Commissioned Research Report

Japan Society for the Promotion of Science – Fellowship for Research in Japan (7-22 May, 2010)

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Citation:
JSPS Fellowship for Research in Japan

Research Report
(cover page)

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Affiliation: Dept. of Earth & Ocean Sciences, University of Waikato, Hamilton, New Zealand
Name of host institution: Kagoshima University
Name of host research: Professor Hiroshi MORIWAKI
Fellowship period:
   From: Fri 7th May 2010
   To: Sat 22 May 2010
Title of research in Japan: Using tephrochronology to study late Quaternary environmental change and archaeology
Date: 20 June 2010

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(a) Outline of academic activities

The academic activities involved a wide range of work including:

1. presenting 4 seminars at four different universities:
   - Kagoshima University, Kagoshima
   - Kyoto Prefectural University, Kyoto
   - Tokyo Metropolitan University, Hachioji, Tokyo
   - Meiji University (Ikuta campus), Kawasaki, Tokyo
   - the seminar presentations were ~50 minutes in duration with questions and
discussion for up to ~30-40 minutes following the presentations

2. presenting a ~40-minute public lecture in Kirishima City (attracted audience >250)

3. presenting/co-presenting two oral papers and two poster papers at the international
   INTAV-J tephra conference “Active tephra in Kyushu” in Kirishima City

4. co-organising and chairing a special session (at the INTAV-J conference) on the Eyjafjöll
   eruption of Iceland eruption
   - session attracted southern Kyushu TV and newspaper coverage

5. leading and taking part in discussions (throughout the INTAV-J conference) on
tephrochronology and its application to the study of environmental change and archaeology
including commenting on papers by Japanese students and many other participants

6. taking part in field work and associated discussions with academics, geoscientists
   (including volcanologists), archaeologists, and students in Kyushu over 5 days during field
excursions associated with the INTAV-J conference

7. undertaking discussions with academics and graduate and undergraduate students, and
   others, at four different universities listed in (1) above

8. co-editing a tour guide and writing/co-writing 5 abstracts before the trip, and editing
   several abstracts by Japanese participants; assisting organising committee in planning and
   preparing for the INTAV-J conference; co-writing 2 newsletter reports after the trip

Saturday 8th May

☐ Seminar 1 presented by Prof Lowe to academic staff, graduates, and visiting archaeologists and
geoscientists at Kagoshima University, Physical Geography Section, Faculty of Law, Economics
and the Humanities:

**Dating Polynesian settlement of New Zealand using tephra layers and other scientific tools**

Hosted by Prof Hiroshi Moriwaki.

I also met with Prof Naoko Nakamura and Assistant Prof Tomoe Sangawa (both at Research
Centre for Archaeology, Kagoshima University); Dr Ryusuke Imura, Dr Toshihiro Nagasako, Dr
Yoshito Kobayashi, and Prof Emeritus Kisei Kinoshita (all Kagoshima University); Dr Yudzuru
Inoue (Kyushu University); and Dr Mitsuhiro Kuwahata (Cultural Heritage Preservation Section,
Miyakonojo City Board of Education, Miyazaki)

Sunday 9th May

☐ Public lecture presented by Prof Lowe (with co-author Prof Moriwaki) at Kokubu Civic Centre,
Kirishima City Hall:

**Connecting with our past: using tephras and archaeology to date the Polynesian settlement of
Aotearoa/New Zealand**

- more than 250 people attended this lecture (hall was full, standing room only)
- reported in Minami-Nippon Shinbun (10th May 2010)

Monday 10th May

INTAV-J international conference ‘Active tephra in Kyushu’: International Field Conference
on Tephrochronology, Volcanism and Human Activity, Kirishima, Japan, 10-14 May, 2010

☐ Oral paper 1 presented by Prof Lowe:

*Tackling uncertainty in tephrochronology: objective 4 of the INTREPID project*
Poster paper 1 presented by Prof Lowe (with co-author Prof Newnham):

*Using tephrochronology to define and date the base of the Holocene for Australasia at Lake Maratoto (New Zealand) — an auxiliary stratotype for the Holocene GSSP*

Poster paper 2 presented by Prof Moriwaki (with co-authors Prof Machida, Dr Nakamura, and Prof Lowe):

*The role of tephras in developing a high-resolution chronology for palaeoenvironmental reconstruction and archaeology in southern Kyushu, Japan, since 30,000 years ago (Kyushu-INTIMATE project)*

