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Paleointensity of the earth's magnetic field during the Laschamp excursion and its geomagnetic implications

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The reversed paleomagnetic direction of the Laschamp and Olby flows represents a specific feature of the geomagnetic field. This is supported by paleomagnetic evidence, showing that the same anomalous direction was recorded at several distinct sites, including scoria of the Laschamp volcano. To examine this anomalous geomagnetic fluctuation, we studied the paleointensity of the Laschamp and Olby flows, using the Thellier method. Twenty-five samples were selected for the paleointensity experiments, and from seven we obtained reliable results. Because the paleointensity results of the Olby and Laschamp flows as well as Laschamp scoria are very similar, they can be represented by a single mean paleointensity, $F = 7.7$ μT. Considering that this low paleointensity is less than 1/6 of the present geomagnetic field and is more characteristic of transitional behavior, our results suggest that the paleomagnetic directions of the Laschamp and Olby flows were not acquired during a stable reversed polarity interval. A more likely explanation is that the Laschamp excursion represents an unsuccessful or aborted reversal.

1. Introduction

When the Laschamp excursion was originally reported in 1967 by Bonhommet and Babkine [1] in two volcanic flows of Laschamp and Olby, it provided the first evidence for a possible short geomagnetic reversal in the Brunhes epoch. Since then, several excursions have been reported [2,3], but many of them are the subject of controversies, particularly those from sedimentary records [4,5]. A key point in the characterization of excursions must be the intensity of the field. For instance, the existence of a period of abnormally low dipole field would enhance non-dipole effects, in which case the directions recorded at Laschamp might not be the result of a true reversed dipole field. On the other hand, the observation of a normal intensity would argue for a full short reversal. Up to now there were only directional data from the reverse flows and those with intermediate directions [6]. Therefore, we have undertaken careful absolute intensity determinations using the Thellier [6] method. We report here the paleointensity results from the reverse Laschamp and Olby flows and from reverse scoria inside the Laschamp crater.

Due to the rapid cooling and acquisition of thermal remanent magnetization (TRM) in extrusive igneous rocks, lavas often represent essentially an instantaneous recording of the geomagnetic field. Moreover, rocks with TRM can, in principle, be used for a complete description of the paleofield including both the intensity and the direction. Nevertheless, secondary magnetizations and special magnetic mineralogy sometimes preclude a good record of the paleofield. Before undertaking the paleointensity experiments, the magnetic properties of the Olby and Laschamp flows were examined to select the most suitable samples for the Thellier paleointensity experiments.

The results of this study provide strong evidence for the geomagnetic origin of the reverse paleomagnetic directions at Laschamp and Olby. The possibility of a self-reversal in the units recording the Laschamp was considered at the time of its discovery; however, alternating fields (AF) and thermal demagnetization [7] as well as preliminary rock magnetic and mineralogic properties [8] did not support this hypothesis. Nevertheless, several reports [9–11] of rock magnetic and miner-

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alogical observations from the reversed flows of Laschamp and Olby argued that the reversed units might represent a self-reversal. We propose in section 5 an alternative explanation of these results which rules out the self-reversal hypothesis.

2. Sampling and paleointensity method

While sampling the Laschamp and Olby flows, the cores were spatially distributed across the flows and over the maximum available horizontal extent in order to find the widest range of magnetic properties. Twenty-nine cores were drilled at one site from the Laschamp flow. One side of the site was clearly affected by lightning, giving rise to a strong deviation of the magnetic compass; however, this effect was not recognized at a distance greater than 10 m. The Olby flow was sampled at three sites: 16 cores at site B, 23 cores at site C and 22 cores at site D (Fig. 1). Generally, two standard cylindrical (1 inch) specimens were cut from each core.

The paleomagnetic experiments and measurements were carried out with the Schonstedt equipment. Most of the paleointensity determinations were performed in a Schonstedt furnace using the Thellier [6] method, modified by Coe [12]. At each temperature stage, the samples were heated twice for 90 minutes in zero field inside a quartz tube evacuated to pressures less than 10^{-12} Torr. For cooling, the quartz tube was moved to the attached cooling chamber. The first cooling was done in null magnetic field, to determine the residual NRM. The second cooling was done in a known applied field to produce a laboratory partial TRM. The temperature reproducibility at each step was approximately 2°C. A few experiments were performed according to the original Thellier method, where the laboratory field is continuously applied during the heating and cooling cycle; the field direction was reversed for the second heating cycle at the given temperature. The residual NRM and the acquired partial TRM are both obtained by vectorial addition and subtraction.

