NUMBER 139 JUNE 2016

QN

Quaternary Newsletter

A publication of the
Quaternary Research Association

QUATERNARY NEWSLETTER

EDITOR:
Dr A. Stone Geography, School of Environment,
Education and Development, The University of Manchester,
Arthur Lewis Building, Oxford Road, M13 9PL
(e-mail: abi.stone@manchester.ac.uk)

Instructions to authors

Quaternary Newsletter is issued in February, June and October. Articles, reviews, notices of forthcoming meetings, news of personal and joint research projects etc. are invited and should be sent to the Editor. Closing dates for submission of copy (news, notices, reports etc.) for the relevant numbers are 1st January, 1st May and 1st September. These dates will be strictly adhered to in order to expedite publication. **Articles must be submitted at least 6 weeks before these dates in order to be reviewed and revised in time for the next issue of QN, otherwise they may appear in a subsequent issue**.

Suggested word limits are as follows: obituaries (2000 words); articles (3000 words); reports on meetings (2000 words); reports on QRA grants (500 words); reviews (1000 words); letters to the Editor (500 words); abstracts (500 words). Authors submitting work as Word documents that include figures must send separate copies of the figures in .eps or .jpg format. In case of the latter, a minimum resolution of 300 dpi is required for accurate reproduction. Quaternary Research Fund and New Researchers Award Scheme reports should limit themselves to describing the results and significance of the actual research funded by QRA grants. The suggested format for these reports is as follows: (1) background and rationale (including a summary of how the grant facilitated the research), (2) results, (3) significance, (4) acknowledgments (if applicable). The reports should not (1) detail the aims and objectives of affiliated and larger projects (e.g. PhD topics), (2) outline future research and (3) cite lengthy reference lists. No more than one figure per report is necessary. Recipients of awards who have written reports are encouraged to submit full-length articles on related or larger research projects.

NB: Detailed guidelines on the formatting of contributions are now available via the QRA webpage and from the editor, including an EndNote style file to help with the formatting of bibliographies for submissions to *QN.*

Argraff/Printed by:
Gwasg Ffrancon Press
BETHESDA
Gwynedd, North Wales
Tel: 01248 601669 Fax: 01248 602634.

COVER PHOTOGRAPH
View of Mount Chelmos on the northern slopes of Psili Korfi, Greece. (see report by Hughes in this issue).

EDITORIAL

I hope that this first half of 2016 has been productive.

As my first issue of *QN* in my role as editor I would to first take the opportunity to thank the outgoing editor Sven Lukas for his hard work over the past four years and for his guidance during the handover.

I'd like to take this opportunity to encourage QRA members to submit research articles to the *QN*. These are particularly valuable for encouraging engagement, communication and debate within our Quaternary community. In this edition we have a particularly excellent selection of research reports from those awarded grants through the Quaternary Research Fund and the New Researchers Award Scheme, with others already lined up for the October edition.

I look forward to the rest of my term editing the *QN* and the continued communication with you, the QRA community.

Wishing you all the best for the summer,

Abi Stone
May 9th 2016

QRA50: TOP 50(80) QUATERNARY SITES – SPOTLIGHT ON A SITE

In 2014 members of the QRA submitted nominations for key sites and localities that have been fundamental to our understanding of the Quaternary landscape of Britain. These were collated into an excellent booklet, freely available on the QRA website (Silva and Phillips, 2015). To encourage ongoing engagement with both this excellent publication and the important sites contained within it, I propose highlighting one of these sites from time to time in the *QN*. In this edition, because of the nice link with Herb Wright helping with a coring expedition in 1979, we put the spotlight on Diss Mere. Please suggest future sites to highlight, and if you have a nice photo, send that to the editor too.

Here is summary from the entry for Diss Mere (Silva and Phillip, 2015, p28), a site nominated by John Birks.

- The first lowland lake in Britain that was studied using a multi-proxy approach using sediment structure and composition, geochemistry, pigments, pollen and diatoms.
- Contains laminated mid-Holocene sediments that demonstrate the 'elm decline' occurring over 5-8 years owing to a pathogen aided by prehistoric human activity (Peglar and Birks, 1993).
- Contamination from historic land-use observed from the mercury content of the sediments (Yang, 2010).

References

Peglar, S.M. and Birks, H. J. B. (1993). The mid-Holocene Ulmus fall at Diss Mere, south-east England – disease and human impact? *Vegetation History and Archaeobotany*, 2, 61-68.

Silva, B., Phillips, E. R. (eds) (2015). *UK Top Quaternary sites: a compilation to celebrate the QRA's semi-centennial year.* Quaternary Research Association, London.

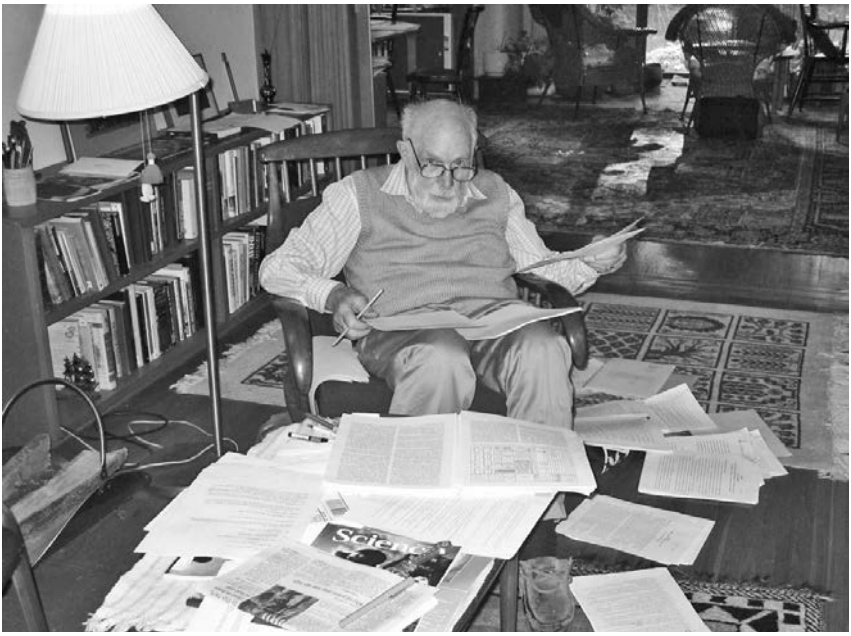
Yang, H. (2010). Historical mercury contamination in sediments and catchment soils of Diss Mere, UK. *Environmental Pollution*, 158, 2504-2510.

OBITUARY

HERBERT E WRIGHT JR (1917-2015)

Quaternary science has lost a giant, Herbert ("Herb") Wright. He was one of the world's most distinguished and active Quaternary scientists. He was a great scientific polymath and a huge intellect within the very broad field of Quaternary research. He made major contributions in many different research areas. These include arid-region geomorphology and landscape history, glacial geology and geomorphology, geo-archaeology, palaeoecology, vegetational and environmental history, palaeolimnology, fire history, landscape management and conservation, peatland ecology, global palaeoclimatology, and field-craft and sediment coring. He has left a rich legacy of outstanding publications, monographs, and edited books, and a very large number of former students and colleagues, many of whom are now leading scholars and are making their own outstanding contributions to many different aspects of Quaternary science.

Herb influenced a vast range of Quaternary science during the twentieth century. He started in the 1940s with geomorphology and landscape history, which naturally progressed to glacial geology and climate history. The study of these primary drivers led him to question their effects on vegetation and environmental history, which resulted in him describing the timing and mechanisms of climate-driven vegetational shifts in North America during the last 15,000 years, including the dynamic role of natural fire in northern forests. He was able to apply this knowledge to wilderness conservation and management. His never-ending curiosity expanded to cover many other aspects of palaeoecology, including lake ontogeny and the history and development of the enormous patterned peatlands of the Northern Hemisphere. Much of his work concentrated on the complex glacial landscape, vegetational, and climate history of Minnesota, but his broader vision led him to a synthesis of global palaeoclimatology. Beyond Minnesota, Wright studied a wide range of research questions elsewhere in North America, and in the Near East, Europe, Asia, Latin America, and Antarctica. His multi-disciplinary approach and great powers of synthesis uncovered how Earth's landscapes and biota have been transformed at a range of scales in the past, due to complex interactions between climate, landform, flora, fauna, and human activity.



Herb Wright in the living room of his house in St Paul, Minnesota (2004) editing chapters of the English translation of the book Cenozoic Climate and Environmental Changes in Russia by AA Velichko *et al*. (2005). Photo: Brigitta Ammann

Herb Wright, who died peacefully after a long illness on 12 November 2015 in St Paul, Minnesota, was born in Malden, Massachusetts on 13 September 1917. He studied at Harvard University under Kirk Bryan Sr. and completed his PhD on arid-region geomorphology and landscape history in New Mexico whilst training to be a B-17 Flying Fortress pilot during 1942–3. He flew many missions over Europe in 1944 and early 1945. In late 1945 he was appointed a teaching assistant at Brown University, Providence (Rhode Island) but moved in 1947 to the Department of Geology (now Department of Earth Sciences), University of Minnesota. He remained there for over 60 years and was appointed Regents' Professor of Geology, Ecology, and Botany in 1974. In 1958 he established a pollen laboratory that, in 1963, became part of the Limnological Research Center (LRC) of which he was appointed the director. The LRC quickly became the leading North American centre and a powerhouse for palaeoecological, palaeolimnological, and neolimnological research.

Herb always realised the importance of scientific networking, communication, and international collaboration, so a key policy of the LRC was to attract a large

number of overseas visitors who provided knowledge and inspiration, cross-fertilisation of ideas, and multi-disciplinary expertise to the group. Between 1959 and 1990, they came from at least 18 countries. Herb supervised more than 80 graduate students, mentored countless others from USA and around the world, and influenced many people's careers. Very many are now leading scholars and making important contributions to diverse areas of Quaternary research. Herb published over 250 papers or monographs and edited 15 influential books and six special issues of journals on a wide range of topics within Quaternary science (selected publications are listed below). For over 50 years, Herb, joyously supported by his wife Rhea, held Wednesday-evening seminars on Quaternary glacial geology, palaeoecology, palaeoclimatology, palaeolimnology, or neolimnology in the Wright home in St Anthony Park, St Paul.

