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Autor: Moscariello, Andrea / Costa, Fidel

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The Upper Laacher See Tephra in Lake Geneva sediments: paleoenvironmental and paleoclimatological implications

by *Andrea Moscariello*[1,2] and *Fidel Costa*[1]

Abstract

Microstratigraphical analysis of Late glacial lacustrine sediments from Geneva Bay provided evidence of a tephra layer within the upper Allerød biozone. The layer consists of alkali feldspar, quartz, plagioclase, amphibole, pyroxene, opaques, titanite and glass shards. Electron microprobe analyses and morphological study of glass shards allowed correlation with the upper part of the Laacher See Tephra of the Laacher See volcano (Eifel Mountains, Germany). Sedimentological features of enclosing lacustrine sediments suggest that a momentary decrease in precipitation occurred in the catchment area and consequent reduction in detrital supply in the lake, after the ash fall-out. This has been interpreted as the environmental response to a momentary cooling following the Laacher See Tephra aerosols emission. Comparison with sedimentological features characterizing the Allerød-Younger Dryas transition highlights the sensitivity of Lake Geneva system in recording both short and long-terms climate-induced environmental changes.

Keywords: sedimentology, geochemistry, tephra, glass shard, Late glacial, Lake Geneva.

Introduction

Layers of tephra found in sediments are very useful chronostratigraphical tools in correlation between sedimentary sequences from distant areas and different environments (e.g. KELLER et al., 1978; MACHIDA and ARAI, 1983; JUVIGNÉ, 1990; SARNA-WOJCICKI et al., 1991; LOTTER et al., 1992; MERKT et al., 1993). Tephra from explosive volcanic eruptions can be, in fact, transported over long distances (e.g. a few thousands of km) in relatively short periods of time (FISHER and SCHMINCKE, 1984). The majority of the studied tephra layers are interstratified within lacustrine or marine sediments, where favorable geological conditions (e.g. low sedimentation rate and negligible erosion) allow tephras to be preserved. Traditionally, palynological investigations have been used to correlate and distinguish between different tephra layers interbedded in lacustrine sediments (e.g. MARTINI, 1970; WEGMÜLLER and WELTEN, 1973). Such methods allow the chronological location of the tephras by means of biozones, the limits of which are generally defined with ^{14}C dating (AMMANN and LOTTER, 1989; LOTTER, 1991). Petrographic and geochemical studies (major and trace elements) of the pyroclastic components with emphasis on the glass shards are increasingly being used to correlate and distinguish between different tephras (WESGATE and GORTON, 1981). Such studies provide a more direct link with the source of the tephra, set the basis for tephra correlation between different localities, and help in the assessment of paleowind directions (e.g. BOGAARD and SCHMINCKE, 1985; MERKT et al., 1993). In Europe, several tephra layers of ages < 15,000 yr BP have been recognized: Laacher See Tephra, 11,000 ^{14}C yr BP (BOGAARD and SCHMINCKE, 1984 and 1985); Vedde Tephra, ~ 10,600 ^{14}C yr BP (BJÖRCK et al., 1992); Saksunarvatn Tephra, ~ 9,000 ^{14}C yr BP (JOHANSEN, 1975; MANGERUD et al., 1986; BJÖRCK et al., 1992); Chaîne des Puys Tephra, 8, 400–9,000 yr BP (GEYH et al., 1974; CONDOMINES et al., 1982). The Laacher See Tephra

[1] Section des Sciences de la Terre, Université de Genève, 13, rue des Maraîchers, 1211 Genève 4, Switzerland. Corresponding author: F. Costa; e-mail: costaf@sc2a.unige.ch.

[2] Central Region Geologic Hazards Team, U.S. Geological Survey, 1711 Illinois St., Golden, CO 80401-USA E-mail: moscarie@ght.cr.usgs.gov.

(Eifel Mountains, Germany) is the most widely distributed (BOGAARD and SCHMINCKE, 1985).

During a detailed microstratigraphic and palynological study carried out in several cores of sediments from the Geneva Bay (MOSCARIELLO, 1996 and A.M. SCHNEIDER in MOSCARIELLO, 1996) a tephra level was found. The goals of this work are (1) to show, by means of petrographic and major element analysis of the glass shards, that this tephra level correlates with the Upper part of the Laacher See Tephra; and (2) to document that large lakes are able to record climatic changes such as those that might be produced by volcanic eruptions.

Tephra occurrence in Swiss Late glacial sedimentary sequences

Up to date, two significant tephra layers have been recognized in Swiss lacustrine sequences: (1) the Laacher See Tephra (LST), related to the Laacher See volcano eruption (Eifel Mountains, Germany) with about 150–200 annual lamina before the end of the Allerød (FIRBAS, 1949 and 1952; MERKT, 1994); and (2) the tephra derived from the Chaine de Puys eruption (French Massif Central), palynologically located at the end of the Boreal time period (FIRBAS, 1949 and 1952).

THE LAACHER SEE TEPHRA

This tephra is the result of the plinian and phreatomagmatic phonolitic eruption of the Laacher See volcano and has become a standard marker horizon in studies of bogs and lacustrine sediments in central and southern Europe (BOGAARD and SCHMINCKE, 1984 and 1985).