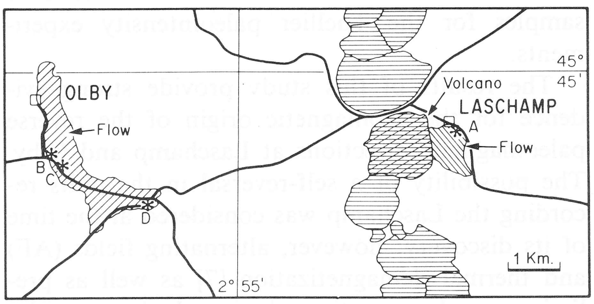

Fig. 1. Location map and sampling sites of the Laschamp and Olby flows (Chaîne des Puys, France). Sites A, B and C are equivalent to sites 5, 1 and 3 from Heller and Petersen [9,10].

3. Magnetic properties

The intensity of magnetization is shown in Fig. 2a. For the Laschamp flow, the group with intensities around 10 A m^{-1} corresponds exactly to the small area which was struck by lightning. For both Olby and Laschamp the average intensity is around 1 A m^{-1}. In contrast, the magnetization intensities for normal polarity flows of the Chaîne des Puys are distributed between 5 and 10 A m^{-1} [7], a ratio of 1/5 in the paleofield can already be suspected. Laboratory viscosity tests [13] were performed for each specimen and the results are shown in Fig. 2b. For the Olby flow, most of the samples have a viscosity index greater than 5%. In contrast, no detectable viscosity was observed at Laschamp, where Mössbauer experiments revealed fine superparamagnetic grains [14], which, however, do not contribute to the remanence.

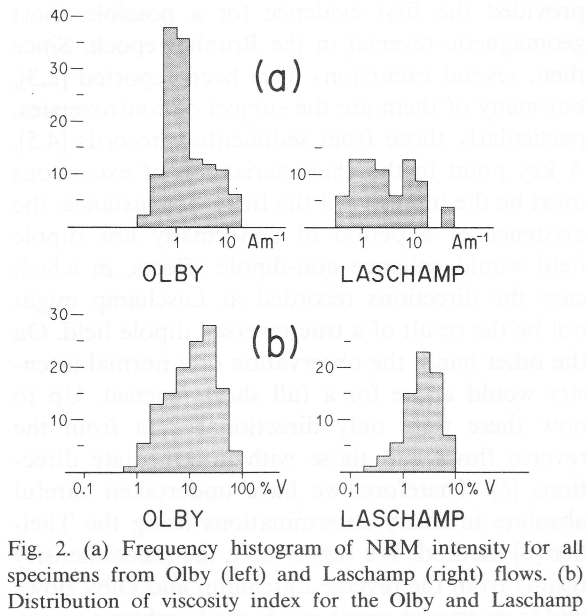

Fig. 2. (a) Frequency histogram of NRM intensity for all specimens from Olby (left) and Laschamp (right) flows. (b) Distribution of viscosity index for the Olby and Laschamp flows.

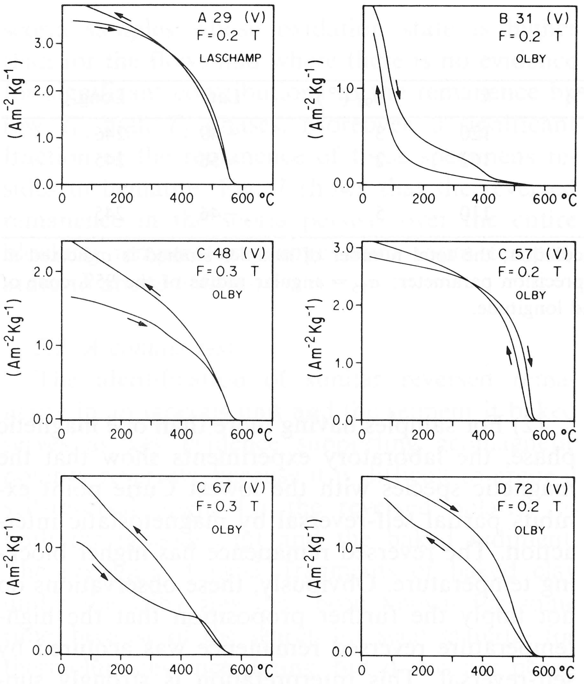

Fig. 3. J_s-T experiments performed in vacuum with an applied field of 0.2 or 0.3 T. One sample (A29) from the Laschamp site A; B31 from Olby site B; C48, C57 and C67 from Olby site C; D72 from Olby site D.