The major underlying theme of Herb's scientific activities was the reconstruction the late-Quaternary landscape history at various spatial and temporal scales to explain the functioning of our present landscapes and ecosystems and how they might respond to climate changes and human impact in the future. Thus he synthesised the climatic and vegetational history of Minnesota and adjacent states using a range of palaeoecological techniques. He made major contributions to the understanding of the complex glacial history of the Great Lakes region. He showed how the landscape controlled the origin of the spectacular surface patterns of the extensive peatlands not only in northern Minnesota, but also in Labrador and central Sweden. With Miron "Bud" Heinselman and others he unravelled the key role of fire in the dynamics of coniferous forests which allowed them to mount a successful but bitter campaign to save an extensive area of un-logged old-growth forest in northernmost Minnesota. Realising the importance of climate changes in controlling landscape and biotic history, Herb co-directed the multi-institutional Co-operative Holocene Mapping Project (COHMAP) with John Kutzbach, Tom Webb, Pat Bartlein, and others in the late 1970s and early 1980s in which past climates were simulated by a global circulation model at 3000 year intervals for the last 18,000 years. Most importantly, the simulation results were validated against actual palaeoclimatic data. COHMAP resulted in a major paradigm shift in Holocene climate research. Another of his major contributions was the development of the subject of geo-archaeology, starting in Lebanon and proceeding to Iraq, Iran, Kurdistan, and Turkey, and subsequently Greece, Labrador, Peru, and Bolivia, showing how the landscape and environment influenced human development. For example, he demonstrated the fundamental role of environmental determinism in early plant domestication in the Near East.

Herb was one of the first people in America to realise that understanding environmental history required continuous data archives back in time, the most informative being lake sediments. A major but often unrealised contribution was his perfection of techniques for coring lake-sediments which has widely facilitated Quaternary research today, particularly palaeoecology and lake history. He had a

passion for field-work and sediment coring and seemed to enjoy it most under difficult or near-impossible winter conditions in Minnesota and the Dakotas, in wilderness areas such as Labrador, Alaska, and the Yukon, and in physically demanding regions such as the Peruvian and Bolivian Andes and the Siberian Altai. His last coring of lake sediments was in the Pirin Mountains in Bulgaria just before his 90th birthday. Many of his field expeditions turned into adventures or, not infrequently, misadventures. Accounts of some of these can be read at http://www.eecrg.uib.no/SedimentalJourneys.htm. As Henry Lamb, Jim Almendinger, Dan Engstrom, and others have noted, Herb had an eccentric and inexplicable disregard for comfort, safety, and functioning equipment, despite his enthusiasm for field-work in remote areas and under difficult conditions.

Besides Herb's major research activities in the Americas and Near East, he had very strong connections with Europe and its Quaternary scientists. In the early 1950s he travelled widely in Europe to meet many Quaternary scientists such as Carl Troll, Julius Büdel, Johannes Iversen, Knut Fægri, Tage Nilsson, Franz Firbas, and Harry Godwin. As a pilot in the 95th Bombardment Group of the Army Air Corps, he was stationed at RAF Horham near Bury St Edmonds in 1944 and 1945. In his spare time he explored on bicycle classical Quaternary sites in East Anglia including Hoxne. He also visited Diss Mere and pondered about its origin, a lake that he revisited in 1979 to help retrieve over 17 m of sediment cores.

Herb populated the pollen laboratory in Minneapolis in 1958 by importing Magnus Fries from Sweden and a Leitz Labolux microscope from Germany. He attracted a cohort of very talented graduate students including Dick Baker, Bob Bright, Ed Cushing, Jock McAndrews, Lou Maher, Tom Shay, Tom Winter, and others. Herb was forced to buy a second Labolux microscope so that each of his students could count pollen in turn for a few hours in the day or night! These microscopes were in use 24 hours a day and helped to produce many outstanding pollen records! After Magnus Fries, many other leading European palaeoecologists came to work with Herb and his students in the 1960s and 1970s including Saskia ("Kiek") Jelgersma, Willem van Zeist, Roel Janssen (all from The Netherlands), Bill Watts (Ireland), Maj-Britt Florin (Sweden), Krystyna Wasylikowa and Kazimierz Wasylik (Poland), Johanna and Eberhard Grüger (Germany), Elizabeth Haworth and Hilary and John Birks (all UK). In the early 1980s Rick Battarbee (UK), Svante Björck and Ingemar Renberg (both Sweden), and Jan Janssens (Belgium) worked at the LRC. Short-term European visitors included Kevin Edwards and RG West (both UK), Jan Mangerud (Norway), Dragica Matulova (Czech Republic), and Brigitta Ammann (Switzerland). Ivanka ("Vania") Stefanova (Bulgaria) was a long-term visitor to the LRC and looked after Herb in his later years. Flowing in the opposite direction, several of Herb's students spent a year in European laboratories such as Copenhagen, Cambridge, Lund, Uppsala, Groningen, and Dublin. This strong European flavour was enhanced by graduate students coming to do MScs or PhDs supervised by

Herb from Ireland (Alan Craig, Henry Lamb, Joan Lennon, Norman Allott), Sweden (Kerstin Griffin, Liz Almgren, Karin Ahlberg), Finland (Liisa Koivo), and Belgium (Dirk Verschuren). Herb's European connections also involved much fieldwork and sediment coring in East Anglia (not only Diss Mere but also Hockham Mere and Sea Mere), northern England, Scotland, Ireland, Norway, Sweden, Czech Republic, Switzerland, Bulgaria, and the Azores as well as in the Georgian Caucasus and the Siberian Altai. On the occasion of his 90th birthday, Herb described himself in 2007 as an honorary European!

Herb's distinguished career was recognised by many awards and honours, including honorary doctorates from Trinity College Dublin and the Universities of Lund and Minnesota, membership of the National Academy of Sciences, a Distinguished Career Award from the American Quaternary Association, and a Lifetime Achievement Award from the International Paleolimnology Association.

We had the good fortune to work with Herb for over 40 years. He had a major influence on our careers, as he did for so many colleagues, by his example and by inspiring loyalty and friendship. He was soft-spoken, economical in words and deeds, and extremely modest. He was always very supportive of our endeavours, deeply caring, and a constant source of encouragement and sound advice. We and many others owe very much to him.

Herb's extensive scientific writings show a similar style of simplicity, conciseness, and elegance. His prowess at editing and synthesising data and ideas is legendary. His legacy to Quaternary science is immense, not only through his research, publications, past students, and mentoring, but also as the role model he provided for all who worked with him. He accomplished so much by developing in a quiet and modest way the stimulating environment of the LRC, inspiring exciting and novel multi-disciplinary research, and encouraging extensive international collaboration.

Selected Publications (in chronological order)

Wright, H.E. (1946). Tertiary and Quaternary geology of the Lower Rio Puerco Area, New Mexico. *Geological Society of America Bulletin*, 57, 383-456.

Wright, H.E. (1952). The geological setting of four prehistoric sites in northeastern Iraq. *Bulletin of the American Schools of Oriental Research*, 128, 11-24.

Wright, H.E. (1955). Valders drift in Minnesota. *Journal of Geology*, 63, 403-411.

Wright, H.E. (1956). Origin of the Chuska sandstone, Arizona-New Mexico - A structural and petrographic study of a Tertiary eolian sediment. *Geological Society of America Bulletin*, 67, 413-434.

Wright, H.E. (1957). The Late-Glacial chronology of Europe - a discussion. *American Journal of Science*, 255, 477-480.

Wright, H.E. (translation of Troll, C. 1944) (1958). Structure soils, solifluction, and frost climates of the earth (*Strukturböden, Solifluktion, und Frostklimate der Erde*), Wilmette, Illinois: US Army Snow, Ice, and Permafrost Establishment, Corps of Engineers.

Wright, H.E and Alt, D. (translation of Büdel, J. 1953) (1959). The 'periglacial'-morphological effects of the Pleistocene climate over the entire world (Die 'periglazial'-morphologische Wirkungen de Eiszeitklimas auf der ganzen Erde). *International Geology Review*, 1, 1-16.

Wright, H.E. (1961). Late Pleistocene climate of Europe: a review. *Geological Society of America Bulletin*, 72, 933-984.

Wright, H.E. (1961). Pleistocene glaciation in Kurdistan. *Eiszeitalter und Gegenwart*, 12, 134-164.

Wright, H.E. (1962). Role of the Wadena lobe in the Wisconsin glaciation of Minnesota. *Geological Society of America Bulletin*, 73, 73-100.

Wright, H.E., Winter, T.C. and Patten, H.L. (1963). Two pollen diagrams from southeastern Minnesota: problems in the regional late-Glacial and Postglacial vegetational history. *Geological Society of America Bulletin*, 74: 1371-1396.

van Zeist, W. and Wright, H.E. (1963). Preliminary pollen studies of Lake Zeribar, Zagros Mountains, southwestern Iran. *Science*, 140, 65-67.

Wright, H.E. (1964). Aspects of the early post-glacial forest succession in the Great Lakes region. *Ecology*, 45, 439-448.

Wright, H.E. (1964). Origin of the lakes in the Chuska Mountains, northwestern New Mexico. *Geological Society of America Bulletin*, 75, 589-597.

Cushing, E.J. and Wright, H.E. (1965). Hand-operated corers for lake sediments. *Ecology*, 46, 380-384.

Wright, H.E. and Frey, D.G. (eds) (1965). *The Quaternary of the United States. A review volume for the VII Congress of the International Association for Quaternary Research*. Princeton University Press, Princeton, NJ, 922pp.

Wright, H.E., Livingstone, D.A. and Cushing, E.J. (1965). Coring devices for lake sediments. In: Kummell, B. and Raup, D.M. (eds) *Handbook of Paleontological Techniques*. WH Freeman, San Francisco, 494-520.

Wright, H.E. (1966). Stratigraphy of lake sediments and the precision of the paleoclimatic record. In: Sawyer, J.S. (ed.) *World Climate from 8000 to 0 BC*. Royal Meteorological Society, London, 157-173.