The Laacher See volcano is characterized by three main phases of volcanism (FRECHEN, 1953; BOGAARD and SCHMINCKE, 1984 and 1985). The Lower part (LLST), termed highly evolved phonolite, with isopach curves of fall-out deposits indicating transport directions mainly to the NE (transport distances up to ~ 1400 km). A Middle part (MLST), divided in A, B, and C, ranges from highly evolved phonolite to mafic phonolite. The distribution of its fallout deposits suggest widely variable transport directions, MLST-A mainly directed to the S (traced up to ~ 350 km from the vent), MLST-B to the NE (found up to ~ 1300 km from the vent) and MLST-C to the S and NE (in both directions fall-out deposits have been found up to ~ 500 km). The Upper part (ULST) is a mafic phonolite. Isopachs of fall-out deposits indicate a S and SW transport direction (for a distance of ~ 800 and 250 km, respectively). Following the reconstruction proposed by BOGAARD and SCHMINCKE (1985), western Switzerland was reached by the ULS and MLS tephras. The LST has already been found in several sedimentary records of small lakes and peat bogs on the Swiss foreland and Jura range (see among others, WEGMÜLLER and WELTEN, 1973; LOTTER et al., 1992; RUCH, 1993; MAGNY and RUFFALDI, 1994; ROLLI et al., 1994). DURET and MARTINI (1965) and MARTINI (1970) also recognized the presence of the LST around the Lake Geneva area.

Organic matter overlying the distal ash in peat bogs has been used to date the LST. A radiocarbon age of about 11,000 ^{14}C yr BP was obtained (11,000 ± 50 ^{14}C yr BP, BOGAARD and SCHMINCKE, 1985; 11,230 ± 40 ^{14}C yr BP, HAJDAS et al., 1995). This radiocarbon age corresponds with an absolute age of 12,350 ± 135 cal. yr BP, as inferred from varve chronology (HAJDAS et al., 1993). Recent ^{40}Ar/^{39}Ar dating of sanidine phenocrysts (BOGAARD, 1995) yielded a more precise age for the LST eruption of 12,900 ± 560 yr BP.

THE CHAÎNE DE PUYS TEPHRA

The Chaine de Puys tephra has a trachytic composition and originated from the explosive volcanism of the Chaîne de Puys in French Massif Central (BROUSSE, 1971). It occurs in early Holocene sediments located stratigraphically above the LST. In the Lake Geneva area it has been found in Lac de Châlain (DURET and MARTINI, 1965) and in the Grande-Bouge bog sediments (JAYET, 1969). Radiocarbon dating indicates an age of 8,400–9,000 yr ^{14}C BP for this tephra. It has been identified in a number of lakes in southern Germany and northern Switzerland (GEYH et al., 1974; CONDOMINES et al., 1982). The petrographic composition and geochemistry of this tephra is distinctly different from the LST due to the dominance of amphibole and plagioclase and the lack of sanidine and titanite (MARTINI, 1970).

Analytical methods

Sedimentological investigations were carried out in Late glacial and Holocene sediments (7 m in thickness) of core F3. Core F3 was collected with a rotary at 13.7 m water depth at about 2 km from the Lake Geneva outlet (Rhone river) in the middle of Geneva Bay (Fig. 1a). After a preliminary palynological examination to define the main biozone boundaries (A.M. SCHNEIDER in MOSCA-