**Wednesday-Thursday 12-13th May**

Field work in Kagoshima Prefecture with INTAV-J group

- included visits to Uenohara Jomon no Mori (archaeological centre), Tenjindan archaeological site, Sakurajima volcano (including active Showa crater of Minamidake volcano, Arimua lookout and 1914 lava flows), Takatoge Pass tephra section, Kurokami buried gate of shrine
- note that because of the foot-and-mouth disease outbreak in Miyazaki Prefecture, we were not able to visit Kirishima volcanoes nor visit Miyazaki Prefecture

**Friday 14th May**

Oral paper 2 presented by Prof Moriwaki (with co-authors Prof Suzuki, Drs Murata and Ikehara, Prof Machida, and Prof Lowe):

*Sakurajima-Satsuma (Sz-S) and Noike-Yumugi (N-Ym) tephras: key tephrochronological marker beds for the last deglaciation, southern Kyushu, Japan*

**Saturday 15th-Mon 17th May**

Field work in central and northern Kyushu Island with INTAV-J group

- included around 5-6 stops each day centred on Unzen volcano, Aso caldera (including Nakadake crater, Kusasenrigahama crater, Noga section near Taketa City), Kuiju and Yufu-Tsurumi volcanoes

**Tuesday 18th May**

Seminar 2 presented by Prof Lowe to undergraduate history/physical environment class at Kyoto Prefectural University, Faculty of Letters:

*Connecting with our past: using tephras and archaeology to date the Polynesian settlement of Aotearoa/New Zealand*

Hosted by Prof Yoshihiro Uemura

**Thursday 20th May**

Seminar 3 presented to graduates and staff of Tokyo Metropolitan University, Dept of Geography:

*Using tephrochronology to synchronize and date records of late Quaternary environmental change in New Zealand (NZ-INTIMATE project)*

Hosted by Prof Takehiko Suzuki

**Friday 21st May**

Seminar 4 presented to graduate and undergraduate students and staff of Meiji University (Ikuta campus, Kawasaki), Faculty of Agriculture:

*Pre-European Maori horticulture in New Zealand and the discovery of unique sweet potato (kumara) garden features in Hamilton*

Hosted by Prof Hiroshi Takesako
Kokubu Civic Centre (Kirishima) ready for Prof Lowe’s public lecture on 9 May 2010 (title slide showing on screen)

Prof Lowe giving oral presentations at INTAV-J “Active Tephra” conference including leading discussions about future activities of INTAV (right)

With co-presenter/host researcher Prof Hiroshi Moriwaki (left) in front of poster paper and with INTAV-J conference committee of which he was a member (right)
Photos of Prof Lowe engaging with colleagues and students during field trips to archaeological sites and tephra-buried soil sections used for palaeoenvironmental reconstruction.
Small eruption of Showa crater, Sakurajima, 12 May 2010

Post-conference excursion group at tephra-buried soil section at Sen-ninzuka, 17 May 2010
In the field at glacial-age Mizorogaike Lake, Kyoto (inset shows host Prof Yoshihiro Uemura, Bukkyo University), 18 May 2010

Host Prof Takehiko Suzuki (left) and a postgrad student met Prof Lowe at Tokyo Metropolitan University, 20 May 2010

Prof Lowe with host Prof Hiroshi Takesako (seated at right) and graduate students at Meiji University (Ikuta campus, Tokyo), 21 May 2010
(b) Impressions/thoughts about science in Japan in the field of tephrochronology and its application to late Quaternary environmental research and archaeology

My fellowship research trip was effectively in two parts. The first was associated largely with the International Field Conference “Active Tephra” on “Tephrochronology, Volcanism and Human Activity” organised by INTAV-J that was held in Kirishima, Kagoshima Prefecture. The second part comprised my lecture tour to visit and interact with colleagues and students at four different universities (beginning with my host university, Kagoshima University). Both the tour and conference focussed directly on my JSPS research topic, namely tephrochronology and its application to late Quaternary environmental research and archaeology. Consequently, I enjoyed many opportunities to see and evaluate the contributions of Japanese tephrochronologists, archaeologists, and other geoscientists to those disciplines. I also contributed my own knowledge.