Cushing, E.J. and Wright, H.E. (eds) (1967). *Quaternary Paleoecology. Proceedings of the VII Congress of the International Association for Quaternary Research*. Yale University Press, New Haven, 440pp.

Martin, P.S and Wright, H.E. (eds) (1967). *Pleistocene Extinctions. The Search for a Cause. Proceedings of the VII Congress of the International Association for Quaternary Research*. Yale University Press, New Haven, 453pp.

Morrison, R.B. and Wright, H.E. (eds) (1967). *Quaternary Soils. Proceedings of the VII Congress of the International Association for Quaternary Research*. Desert Research Institute, University of Nevada, 338pp.

Wright, H.E. (1967). A square-rod piston sampler for lake sediments. *Journal of Sedimentary Petrology*, 37, 975-976.

Wright, H.E., McAndrews, J.H. and van Zeist, W. (1967). Modern pollen rain in West Iran, and its relation to plant geography and Quaternary vegetational history. *Journal of Ecology*, 55, 415-443.

Morrison, R.B. and Wright, H.E. (eds) (1968). *Means of Correlation of Quaternary Successions. Proceedings of the VII Congress of the International Association for Quaternary Research*. University of Utah Press, 631pp.

Osburn, W.H. and Wright, H.E. (eds) (1968). *Arctic and Alpine Environments. Proceedings of the VII Congress of the International Association for Quaternary Research*. Indiana University Press, Bloomington, 308pp.

Wright, H.E. (1968). The natural environment of early food production north of Mesopotamia. *Science*, 161, 334-339.

Wright, H.E. (1968). The roles of pine and spruce in the forest history of Minnesota and adjacent areas. *Ecology*, 49, 937-955.

Wright, H.E. (1968). Climatic change in Mycenean Greece. *Antiquity*, 42, 123-127.

Florin, M.-B. and Wright, H.E. (1969). Diatom evidence for the persistence of stagnant glacial ice in Minnesota. *Geological Society of America Bulletin*, 80, 695-704.

Wright, H.E. (ed.) (1969). *Quaternary Geology and Climate. Proceedings of the VII Congress of the International Association for Quaternary Research*. National Academy of Sciences, 310pp.

Wright, H.E. and Watts, W.A. with contributions by Waddington, J.C.B., Jelgersma, S., Ogawa, J. and Winter, T.C. (1969). Glacial and vegetational history of northeastern Minnesota. *Minnesota Geological Survey*, SP-11, 1-59.

Wright, H.E. (1971). Late Quaternary vegetational history of North America. In: Turekian, K.K. (ed.) *The Late Cenozoic Glacial Ages*. Yale University Press, New Haven, 425-464.

Wright, H.E. (1972). Quaternary history of Minnesota. In: Sims, P.K. and Morey, G.B. (eds) *Geology of Minnesota: A Centennial Volume*. Minnesota Geological Survey, St Paul, 515-548.

Wright, H.E. (1972). Interglacial and postglacial climates: the pollen record. *Quaternary Research*, 2, 274-282.

Wright, H.E. (1972). Physiography of Minnesota. In: Sims, P.K. and Morey, G.B. (eds) *Geology of Minnesota: A Centennial Volume*. Minnesotan Geological Survey, St Paul, 561-580.

Heinselman, M.L. and Wright, H.E. (1973). Preface to the ecological role of fire in natural conifer forests of western and northern North America. *Quaternary Research*, 3, 317-318.

Wright, H.E. (1973). Tunnel valleys, glacial surges, and subglacial hydrology of the Superior lobe, Minnesota. *Geological Society of America Memoir*, 136, 251-276.

Wright, H.E. (1973). Quaternary science and public service. *Quaternary Research*, 3, 515-519.

Wright, H.E., Matsch, C.L. and Cushing, E.J. (1973). Superior and Des Moines lobes. *Geological Society of America Memoir*, 136, 153-185.

Wright, H.E. (1974). Landscape development, forest fires, and wilderness management. *Science*, 186, 487-495.

CLIMAP Project Members (1976). The surface of the ice-age earth. *Science*, 191, 1131-1137.

Wright, H.E. (1976). The environmental setting for plant domestication in the Near East. *Science*, 194, 385-389.

Wright, H.E. (1976). Pleistocene ecology - some current problems. *Geoscience and Man*, 13, 1-12.

Wright, H.E. (1976). The dynamic nature of Holocene vegetation: a problem in paleoclimatology, biogeography, and stratigraphic nomenclature. *Quaternary Research*, 6, 581-596.

Wright, H.E. and Stein, J.K. (1976). Glacial surges and flood legends. *Science*, 193, 1268-1269.

Wright, H.E. (1977). Quaternary vegetation history - some comparisons between Europe and America. *Annual Review of Earth and Planetary Science*, 5, 123-158.

Amundson, D.A. and Wright, H.E. (1979). Forest changes in Minnesota at the end of the Pleistocene. *Ecological Monographs*, 49, 1-16.

Watson, R.A. and Wright, H.E. (1980). The end of the Pleistocene: a general critique of chronostratigraphic classification. *Boreas* 9, 153-162.

Wright, H.E. (1980). Surge moraines of the Klutlan Glacier, Yukon Territory, Canada - Origin, wastage, vegetation succession, lake development, and application to the late-glacial of Minnesota. *Quaternary Research*, 14, 2-18.

Wright, H.E. (1980). Cores of soft lake sediments. *Boreas*, 9, 107-114.

CLIMAP Project Members (1981). Seasonal reconstructions of the Earth's surface at the last glacial maximum. *Geological Society of America Map and Chart Series*, MC-36.

Glaser, P.H., Wheeler, G.A., Gorham, E. and Wright, H.E. (1981). The patterned mires of the Red Lake peatland, northern Minnesota: vegetation, water chemistry and landforms. *Journal of Ecology*, 69, 575-599.

Wright, H.E. (1981). Vegetation east of the Rocky Mountains 18,000 years ago. *Quaternary Research*, 15, 113-125.

Foster, D.R., King, G.A., Glaser, P.H. and Wright, H.E. (1983). Origin of string patterns in boreal peatlands. *Nature*, 306, 256-258.

Wright, H.E. (ed) (1983). *Late Quaternary Environments of the United States* (2 volumes). University of Minnesota Press, Minneapolis, 407 and 277pp.

Engstrom, D.R. and Wright, H.E. (1984). Chemical stratigraphy of lake sediments as a record of environmental change. In: Haworth EY and Lund JWG (eds) *Lake Sediments and Environmental History*. University of Leicester Press, Leicester, 11-67.

Hansen, B.C.S., Wright, H.E. and Bradbury, J.P. (1984). Pollen studies in the Junín area, central Peruvian Andes. *Geological Society of America Bulletin*, 95, 1454-1465.

Velichko, A.A., Wright, H.E. and Barnosky, C.W. (eds) (1984). *Late Quaternary Environments of the Soviet Union*. University of Minnesota Press, Minneapolis, 327pp.

Wright, H.E. (1984). Sensitivity and response time of natural systems to climatic change in the late Quaternary. *Quaternary Science Reviews*, 3, 91-131.

Wright, H.E., Mann, D.H. and Glaser, P.H. (1984). Piston corers for peat and lake sediments. *Ecology*, 65, 657-659.

Kutzbach, J.E. and Wright, H.E. (1985). Simulation of the climate of 18,000 years BP: results for the North American/North Atlantic/European sector and comparison with the geologic record of North America. *Quaternary Science Reviews*, 4, 147-187.

Barnosky, C.W., Grimm, E.C. and Wright, H.E. (1987). Towards a postglacial history of the northern Great Plains: a review of the paleoecological problems. *Annals of Carnegie Museum*, 56, 259-273.

Ruddiman, W.F. and Wright, H.E. (eds) (1987). North America and Adjacent Oceans During the Last Deglaciation (The Geology of North America, Volume K-3). *Geological Society of America*, 501pp.

COHMAP Members (1988). Climatic changes of the last 18,000 years: observations and model simulations. *Science*, 241, 1043-1052.

Wright, H.E. (1989). The amphi-Atlantic distribution of the Younger Dryas paleoclimatic oscillation. *Quaternary Science Reviews*, 8, 295-306.

Engstrom, D.R., Hansen, B.C.S. and Wright, H.E. (1990). A possible Younger Dryas record in southeastern Alaska. *Science*, 250, 1383-1385.

Engstrom, D.R., Whitlock, C., Fritz, S.C. and Wright, H.E. (1991). Recent environmental change inferred from the sediments of small lakes in Yellowstone's northern range. *Journal of Paleolimnology*, 5, 139-174.

Wright, H.E. (1991). Coring tips. *Journal of Paleolimnology*, 6, 37-49.

Wright, H.E. (1992). Patterns of Holocene climatic change in the midwestern United States. *Quaternary Research*, 38, 129-134.

Wright, H.E., Coffin, B. and Aaseng, N.E. (eds) (1992). *The Patterned Peatlands of Minnesota*. University of Minnesota Press, Minneapolis, 327pp.

Wright, H.E. and Bartlein, P.J. (1993). Reflections on COHMAP. *The Holocene*, 3, 89-92.

Wright, H.E., Kutzbach, J.E., Webb, T., Ruddiman, W.F., Street-Perrott, F.A. and Bartlein, P.J. (eds) (1983). *Global Climates Since the Last Glacial Maximum*. University of Minnesota Press, Minneapolis, 569pp.

Hansen, B.C.S., Seltzer, G.O. and Wright, H.E. (1994). Late Quaternary vegetational change in the central Peruvian Andes. *Palaeogeography Palaeoclimatology Palaeoecology*, 109, 263-285.

Arkhipov, S.A., Ehlers, J., Johnson, R.G. and Wright, H.E. (1995). Glacial drainage towards the Mediterranean during the middle and late Pleistocene. *Boreas*, 24, 196-206.

Ahlberg, K., Almgren, E., Wright, H.E., Ito, E. and Hobbie, S. (1996). Oxygen-isotope record of Late-Glacial climatic change in western Ireland. *Boreas*, 25, 257-267.