Whitney et al. [8] concluded that the remanence, in the samples which they analyzed, resided in single-domain grains. To check this hypothesis, we performed a low-temperature test for 24 specimens by cooling the samples in zero field to liquid nitrogen temperature. The effect on the remanence was not very important for the Laschamp samples while a significant reduction of the remanence was observed for many samples of the Olby flow during cooling in zero field. This behavior can be interpreted as an indication of relatively more multidomain grains for the Olby flow [15]. Thermomagnetic experiments also show a great variety of behavior and instability for Olby, while Curie points above 500 °C are predominant for Laschamp. Some examples are given in Fig. 3. This conclusion was already reached by Heller and Petersen [9,10].

4. Directional behavior

The natural remanent magnetization (NRM) was frequently affected by secondary remanences

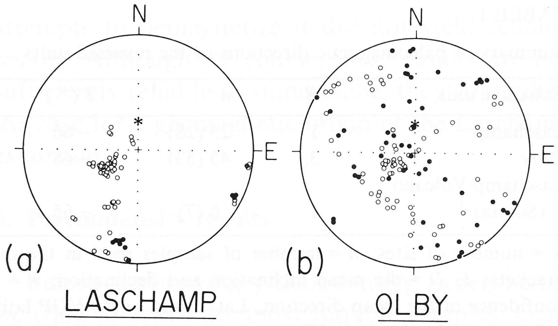

Fig. 4. Stereographic projections of the NRM directions of (a) Laschamp, and (b) Olby samples. The star represents the direction of the axial dipole field. Solid symbols are on the lower hemisphere and open symbols on the upper hemisphere.

(Fig. 4a, b), but even for NRM there was a recognizable clustering of directions around the southwest reversed direction, initially reported by Bonhommet [1,7]. AF demagnetization generally removed the secondary components (Fig. 5). Fig. 6 shows the evolution of the magnetic directions for the Olby flow after AF cleaning to 20 mT, and the stable paleomagnetic directions show no samples with normal polarity. This result contrasts with the study of Heller and Petersen [9,10], who claim that 40–44% of the samples from the Olby flow were normal after AF cleaning. The remanence of the Laschamp samples is stable and the primary reversed direction is well recorded and readily identified even for the NRM, except for the specimens affected by lightning. Samples from Olby, whose NRM is close to the characteristic direction found by AF cleaning, behave well during progressive thermal demagnetization, but samples with large secondary components generally be-

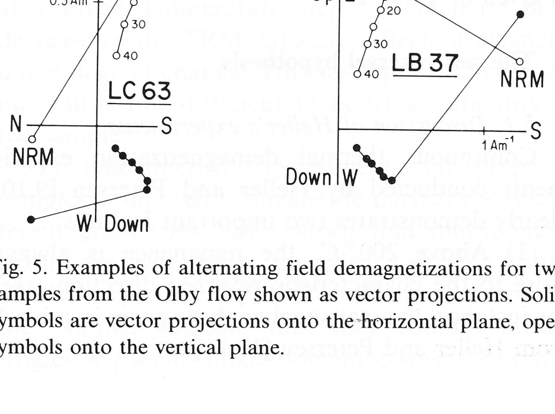

Fig. 5. Examples of alternating field demagnetizations for two samples from the Olby flow shown as vector projections. Solid symbols are vector projections onto the horizontal plane, open symbols onto the vertical plane.

TABLE 1

Summary of paleomagnetic directions of the reversed units

Extrusive unit	N	n	I (°)	D (°)	k	α_{95} (°)	Lat.	Long.
Laschamp	1	23 (28)	−66	241	120	3	−49	246
Olby	3	43 (53)	−68	231	162	2	−56	245
Laschamp Volcano (Scoria) [a]	1	6 (7)	−65	239	110	5	−46	245

N = number of sites; n = number of samples used in the mean calculation; the total number of samples studied is indicated in brackets; I, D = the mean inclination and declination; k = Fisher precision parameter; α_{95} = angular radius of the 95% cone of confidence of the mean direction; Lat., Long. = the VGP latitude and longitude.

[a] Data from Bonhommet [7].