Conference and field work

At the conference, 42 of the 76 participants in total (60%) were from Japan. Together they presented 20 oral papers out of 50 (40%), and 25 poster papers out of 40 (62%). I was impressed in most cases at the standard of research that was presented, with both excellent content and presentation skills on display. Only one or two talks and posters were perhaps not so well prepared (although I unequivocally admired the efforts of the presenters, and I acknowledge the difficulty in presenting research results in English to an international audience). I was impressed to see, for example, new approaches to age modelling being adopted by Prof Naoka Nakamura and others in using Bayesian-based radiocarbon probability distributions for archaeological research being undertaken in Kyushu. Also, colleague Prof Hiroshi Moriwaki is the first in Japan to use the highly-successful INTIMATE approach (Integration of ice-core, marine and terrestrial records to study the glacial-interglacial transition of the past 30,000 years). His research included an impressive integration of marine and terrestrial records for that time period, as well as archaeological records, linked and synchronized using widespread marker tephra layers. Some new aspects of volcanicological research were very well described by Prof Tetsuo Kobayashi and keynote speaker Prof Mitsuhiro Nakagawa. I was especially impressed by the work being undertaken on the famous Lake Suigetsu varved sediment sequence that was reported brilliantly by Prof Takeshi Nakagawa in his keynote presentation. The sequence is critically important in the quest for an accurate global radiocarbon calibration curve for the period from 50,000 to 26,000 calendar years ago. Prof Nakagawa’s talk showed how Japanese research in this area, integrating ITRAX XRF core scanning technology with 600 new radiocarbon ages on the varves, is leading the way to develop a new calendrical record of climatic change and calibration. He showed also how tephra layers were able to link the record to other palaeoenvironmental sequences containing the same deposits. Prof. Nakagawa also presented new calendar age estimates for several key marker tephras in Japan, including Akahoya (K-Ah) tephra (7263 ± 53 cal BP, 3σ range) and the Aira-Tn (AT) tephra (30,058 ± 384 cal BP, 3σ range). These ages were the first I have ever seen reported at 3 standard deviations in terms of error. The remarkable field excursions also showcased Japanese research and understanding to a very high level. The trips were well planned and led and participants were provided with excellent, comprehensive field notes all in colour. All participants were very impressed at the high level of research that was being undertaken, and the tephra-dated archaeological sites (Uenohar Jomon no Mori, Tenjindan) were especially stunning.

Prof Nakagawa explaining new work on the Lake Suigetsu core SG06

New calendrical age obtained on the K-Ah tephra from the Lake Suigetsu sequence
Lecture tour

Seminar 1 (Sat 8th May, “Dating Polynesian settlement of New Zealand using tephra layers and other scientific tools”) was presented at Kagoshima University and, as noted above, drew considerable questions and discussion from a wide range of participants including academics, visiting geoscientists, and graduate students. The use of tephrochronology as a dating and linking tool in archaeology, and palaeoenvironmental reconstruction relating to initial human impacts (via deforestation by burning), was presented along with a wider picture of settlement of the Pacific Ocean region during the second part of the Holocene. Some surprise at the very late settlement (post-c. 1280 AD) of New Zealand was expressed, this new finding being a focus of my talk. I was impressed that Ayumi Yamamoto (International Relations Office, Kirishima City), who was to translate my public lecture on a similar topic the next day, came to this seminar to better prepare herself – an excellent example of hard work and devotion to duty to provide the best possible translation. I was introduced and hosted by tephrochronologist Prof Hiroshi Moriwaki (Kagoshima University).

My public lecture (Sun 9th May, “Connecting with our past: using tephras and archaeology to date the Polynesian settlement of Aotearoa/New Zealand”) began with an introduction to the classical Greek and Roman (Mediterranean) origins of the word tephra and its derivatives tephrostratigraphy and tephrochronology. My talk then presented the problems and evidence associated with dating the earliest Polynesian settlement of Aotearoa (New Zealand). Some interesting and pertinent questions were received from the large audience, via Ayumi Yamamoto, at the Kokubu Civic Centre. The talk was well received and was described in the newspaper the next day.
Seminar 2 (Tues 18th May, “Connecting with our past: using tephras and archaeology to date the Polynesian settlement of Aotearoa/New Zealand”) was effectively the public lecture talk but slightly modified and presented to a history/physical environment class at Kyoto Prefectural University in Kyoto. Because the class was at undergraduate level then this seminar was appropriate, and the references to classical Greek and Roman history as well as early New Zealand history were well received. I was introduced and hosted by geomorphologist Prof Yoshihiro Uemura (Bukkyo University, Kyoto), who also translated and emphasised parts of my talk as it progressed. Some discussion was entered into at the conclusion and Prof Uemura, who has undertaken historical-environmental research in New Zealand, expressed surprise at the new ‘late settlement’ model for Polynesian settlement of Aotearoa/New Zealand. Thus it was an important lecture because Prof Uemura sometimes uses New Zealand examples in his teaching.