Berglund, B.E., Birks, H.J.B., Ralska-Jasiewiczowa, M. and Wright, H.E. (eds) (1996). *Palaeoecological Events During the Last 15000 Years: regional syntheses of palaeoecological studies of lakes and mires*. J. Wiley and Sons, Chichester, 764pp.

Birks, H.H., Battarbee, R.W., Beerling, D.J., *et al*. (1996). The Kråkenes late-glacial palaeoenvironmental project. *Journal of Paleolimnology*, 15, 281-286.

Hu, F.S., Slawinski, D., Wright, H.E., *et al*. (1999). Abrupt changes in North American climate during early Holocene times. *Nature*, 400, 437-440.

Birks, H.H. and Wright, H.E. (eds) (2000). Special Issue: The Reconstruction of the Late-Glacial and Early-Holocene Aquatic Ecosystems in Kråkenes Lake, Norway. *Journal of Paleolimnology*, 23, 115pp.

Ahlberg, K., Almgren, E., Wright, H.E., *et al*. (2001). Holocene stable-isotope stratigraphy at Lough Gur, County Limerick, western Ireland. *The Holocene*, 11, 367-372.

Yu, Z. and Wright, H.E. (2001). Response of interior North America to abrupt climate oscillations in the North Atlantic region during the last deglaciation. *Earth-Science Reviews*, 52, 333-369.

Blyakharchuk, T.A., Wright, H.E., Borodavko, P.S., *et al*. (2003). The development of the landscape of the central Altai Mountains in the late Glacial and Holocene according to pollen data from three lakes on the Ulagan plateau. *Palaeogeography Palaeoclimatology Palaeoecology*, 209, 259-279.

Wright, H.E. and Thorpe, J.L. (2004). Climatic change and the origin of agriculture in the Near East. In: Mackay, A.W., Battarbee, R.W., Birks, H.J.B., *et al*. (eds) *Global Change in the Holocene*. Arnold, London, 49-62.

Wright, H.E. (2005). Contrasts in the Quaternary of mid-North America and mid-Eurasia: notes on Quaternary landscapes of western Siberia. *Journal of Quaternary Science*, 20, 813-819.

Stefanova, I., Lazarova, M. and Wright, H.E. (2006). Elevational gradients during the Late Glacial/Holocene vegetational transition. *Vegetation History and Archaeobotany*, 15, 215-230.

Blyakharchuk, T.A., Wright, H.E., Borodavko, P.S., *et al*. (2007). Late Glacial and Holocene vegetational history of the Altai Mountains (southwestern Tuva Republic, Siberia). *Palaeogeography Palaeoclimatology Palaeoecology*, 245, 518-534.

Blyakharchuk, T.A., Wright, H.E., Borodavko, P.S., *et al*. (2008). The role of pingos in the development of the Dzhangyskol lake-pingo complex, central Altai Mountains, southern Siberia. *Palaeogeography Palaeoclimatology Palaeoecology*, 257, 404-420.

Wasylikowa, K., van Zeist, W., Wright, H.E., *et al*. (2008). The Lake Zeribar palaeoecology: a synthesis. In: Wasylikowa, K. and Witkowski, A. (eds) *The Palaeoecology of Lake Zeribar and Surrounding Areas, Western Iran, During the Last 48,000 Years*. ARG Gantner Verlag KG, Ruggell, Diatom Monographs 8, 303-322.

Wright, H.E. (2010). High points in paleolimnological studies as viewed by a convert. *Journal of Paleolimnology*, 44, 497-503.

Ammann, B., Wright, H.E., Stefanova, V., *et al*. (2013). The role of peat decomposition in patterned mires: a case study from the central Swiss Alps. *Preslia*, 85, 317-332.

Ammann, B., van der Knaap, W.O., Lang, G., *et al*. (2014). The potential of stomata analysis in conifers to estimate presence of conifer trees: examples from the Alps. *Vegetation History and Archaeobotany*, 23, 249-264.

Sedimental Journeys web-site

The web-site http://www.eecrg.uib.no/SedimentalJourneys.htm has many contributions from Herb's friends and colleagues about his life and legacy. It contains a detailed biography of Herb, a complete list of his publications 1943-2014, many picture galleries and presentations, accounts of field expeditions, a school essay written by Herb in 1932, a history of the LRC, and poems written in his honour on the occasions of his 80th and 90th birthdays.

John and Hilary Birks
Department of Biology
University of Bergen
Postbox 7803
N-5020
Norway
john.birks@uib.no
hilary.birks@uib.no

NEW RESEARCHERS AWARD SCHEME

REINTERPRETING THE PATTERN AND STYLE OF LAST CORDILLERAN ICE SHEET RETREAT ON THE THOMPSON PLATEAU, BC, CANADA.

Introduction and Rationale

The last Cordilleran Ice Sheet (CIS) over British Columbia (BC) lacks detailed study compared with coeval ice sheets. The prevailing conceptual model for the deglaciation of the southern interior plateau is of stagnation and downwasting (Fulton, 1991). This model has been used to explain the apparent lack of recessional moraines and accounts for the presence of glacial lakes in the Nicola and Thompson valleys as dammed by lobes of dead ice in valley bottoms where ice was thickest (Fulton, 1969). This conceptual model is contrary to contemporary ice sheets, where retreat was generally more active and punctuated by readvances. Recent studies have reconstructed systematic retreat of the CIS on the southern Fraser Plateau on the basis of meltwater landforms (Margold *et al*., 2013; Perkins and Brennand, 2015) and moraines (Perkins, 2015). This project is a reinvestigation of the deglacial landforms of the Nicola and Thompson basins, and tests competing stagnation and systematic retreat hypotheses at the key site in the development of the former (Fulton, 1967).

Preliminary Results

A key finding of this project is the identification of ice-flow-transverse ridges around the northern and eastern parts of the Nicola Basin, particularly around Chapperon Lake (Figure 1A). Sediment exposures within some of these ridges reveal stacked till, glaciofluvial gravel, and folded and faulted laminated silt and clay, implying glaciotectonism. On this basis, the ridges are interpreted as de Geer moraines, implying active or staged retreat within the lake basin (e.g. Lindén and Möller, 2005). The moraines trend northeast to southwest, recording recession to the northwest. An exposure of interbedded grounding-line diamicton and laminated silt and clay also implies an active ice margin oscillating within the lake basin. Active recession is further implied by two separate grounding line deposits, to the north and west of the Nicola Basin (Figure. 1A), identified on the basis of glaciotectonised gravel and diamicton overlying and overlain by lake sediment, which imply limited readvances into the ice-dammed lake.

On the basis of the elevations of deltas and shorelines, and the extent of lake bottom sediment, five lake stages for glacial Lake Nicola (gLN) have been reconstructed in the Nicola Basin (Figure 1), adding one (Chapperon stage; Figure 1B) to

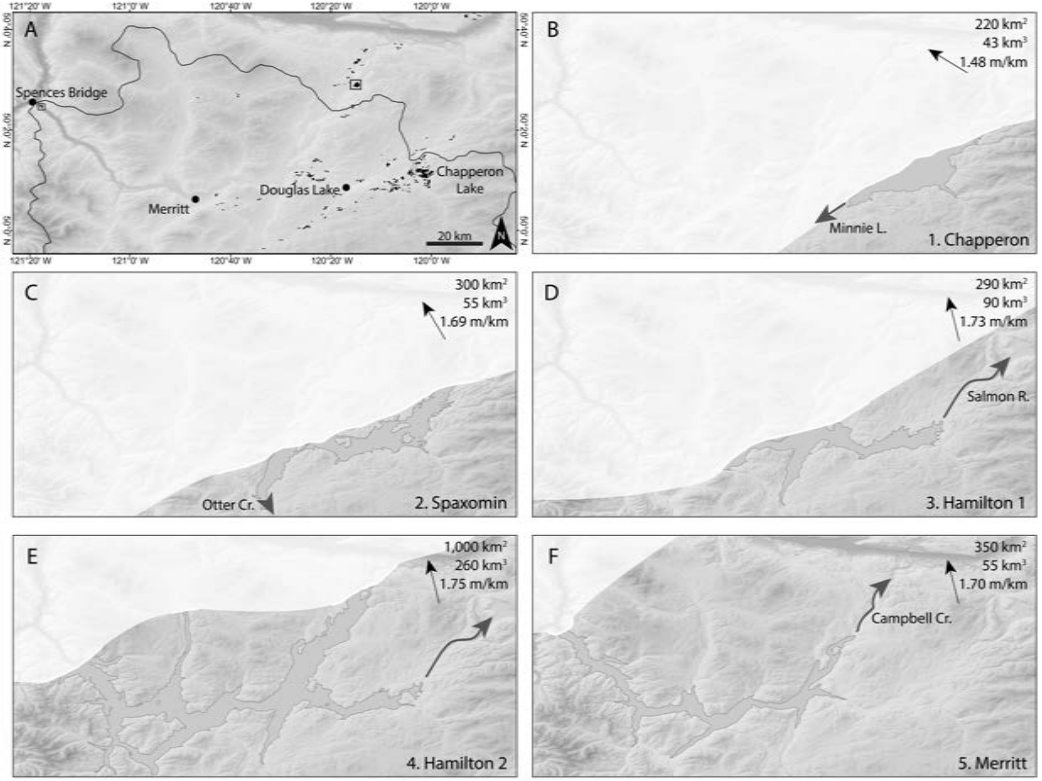


Figure 1. Reconstructed glacial lake stage (dark grey) and ice margin (white) history for the Nicola Basin (outlined), demonstrating systematic northwestward retreat of a contiguous ice margin. A: Locations of moraines (black lines) and grounding line deposits (within black boxes); B–F: Glacial lake stages: Chapperon (B), Spaxomin (C), Hamilton 1 (D), Hamilton 2 (E), and Merritt (F). Reconstructed area and volume of each lake stage is noted in top right. Large arrows show lake outflows; small arrows show direction of reconstructed glacioisostatic gradient, with magnitude of tilt noted.

those previously reconstructed (Matthews, 1944; Fulton and Walcott, 1975), and clarifying the extent of the Quilchena stage towards the east of the basin, renaming it the Spaxomin stage (Figure 1C). The lake expanded and lowered to the northwest as progressively lower outlets were opened by ice recession in this direction. Glacioisostatic tilts, reconstructed for each lake stage using the elevation of mapped shorelines derived from DEMs, record consistent tilts to the northwest of around 1.7 m/km (Figure 1). This implies an ice surface slope down to the southeast, and likely active ice flow in this direction. Therefore, the reconstructed lakes support interpretations from the de Geer moraines, recording ice recession was to the northwest along a generally contiguous ice margin, rather than stagnation and downwasting as previously proposed.