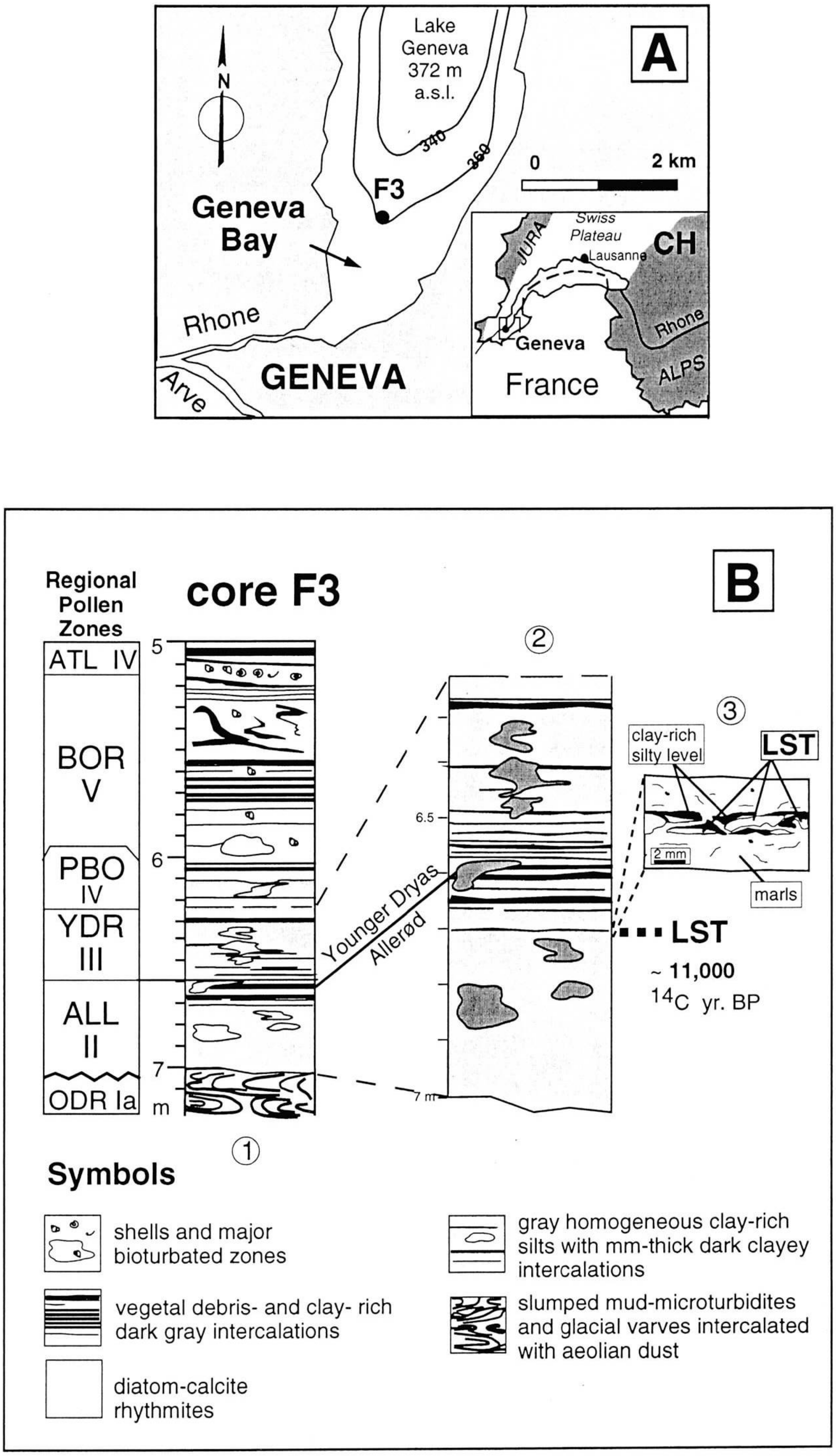

Fig. 1 (A) Location of the study area and core F3, (B) detailed stratigraphic log of Allerød and Boreal biozones, with the stratigraphic position of the LST level.

RIELLO, 1996), thin sections with an overlap of one-centimeter were prepared throughout the Allerød and Boreal biostratigraphic intervals following the method described in DIDIÉ (1991). By this method, a tephra layer was found at a sediment depth of about 6.70 m which correlates with the Allerød biozone (Figs 1 b and 2). No tephra layers have been identified within the Boreal biozone or in any other core (see MOSCARIELLO, 1996, for a discussion).

Major element analyses were performed using the electron microprobe (Cameca SX-50) of the Institut de Minéralogie et Pétrographie of the Université de Lausanne. Glass analyses were carried out using WDS, with an accelerating voltage of 15 kV, and 7 nA of beam current. Large areas (25 μm^2) were analyzed with a rastering beam. Relative precision (in %) of glass shard analyses is the following (2-sigma): SiO_2 (2), TiO_2 (8), Al_2O_3 (2), FeO* (3.5) (FeO*: total iron as Fe^{2+}), MnO (12), MgO (8), CaO (3.5), Na_2O (3), K_2O (3), P_2O_5 (26). P_2O_5 in many cases was below the limit of determination.

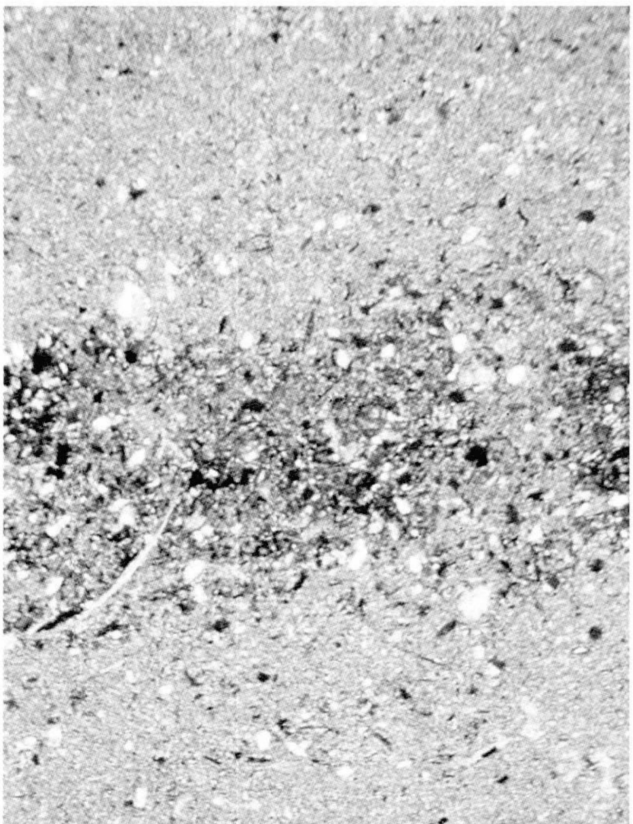

Fig. 2 Crossed polars microphotograph of the LST ash level (darker in color) interbedded within lacustrine marls.