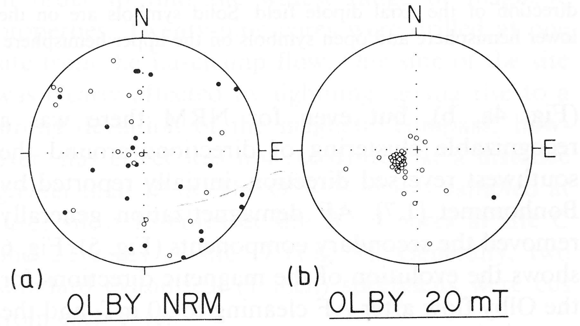

Fig. 6. Stereographic projections of paleomagnetic directions of Olby specimens. (a) NRM; (b) after AF demagnetization to 20 mT. After AF cleaning, the directions of the residual remanence clearly cluster around the characteristic reversed direction (same convention as in Fig. 4).

come incoherent and unstable. Thermomagnetic experiments reveal that unstable behavior of the directions can be correlated with the presence of low Curie point magnetic phases. Samples exhibiting stable paleomagnetic directions have a single magnetic phase and Curie points above 500 ° C. This class includes all the samples which have NRMs close to the characteristic direction. A summary of the cleaned paleomagnetic directions is given in Table 1.

5. The self-reversal hypothesis

5.1. Discussion of Heller's experiments

Continuous thermal demagnetization experiments conducted by Heller and Petersen [9,10] clearly demonstrates two important features:

(1) Above 200 ° C, the remanence is always close to the characteristic reversed direction (see, for instance, the statistical analysis given in table 1 from Heller and Petersen [10,11]).

(2) For samples having more than one magnetic phase, the laboratory experiments show that the magnetic species with the lowest Curie point exhibits partial self-reversal by magnetostatic interaction. The reversed remanence has higher blocking temperature. Obviously, these observations do not imply the further proposition that the high-temperature reversed remanence was acquired by self-reversal. This interpretation is strongly supported by similar behavior observed in recent Colombian volcanic pumices which have very strong self-reversed components with very low unblocking temperatures, while the primary normal direction was clearly defined at higher temperature [16].

Finally, the samples with a single high Curie temperature always carry the primary reversed direction. Hence magnetostatic interactions cannot be responsible for this high-temperature reversed remanence. An example is given in the red

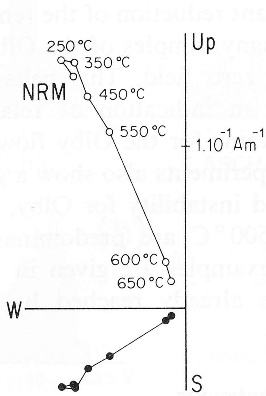

Fig. 7. Thermal demagnetization of a scoria sample from the Laschamp volcano, showing that the characteristic reversed direction is retained over the entire blocking temperature spectrum to above 600 ° C. Symbols as in Fig. 5.

scoria samples whose oxidation state is higher than for the flows and where there is no evidence for significant contributions to the remanence by low T_C/high T_I phases. Moreover, a significant fraction of the remanence of these specimens resides in hematite. Fig. 7 shows that the reversed remanence in the scoria persists over the entire blocking temperature range from room temperature to above 650 ° C.

5.2. A contact test

The identification of similar reversed remanence in an igneous unit and the seiment it baked serves as key evidence supporting geomagnetic polarity reversals, because it is difficult to argue a self-reversal origin for the reversed polarity of both the igneous unit and the baked sediment. The presence of small fragments of baked clay under the Olby flow has been known for some time, because of the search for such material for thermoluminescence dating, but it was not possible to find enough material for a reliable paleomagnetic work. Only two oriented samples of baked sediment underlying the Olby flow were obtained. The intensity of magnetization of one sample was 0.06 A m^{-1}, and the NRM direction ($D = 240$ °, $I = -40$ °) was upwards. Upon stepwise thermal demagnetization there was a sharp drop in intensity (Fig. 8) at 250 ° C. However, the orthogonal projection diagram (Fig. 8) shows that the remanence direction remained upwards and southwest up to 550 ° C. The second sample had an NRM direction close to the first one, but

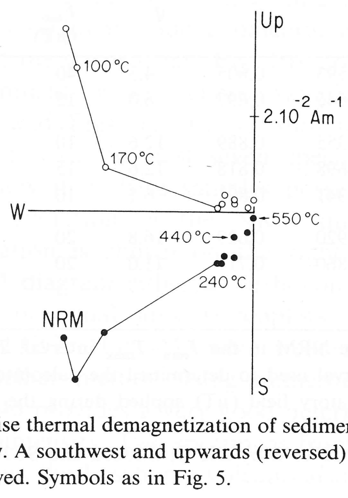

Fig. 8. Stepwise thermal demagnetization of sediment baked by the Olby flow. A southwest and upwards (reversed) direction is clearly observed. Symbols as in Fig. 5.

attempts to demagnetize it did not yield reliable results. Although, of course, these results are not sufficiently reliable to stand alone, they strengthen the case for a geomagnetic origin of the Laschamp excursion.

