European Science Foundation
Standing Committee for Life, Earth and Environmental Sciences (LESC)

ESF LESC EXPLORATORY WORKSHOP

Building a tephrochronological framework for Europe: the key to better models of abrupt environmental change

Final report

Swansea, United Kingdom, 9-12 April 2005

Convened by:
Siwan Davies[①] and Stefan Wastegård[②]

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1. EXECUTIVE SUMMARY

Background and workshop objectives

A number of dramatic and short-lived climatic events punctuated the Late Quaternary period, with large temperature shifts (5-10 °C), in some cases, thought to have occurred within a human lifetime. The forcing mechanisms involved in these abrupt fluctuations and the accompanying environmental effects however, are poorly understood, largely due to the dating uncertainties that prevent the timing and rate of these events to be ascertained in widely separated localities within the North Atlantic region. One method that offers considerable potential for improving chronological models and for effecting precise tie-points between diverse palaeoenvironmental records is tephrochronology. This is one of the few techniques that can provide the required precision to construct better models of past climatic changes. The virtually instantaneous atmospheric deposition of tephra (pyroclastic material generated during volcanic eruptions) following an eruption can lead to effectively time-parallel 'marker horizons' and precise correlations between diverse stratigraphical records in which the tephra particles become incorporated. Although, not entirely a new technique, recent and novel analytical developments have widened the possibilities and scope of tephrochronology in European palaeoclimate studies. During the 1990s a number of new discoveries were made indicating that cryptotephras (horizons with a low concentration of volcanic glass shards <100 μm in size, such that the layer of ash is invisible to the naked eye) can be traced in sedimentary sequences located hundreds and even thousands of kilometres from volcanic sources, in regions not traditionally associated with tephrochronological research. These discoveries emphasise the potential of using such time-parallel marker horizons for precise correlation of sequences on a continent-wide scale.

The application of this technique is however, in its infancy and considerable work is required before its full potential can be realised. As such, the aims of the workshop was to facilitate the exchange of ideas on new analytical advances (e.g. geochemical techniques and extraction methods) that may aid in addressing some of the difficulties (e.g. reliability of extraction techniques, chemical stability of shards and reporting of results) that are currently hampering the development and progress of European tephrochronology as well as increasing collaborative links across Europe. The two key aims of the workshop was to develop an agreed protocol for standardised laboratory procedures and reporting of results and the establishment of a centralised European archive.

Workshop programme

The workshop was organised by **Siwan Davies,** University of Wales Swansea and **Stefan Wastegård,** Stockholm University. A total number of 23 scientists from nine

European countries and Australia participated and the key outcomes of the workshop will be published as a special issue of ***Journal of Quaternary Science*** with Siwan Davies and Stefan Wastegård as guest editors.

The workshop was held over three days and organised around six thematic oral sessions with one main poster session. These themes were identified as central to the advancement and successful application of tephrochronology and were as follows:

- **Methods for detecting, isolating and quantifying cryptotephras**
- **Geochemical fingerprinting techniques**
- **Protocols for standardised laboratory work and reporting results**
- **Key tephra markers in Europe: age estimates and current geographical distributions with a focus on the Last Termination and Holocene**
- **Initiation of a European-wide data base: how do we proceed?**
- **Long-term objectives of tephra research - What are the key palaeoclimate questions in the Late Quaternary?**

Invited keynote lectures were given by workshop participants to raise key research questions and present new analytical developments within these themes. These were followed by break-out discussion sessions. Workshop participants were also invited to present posters on their research.

Outcomes of workshop

A number of future directions were discussed at the workshop and a summary of the main outcomes are as follows (see also scientific content and assessment of results sections):

1. A detailed protocol for standardised laboratory work and reporting of results was agreed.
2. It was proposed and agreed that the TEPHRABASE database should be further developed as a centralised archive to include data from all European volcanic sources.
3. A new inter-laboratory exercise of electron probe micro-analysis will be initiated and led by **John Hunt**.
4. Dissemination of results and the workshop outcomes will be undertaken through the publication of a special issue and the establishment of a new online discussion forum will enable scientists to keep abreast of new analytical developments.
5. It was anticipated that a number of small collaborative ventures may arise from discussions at this workshop particularly involving participants from countries where there is no tradition of undertaking tephrochronological investigations.