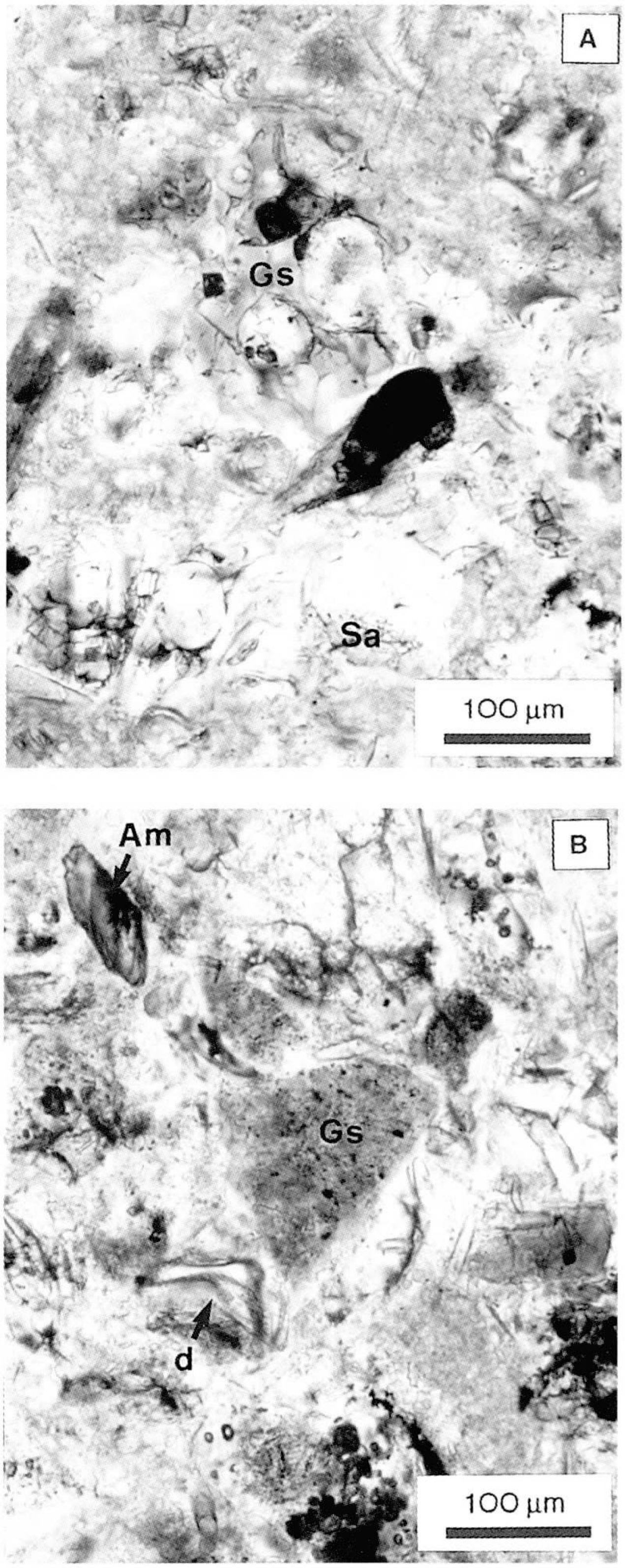

Fig. 3 Microphotograph of the two main types of glass shards found in the ash level of late Allerød sediments: (A) vesicle-poor glass shard, light brown in color with large vesicles (type d of BOGAARD and SCHMINCKE, 1985) and (B) glass shard with abundant, rounded and small vesicles and mineral inclusions (type g of BOGAARD and SCHMINCKE, 1985). The latter is characteristic of the ULST. Gs: glass shard; Am: amphibole; Sa: sanidine; d: diatom.

Tab. 1 Electron microprobe major element analyses of the glass shards found in Geneva Lake sediments.