Investigations within the lake outflows from the Nicola Basin have revealed potential outburst flood sediments and landforms. In particular Campbell Creek, the outflow for the Merritt stage, resembles a recessional cataract upstream, and downstream contains coarse boulder bars and terraces. Where Campbell Creek enters the Thompson Valley, a large gravel deposit overlies lake silts, and comprises trough and antidune cross-bedded sand and gravel, in turn overlain by deltaic foresets prograding to the higher stage of glacial Lake Thompson (gLT; Johnsen and Brennand, 2004). The topsets of this delta contain coarse cobble-boulder gravel, with large diamicton intraclasts, while the foresets are overlain by further fine lake sediments. This deposit is interpreted as a high energy flood into gLT accounting for the coarse deposits, with a return to low energy conditions recorded in the overlying silt. This flood also accounts for the upstream landforms of Campbell Creek, and occurred from a breach of the ice dam impounding the Hamilton 2 stage (Figure 1E) that drained to the lower Merritt stage (Figure 1F). Initial numerical modelling estimates peak discharge of this flood in the order of $10^5\ m^3s^{-1}$.

Conclusions

The lake and ice margin reconstructions presented here support the generally systematic retreat of a contiguous ice margin to the northwest, consistent with interpretations further north on the southern Fraser Plateau (Margold *et al*., 2013; Perkins and Brennand, 2015). Further, glaciotectonic moraines, overridden lake sediments and grounding line deposition within the basin imply active recession and readvances, supported by glacioisostatic tilt to the northwest, implying an ice surface slope down to the southeast. These results encourage the rejection of the CIS stagnation hypothesis within its key type site, and suggest this paradigm requires thorough reappraisal.

Acknowledgments

We greatly appreciate the financial support of the Quaternary Research Association in the form of a New Research Worker's Award. Funding for this project was also provided by a BSG Postgraduate Research Award and a GSA Graduate Research Grant award to J.E. Cripps, and an NSERC Discovery Grant and an SFU VPR Bridging Grant awarded to T.A. Brennand. The landowners of the Nicola and Thompson basins are thanked for permitting land access throughout this project. The Upper Nicola Indian Band is also thanked for providing logistical support. Suzann Rowden, Kate Bujnowicz, Qihao (George) Sun and Rahim Gaidhar provided valuable field assistance.

References

Fulton, R.J. (1967). *Deglaciation studies in Kamloops region, an area of moderate relief, British Columbia.* Geological Survey of Canada Bulletin*,* 154, 36 pp.

Fulton, R.J. (1969). Glacial lake history, Southern Interior Plateau, British Columbia. *Geological Survey of Canada,* Paper 69/37.

Fulton, R.J. (1991). A conceptual model for growth and decay of the Cordilleran Ice Sheet. *Geographie physique et Quaternaire*, 45, 281-286.

Fulton, R.J. and Walcott, R.I. (1975). Lithospheric flexure as shown by deformation of glacial lake shorelines in southern British Columbia. *GSA Memoir*, 142, 163-173.

Johnsen, T.F. and Brennand, T.A. (2004). Late-glacial lakes in the Thompson Basin, British Columbia: paleogeography and evolution. *Canadian Journal of Earth Sciences*, 41, 1367-1383.

Lindén M. and Möller P. (2005). Marginal formation of De Geer moraines and their implications to the dynamics of grounding-line recession. *Journal of Quaternary Science,* 20, 113-133.

Margold, M., Jansson, K.N., Kleman, J. Stroeven, A.P. and Clague, J.J. (2013). Retreat pattern of the Cordilleran Ice Sheet in central British Columbia at the end of the last glaciation reconstructed from glacial meltwater landforms. *Boreas*, 42, 830-847.

Matthews, W.H. (1944). Glacial lakes and ice retreat in south-central British Columbia. *Transactions of the Royal Society of Canada*, 38, 39-57.

Perkins, A.J. (2015). Refining the Pattern and Style of Deglaciation on the Southern Fraser Plateau and Environs. Unpublished Ph.D. Thesis, Simon Fraser University, 293 pp.

Perkins, A.J. and Brennand, T.A. (2015) Refining the pattern and style of Cordilleran Ice Sheet retreat: palaeogeography, evolution and implications of lateglacial ice-dammed lake systems on the southern Fraser Plateau, British Columbia, Canada. *Boreas*, 44, 319-342.

Jonathan E. Cripps
Department of Geography, Simon Fraser University
8888 University Drive
Burnaby, BC, Canada
jecripps@sfu.ca

Tracy A. Brennand
Department of Geography, Simon Fraser University
8888 University Drive
Burnaby, BC, Canada
tabrenna@sfu.ca

DEVELOPING A CRYPTOTEPHRA FRAMEWORK FOR NORTH AMERICA: TRACE ELEMENT CHARACTERISATION OF HOLOCENE TEPHRA FROM NORTHWESTERN SOURCES

Background and rationale

The main source areas for tephra deposits found across Alaska and northern Canada are the Aleutian Arc-Alaska Peninsula and Wrangell volcanic field. Within these geologically active areas 96 of Alaska's 130 volcanoes and volcanic fields are known to have been active either historically or within the Holocene (Miller *et al*., 1998; Alaska Volcano Observatory, 2014). Recently discovered ultra-distal cryptotephra records (>5,000km from their source) have expanded the known distribution of Holocene beds from Alaska and the Cascades into eastern Canada (Pyne-O'Donnell *et al*., 2012), the eastern United States (Jensen *et al*., 2014a ; Mackay *et al*., 2016), and Europe (Jensen *et al*., 2014b; Figure 1). This indicates the potential for developing a cryptotephra framework across North America and beyond.

To date, the majority of tephra studies in northwestern North America have been limited to areas where visible tephra are present. There are proximal records for several specific volcanic sources, or projects focused on key sites in southwest Alaska and the eastern Aleutian arc, however many of these studies report bulk whole rock analyses which are not comparable with data from distal glass samples. A complete characterisation of tephra attributes is needed in order to distinguish between eruptions that have similar or identical major element geochemistry, particularly in this region where frequently erupting volcanoes and large multifaceted eruptions are common.

In order to support on-going work developing cryptotephra major element geochemistry datasets, the trace element characterisation of tephra from three sites in Alaska and the Yukon Territory using Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) (Pearce *et al*., 2011) was undertaken at Aberystwyth University. This was supported in part by the QRA New Workers Research Award, as well as funds from the Natural Science and Engineering Research Council of Canada.

Preliminary Results

Individual glass shards from a total of 25 tephra samples were analysed in January 2016; these included 22 distal cryptotephra from three different sites and 3 newly characterised proximal samples from the early Holocene caldera eruption of Fisher (Carson *et al*., 2002). These samples were chosen to target specific questions regarding eruptive histories (e.g. reworking vs. multiple eruptions), test distal

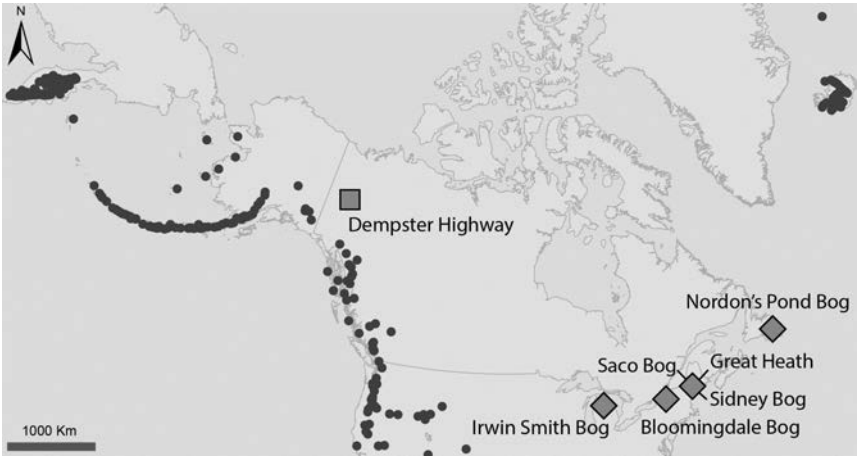


Figure 1. Map showing sites with ultra-distal cryptotephra records in North America (diamonds) and a distal site in the central Yukon Territory referred to in this report (Dempster Highway; square). Black circles represent volcanoes known to have been active in the Holocene (Siebert et al., 2010).

correlations, and investigate samples which do not correlate with well-known tephra and have no currently identified sources.

Eight of the cryptotephra analysed had major element geochemistry indistinguishable from the White River Ash sourced from Mt. Churchill, the closest volcano to the Dempster Highway coring site in central Yukon Territory (Figure 1) known to be active in the Holocene. At proximal sites the White River Ash tephra (comprising at least two eruptive events) have very similar major element data, but subtle variations in their trace element and associated mineral geochemistry have been interpreted as evidence for multiple closely spaced eruptions or the eruption of a zoned magma body (Preece *et al*., 2014). The cryptotephra analysed here, however, are deposited at different times with separate peaks in shard concentration; trace element analyses were undertaken to help determine if they represent reworking or multiple primary ashfall events. The new data show subtle variations similar to those previously reported and Principle Components Analysis has been undertaken to establish which elements are responsible for the variation and if that supports the hypothesis of multiple eruptions.

A potential distal correlative for the caldera forming eruption of Fisher, not previously reported outside of the Aleutians, has major element data that match well with concurrently analysed proximal material. However, this complex caldera formation has four associated tephra identified in the proximal record based on stratigraphy and major element geochemistry. The trace element data produced

here show a wide range of analyses both within and between the proximal samples, most likely demonstrating crystal fractionation.