6. Paleointensity results

Before performing paleointensity experiments, we tried to select the most suitable samples. Generally, the criteria used in selecting samples for paleointensity studies were based on a low viscosity index, single high Curie temperatures and high degree of reversibility during strong field thermomagnetic analyses. In addition, NRM with minimum secondary overprinting is a very important selection parameter [17]. For example most of the Laschamp samples are not severely affected by secondary remanences, whereas for the Olby flow, only 1 core from site B, 3 from site D and 6 from site C satisfied this criterion. We note that 4 of the last 6 cores correspond to the top of the flow, which might have experienced more intense high-temperature oxidation during the initial cooling of the flow. In all, twenty-five samples were selected; all had a viscosity index less than 5% and a good reversibility in the strong field thermomagnetic measurements. During the Thellier experiments, the samples were treated with different procedures and various applied fields (10, 15, 20 and 40 μT). Two-thirds of the samples were rejected, because of concave-up NRM-TRM diagrams resulting from three causes:

(1) Progressive increase in the TRM capacity due to chemical changes during the heatings. This cause can usually be detected by the PTRM checks [6], which consist of measuring the PTRM acquired at a lower temperature after the sample was heated at a higher-temperature step. An increase or a decrease in the TRM capacity reflects a magnetic mineralogical change. This test appears necessary but still is not sufficient to assert a suitability of the sample.

(2) Paleointensity experiments on prepared samples composed of magnetite particles with different grain sizes have shown that multidomain grains can give rise to non-ideal behavior during Thellier experiments [18]. Even if the properties of the samples indicate that they contain mostly single- or pseudo-single-domain grains, the contri-

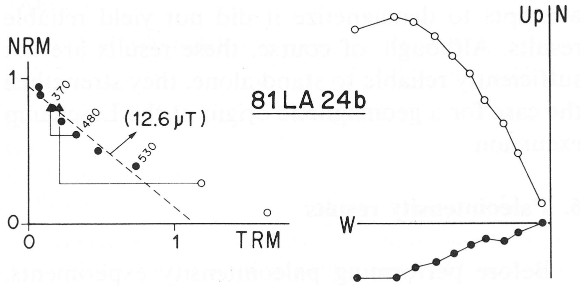

Fig. 9. Example of a NRM-TRM diagram of a Thellier paleointensity experiment with typical concave-up behavior but no large variations in the PTRM capacity at lower temperatures. The remanence direction rotates slightly towards a more upward characteristic inclination, showing that the NRM might not be a pure TRM at the lower temperatures. This is the reason we rejected samples with this type of behavior. (All the NRM-TRM diagrams are normalized by the total NRM.)

bution of some fraction of multidomain grains to the remanence might produce concave up behavior. Such behavior was observed for samples from Olby site D, for which no significant result was obtained.

(3) Even though samples with large secondary magnetizations were avoided, samples selected for paleointensity studies were not usually absolutely free from small secondary components, and they probably exhibited varying but minor amounts of VRM or IRM which alter the lower part of the temperature spectrum. An example is given by the sample LA24b (Fig. 9) where the progressive

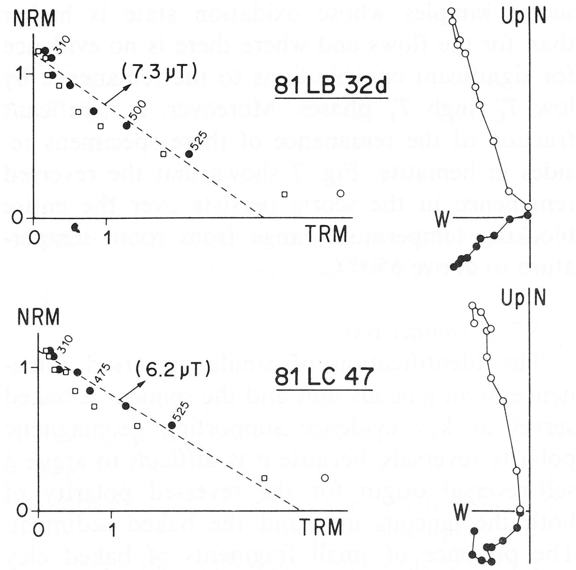

Fig. 10. NRM-TRM diagram of Thellier paleointensity experiments with the addition of 10 mT AF cleaning of the NRM (solid circles: no AF cleaning of the PTRM at each step; squares: 10 mT AF cleaning of the PTRM at each temperature step). Evolution of the NRM during thermal demagnetization is shown at right on a vector projection plot.

destruction of the secondary component induces a systematic shift of the remanence through the characteristic direction. In order to minimize this problem, an AF cleaning at 10 mT was introduced for the NRM and after each PTRM acquisition;