2. SCIENTIFIC CONTENT OF THE EVENT

The workshop was held over three days and organised around six thematic oral sessions with one main poster session. These themes were identified as central to the advancement and successful application of tephrochronology and were as follows:

- **Methods for detecting, isolating and quantifying cryptotephras**
- **Geochemical fingerprinting techniques**
- **Protocols for standardised laboratory work and reporting results**
- **Key tephra markers in Europe: age estimates and current geographical distributions with a focus on the Last Termination and Holocene**
- **Initiation of a European-wide data base: how do we proceed?**
- **Long-term objectives of tephra research - What are the key palaeoclimate questions in the Late Quaternary?**

Invited keynote lectures were given by workshop participants and were followed by break-out discussion sessions. Workshop participants were also invited to present posters on their research.

The workshop opened on the afternoon of Saturday 9th April 2005 with a presentation by the ESF representative **Olgeir Sigmarsson** and a keynote lecture by **Chris Turney**, the President of SCOTAV[1]. Chris Turney outlined the key aims of the workshop and the draft protocol for tephrochronology studies published in Turney *et al.* (2004)[2]. One of the key intended aims of the workshop was to develop an agreed protocol for standardised reporting of results and Chris Turney highlighted the most recent developments in tephrochronology studies and, more specifically, cryptotephra work and emphasised the importance of developing an agreed protocol.

In the first session on Sunday 10th April, an overview of the **Methods for detecting, isolating and quantifying cryptotephras,** was presented by **Stefan Wastegård** (terrestrial), **Siwan Davies** (ice-cores) and **Haflidi Haflidason** (marine). Stefan Wastegård summarised the key developments in the methods used to detect and isolate cryptotephra deposits in lake and peat sediments and Haflidi Haflidason outlined the recent progress made at the University of Bergen to successfully extract cryptotephra deposits from marine sediments. New findings of tephra from the NorthGRIP ice-core were presented for the first time by Siwan Davies. This was followed by a session on **Geochemical fingerprinting techniques,** which included a

[1] SCOTAV - International Quaternary Union Association (INQUA) Sub-COmmission for Tephrochronology and Volcanism.

[2] Turney, C. S. M., Lowe, J. J., Davies, S. M., Hall, V. A., Lowe, D. J., Wastegård, S., Hoek, W. Z., Alloway, B., SCOTAV & INTIMATE members. 2004: Tephrochronology of Last Termination sequences in Europe: a protocol for improved analytical precision and robust correlation procedures (a joint SCOTAV-INTIMATE proposal). *Journal of Quaternary Science 19*, 111-120.

presentation on electron microprobe analysis and interlaboratory comparison by **John Hunt**. **Nick Pearce** presented new developments in the use of LA-ICP-MS for trace element analysis of tephra deposits and outlined a number of issues that need to be addressed prior to the successful application of this technique for routine cryptotephra work - one of the most notable being the impurities present in the mounting resin that may significantly contribute to the trace element concentration of small glass shards. The last keynote lecture of this session was given by **Simon Blockley** who explored the importance of understanding the chemical stability of volcanic glass in different depositional environments. The importance of obtaining reliable geochemical analyses was discussed during the break-out session and it was agreed that a new interlaboratory comparison of electron microprobe analyses will be initiated and led by **John Hunt.**

Protocols for standardised laboratory work and reporting results were discussed during the third session. Following the publication of the draft protocol by Turney *et al*. (2004)[2], it was agreed that the recommendations in this paper should remain, but some new proposals were also suggested by the workshop participants. These included detailed *site location information* (site map, depth of core, site elevation, water depth, underlying geology, UTM co-ordinates (based on WGS84) and associated publications), *stratigraphical context* (description of contact/boundary between visible tephras and host material, method of quantifying cryptotephra concentrations), *tephra characteristics* (concentration of lithics) and *geochemical data* (standards used, operating conditions of e.g. electron microprobe, correction procedures employed).