Seminar 3 (Thurs 20th May, “Using tephrochronology to synchronize and date records of late Quaternary environmental change in New Zealand (NZ-INTIMATE project”) was given at Tokyo Metropolitan University which has a strong group of academics and graduate students who are involved in palaeoenvironmental research including using tephrochronology in palaeoclimatic reconstructions for the Quaternary. This seminar, hosted by tephrochronologist Prof Takehiko Suzuki, initially emphasised the way in which tephras are identified and correlated in New Zealand and introduced new Bayesian-probability based ‘wiggle-match’ dating that has been developed to improve age models for key marker tephras in New Zealand. Four case studies involving key tephra layers were then presented to illustrate the development and application of the NZ-INTIMATE project. There were numerous questions and considerable discussion following the seminar. I was impressed at the excellent level of understanding and the good questions. A week or two later Prof Suzuki told me via email that there had been considerable interest in my presentation and that some aspects were still being discussed in the department.

Seminar 4 (Fri 21st May, “Pre-European Maori horticulture in New Zealand and the discovery of unique sweet potato (kumara) garden features in Hamilton”) was presented to a class of both graduate and undergraduate students and several faculty members, including my host Prof Hiroshi Takesako, at the Ikuta campus of Meiji University, Kawasaki, Tokyo. Because these students were studying mainly soil science, this seminar included descriptions and illustrations of archaeology and pre-European horticultural gardening techniques used by early Maori (descendents from Polynesian settlers) in growing imported tropical crops, chiefly sweet potato, in a temperate landscape since c. 700 years ago. The seminar was thus a mix of science and history. Prof Takesako translated much of the talk to the group as I presented it. A number of students asked very good questions at the conclusion.

Conclusion

My impression is that Japanese geoscientists engaged in tephrochronological studies dealing with late Quaternary palaeoenvironmental reconstructions and archaeology are making substantial contributions both nationally and internationally. Some research is extremely important globally and was well showcased during my time in Japan as a JSPS Fellow during the lecture tour and the “Active Tephra” meeting and associated field excursions. The importance of tephrochronology as a linking and dating technique was well understood by Quaternarists and archaeologists. Japanese students seemed interested and engaged with my research.

In all seminars and oral presentations, and in subsequent newsletter articles, the role of JSPS in supporting my research trip to Japan was noted prominently.
## (c) List of articles published during and after fellowship period

Conference abstracts published: 5  
Conference field tour guidebook: 1  
International and national newsletter articles: 2

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* International Union for Quaternary Research  
* See appendices pp. 14-22
(d) Comments or suggestions to JSPS concerning fellowship programme

The fellowship programme is extremely important in maintaining strong international connections between Japanese researchers and overseas visitors. As well as continuing discussions and presenting papers with Prof Moriwaki relating to the development and application of tephrochronology to studies of past environments and to archaeology (see list of publications and appendices), I very much enjoyed presenting the seminars and meeting geoscientists and students interested in the topics during the lecture tour. The meeting of nearly 80 tephrochronologists, both from Japan and elsewhere, for the “Active Tephra” conference in Kirishima City, along with associated fieldwork, was very useful because such a meeting enabled me to engage with, and contribute to, the very latest tephrochronological and related palaeoenvironmental research being undertaken in Japan and in other countries.

Without doubt, there is no substitute to face-to-face meetings with people (one-to-one or in groups) to make and cement strong research relationships and friendships, and to help advance and disseminate knowledge. The JSPS fellowship programme fulfils this necessity for the science community.

(e) Other comments

I wish to record my gratitude to JSPS for awarding this invitation fellowship and especially for providing business class air tickets. Both were very much appreciated, as was the high level of hospitality I received in Japan. I wish to thank my own university for allowing me time to travel to Japan, and colleagues for helping with teaching arrangements in my absence. I especially thank my host researcher and colleague Prof Hiroshi Moriwaki (Kagoshima University) for all his help and support in obtaining the fellowship and business-class tickets, and encouragement and hospitality. I also appreciated support and hospitality from Prof Yoshihiro Uemura (Bukkyo University), Prof Takahiko Suzuki (Tokyo Metropolitan University), Prof Hiroshi Takesako (Meiji University, Ikuta campus), and Prof Koji Okumura (Hiroshima University). Staff members who on behalf of JSPS supported my trip (providing tickets etc) were exemplary. I also acknowledge support and encouragement from Mayor Shuji Maeda of Kirishima City in hosting the “Active Tephra” conference and in inviting me to give a public lecture.

It was a great privilege to share the stage with the second public speaker, Emeritus Professor Hiroshi Machida, who spoke after me at the public lecture in Kirishima City. Ayumi Yamamoto provided excellent translations. I also thank colleagues who provided photographs, some of which have been used in this report.