TABLE 2

Paleointensity results

Sample	J_{NRM} (A m^{-1})	D (°)	I (°)	N	T_{min} (°C)	T_{max} (°C)	f	g	q	F_{lab} (μT)	F (μT)
81LA27a	1.70	237	−60	6	230	525	0.593	0.605	4.3	40	7.7
81LA28b	2.03	251	−69	6	300	530	0.545	0.697	6.0	15	8.5
81LC46	1.85	221	−75	11	240	530	0.355	0.889	12.6	10	7.5
81LC48b	1.04	188	−76	8	230	550	0.698	0.818	12.6	15	5.7
81LC57c	1.15	258	−61	15	150	540	0.341	0.891	6.1	10	10.6
SC303a	1.52	226	−65	7	270	590	0.920	0.629	16.8	20	7.3
SC303b	0.98	217	−63	7	270	590	0.860	0.717	11.0	20	6.4

Mean: 7.7 ± 1.6 μT

J_{NRM} = intensity of the magnetization; D, I = declination and inclination of the NRM in the T_{min}–T_{max} interval. T_{min}, T_{max} = minimum, maximum temperature; N = number of points in the T_{min}–T_{max} interval used to determined the paleointensity; f, g, q = NRM fraction, gap factor and quality factor respectively [39]; F_{lab} = laboratory field (μT) applied during the experiment; F = the paleointensity.

Samples 81LA27a and 81LA28b from Laschamp site A; 81LC46, 81LC48b, 81LC57c: Olby site C; SC303a and SC303b are two specimens from a block of scoria of the Laschamp volcano.

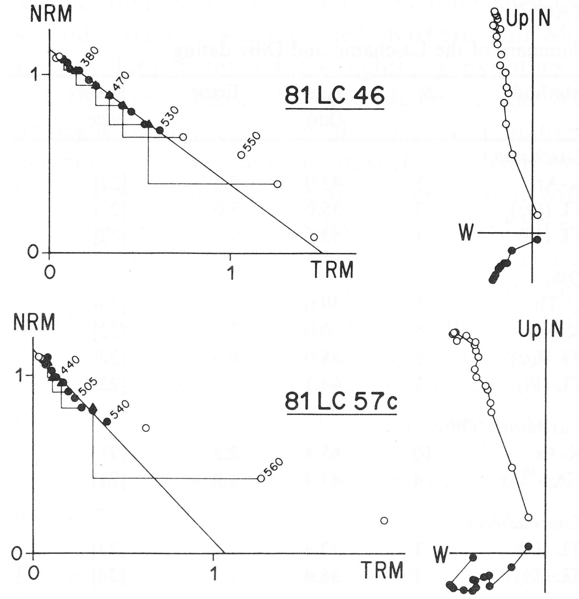

Fig. 11. Paleointensity results by the original Thellier method for two samples from Olby site C. Black dots correspond to points used to calculate the slope. Triangles represent PTRM checks. Thermal demagnetizations of the NRM are shown as the orthogonal plots.

this procedure was tried on 6 specimens. Fig. 10 shows two examples for which an AF cleaning was performed. The circles correspond to the PTRMs before cleaning and the squares correspond to the cleaned PTRMs. This procedure, even though it allows a better determination of the primary natural remanence, does not improve the linearity of the NRM-TRM curve, as previously noted by Coe and Grommé [19]. Although we decided not to consider these results, it is interesting to notice that these samples provide a paleointensity (i.e. the slope of the dashed line, Fig. 10) close to the mean determined for the 7 chosen samples.

Table 2 and Figs. 11, 12, 13 summarize the paleointensities of the best seven specimens. In order to show that these samples possess remanence, the evolution of the NRM during the demagnetization is shown on the right of each NRM-TRM diagram either as orthogonal vector projections or equal area stereoplots. Samples LC46 and LC57c (Fig. 11) were treated by the original Thellier method using numerous steps. Sample LC46 provides a very good determination of the paleointensity. Two specimens from a block of scoria from the Laschamp volcano also provide

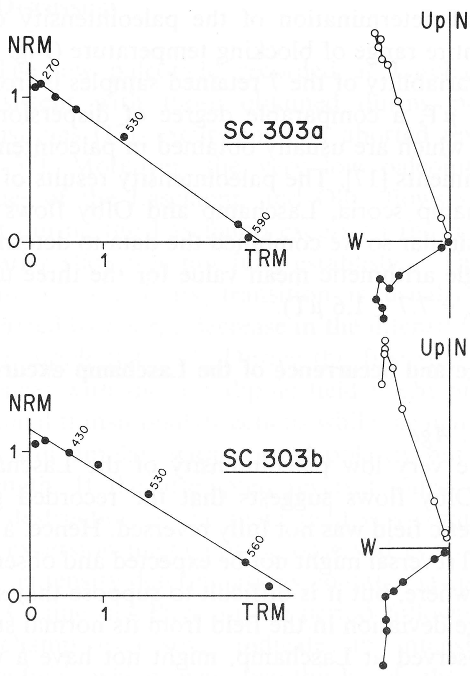

Fig. 12. Paleointensity results, using the Coe version of the Thellier method, for two specimens of a scoria block from the Laschamp volcano. Symbols and conventions as in Fig. 11.