Significance

These new analyses allow detailed investigation of tephra from northwestern North American sources, particularly those which have the potential to be far-travelled and widely utilised. Additionally, they provide a dataset of glass analyses for multiple Holocene eruptions and various sources to aid future work.

The comparison of fully characterised tephra deposits from proximal, distal, and ultra-distal settings allows complex volcanic histories and issues of preservation (e.g. reworking, taphonomy) to be identified. This also highlights areas of importance that warrant further examination. Additionally, it allows tephra deposits to be reliably employed in other fields e.g. as chronostratigraphic tools, to test geophysical models, and to inform modern hazard assessments. North American cryptotephra, which are currently undergoing an upturn in interest, are increasingly reported at new locations and new data, such as produced here, supports their continued use and enhances their utility.

Acknowledgements

Trace element analyses undertaken at the University of Aberystwyth were enabled by the Quaternary Research Association New Research Worker's Award, and funds from the Natural Science and Engineering Research Council of Canada. The support of my supervisor, Dr. Duane Froese, is gratefully acknowledged, as is the help of Prof. Nick Pearce in undertaking the research and data analyses. Many thanks to Dr. John Fournelle and Dr. Eric Carson for providing proximal samples of tephra from Fisher for analysis.

References

Alaska Volcano Observatory (2014). *Alaska Volcano Observatory Online Library*. Available at: http://www.avo.alaska.edu/downloads/. [Accessed 30 September 15].

Carson, E.C., Fournelle, J.H., Miller, T.P. and Mickelson, D.M. (2002). Holocene tephrochronology of the Cold Bay area, southwest Alaska Peninsula. *Quaternary Science Reviews*, 21, 2213-2228.

Jensen, B., Mackay, H., Pyne-O'Donnell, S., Plunkett, G., Hughes, P., Froese, D. and Booth, R. (2014a). Exceptionally Long Distance Transport of Volcanic Ash: Implications for Stratigraphy, Hazards and the Sourcing of Distal Tephra Deposits. *AGU Fall Meeting Abstracts*, 1, 03.

Jensen B.J.L, Pyne-O'Donnell S., Plunkett G., Froese, D.G., Hughes, P.D.M., Sigl, M., McConnell, J.R., Amesbury, M.J., Blackwell, P.G., van den Bogaard, C., Buck, C.E., Charman, D.J., Clague, J.J., Hall, V.A., Koch, J., Mackay, H., Mallon, G., McColl, L., and Pilcher, J.R. (2014b). Transatlantic distribution of the Alaskan White River Ash. *Geology*, 42, 875–878.

Mackay, H., Hughes, P.D.M., Jensen, B.J.L., Langdon, P.G., Pyne-O'Donnell, S.D.F., Plunkett, G., Froese, D.G., Coulter, S. and Gardner, J.E. (2016). A mid to late Holocene cryptotephra framework from eastern North America. *Quaternary Science Reviews*, 132, 101-113.

Miller, T.P., McGimsey, R.G., Richter, D.H., Riehle, J.R., Nye, C.J., Yount, M.E., and Dumoulin, J.A. (1998). *Catalog of the historically active volcanoes of Alaska: U.S. Geological Survey Open-File Report OF* 98-0582, 104 p.

Pearce, N.J.G., Perkins, W.T., Westgate, J.A. and Wade, S.C. (2011). Trace-element microanalysis by LA-ICP-MS: The quest for comprehensive chemical characterisation of single, sub-10 μm volcanic glass shards. *Quaternary International*, 246, 57-81.

Preece, S.J., McGimsey, R.G., Westgate, J.A., Pearce, N.J.G., Hart, W.K. and Perkins, W.T. (2014). Chemical complexity and source of the White River Ash, Alaska and Yukon. *Geosphere*, 10, 1020-1042.

Pyne-O'Donnell, S.D.F., Hughes, P.D.M., Froese, D.G., Jensen, B.J.L., Kuehn, S.C., Mallon, G., Amesbury, M.J., Charman, D.J., Daley, T.J., Loader, N.J., Mauquoy, D., Street-Perrott, F.A. and Woodman-Ralph, J. (2012). High-precision ultra-distal Holocene tephrochronology in North America. *Quaternary Science Reviews*, 52, 6-11.

Siebert, L., Simkin, T., Kimberly, P. (2010) *Volcanoes of the World*, 3rd ed. Berkley: University of California Press, 586 pp.

Lauren Davies
1-26 Earth Sciences Building
University of Alberta
Department of Earth and Atmospheric Sciences
Edmonton, AB
T6G 2E3
ljdavies@ualberta.ca

BUILDING A NEW CLIMATE CHANGE RECORD FROM MIS10 UNTIL THE HOLOCENE FOR THE ITALIAN PENINSULA

Background and rationale

Rainwater infiltrating through the soil enters a cave through the fractures of the limestone bedrock dissolving it and becoming enriched in Ca and Carbonate. Once in the cave, the CO_2 contained in the drop of water degasses and $CaCO_3$ re-precipitates forming speleothems (i.e. stalagmites). As speleothems slowly grow, they lock into their layers the chemical signatures of the rainwater, acting like 'weather stations'. To gain palaeoclimatic information from speleothems, petrographic, isotope ($\delta^{18}O$ and $\delta^{13}C$) and trace elements variability are required, and their chronology is constrained by U-Th dating (Fairchild and Baker 2012). The current research focuses on a multi-proxy study of stalagmites collected from the sites of Frasassi (Central Italy) and Lamalunga (South Italy) caves, on the East coast of the Italian Peninsula. Lamalunga contains a complete Neanderthal skeleton coated by coralloid speleothem crusts, making this cave particularly important for paleoanthropological reasons. The interest into Frasassi surrounds it being a hypogenic cave system that develops because of the corrosive action of sulfidic waters and vapours. The record from Frasassi complements that of Lamalunga.

Expenses for the 2015 fieldwork campaign were supported by the QRA New Research Workers Award. Six stalagmites were sampled at Frasassi and seven coralloids associated with the bones were collected from Lamalunga cave (see Figure 1 for examples). A total of 153 U-Th analyses of Frasassi and Lamalunga samples were performed using multi-collector inductively coupled plasma-mass spectrometry at the University of Melbourne.

Results

With the new stalagmites sampled at Frasassi cave, it has been possible to improve accuracy of previous existing chronology (Taddeucci 1994) and extend the record from 380 ka to the Holocene (MIS 10b - MIS 1) confirming that speleothems have been continuously growing in the Frasassi cave system. The ages of the coralloids from Lamalunga cave in association with the human bones span from 53 ka to 3.8 ka (MIS 3 – MIS 1).

Significance

The continuous record from Frasassi cave will permit the reconstruction of climate change over the last 380 ka. The new chronological database will allow this record to become a key reference point for the Mediterranean region and

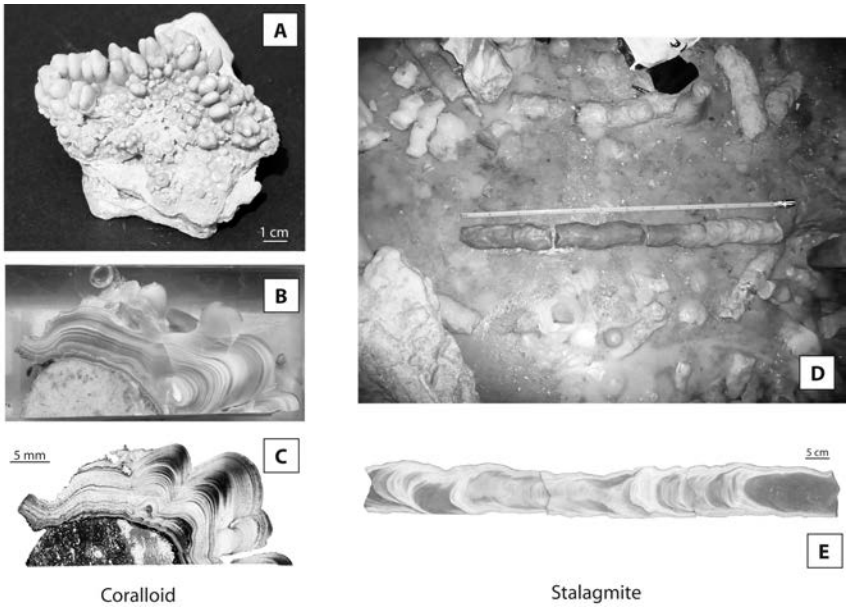


Figure 1. (A) Fragment of bed-rock covered by coralloids, (B) longitudinal section of one single coralloid and (C) photo of the same obtained with optical microscopy (Lamalunga Cave, Italy). (D) Stalagmite *in situ* and (E) its longitudinal section (Frasassi Cave, Italy).

beyond. The Lamalunga cave site provides an opportunity to test coralloids as novel archives of paleoclimate, given that they are slow-growing and highly sensitive to hydrology. Their isotopic and trace element results coupled with the Frasassi record will yield an unprecedented record of climate events over the last ~400ka.

Acknowledgments

Fieldwork expenses were supported by a QRA New Research Workers Award. The PhD research is founded by an Endeavour Award scholarship. We thank the Frasassi Cave Consortium, Sandro Mariani, the Soprintendenza Archeologia della Puglia and the Centro Altamurano Ricerche Speleologiche.

References

Fairchild, I.J. and Baker, A. (2012). Speleothem Science: From Process to Past Environments. *Wiley-Blackwell*,

Taddeucci, A., T.P., Voltaggio, M. (1994). ^{230}Th dating of the speleothems from "Grotta del Fiume-Grotta del Vento" Karst system in Frasassi (Ancona, Italy) and paleoenvironmental implications. *International Journal of Speleology*, 23, 79-90.