Prof Hiroshi Machida engaging with colleagues and researchers following his public lecture, and Prof Lowe’s, in Kokubu Civic Centre, Kirishima, 9th May 2010
Connecting with our past: using tephras and archaeology to date the Polynesian settlement of Aotearoa/New Zealand

Prof David J. Lowe  
University of Waikato, Hamilton, New Zealand

with Prof Hiroshi Moriwaki  
Kagoshima University, Kagoshima, Japan

Public lecture: “Active Tephra 2010” international tephra conference, Kirishima, Kagoshima Prefecture, Japan, 9th May 2010

Volcanic-ash (tephra) from a powerful volcanic eruption can be blown over wide areas of land, sea, and ice. The tephra falls to the ground very quickly, forming a layer made up of fragments of rock and pumice, glass particles, and mineral grains (crystals). The tephra layer marks a very short time period, usually a matter of only days to perhaps weeks (the duration of the eruption), and it is the same age wherever it occurs because of its rapid deposition through the atmosphere during the eruption. The layer may be characterized or ‘fingerprinted’ by geochemical analysis and its age determined by a range of methods. Once fingerprinted and dated, the tephra layer provides a time plane that can be used to connect and date geological or archaeological deposits or events at any sites where it occurs.

In this talk, the use of tephra layers as a unique dating tool in archaeology will be presented first. Then the focus will turn to Aotearoa/New Zealand and the question of when it was initially settled by seafarers from eastern Polynesia. As the last substantial landmass in the world to be settled by humans, the timing of the initial settlement of Aotearoa/New Zealand in the southwest Pacific has been controversial and the evidence open to differing interpretations because of various problems. But the use of tephra layers to connect evidence from both archaeological and natural sites (such as peat bogs and lakes), and to provide dates, has been a critical tool in helping to finally establish the date of initial settlement by Polynesians. The talk will be fully illustrated.
INTERNATIONAL UNION FOR QUATERNARY RESEARCH
INTERNATIONAL FOCUS GROUP ON TEPHROCROHNOLGY
AND VOLCANISM (INTAV)

ACTIVE TEPHRA in Kyushu, 2010

INTRA-CONFERENCE FIELD TRIP GUIDES

International Field Conference and Workshop on Tephrochronology,
Volcanism, and Human Activity
Kirishima City, Kyushu, Japan, 9-17 May, 2010
INTERNATIONAL UNION FOR QUATERNARY RESEARCH
INTERNATIONAL FOCUS GROUP ON TEPHROCHRONOLOGY
AND VOLCANISM (INTAV)

International Field Conference and Workshop on
Tephrochronology, Volcanism, and Human Activity

*Active Tephra in Kyushu, 2010*
Kokubu Civic Center, Kirishima City,
Kagoshima Prefecture, Kyushu, Japan
9-17 May, 2010

INTRA-CONFERENCE FIELD TRIP GUIDES

Edited by
H. Moriwaki and D. J. Lowe
INTRODUCTION TO KYUSHU

1. Outline of tectonic setting and explosive volcanism of southern Kyushu
   H. Machida

2. Active volcanoes in Kyushu
   T. Kobayashi

3. Late Pleistocene and Holocene tephras in southern Kyushu
   H. Moriwaki

4. Shirasu ignimbrite plateaux in southern Kyushu
   S. Yokoyama

5. Tephra-derived soils in Kyushu
   Y. Inoue

6. Lucidophyllous forest (evergreen broad-leaved forest) development since the Last Glacial period in southern Kyushu, Japan, clarified by phytolith studies
   S. Sugiyama

7. Deep-sea tephras around southern Kyushu
   H. Moriwaki

8. Developments of coastal lowlands and environments around Kagoshima Bay in relation to Holocene tephrachronology
   H. Moriwaki

9. Tephras and archaeology in southern Kyushu
   H. Moriwaki, N. Nakamura & T. Sangawa

10. Physiography in Kyushu
    T. Nagasako

INTRA-CONFERENCE FIELD TRIP GUIDE
Leaders: H. Moriwaki, T. Kobayashi & R. Imura

DAY 1: Kirishima and its surrounding area
Leaders: R. Imura & H. Moriwaki
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T. Kobayashi
Tackling uncertainty in tephrochronology: objective 4 of the INTREPID project

David J. LOWE*

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A central goal of INTREPID (Enhancing tephrochronology as a global research tool) is to advance understanding and efficacy in fingerprinting, correlating, and dating techniques, and to evaluate and quantify uncertainty in tephrochronology. (The 'ID' at the end of INTREPID is intended to evoke tephra identification as a core function.) Although new research in tephrochronology clearly is underway in many areas, INTREPID was initiated in 2009 through INTAV as an overarching project to integrate many of these projects more coherently. Funding support for kick-starting INTREPID at ‘Active Tephra 2010’ was provided through the Stratigraphy and Chronology Commission of INQUA (project 0907). Thus INTREPID aims not only to improve integration of work underway but also to provide an opportunity to develop the discipline to a higher level and hence enhance its application in Quaternary research. Its ultimate success requires a collective, global-ephra-community based approach with additional expertise from allied disciplines (e.g. volcanic petrology, Bayesian modelling). Affiliated projects involving tephrochronology include VAST, INTIMATE, SMART, RHOTOR, RESET, and SUPRANET.