sample	SiO_2	TiO_2	Al_2O_3	FeO*	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5"	Total
I.7	59.4	0.59	19.7	2.32	0.17	0.30	1.79	6.90	7.10	0.08	98.42
II.5	60.1	0.53	19.2	1.99	0.15	0.26	1.75	6.43	7.74	0.09	98.28
I.7	59.5	0.51	19.6	2.50	0.05	0.30	1.84	6.75	7.37	0.14	98.53
III.11	60.3	0.63	18.8	2.43	0.12	0.31	1.92	6.73	7.25	0.00	98.42
III.12	59.7	0.55	19.3	1.62	0.09	0.21	2.07	5.41	6.46	0.07	95.51
III.17	60.2	0.59	19.4	2.23	0.20	0.26	1.53	7.76	7.06	0.04	99.27
IV.18	60.3	0.64	19.8	2.33	0.15	0.22	1.95	6.63	7.05	0.11	99.24
VI.26	59.9	0.59	19.0	2.44	0.09	0.30	1.79	7.32	6.94	0.04	98.34
VI.27	59.6	0.59	18.9	2.17	0.20	0.29	1.68	6.47	7.35	0.10	97.27
VI.28	59.1	0.50	19.3	2.25	0.21	0.19	1.59	6.02	7.12	0.17	96.49
VII.36	61.0	0.43	19.5	2.28	0.29	0.22	1.59	6.91	6.65	0.00	98.81
VIII.40	57.1	0.58	18.9	2.16	0.10	0.28	1.81	6.03	7.25	0.01	94.15
VIII.41	61.1	0.58	19.5	2.40	0.15	0.29	1.85	6.90	6.63	0.11	99.53
IX.44	58.2	0.53	18.7	2.29	0.16	0.25	1.72	7.04	7.14	0.13	96.17
IX.45	59.1	1.12	19.9	2.11	0.18	0.22	1.60	7.32	7.19	0.21	98.88
X.48	60.0	0.62	19.2	2.26	0.16	0.27	1.86	6.90	6.77	0.10	98.16
XI.49	59.7	0.60	19.0	2.28	0.28	0.29	1.49	7.21	6.77	0.06	97.69
XI.52	58.4	0.68	18.5	2.62	0.20	0.42	2.29	6.60	6.02	0.06	95.69

* Total iron as Fe^{2+} " many analyses below limit of determination

Tab. 2 Comparison between mean chemical composition normalized to 100% of the LST-glass shards found in Lake Geneva with those described by BOGAARD and SCHMINCKE (1985).

	Lake Geneva		ULST (§)		MLST C (§)	
	mean (20)	2 σ	mean (30)	2 σ	mean (27)	2 σ
SiO_2	61.00	0.60	59.90	0.80	60.50	0.60
TiO_2	0.62	0.14	0.43	0.23	0.18	0.07
Al_2O_3	19.60	0.30	20.20	0.50	21.00	0.20
FeO*	2.33	0.22	2.33	0.33	1.92	0.23
MnO	0.17	0.06	0.01"	0.04	0.02"	0.05
MgO	0.28	0.05	0.20"	0.25	0.06"	0.09
CaO	1.83	0.22	1.80	0.61	1.41	0.27
Na_2O	6.89	0.50	7.15	0.80	7.42	0.64
K_2O	7.16	0.40	7.80	0.46	7.21	0.47
P_2O_5"	0.09	0.06	nd	nd	nd	nd
Total°	100 (97.71)	1.51	100 (96.10)	1.20	100 (95.20)	2.30

* Total iron as Fe^{2+}
° in brackets original total of electron microprobe analyses
" many analyses below limit of determination
§ Data from BOGAARD and SCHMINCKE, 1985
nd = not determined

Sedimentology and Mineralogy

The tephra level consists of several irregularly-shaped lenses of 2–5 mm in length and 0.4 to 1.2 mm thick. The lenses contain crystals and glass shards ranging in size from < 80 to 350 µm and from 40 to 120 µm respectively. The tephra level consists of: around 25% vol. of sanidine and plagioclase; ~ 5% vol. of clinopyroxene, amphibole, Fe–Ti oxides and titanite and ~ 10% vol. of glass shards. Foreign components include quartz, rock fragments, shapeless organic matter and abundant diatom frustules (Figs 3 a and 3 b). This mineral composition is similar to that described for the tephra in the Allerød biozone by MARTINI (1970), NEGENDANK (1984) and BOGAARD and SCHMINCKE (1985). Upper and lower contacts between ash lenses and the host sediment are both progressive and sharp. Dispersed and glass shards and volcanic crystals are found through a zone located 1 cm above the tephra layer.

Lacustrine marls enclosing the ash layer are light gray, homogeneous, structureless clay-rich marls with scattered clasts (< 80 µm to 1 mm in diameter). The lacustrine sediment is composed mainly of calcite (around 46% vol.) with subordinate phyllosilicates, quartz, dolomite, plagioclase, and clay minerals (MOSCARIELLO, 1996). The clay minerals generally form small pellets of 0.2–0.5 mm in diameter. Calcite is mainly of detrital origin, but endogenic crystals were also identified by scanning electron microscopy analysis (MOSCARIELLO, 1996).

A dark gray, discontinuous level of clay-rich silt, up to 800 μm in thickness, occurs in close proximity above the pyroclastic material (Figs 1b and 3). Significant bioturbation (associated with biogenic materials such as shell fragments, diatom frustules or organic matter) widely affects these sediments. The primary structures have been in some places obliterated by this process and the stratigraphic relation between the ash level and the clay-rich level is no longer recognizable.

Petrography and geochemistry of the glass shards

Two different morphological types of glass shards have been recognized. One is light brown, vesicle poor, with rounded vesicles and is very similar to type d of BOGAARD and SCHMINCKE (1985). The other is dark brown, with abundant small rounded vesicles and frequent mineral inclusions. It is very similar to type g of the previous paper (see Figs 3a and 3b for glass shards morphology). While glass shards of type d occur in various levels of the LST, glass shards of type g are only found in the ULST.