Valentina Vanghi
School of Environmental and Life Sciences
The University of Newcastle
Callaghan NSW 2308
Australia
valentina.vanghi@uon.edu.au

MULTIPLE MECHANISMS OF MINOR MORAINE FORMATION AT AN ALPINE VALLEY GLACIER, SILVRETTAGLETSCHER, SWITZERLAND

Background and rationale

Funding from the QRA New Research Worker's Award was used for fieldwork at Silvrettagletscher, Switzerland (Figure 1) in June and September 2015 by contributing to accommodation costs at the local mountain hut, Silvrettahütte. Fieldwork focused on detailed sedimentological and geomorphological descriptions of minor moraines in the glacier foreland.

Seven moraines without ice cores were excavated perpendicular to ridge crests for analysis in three different zones of the foreland. This allowed for observations and measurements of sedimentological landform architecture, e.g. bed or facies thickness and contacts, geometry, and deformation structures. Sedimentological observations and measurements included sediment composition and size and clast roundness and form. Control samples from englacial debris septa, subglacial, supraglacial, and glaciofluvial environments were measured to compare to exposure samples.

Geomorphological mapping of the foreland focused on the area directly in front of the modern ice front. Mapping of the ice front and foreland included a combination of field observations and aerial imagery from 2000 to 2013. The geomorphology of minor moraines in the foreland was explored through basic measurement methods on moraines that were excavated for sedimentological excavation. This included the length of the entire moraine and width in representative locations, slope angles at representative locations, and the orientation as a whole and in sections.

Results

The Silvrettagletscher foreland contains at least 100 minor moraines between the 2003 and 2015 ice margins and numerous older minor moraines. Minor moraines formed around 2003 and later have been formed in a portion of the foreland dominated by a reverse bedrock slope. The interpretation of the sedimentology in seven exposures through these moraines reveal four mechanisms of moraine formation, dependent on location in the foreland and characteristics of the ice front:

1. Melt-out of controlled moraine ice cores
2. Freeze-on of basal sediment on a reverse bedrock slope
3. Push of pre-existing sediment on a reverse bedrock slope (with and without an ice core)
4. Push of pre-existing glaciolacustrine sediment

Figure 1. The Silvrettagletscher, Switzerland, field area. (A) Location in Europe. Inset box shows location of B. (B) Location near the border between Switzerland and Austria, outside of Klosters-Serneus, Switzerland. Inset box indicates location of the Silvrettagletscher foreland. (C) Photograph of the Silvrettagletscher foreland in September 2015.

Significance

This research is only the third study to explore the detailed sedimentological composition and geomorphology of minor moraines in the Alps. Push moraines, with and without reverse bedrock slopes, have previously been described in other high-mountain settings and specifically in the Alps (Lukas, 2012; Wyshnytzky and Lukas, in prep). Freeze-on of basal till has only been described in lowland, maritime settings (Andersen and Sollid, 1971; Krüger, 1995; Evans and Hiemstra, 2005; Reinardy *et al*., 2013; Chandler *et al*., 2016). The role of controlled moraines moraines on minor moraine formation has only been described on a larger scale (Evans, 2009). The primary significance of these findings is that preexisting foreland geometry, here as a reverse bedrocks slope, can have the dominant control on minor moraine formation. Additionally, this research shows that minor moraines may form in several different ways across a single ice front, depending on sediment supply, ice front dynamics, and bedrock geometry.

Acknowledgements

CEW was funded by a Queen Mary University of London Principal's studentship while this work was carried out. This project received additional funding from the Queen Mary University of London Postgraduate Research Fund, the Royal Geographical Society Dudley Stamp Memorial Award, the International Association of Sedimentologists Postgraduate Grant Scheme, and the Quaternary Research Association New Research Worker's Award. Silvrettahütte provided necessary accommodation and logistical support.

References

Andersen, J. L. and Sollid, J. L. (1971). Glacial Chronology and Glacial Geomorphology in the Marginal Zones of the Glaciers, Midtdalsbreen and Nigardsbreen, South Norway. *Norsk Geografisk Tidsskrift – Norwegian Jounral of Geography*, 25(1), 1-38.

Chandler, B.M.P., Evans, D.J.A, and Roberts, D.H. (2016). Characteristics of recessional moraines at a temperate glacier in SE Iceland: Insights into patterns, rates and drivers of glacier retreat. *Quaternary Science Reviews*, 135, 171-205.

Evans, D.J. A. (2009). Controlled morains: origins, characteristics and palaeoglaciological implications. *Quaternary Science Reviews*, 28(3-4), 183-208.

Evans, D.J.A. and Hiemstra, J.F. (2005). Till deposition by glacier submarginal, incremental thickening. *Earth Surface Processes and Landforms*, 30(13), 1633-1662.

Krüger, J. (1995). Origin, chronology and climatological significance of annual-moraine ridges at Myrdalsjökull, Iceland. *The Holocene*, 5(4), 420-427.

Lukas, S. (2012) Processes of annual moraine formation at a temperate alpine valley glacier insights into glacier dynamics and climatic controls. *Boreas*, 41(3), 463-480.

Reinardy, B.T.I., Leighton, I., and Marx, P.J. (2013) Glacier thermal regime linked to processes of annual moraine formation at Midtdalsbreen, southern Norway. *Boreas*, 42(4), 896-911.

Wyshnytzky, C.E. and Lukas, S. (in prep) Mechanisms of minor push moraine formation in the Schwarzensteinkees, Austria, Alpine foreland.

Cianna E. Wyshnytzky
The School Of Geography
Queen Mary University of London
Mile End Road
London E1 4NS
c.e.wyshnytzky@qmul.ac.uk

QUATERNARY RESEARCH FUND

QUATERNARY GLACIERS AND CLIMATE IN THE PELOPONNESE, GREECE

Background and rationale

The mountains of the Peloponnese are strategically important for understanding the relationship between glaciers and climate because of their position at the tip of the Balkan Peninsula (Pope *et al*. 2016). It is well established that glaciers have a close relationship with climate (e.g. Ohmura *et al*., 1992) and temporally-constrained glacier-climate reconstructions from the Peloponnese will provide interesting comparisons with not only other glacial records in the Mediterranean region, but also with other records of environmental change such as fluvial sediments downstream (Woodward *et al*., 2008) as well as long lake sediment sequences (e.g. Tzedakis *et al*. 2002; Wilson *et al*., 2008). The mountains of Greece were glaciated on multiple occasions during the Pleistocene. On Mount Tymphi in NW Greece, different generations of moraines have been dated and assigned to at least three separate cold stages: the Skamnellian Stage (Marine Isotope Stage [MIS] 12); the Vlasian Stage (MIS 6), and; the Tymphian Stage (MIS 5d-2) (Hughes *et al*. 2006a).

New research funded by the QRA was undertaken in July 2015 on both Mount Chelmos and Mount Ziria (2376 m a.s.l.; also known as Mount Kyllini) c. 15 km to the east of Mount Chelmos, in collaboration with Richard Pope (University of Derby) and Emmanuel Skourtsos (University of Athens). On Mount Ziria moraines are very large and well-preserved on the western slopes and mark the margins of outlet glaciers from an ice cap that formed over the central high plateau of this mountain. The geomorphology was mapped in the field and samples were taken for ^{36}Cl exposure dating.

Results

The research in the Peloponnese by Pope *et al*. (2016) has shown that Mount Chelmos (2355 m a.s.l.; Figure 1) was glaciated by a plateau ice field during the most extensive Pleistocene glaciation. Valley glaciers radiated out from an ice field centred over the central plateau of the massif (Figure 1A). The largest glaciations were Middle Pleistocene in age and this is confirmed by U-series dating of secondary carbonate cements. Smaller valley and cirque glaciers formed later and boulders on the moraines of these glacial phases have been dated using ^{36}Cl exposure dating (Table 1). These ages indicate a Late Pleistocene age with glacier advance/stabilisation at 40-30 ka, glacier retreat at 23-21 ka and advance/stabilisation at 13-10 ka. This indicates that the glacier maximum of the last