INTREPID has five interlinked objectives: (1) new characterization techniques; (2) improved guidelines and protocols for geochemical data acquisition and quality; (3) developing regional databases; (4) objective correlation and quantification of uncertainty; and (5) improving age models for key marker tephras (see also http://www.sees.auckland.ac.nz/about_us/intav.shtml). Here I introduce objective 4: more fully, to evaluate and develop more objective ways of correlating tephras and cryptotephras from different places using appropriate statistical techniques, and to develop numerical measures of (un)certainty. The tremendous benefits of tephrochronology as a unique linking, dating and synchronizing tool in palaeoenvironmental and archaeological research, and in documenting volcano history and volcanic hazard analysis, are well known, but some of the problems that arise in practice are not often discussed openly. Sometimes correlations are made with considerable subjectivity. Various statistical techniques are available to help, including similarity coefficients, cluster analysis, and discriminant function analysis (DFA), but each has potential problems. Can we do better – perhaps ultimately attaining a CSI-level of effectiveness at least at the regional level? The consequences of miscorrelation may be serious and include the incorrect positioning of isochrons, misassociation of palaeoclimatic or archaeological events (i.e. incorrect linking/synchronization), or transferral of incorrect ages. The quantification of uncertainty should enable the significance of such miscorrelation to be assessed probabilistically using an iterative modelling approach and sensitivity analysis.

Many possible steps lead to miscorrelation: (1) stratigraphic error in field work; (2) assigning an incorrect age unwittingly to a tephra from which subsequent faulty age-based correlations are made; (3) incompleteness of stratigraphic records of tephra-erupting episodes against which to attempt correlation; (4) a paucity or inadequacy of characterization data of potential correlatives; (5) lack of recognition that tephra deposits from an eruption episode may have multiple fingerprints temporally and spatially because of magmatic changes during their eruption, or because of microfossils (chiefly in andesitic or basaltic glass); (6) by tephras having very similar thus ambiguous compositions, i.e., non-unique ‘fingerprints’; (7) by inappropriate geochemical analysis leading to faulty or inadequate characterization so that analytical data are compromised; (8) by reworking of a tephra (or cryptotephra shard dispersal) to a different stratigraphic position so that isochron positioning is compromised; (9) by replication of sequences of tephra-bearing sediments in cores because of localised slumping/redeposition or because of faulty retrieval; (10) by uncritical attribution of a tephra, e.g., to an acid peak in an ice core without supportive compositional data derived from analysis of associated glass shards; (11) statistical misadventure whereby miscorrelation may arise, e.g., in DFA because the database/training set is not comprehensive, or data are of poor quality. Reducing uncertainty involves using multiple criteria, rigorous analyses (with standards documented, uncertainty reported), and comprehensive sequences especially those containing interfingering tephras from different sources such as occur in distal sediments including ice. Multiple, interconnected sites may be needed to develop comprehensive regional records. The recognition and quantification of uncertainty in tephrochronology can be used in age-probability modelling and stratigraphic applications.
Using teprochronology to define and date the base of the Holocene for Australasia at Lake Maratoto (New Zealand) – an auxiliary stratotype for the Holocene GSSP

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Holocene (meaning ‘entirely recent’) is the most recent interval of Earth history, and includes the present day. Alternative terms ‘Recent’ and ‘Post-glacial’ have no formal status. Even though the Holocene has been recognised as a stratigraphic unit of series status since 1885, a proposal for the definition of its base (the Pleistocene-Holocene boundary, PHP) was not formally ratified until May 2008 by IUGS. The Holocene Global Stratotype Section and Point (GSSP) is located at 1492.45 m depth within the NorthGRIP ice core, reflecting the first signs of warming at the end of the YD/Greenland Stadial-1 cold phase, and is dated at 11,700 ± 99 cal yr before AD 2000 (~2CI) (ref. 1). Five global auxiliary stratotypes, effectively regional reference locations, were recognized, with the PHP defined using tephra layers in lake sediments for three regions: Europe (Ulmener Maar tephra, Germany), East Asia (U-Okı tephra, Japan), and Australasia (Konini tephra, New Zealand). The auxiliary GSSP for Australasia – effectively Australia, New Zealand, and neighbouring islands in the South Pacific – is at Lake Maratoto (in which Konini tephra occurs), and the lake and its tephra-bearing sedimentary record is the main focus of this paper.