Electron microprobe analyses have been carried out on glass shards (see Tab. 1 and 2). The low totals can be attributed to the presence of water and to sodium devolatilization, (i.e. LUHR, 1990; see analytical techniques). All analysed glass shards have a mafic phonolitic composition, overlapping that of the Laacher See volcanic materials. In order to be able to compare glass compositions with those of BOGAARD and SCHMINCKE (1985), the analyses have been recalculated to 100% anhydrous (Tab. 2). An initial comparison of the mean chemical compositions of Lake Geneva glass shards with those of the two mafic members of the Laacher See volcano (MLST-C and ULST) shows that most oxides are more similar to the ULST than to the MLST-C. In order to further distinguish between these two tephras,

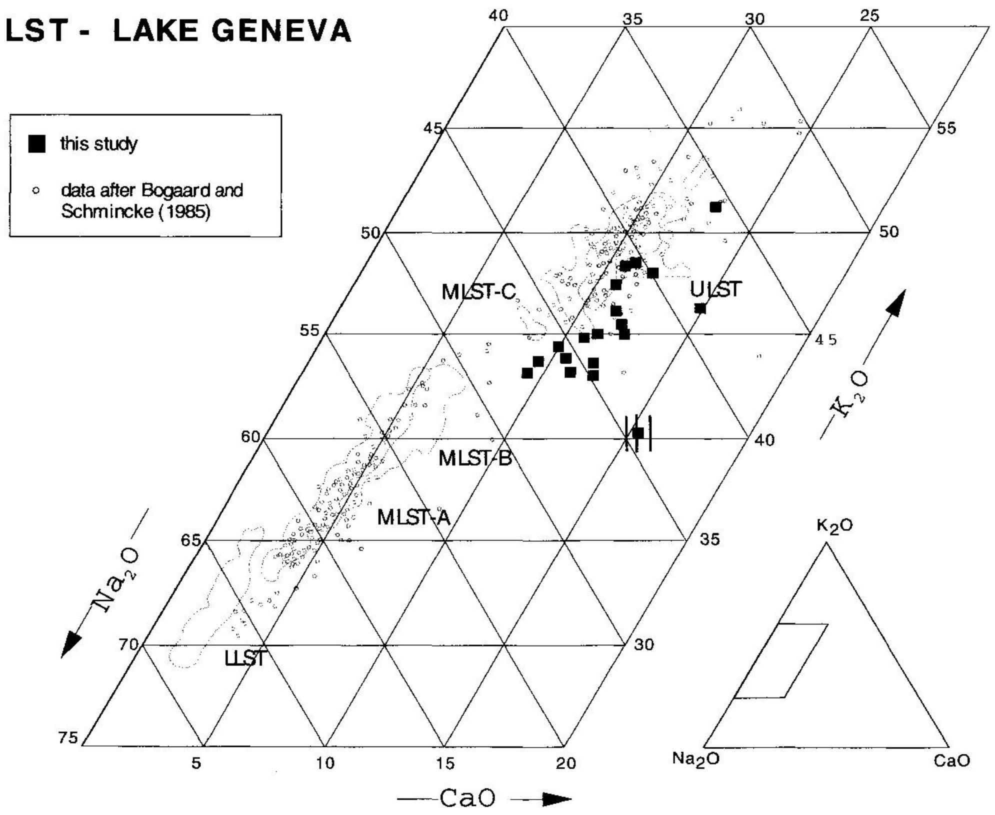

Fig. 4 Comparison of glass shards' composition from distal S-fan deposits, mean composition of glass shards from near-vent reference of the Laacher See volcano and glass shards found in Lake Geneva sediments. Note that the last do not fall clearly in any single field of the LST. All analysis have been recalculated to 100% and projected in the ternary plot Na_2O : K_2O : CaO. Figure modified and data sources from BOGAARD and SCHMINCKE (1985).

glass shards composition were plotted on the ternary diagram $Na_2O : K_2O : CaO$ as proposed by BOGAARD and SCHMINCKE (1985). As it can be seen in figure 4, there is significant scatter of the data, and it is not possible to determine if the tephra correlates with the MLST-C or the ULST. Although BOGAARD and SCHMINCKE (1985) chose these three oxides because they vary the most between the different LST members, Na and K are elements known to be mobile during water-rock interactions (STEWARD, 1979) as well as during electron microprobe analyses. In order to circumvent this problem, we have used FeO*, Al_2O_3 and CaO to distinguish between the MLST-C and ULST. As can be seen in figure 5, these oxides discriminate between the two mafic members of the LST. Lake Geneva glass shards group around the mean composition of the ULST.

Interpretation and discussion

The Allerød sediments were deposited in a calm lacustrine environment characterized by an estimated moderately low sedimentation rate of about $f \approx 0.3$ mm/yr (MOSCARIELLO, 1996).

Dispersal and mixing of tephras within enclosing sediments has already been described in previous studies (e.g. MCCOY, 1981), showing that it is commonly difficult to determine the processes responsible for the dispersal. The composite shape of the tephra level (lenses) is interpreted as the result of: (1) a relatively short transport occurring in the water before deposition and (2) the subsequent bioturbation processes.

