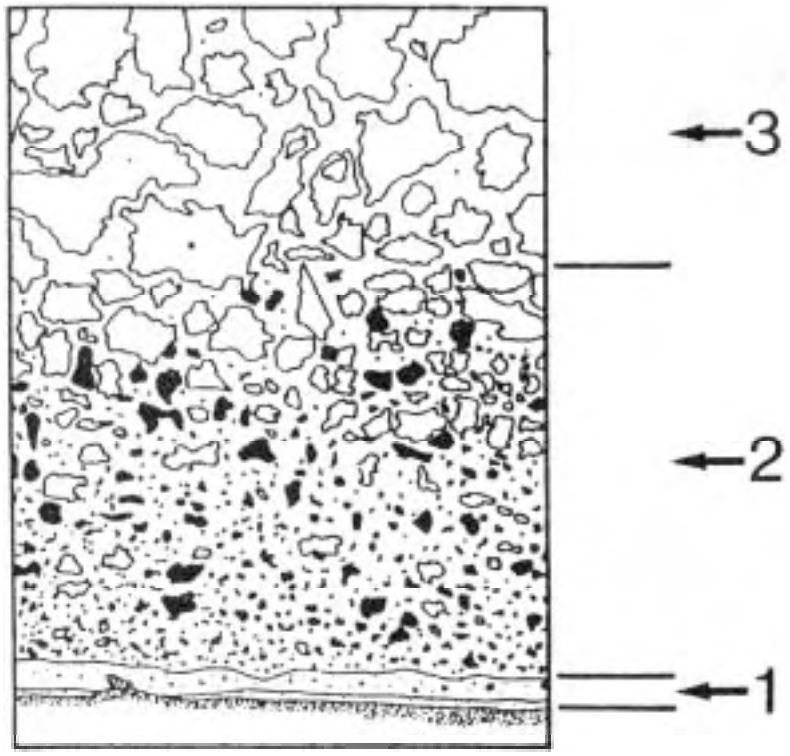

Figure 6: Thin section in CF3 tephra. Width : 7 cm (after VERNET, 1992). 1: phreatomagmatic blast deposit. 2: mixture of phreatomagmatic and magmatic products. 3: strombolian plume ash-fall.

ZONE	MORGE BASIN									
TEPHRA	LA MOUTADE		CELLULE	ROUZAT Upper	ROUZAT Lower	GIMEAUX UPPER		LES ROCHES	SAINT-HIPPOLYTE	
LOCALITY	Saint Bonnet	Cellule		Rouzat		Gimeaux			Saint Bonnet	St Hippolyte
LAYER	3	3	8 top	Young travertine	Old Travertine	3 top		3 bottom	Fw2 Sardon	Tuff-ring
COMPOSITION*										
SiO2	49,30	46,40	51,96	50,31	47,31	55,40	58,06	53,60	47,39	50,95
Al2O3	14,73	15,10	16,95	17,96	15,62	18,09	18,96	18,50	15,18	15,80
Fe2O3	7,41	7,66	8,24	7,66	8,28	5,52	4,52	5,80	11,30	11,50
MgO	3,15	3,48	3,27	3,06	3,41	1,08	1,12	1,99	6,76	5,53
CaO	11,92	9,68	7,36	10,92	12,35	5,58	5,32	7,83	10,30	8,86
Na2O	3,25	2,97	4,50	3,83	3,27	5,34	5,49	4,75	2,97	3,17
K2O	2,34	2,32	2,39	1,89	2,28	3,36	3,11	2,60	1,59	1,89
TiO2	1,13	1,39	1,62	2,64	2,38	1,23	1,30	1,86	2,27	2,23
MnO	0,15	0,14	0,19	0,13	0,13	0,13	0,12	0,13	0,18	0,18
H2O+	6,80	10,86	1,37	1,28	4,10	2,50	1,27	1,48	0,88	0,63
H2O-	0,24	0,00	1,73	0,00	0,75	1,00	0,36	0,40	0,45	0,29
Total :	100,42	100,00	99,58	99,68	99,88	99,23	99,63	98,94	99,27	101,03
**On selected scorias*										

ZONE	CLERMONT BASIN						
TEPHRA	CF1	CF2		CF3		CF4	CF5
LOCALITY	Creux Rouge	Blanzat Street	Sous les Vignes Street		Blanzat Street		Ss les Vignes St
LAYER	4	(Camus sample)	1	2a	(Camus samples)		3c
COMPOSITION*							
SiO2	60,60	51,98	51,39	48,43	49,39	50,13	69,24
Al2O3	17,10	17,18	16,12	16,77	17,36	16,66	15,90
Fe2O3	6,10	9,65	9,61	11,67	11,74	10,75	2,03
MgO	3,70	3,36	3,62	4,31	4,48	3,97	0,67
CaO	2,90	7,19	8,72	8,13	8,14	7,64	1,39
Na2O	2,50	4,78	4,43	4,28	4,18	3,90	5,47
K2O	6,60	2,80	2,49	2,42	2,13	2,51	4,46
TiO2	1,30	1,82	1,77	2,31	2,35	2,08	0,35
MnO	0,08	0,22	0,20	0,21	0,20	0,20	0,12
H2O+	0,00	0,00	1,84	0,42	0,00	0,00	1,06
H2O-	0,08	0,00	0,64	0,50	0,00	0,00	0,12
Total :	100,96	98,98	100,83	99,45	99,97	97,84	100,81
**On selected scorias*							

Tableau 1 : Composition chimique des téphras identifiées en Limagne. Analyses par fluorescence X réalisées au Centre de Recherches Volcanologiques, Clermont-Ferrand.

Table 1: Chemical composition of identified tephra in Western Limagne. X-Fluorescence analysis, Centre de Recherches Volcanologiques, Clermont-Ferrand.

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