Lake Maratoto in northern North Island, New Zealand, is one of 30 small riverine lakes near Hamilton in the Waikato lowlands formed c. 20 cal. ka by glacio-isostatic uplift of the ancestral Waikato River system. It preserves a continuous sedimentary sequence since the LGM (or soon thereafter) from which detailed pollen and teprostratigraphic records have been obtained, as well as chironomid, cladocera, sedimentary pigments, geochemical and stable isotope (13C) data. An extensive stratigraphic survey, including 33 lake cores and use of ground penetrating radar, and 34 14C dates, enabled the development of the lake and adjacent bog to be reconstructed in detail (ref. 2).

The base of the Holocene can be pinpointed using tephrostratigraphy with palynostratigraphy. Full Holocene warmth, as reflected in the pollen sequence, is attained at close to the time of deposition of the Egmont-derived andesitic Konini tephra, dated at 11,720 ± 220 cal. yr BP (2CI) at Kaipo bog (ref. 3) (Konini tephra in Lake Maratoto sediment was dated at 11,305–12,049 cal. yr BP (2CI), calibrated from Wk-519, 10,100 ± 100 14C yr BP). Konini tephra, known originally as tephra Eg-11, has been correlated via its hornblende-clinoopyroxene dominated ferromagnesian mineralogical assemblage and by electron microprobe analysis of glass shards (refs. 4, 5). In a 3-m long core from L. Maratoto (known variously as core X79/1, core MoA/1, and core 4.1a), Konini tephra is preserved as a pale grey fine-ash layer 2–3 mm in thickness at a depth of 1.50 m below Taupo tephra. Its stratigraphic position is constrained by two easily recognised and distinctive tephra markers: a greyish-black coarse andesitic ash (Mangamate) lies above it at 1.40–1.45 m depth, and a white and cream, fine and medium-beded rhyolitic ash (Waiohau) lies below it at 1.67–1.70 m depth.

Attainment of full climatic warmth associated with the onset of the Holocene at around the time of deposition of Konini tephra has been reported from other North Island pollen sites (ref. 6). Lake Maratoto is located 3 km southwest of Hamilton International Airport and 1.5 km due west of State Highway 3. There is easy access by vehicle directly to the northern shore of the lake on a well-surfaced farm road. Although on private land, the lake is protected from any development in perpetuity by a covenant under the QE II National Trust Act of 1977.

(3) Lowe, D.J. et al. 2008, Quaternary Science Reviews 27, 95–126.
Sakurajima-Satsuma (Sz-S) and Noike-Yumugi (N-Ym) tephras: key tephrochronological marker beds for the last deglaciation, southern Kyushu, Japan

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Two prominent tephras, Sakurajima-Satsuma (Sz-S) and Noike-Yumugi (N-Ym), provide key marker beds for dating and synchronizing palaeoenvironmental and archaeological records in the last deglaciation in southern Japan. We identified both tephras in a marine core (IMAGES MD98-2195) in the northern East China Sea and related their stratigraphic positions with respect to the marine oxygen isotope chronology. Here, we examine their identification based on the chemical composition of glass shards derived from the tephras in MD98-2195, and discuss their relationship with the NGRIP ice-core chronology and hence implications for the chronology of the terrestrial palaeoenvironmental and archaeological records in Kyushu as part of our programme developing a chronological framework for the Kyushu-INTIMATE project.

In MD98-2195, Sz-S and N-Ym are both white, vitric, ash-grade tephras. Sz-S is 8 mm thick at 9.12 m depth and N-Ym is 30 mm thick at 9.30 m depth. On the basis of their glass major-element compositions, Sz-S was erupted from Sakurajima volcano near Kagoshima, southern Kyushu, and N-Ym was erupted from Kuchierabujima volcano 90 km south of Satsuma peninsula, southern Kyushu. Mean electron microprobe-derived analyses (wt %) are as follows. (1) Sz-S: SiO2: 75.51; Al2O3: 13.20; TiO2: 0.43; FeO: 1.93; MnO: 0.08; MgO: 0.38; CaO: 1.74; Na2O: 3.42; K2O: 3.32 (wt %). (2) N-Ym: SiO2: 75.47; Al2O3: 12.82; TiO2: 0.53; FeO: 2.38; MnO: 0.09; MgO: 0.40; CaO: 1.76; Na2O: 3.35; K2O: 3.20. N-Ym tephra contains distinct banded pumices in proximal areas or its distribution, and electron microprobe analyses reveal compositional diversity within individual lapilli-sized clasts.