The ash fall on the lake surface was partly dispersed by currents of moderate velocity (measured in present times at 0.08 m/s near the lake outlet). The settling rate of the ash material had to be sufficiently rapid, in comparison with the bottom current velocity, to allow the accumulation of a distinct sedimentary level. Deposition on the lake bed had therefore occurred in a short timeframe (hours), though estimates indicate a water depth between 50 and 30 m at that time (MOSCARIELLO, 1996). This condition (with no wave-induced bottom reworking) favored the preservation of such a thin level.

Even if significant bioturbation processes occurred after, the ash and the clay-rich silt level were deposited in close proximity (resulting in the loss of the original primary structure), the ash lenses are confined in a well defined stratigraphic position. This observation suggests that deposition occurred during a single fall-out event and is not the result of secondary sedimentation processes. Since relatively small quantities of ash fell in this region after the Laacher See eruption (DURET and MARTINI, 1965; MARTINI, 1970; BOGAARD and SCHMINCKE, 1985), the reworking of the LST (resulting from either land rain off or shallow water wave action), would have completely dispersed and mixed the volcanic material within the lake sediments, thus preventing preservation of the ash level.

Moreover, the abundance of diatoms within the tephra layer suggests that deposition occurred during the springtime algal bloom. This diatom abundance is consistent with data found in German lacustrine sequences, which were undergoing laminated sedimentation during the tephra deposition, and clearly indicates that the LST eruption occurred during springtime (ZOLITSCHKA, 1990; A. BRAUER, pers. comm., 1996).

PALEOENVIRONMENTAL AND PALEOCLIMATOLOGICAL IMPLICATIONS

The microtexture and composition of the clay-rich layer in close proximity above the LST layer, are similar to the clay-rich levels that occur higher in core F3 within the Allerød and Younger Dryas biozones (Figs 1b and 2). The clay-rich layers are generally thicker (up to 6 mm thick) in comparison with that found above the Laacher See tephra and are especially frequent at the base of the overlying Younger Dryas biozone (Figs 1b and 2). These layers have previously been interpreted (MOSCARIELLO et al., in press) as the sedimentary response to a momentary interruption in detritus supply, probably related to decreased precipitation (dry winter seasons ?) in the catchment area. The same interpretation is proposed

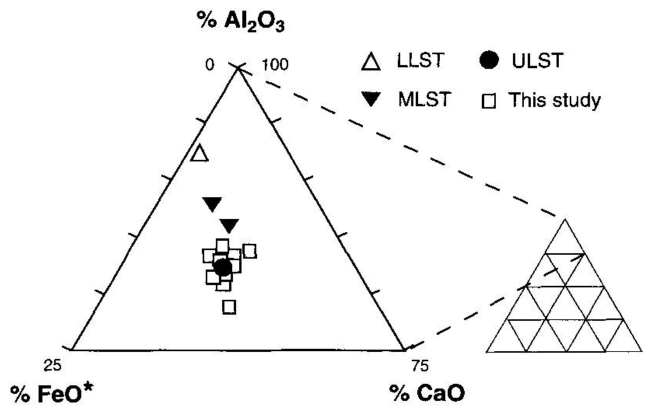

Fig. 5 Comparison of mean glass shards composition from near-vent reference of the Laacher See volcano (BOGAARD and SCHMINCKE, 1985) and glass shards found in Lake Geneva sediments. Note that the majority of the glass shards fall on the ULST mean when plotted in the ternary plot $FeO^* : Al_2O_3 : CaO$.

here for the thin clay-rich layer deposited after the LST fall-out.

Two alternative interpretations are proposed to explain the occurrence of such a paleoenvironmental signature close to the LST. The interpretations include: (1) the signature of a climate-induced change in sedimentation processes, possibly related to the long-term climate deterioration of the Younger Dryas climate reversal; or (2) a record of a local, transient, climate modification related to the LST eruption. Considering the first interpretation, the thin clay-rich level can be explained as the precursor of the identical signatures that occurred during the upper Allerød and the Younger Dryas biozones (Fig. 1b). No relation with LST event exits in this case.

Biological and sedimentological proxies from many lacustrine sequences in the region near the LST eruption center have clearly demonstrated that no direct relationship exists between LST and the successive long-term Younger Dryas climatic deterioration (ZOLITSCHKA, 1990; BRAUER and NEGENDANK, 1993; BRAUER, 1994; MERKT, 1994). The frequency and length of dry periods during the Allerød-Younger Dryas transition, recorded in Lake Geneva sediments, suggest that significant and persistent decreases in rain-fall regime and air humidity occurred at that time. The decrease in detritus supply in Lake Geneva during the Allerød-Younger Dryas transition is therefore a consequence of the increased air dryness and cooling at the end of the Allerød time period. Change in air conditions was in response to significant alteration of the atmospheric circulation patterns in the northern hemisphere (ALLEY et al., 1993). This evidence is also confirmed by pollen records in many small lakes (MERKT, 1994), where the Allerød-Younger Dryas transition is less abrupt than commonly thought. Likewise, the calculated snow accumulation rates in Greenland for the same time interval indicate a progressive and gradual decrease in air moisture about one hundred years before the Younger Dryas onset (ALLEY et al., 1993). The occurrence of the first dryer climate signature in Lake Geneva sediments, 200 years before the Younger Dryas onset, would predate by about one hundred years the beginning of the climate deterioration in this region. None of the existing sedimentological, geochemical and biological data (pollens, diatoms, molluscs, stable isotopes, see MOSCARIELLO, 1996) support this different climatic scenario for the Lake Geneva area.