Regional tephrochronology frameworks for the Last Termination and Holocene in Europe was the theme of the next session: **Key tephra markers in Europe: age estimates and current geographical distributions.** The Icelandic tephrochronology framework was presented by **Gudrun Larsen** (terrestrial) and **Jon Eiríksson** (marine); the French Massif Central by **Jean-Paul Raynal**; the Eifel area by **Christel van den Bogaard**; the Italian and Mediterranean by **Sabine Wulf**; and a summary of the distal and cryptotephra investigations in North-West Europe was given by **Stefan Wastegård.**

The keynote of the following session: **Initiation of a European-wide data base: how do we proceed?**, was given by **Anthony Newton** who manages the TEPHRABASE (www.tsunami.geo.ed.ac.uk/~tephra/) database at the University of Edinburgh, UK. Anthony Newton highlighted a number of major revisions that had recently been undertaken and suggested that all European tephra analyses should be submitted to this database, rather than setting up a new archive. A number of database issues were discussed including the format, content and search criteria and participants were in favour of providing data for this database. Some reservations were however, encountered, particularly in relation to the time involved for the conversion of

unpublished 'raw' data into electronic form. Participants were keen to see a central archive but the time involved in transferring data was considered to be significant. Funding possibilities were discussed for the creation of a temporary position to liaise with different tephra laboratories in Europe for data collection. A presentation of the PANGAEA web site and database was also given by **Hans-Joachim Wallrabe-Adams**.

The last session focussed on **Long-term objectives of tephra research - What are the key palaeoclimate questions in the Late Quaternary?**, with a keynote presentation by the President of the INTIMATE[3] project, **Wim Hoek**. The key applications of tephra research were outlined including the potential for precise correlation of marine, terrestrial and ice-core records to determine the timing and duration of rapid climatic changes (e.g. Dansgaard Oeschger events) in widely separated localities and to improve our understanding of the complex spatial patterns and climatic gradients in NW Europe during the Late Quaternary. An open discussion led by **Jon Pilcher** followed this presentation and explored some of the key palaeoclimate applications and other possible research areas that tephrochronology could be employed e.g. archaeology and sedimentology.

During the workshop 21 posters were displayed. The posters presented new developments in cryptotephra extraction (**Simon Blockley**), new methods for trace element analysis of marine tephras from the North Atlantic (**Haflidi Haflidason**) and New Zealand **(Nick Pearce)**, new advances in the construction of regional tephrochronology frameworks within Europe (**Jane Boygle, Achim Brauer**, **Wim Hoek, John Hunt, Anette Mortensen (not present), Jon Pilcher, Chris Turney, Hans-Joachim Wallrabe-Adams, Stefan Wastegård)** and applications of tephrochronology for determination of marine reservoir ages (**Jon Eiriksson, Karen-Luise Knudsen, Martine Paterne)** and for the construction of chronologies for long core sequences **(Daniel Veres)**. **Anthony Newton** also presented a poster outlining the key elements of the TEPHRABASE database. The potential of undertaking tephra investigations in new areas of Europe was also presented by **Maja Andrič** (Slovenia) and **Daniel Veres** (Romania).

The workshop formal dinner at Castellamare, Bracelet Bay, Mumbles brought the meeting to a close on Monday 11th April 2005.

[3] INTIMATE (INTegration of Ice, Marine and Terrestrial records from the Last Termination – a core programme of the INQUA Palaeoclimate Commission.

3. ASSESSMENT OF THE RESULTS, CONTRIBUTION TO THE FUTURE DIRECTION OF THE FIELD

Closing remarks and general synthesis of the workshop was led by **Siwan Davies** who summarised the main outcomes of the workshop and the future developments for the European tephra community. The consensus view of the European tephrochronology community was as follows:

1. A detailed protocol for standardised laboratory work and reporting of results was agreed. Adopting this protocol in the reporting of results and submission of data for the TEPHRABASE database was seen as an essential objective for the tephra community, particularly as this could form the basis for scientists that are not specialists in tephrochronology to access and apply the information in different scientific realms e.g. studies of palaeoclimate, volcanic history and archaeology.
2. Further development of the TEPHRABASE database was seen as a central part of achieving the above. Participants were encouraged to submit their data and funding possibilities were discussed and would be explored by **Anthony Newton**.
3. It was proposed that a new inter-laboratory exercise of electron probe micro-analysis should be initiated and led by **John Hunt**.
4. A number of different recommendations were suggested for dissemination of information presented at the workshop and for future correspondence amongst the tephra community. These included:
    a. Special issue on tephra studies in *Journal of Quaternary Science*,
    b. Online discussion forum/listserver for discussion of new developments and methodological issues that could be accessed by the European scientific community (including those who did not attend the meeting), and
    c. A report of the workshop would be placed on the SCOTAV and workshop web page and the ESF webpage.
5. It was anticipated that a number of small collaborative ventures may arise from discussions at this workshop particularly involving participants from countries where there is no tradition of undertaking tephrochronological investigations.