The 14C age of Sz-S is c. 12,800 cal yr BP. The stratigraphic position of this ash is at the early stage of the late-glacial reversal (cooling) in oxygen isotope records of MD98-2195 core, which correspond to GS-1 in the ice-core events of NGRIP (GIicc05). The site of MD98-2195 is located 200 km west of Sakurajima volcano. Its wide distribution and its key chronostratigraphic position marking the start of GS-1 indicate that this tephra is a critical isochron for palaeoenvironmental reconstructions and for dating prehistoric culture in southern Kyushu to GS-1.

N-Ym tephra is more than 5 m thick on Kuchierabujima Island, but no counterpart of this tephra had previously been found beyond this island. Its occurrence in core MD98-2195 180 km northwest of the source volcano Kuchierabujima, and at Tanegashima 80 km east of this volcano, now suggest that N-Ym is widespread. The 14C ages of charcoal in this tephra, c. 14,900 cal yr BP, correspond approximately to the transition between GS-2a and GI-1e in NGRIP. Oxygen isotope values at the stratigraphic position of this tephra in MD98-2195 show a rapid decline.
The role of tephras in developing a high-resolution chronology for palaeoenvironmental reconstruction and archaeology in southern Kyushu, Japan, since 30,000 years ago (Kyushu-INTIMATE project)

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Collective research efforts to integrate ice core, marine and terrestrial records over the past 30,000 years have been undertaken in the North Atlantic and Australasian INTIMATE projects to determine the nature, timing, and regional to global extent of abrupt climatic and environmental change. In Japan, such integration has not yet been conducted, although numerous palaeoenvironmental records have been accumulated. Palaeoenvironmental and archaeological records spanning the past 30,000 years have been also obtained in southern Kyushu and surrounding area notably the East China Sea and western Pacific. Here, we present a diagram that integrates marine oxygen isotope changes, recorded from cores obtained from the East China Sea and western Pacific near Kyushu, with sea-level change and coastal palaeoenvironmental change, vegetation records, and palaeoenvironmental records of southern Kyushu, together with benchmark records from the NGRIP core and its associated age model (GICC05), a coral-based sea-level, and a pollen record from central Japan.

Tephra beds are critical for establishing a high-resolution chronology and for providing the means (via tephrochronology) to integrate and synchronize these palaeoenvironmental and archaeological records of southern Kyushu to enable them to be examined in regional and global contexts. More than 90 tephra beds have been documented for the past 30,000 years in southern Kyushu. Because many of those tephra beds are chronostratigraphically related to events or changes evident in both environmental and archaeological records, southern Kyushu is one of the most suitable regions in Japan for developing a robust chronology and for integrating high-resolution records to a common calendrical time scale. We identify here key marker tephras that are especially relevant as isochrons for climatic and archaeological events since 30,000 years ago. In particular, we note the chronostratigraphic juxtapositions of tephra in relation to high-resolution oxygen isotope changes identified in a marine core (MD98-2195) from the East China Sea. The Aira-Tn tephra, aged c. 29,000 cal. yr BP, and the K-Ah tephra, aged c. 7300 cal. yr BP, are critically important widespread marker beds for the entire Japanese islands and for surrounding seas. Sakurajima-Satsuma tephra (Sz-S), erupted from Sakurajima volcano c. 12,800 cal. yr BP, and Noike-Yumugi tephra (N-Ym), erupted from Kuchiarabujima volcano c. 14,900 cal. yr BP, provide important isochrons for the last deglaciation. Their occurrence both in MD98-2195 and in terrestrial palaeoenvironmental and archaeological records of southern Kyushu enables all these records to be linked directly with the NGRIP ice-core records via tephrochronology and hence allows palaeoenvironmental changes in southern Kyushu to be discussed in a hemisphere-wide context. A precise chronology of archaeological documents relevant to tephras has been made in southern Kyushu.

Epoch-making events, such as the beginning of housing settlement and the change from palaeolithic to ceramic culture, occurred during the last deglaciation, and can be interrelated using the Sz-S and other tephras. A more precise correlation established partly using tephrochronology enables the relationships between palaeoenvironmental change and human activities to be examined more critically, and the opportunity to evaluate the possible impacts of environmental change, including climatic events and volcanic activity, on human activities. Similar studies are the focus of the RESET project in Europe ("Response of humans to abrupt environmental transitions").