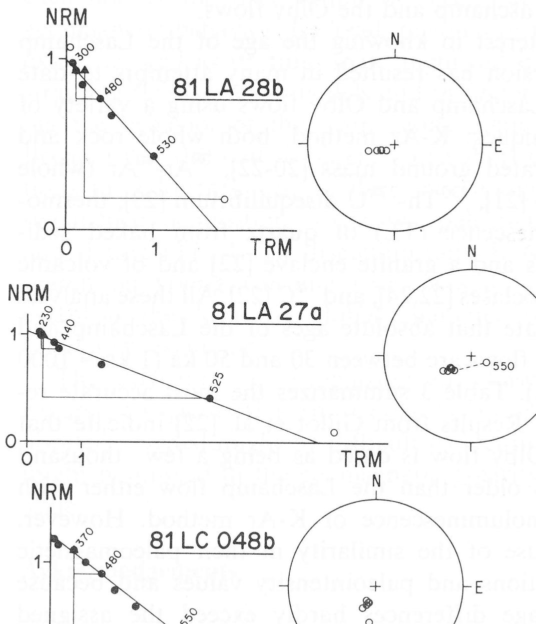

Fig. 13. Paleointensity results by the Coe version of the Thellier method; the evolution of the NRM thermal demagnetizations is shown on an equal area projection.

a good determination of the paleointensity over the entire range of blocking temperature (Fig. 12). The variability of the 7 retained samples is from 5 to 10 μT, a comparable degree of dispersion to those which are usually obtained in paleointensity experiments [17]. The paleointensity results of the Laschamp scoria, Laschamp and Olby flows are very similar so we combined the data to determine a single arithmetic mean value for the three units ($F_{mean} = 7.7 \pm 1.6$ μT).

7. Age and occurrence of the Laschamp excursion

7.1. Age

The very low paleointensity of the Laschamp and Olby flows suggests that the recorded geomagnetic field was not fully reversed. Hence, a full global reversal might not be expected and observed everywhere, but it is difficult to suppose that such a large deviation in the field from its normal state, as observed at Laschamp, might not have a very large geographic extent. Numerous excursions have been reported for the recent geological past, but before trying to correlate them with the Laschamp, it is necessary to sum up the available dating of the Laschamp and the Olby flows.

Interest in knowing the age of the Laschamp excursion has resulted in many attempts to date the Laschamp and Olby flows using a variety of techniques: K-Ar method, both whole rock and separated ground mass [20-22], ^{39}Ar-^{40}Ar (whole rock) [21], ^{230}Th-^{238}U disequilibrium [23], thermoluminescence (TL) of quartz from baked sediments and a granite enclave [22] and of volcanic plagioclases [22,24], and ^{14}C [22]. All these analyses indicate that absolute ages of the Laschamp and Olby flows are between 30 and 50 ka (1 ka = 1000 years). Table 3 summarizes the most accurate results. Results from Gillot et al. [22] indicate that the Olby flow is dated as being a few thousand years older than the Laschamp flow either with thermoluminescence or K-Ar method. However, because of the similarity in their paleomagnetic directions and paleointensity values and because the age differences hardly exceed the assigned uncertainties, it is difficult to know whether these differences are significant. Apart from the slight discrepancy between the ages of Laschamp and Olby, thermoluminescence dating seems to give lower values than the K-Ar method. The Louchadières flow has also an intermediate direction [1,7] which cannot be related to normal secular variations and it is highly likely that this flow is contemporaneous with Laschamp and Olby. Moreover, the TL datings from two sites of the Louchadières flow are similar to those from Laschamp and Olby.