4. WORKSHOP PROGRAMME

Saturday 9 April 2005

08:00-09:00	*For those arriving on 8/04/05 - Breakfast, Refectory, Fulton House*
Afternoon	Arrival of participants
16:00-17:00	*Coffee/Tea and refreshments, Café West, Fulton House*
17:30	Seminar room FH3 Fulton House

Welcome and Introduction
Siwan Davies, **Stefan Wastegård,**

Mike Barnsley, University of Wales Swansea

Presentation of the European Science Foundation (ESF)
Olgeir Sigmarsson (Standing Committee for Life, Earth and Environmental Sciences)

Food for thought: Outlining the draft protocol for tephrochronology studies - Key aims of the workshop

Keynote presentation:
Chris Turney, President of INQUA SCOTAV

General discussion
Chair: **Siwan Davies**

18:45 *Dinner, Refectory, Fulton House*

Sunday 10 April 2005

07:30-09:00	Breakfast, Refectory, Fulton House
09:00-10:30	Seminar room FH3, Fulton House

Methods for detecting, isolating and quantifying cryptotephras
Extraction techniques for ice, marine and terrestrial deposits
Chair: **Karen Luise Knudsen**

09:00-09:30 Keynote presentation (terrestrial): **Stefan Wastegård**

09:30-09:50 Keynote presentation (marine): **Haflidi Haflidason**

09:50-10:10 Keynote presentation (ice): **Siwan Davies**

General discussion

10:30-11:00	*Coffee break and posters, Café West, Fulton House*
11:00-13:00	**Geochemical fingerprinting techniques** *Chair:* **Martine Paterne**
	11:00–11:30 Electron microprobe analysis and interlaboratory comparisons. Keynote presentation: **John Hunt**
	11:30-12:00 LA-ICP-MS: current status and future potential. Keynote presentation: **Nicholas Pearce**
	12:00-12:30 Testing the stability of volcanic glass. Keynote presentation: **Simon Blockley**
	General discussion
13:00-14:00	*Lunch, Refectory, Fulton House*
14:00- 16:00	**Protocols for standardised laboratory work and reporting results** *Chair:* **Chris Turney** 1. Stratigraphic and descriptive information 2. Geochemical procedures 3. Dating of tephra layers
16:00-17:00	*Coffee and posters, Café West, Fulton House*
17:00-18:00	**Key tephra markers in Europe: age estimates and current geographical distributions with a focus on the Last Termination and Holocene** Compiling the European tephrochronology framework (Icelandic, Eifel, Germany, Massif Central, Italian and Aegean volcanic sources) *Chair:* **Jane Boygle**
	17:00-17:30 Keynote presentation – *Iceland:* **Gudrun Larsen**
	17:30-18:00 Keynote presentation – *Iceland:* **Jon Eiríksson**
18:45	*Dinner, Refectory, Fulton House*

Monday 11 April 2005

07:30-09:00	Breakfast, Refectory, Fulton House
09:00-11:00	Department of Geography, room 226a
	Chair: **Jane Boygle**
	09:00-09:30 Keynote presentation – *Mediterranean:* **Sabine Wulf**

09:30-10:00 Keynote presentation – *France:* **Jean Paul Raynal**

10:00-10:30 Keynote presentation – *Eifel*: **Christel van den Bogaard**

10:30-11:00 **Distal tephrochronology during the Last Termination and Holocene in Europe: an overview** **Stefan Wastegård**

1. Correlating the records: where do we currently stand?
2. Where are the key geographical areas or palaeoclimate records that require further investigation?
3. What are the key issues and problems that can be addressed with the new analytical developments?

General discussion

11:00-11:30 *Coffee break and posters, Geography foyer*

11:30-13:00 **Initiation of a European-wide data base: how do we proceed?**

11:30-12:00 Keynote presentation: **Anthony Newton**

General discussion
Chair: **Hans-Joachim Wallrabe Adams**

Issues to be discussed include:

1. Format, content and design
2. Search criteria
3. Location and maintenance
4. Sources of funding
5. Access
6. Data protection
7. Keeping abreast of future analytical developments e.g. LA-ICP-MS methods, extraction techniques: do we need an online discussion forum?

13:00-14:00 *Lunch, Refectory, Fulton House*

14:00-16:00 **Long-term objectives of tephra research**
What are the key palaeoclimate questions in the Late Quaternary?