The sensitivity of Lake Geneva during the Late glacial and Holocene transition in recording long and short time climate-induced changes in detrital supply, is clearly demonstrated in a previous study (MOSCARIELLO et al., in press). A relationship between the LST eruption and decreased precipitation in the lake catchment area could therefore be inferred (interpretation n. 2), even if no direct link can be established with certainty. Important influences in the lacustrine environment related to the LST eruption are reported also for several small lakes in central Europe. In those lakes, marked changes in sedimentation and biochemical signals have been recorded for several decades after the LST arrival (SCHULTZE, 1988/89; MERKT, 1994; BRAUER and NEGENDANK, 1993).

Moreover, decreased surface temperatures as a consequence of historical volcanic eruptions is well documented (e.g. LAMB, 1970; MALATESTA, 1985; RAMPINO and SELF, 1982; HANDLER, 1989). For example, the large concentrations of aerosols in the stratosphere following the eruption of Mt. Pinatubo induced a reduction in total solar radiation at the Earth's surface and a drop in the monthly mean surface temperature of about 0.75 °C during the first year after the event (HOUGHTON et al., 1995). Changes in average net radiation at the top of the troposphere were recorded within the first two years after Mt. Pinatubo's eruption (MINNIS, 1994). The climatic impact of volcanic eruptions is determined by the amount of sulfate aerosol formed in the stratosphere, rather than by the amount of injected ash (RAMPINO and SELF, 1982; RAMPINO et al., 1988; PINTO et al., 1989). Recent petrologically-based estimates of the amount of SO_2 that the Laacher See eruption might have introduced in the atmosphere yield minimum values around 10 to 12 Mt (HARMS et al., 1997). This quantity of SO_2 is larger than the petrological estimates for most historical eruptions. For example, 34 Mt of SO_2 were produced by the 1815-Tambora eruption, 1.9 Mt by the 1883-Krakatau eruption, 7.8 Mt by the 1912-Katmai eruption, 0.05 Mt by the 1982-El Chichón eruption (estimates from DEVINE et al., 1984) and less than 0.01 Mt by the 1991-Mt. Pinatubo eruption (GERLACH et al., 1996). It is worth noting that petrological estimates of gas emissions are minimum values, and that estimates by remote sensing methods can give much higher quantities (see GERLACH et al., 1996 for Pinatubo data).

Short-lived (ranging from month to years) influence on the meteorological system (troposphere circulation pattern) induced by the LST-event could have produced similar effects on central Europe. Lower surface temperatures and lower evaporation rates due to LST aerosols emissions could have favored a significant decrease in air-moisture and precipitation in the months following the eruption. The sedimentological signature positioned above the LST tephra in Lake Geneva sediments could, therefore, represent a decrease in erosional processes and river discharge from the Rhone catchment area that is related to the tropospheric cooling induced by the LST eruption.

The paleoenvironmental reconstruction inferred from Lake Geneva sediments could be also recorded in other lacustrine sedimentary sequences occurring, at least, in the northwestern Alpine foreland. Further comparable detailed sedimentological observations concerning the LST layer, the enclosing sediments, and their paleoenvironmental significance are needed to verify such a volcanic-induced short-lived climatic scenario.

Conclusions

Petrographic and geochemical analyses of glass shards allowed correlation of the tephra level found in Lake Geneva with the upper part of the Laacher See Tephra.

The presence of ULST in Geneva Bay sediments provides further evidence regarding the chronological framework of the sedimentary succession. Microstratigraphical investigations provided the only tool for detecting very thin tephra level accumulated far away from the eruptive center in a sedimentary environment characterized by moderate hydrodynamicity. Nevertheless, high energy sedimentary processes such as those that occurred during the Boreal time period (MOSCARIELLO, 1996), can strongly reduce the possibility of tephra preservation.

Comparison of the sedimentary signatures recorded shortly after the LST event with those signatures related to the global climate alteration at the Allerød-Younger Dryas transition emphasizes the sensitivity of the Lake Geneva system in recording short-term and long-term climate-induced environmental changes.

The short-lived climate alteration induced by the LST eruption and the climate changes occurred at the beginning of the climate reversal of the Younger Dryas, produced the same sedimentary signature, although it was induced by very different causes. This was possible because of the presence of a large catchment area characterized by regions that were highly sensitive to erosional processes. Small alterations of climate (e.g. rainfall regime) resulted in rapid modification in the type of lacustrine sediments deposited. Additionally, during the Late glacial-early Holocene transition, rapid changes in the amount of sediment inflow to the lake responded more quickly than other climate-dependent such as vegetation indicators that recorded no gradual climate worsening during the late Allerød time period (MOSCARIELLO, 1996).

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