TABLE 3

Summary of the Laschamp and Olby dating

Method	N	Age (ka)	Error	Reference
Laschamp				
K-Ar	5	43.0	5.0	[22]
TL (Qz)	3	35.0	3.0	[22]
TL (Pl)	1	33.5	–	[22]
Olby				
U-Th	1	39.0	–	[23]
K-Ar	5	50.0	7.5	[22]
TL (Qz)	5	38.0	6.0	[22]
TL (Pl)	1	44.1	–	[22]
Laschamp / Olby				
K-Ar	10	45.4	2.5	[21]
^{39}Ar-^{40}Ar	4	47.4	1.9	[21]
Louchadières				
TL (Pl)	1	33.8	–	[24]
TL (Pl)	1	36.4	–	[24]

N = number of experiments. Error estimates from Gillot et al. [22] are 2 s.d. while results from Hall and York [21] are weighted averages with 1 s.d. error estimates.

7.2. Occurrence

Establishing whether the Laschamp excursion is local or global requires comparison with excursions found elsewhere.

Lake Mungo. The Lake Mungo geomagnetic excursion, one of the most widely known, was identified in prehistoric aboriginal fireplaces [25,26]. High paleointensity associated with intermediate paleomagnetic directions were apparently recorded. A question arises: are these intermediate fields of geomagnetic origin? Two nearly antipodal directions were measured over 4 m in the same group of fireplaces. Taking into account the high paleointensity proposed by Barbetti and McEhlinny [26], at least a few centuries would be expected to separate these two field directions to exhibit acceptable secular variation of the geomagnetic field. In addition, it must be assumed that one side of the aboriginal group of fireplaces was not thermally reactivated at the time when the second direction was recorded. Barbetti and McEhlinny [26] dismissed the lightning hypothesis, but they recognized that the shape of the AF demagnetization curve of the natural remanent magnetization was not incompatible with an isothermal origin for the remanence associated with the Lake Mungo intermediate directions. Moreover, the two main directions have a spatial distribution at the site with a maximum paleointensity which occurs at the center of the site for both directions. In the end, perhaps an external magnetic origin such as lightning might explain the Lake Mungo excursion. This interpretation would remove the difficulty of explaining such intense intermediate fields, which are generally not found during polarity transitions.

Excursions recorded in sediments. Critical reviews by Verosub [5] and Merrill and McEhlinny [3] suggest that most of the excursions inferred in late Pleistocene are inconclusively supported and probably not of geomagnetic origin. Recent secular variation studies on lake sediments up to 30,000 years show no evidence for geomagnetic excursions in this period [27,28]. The best supported excursion seems to be the Mono Lake excursion [29,30], with an age estimate of 25,000 years, more than 10,000 years younger than the Laschamp excursion. Hence, it is difficult to argue that these two excursions represent the same geomagnetic phenomenon. However, new unpublished data (R.S. Coe, personal communication, 1987) tend to limit this discrepancy.

Excursions recorded in lavas flows. A reversed direction was found in welded tuff in Japan [31]. This welded tuff is intercalated in sand and gravel beds which were dated at 30,000 years by radiocarbon. Therefore it might correlate with the Laschamp.

Geological considerations and paleomagnetic results of lavas in southwestern Iceland have led Kristjansson and Gudmunsson [32] to propose a geomagnetic excursion of Wisconsinan age. Although the potassium content in these flows is very low, making the dating difficult, preliminary results indicate that ages in the range 30–60 ka might be attributed to these transitional flows [33,34].

8. Discussion

The low paleofield recorded at Laschamp is consistent with those obtained during polarity transitions [17], excursions and aborted reversals [35–37]. Moreover, the very low paleointensity values of the Laschamp and Olby flows suggest that during the Laschamp excursion the reversed polarity state was not fully established. The first phase of a polarity transition is usually characterized by a large decrease in the intensity of the main dipole field [17]. During this first step, interferences with the non-dipole field might produce regional transitional directions while the main field was still dipolar, with normal polarity but lower strength. If the attempted reversal failed before the destruction of the main field was completed, the excursion might not be observed everywhere. Paleointensity determinations on dated lavas from the Chaîne des Puys, in the period following the Laschamp excursion, indicate an intensity of paleofield which was two-thirds of the mean archeomagnetic field [38]. This fact supports an anomalous behavior of the geomagnetic field at that time. The major importance of the Laschamp excursion is the observation of recent unstable geomagnetic behavior. Its local, regional or global extent as well as its time span might aid in constraining field reversal models and in understanding the behavior of the main geomagnetic field. Because it is difficult to observe such short transitions in sediments, due to the time-averaging of remanence acquisition, extensive paleomagnetic and dating (TL, U-Th disequilibrium, K-Ar) research on young volcanic rocks would help to establish the local or global character of the Laschamp excursion.

The difficulty in recognizing the Laschamp excursion suggests that short polarity reversals or aborted reversal might be difficult to identify and might be missed in the geomagnetic polarity time scale.

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