14:00-14:30 Keynote presentation:
Wim Hoek, INTIMATE President

	General discussion *Chair:* **John Pilcher**
16:00-16:30	*Coffee break and posters*
16:30-18:00	**Closing remarks and general synthesis** *Chair:* **Siwan Davies** Discussion of themes for special issue (ed **Siwan Davies**, **Stefan Wastegård**)
19:30	*Workshop formal dinner, Castellamare, Bracelet Bay, Mumbles.*

Tuesday 12 April 2005

09:00	*Departure of participants*

Posters presented during the workshop

Methods for detecting, isolating and quantifying cryptotephras

Simon Blockley: A new and less destructive laboratory procedure for the physical separation of distal glass tephra shards from sediments

Geochemical fingerprinting techniques

Haflidi Haflidason: The tephrostratigraphical record of MIS5 in cores from the S-Norwegian Margin, analysed both by the EMP and by the Laser Ablation ICP-MS techniques

Nick Pearce: Correlation of distal volcanic deposits using single shard laser ablation ICP-MS analysis

Nick Pearce: Precise correlation of Mid-Pleistocene silicic volcaniclastic deposits from the Auckland region, New Zealand using single grain major and trace element geochemistry

Key tephra markers in Europe: age estimates and current geographical distributions

Distal tephrochronology during the Last Termination and Holocene in Europe

Achim Brauer: Calendar year dating of the Laacher See tephra in the Eifel varve chronology

Hans-Joachim Wallrabe-Adams: Marine tephra in the North Atlantic

Haflidi Haflidason: The tephrostratigraphical record of MIS5 in cores from the S-Norwegian Margin, analysed both by the EMP and by the Laser Ablation ICP-MS techniques

Jane Boygle: Icelandic tephra in Sweden

Wim Hoek: Towards a tephrochronological framework for the Netherlands

John Hunt: Jan Mayen as a tephra source in the Late Holocene tephrochronological record

Anette Mortensen (not attending), M. Bigler, K. Grönvold, S. Johnsen, JP Steffensen, **Siwan Davies**: Tephra layers in two Greenland ice cores - Frequency, composition and origin of eruptions from 33-10ka BP (GRIP calendar ice core age)

Jon Pilcher: Some new tephras from the Arctic

Chris Turney: Extending the limits of Last Glacial-Interglacial Transition (LGIT; 14-9 ka ^{14}C BP) tephras in Ireland and Denmark

Stefan Wastegård: Tephrochronology and early Holocene environmental changes on the Faroe Islands

Stefan Wastegård: Towards a Holocene tephrochronology for Sweden

Initiation of a European-wide data base

Anthony Newton: Tephrabase: a tephrochronological database

Applications and long-term objectives of tephra research

Maja Andrič: Palynologist's ignorant questions about tephrochronology: case studies from Slovenia

Jon Eiriksson, Karen-Luise Knudsen, Gudrun Larsen, Simonarson, L. A: Tephra isochrons used for reconstruction of marine reservoir ages: tracing palaeoceanographic changes in the North Atlantic

Martine Paterne: Determination of marine radiocarbon reservoir age from land-sea tephra analyses

Daniel Veres: How to get satisfactory age control on a 60 ka old lacustrine sequence?

Daniel Veres: Late Quaternary tephra occurrences and possible tephra sources in Romania

5. LIST OF PARTICIPANTS

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6. STATISTICAL INFORMATION ON PARTICIPANTS

Workshop participants (from left to right) Back row: Stefan Wastegård, Anthony Newton, Haflidi Haflidason, Gudrun Larsen, Olgeir Sigmarsson (ESF representative), Daniel Veres, Martine Paterne. Middle row: Simon Blockley, Hans-Joachim Wallrabe-Adams, Chris Turney, Jon Eiríksson, John Hunt, Achim Brauer, Jon Pilcher, Sabine Wulf. Front row: Siwan Davies, Karen Luise Knudsen, Wim Hoek, Christel van den Bogaard, Jane Boygle, Maja Andrič, Nick Pearce and Jean-Paul Raynal; Gérard Vernet (not in the photograph).

Countries of origin	
Denmark	1
France	3
Germany	4
Iceland	2
Netherlands	1
Norway	1
Slovenia	1
Sweden	2
United Kingdom	7
Australia	1

Gender distribution	
Female	8
Male	15

Age distribution	
Under 35	6
Over 35	17