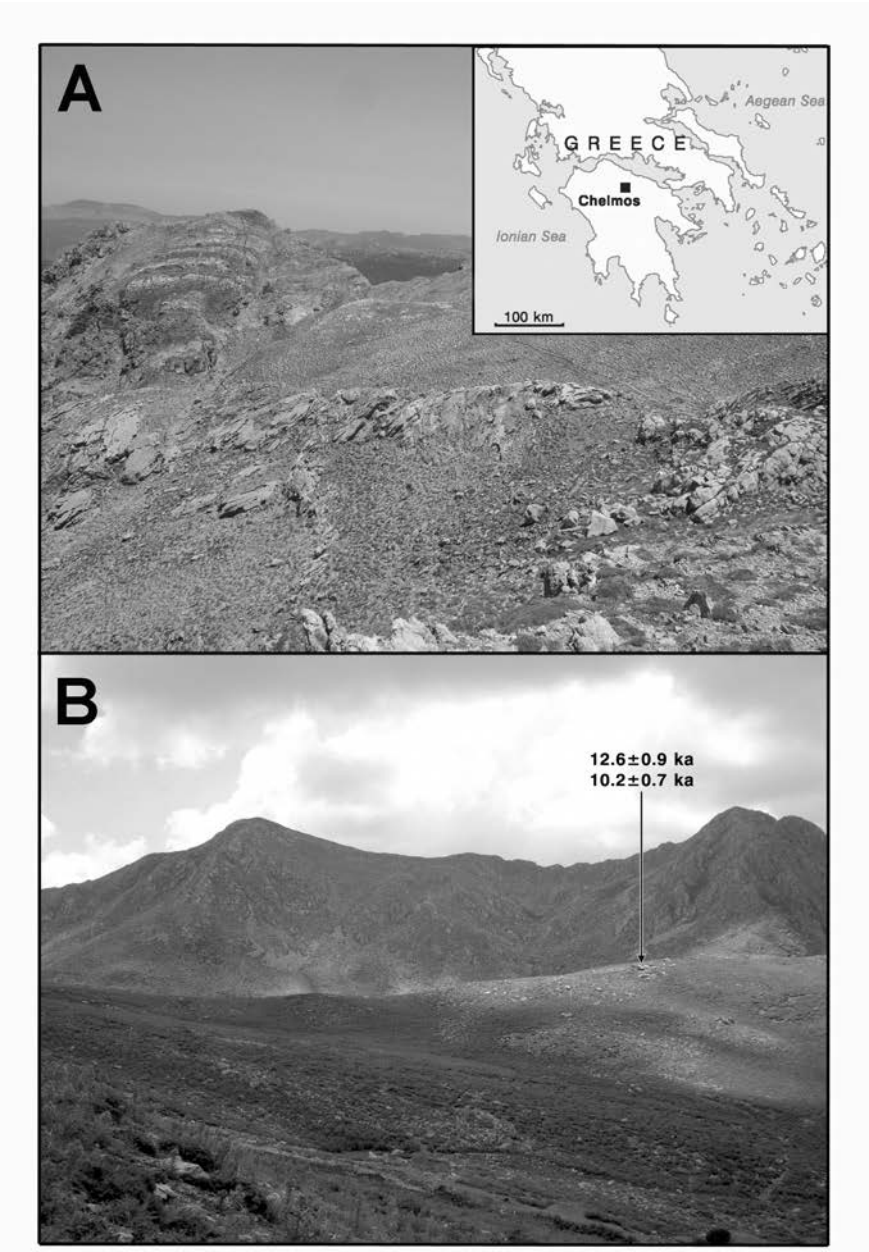


Figure 1. (A) Ice-moulded bedrock and perched glacially-transported boulders on the summit plateau of Mount Chelmos, on the northern slopes of Psili Korfi (2355 m a.s.l.), (B) Younger Dryas moraines in the northern cirque of Profitas Ilias (2282 m a.s.l.), Mount Chelmos (from Pope *et al*. 2016). The inset map shows the position of Mount Chelmos in Greece.

cold stage occurred during MIS 3, several thousand years before the global Last Glacial Maximum (LGM; MIS 2). Significantly, the last phase of moraine building occurred has been dated to the Younger Dryas (Fig. 1B).

Table 1. Summary of exposure age data (^{36}Cl) from moraine surfaces on Mount Chelmos published in Pope *et al*. (2016).

Morphostrat Unit	^{36}Cl Exposure Ages	Geomorphological context	Correlations
4	10.2 ± 0.7 12.6 ± 0.9	End moraine	Younger Dryas Glacier stabilisation/ advance
3	21.2 ± 1.6 21.6 ± 1.6 22.9 ± 1.6	Recessional moraines	LGM Glacier retreat
2	30.4 ± 2.2 39.9 ± 3.0	End moraine	MIS 3 Glacier stabilisation /advance
1	Undated	Moraines and till down-valley of unit 2	Middle Pleistocene

Significance

This is the first time moraines have been dated to this period in Greece and supports earlier suggestions from undated moraines on Mount Smolikas in northern Greece (Hughes *et al*. 2006b). The Late Pleistocene moraine chronology from Mount Chelmos provides preliminary insight into glacier history of Greece during the last cold stage. The new ^{36}Cl exposure ages not only confirm earlier suggestions of an early glacier maximum in Greece (cf. Hughes *et al*., 2006c), but also indicate the presence of glaciers in this area through the global LGM and also during the Younger Dryas. The absence of Late Pleistocene rock glaciers on Mount Chelmos may indicate wetter conditions in this area compared with further north in Greece, where rock glaciers were abundant at the global LGM (Hughes *et al*., 2003).

Acknowledgements

Richard Pope (University of Derby) and Emmanuel Skourtsos (University of Athens) for their continued collaboration and support in the field. I am grateful to the QRA for supporting this research.

References

Hughes, P.D., Gibbard, P.L., Woodward, J.C. (2003). Relict rock glaciers as indicators of Mediterranean palaeoclimate during the Last Glacial Maximum (Late Würmian) of northwest Greece. *Journal of Quaternary Science,* 18, 431-440.

Hughes, P.D., Woodward, J.C., Gibbard, P.L., Macklin, M.G., Gilmour, M.A., Smith G.R. (2006a). The glacial history of the Pindus Mountains, Greece. *Journal of Geology,* 114, 413-434.

Hughes, P.D., Woodward, J.C., Gibbard, P.L. (2006b). The last glaciers of Greece. *Zeitschrift für Geomorphologie*, 50, 37-61.

Hughes, P.D., Woodward, J.C., Gibbard, P.L. (2006c) Late Pleistocene glaciers and climate in the Mediterranean Region. *Global and Planetary Change*, 50, 83-98.

Ohmura, A., Kasser, P., Funk, M. (1992) Climate at the equilibrium line of glaciers. *Journal of Glaciology* 38, 397-411.

Pope, R.J., Hughes, P.D., Skourtsos, E. (2016). Glacial history of Mt Chelmos, Peloponnesus, Greece. In: Hughes, P.D., Woodward, J.C. (2016) *Quaternary glaciation in the Mediterranean Mountains*. Geological Society of London Special Publications 433. http://doi.org/10.1144/SP433.11

Tzedakis P.C., Lawson I.T., Frogley M.R., Hewitt G.M., Preece R.C. (2002). Buffered Tree Population Changes in a Quaternary Refugium: Evolutionary Implications. *Science*, 297, 2044-2047.

Wilson, G.P., Reed, J.M., Lawson, I.T., Frogley, M.R., Preece, R.C., Tzedakis, P.C. (2008). Diatom response to the last Glacial-Interglacial transition in the Ioannina basin, northwest Greece: implications for Mediterranean palaeoclimate reconstruction. *Quaternary Science Reviews*, 27, 428-440.

Woodward, J.C., Hamlin, R.H.B., Macklin, M.G., Hughes, P.D., Lewin, J. (2008). Glacial activity and catchment dynamics in northwest Greece: Long-term river behaviour and the slackwater sediment record for the last glacial to interglacial transition. *Geomorphology*, 101, 44-67.

Philip Hughes
Geography
School of Environment, Education and Development
The University of Manchester
Manchester M13 9PL
philip.hughes@manchester.ac.uk

NORTHEAST GREENLAND CAVES PROJECT: CONSTRUCTING A SPELEOTHEM-DERIVED RECORD OF CLIMATE CHANGE FOR THE ARCTIC

Background and rationale

Multiple lines of evidence currently demonstrate that the climate is changing across our planet (Cubasch *et al*., 2013), and that the Arctic in particular is especially vulnerable to these changes, warming up twice as fast as the global average (Bekryaev *et al*., 2010). Understanding how the climate in the Arctic will develop in the future and its subsequent effects is thus a major concern. At present, some of the highest quality palaeoclimate records for the Arctic are available from the Greenland ice cores (e.g., Johnson *et al*., 1992; Dansgaard *et al*., 1993; Grootes *et al*., 1993; NGRIP, 2004; NEEM, 2013), with both the NGRIP (NGRIP, 2004) and NEEM (NEEM, 2013) ice cores containing valuable information about the climate during the Last Interglacial. Unfortunately, records that cover previous interglacials in Greenland are absent yet highly important for facilitating understanding of how the present interglacial may develop.

This project seeks to address this fundamental knowledge gap, by creating the first speleothem-derived palaeoclimate record for Greenland. Caves containing speleothem deposits are present at 80.2°N in Kronprins Christian land, Northeast Greenland (Davies and Krinsley, 1960). Today, the caves are located in a semi-arid permafrost region, hence modern speleothem deposition is not possible. The presence of the speleothem deposits thus indicates a previous wetter and warmer climate. Through analysis of the speleothem deposits, this project seeks to establish: 1) when in the geologically recent past was Greenland warmer than today? and 2) what was the nature of the climate during those warm intervals?

Results and Significance

Thanks, in part, to support from the QRA Research Fund, an expedition to the caves took place during the summer of 2015 (Figure 1). After seven days of travelling by air, boat and foot, five people spent three days documenting 26 caves and collecting 16 pilot speleothem samples. Results from the preliminary U-Th and stable isotope analyses of the samples are encouraging, and demonstrate the potential of using speleothem records to extend our knowledge of interglacial climates in Greenland during the mid-Pleistocene.

Acknowledgements

NEGCP would like to thank CASP, Jean-François Loubiere, Prof. Paul Smith, and Polarsphere Ltd for assistance with logistics and planning, and Dr. Yanbin Lu for laboratory assitance. The expedition was funded and sponsored by National

Figure 1. Looking out of one of the larger cave entrances in the valley of Grottedalen, Kronprins Christian land, Northeast Greenland.

Geographic Society, University of Innsbruck Nachwuchsförderung, University of Minnesota, Comer Family Foundation, Petzl Foundation, Go Balance Ltd. (formerly Celestial Green Ventures), Phil and Lin Shone, Innsbruck Quaternary Research Group, Gina Moseley, Mount Everest Foundation, Austrian Academy of Sciences General Promotions Fund, British Cave Research Association, Transglobe Expedition Trust, Robbie Shone, Sue & Pete Moseley, National Speleological Society, Quaternary Research Association, Wilderness Lectures, Ghar Parau Foundation, Limestone Research & Consultancy Ltd., Andy Eavis, Joe Immen, Thomas Arbenz, Chris Blakeley, Harry & Alice Carson, Russell Dowling, Per Ellingson, Ian Fairchild, David Gibson, Glenys Hawkins, Mike Higgins, Amy Hinkle, Chris & Julie Leech, Kate Newton, Lindsey Nicholson, Jonathan Vetterlein, Jeff Wade, Petzl, Hilti, Ortlieb, Voltaic, Swarovski Optik, Suunto, Bellroy, Virgin Balloon Flights, The Megha Bag, Scanlico Denmark.

References

Bekryaev, R.V., Polyakov, I. V., Alexeev, V.A. (2010). Role of polar amplification in long-term surface air temperature variations and modern Arctic warming. *Journal of Climatology*, 23, 3888-3906.

Cubasch, U., Wuebbles, D. Chen, M.C. Facchini, D. Frame, N. Mahowald, Winther, J.-G. (2013). Introduction. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group 1 to the Fifth Assessment Report*

of the intergovernmental Panel on Climate Change. Stocker, T.F., Qin, D., Plattner, G.-K., Tignor, M., Allen, S. K., Boschung, J., Nauels, A., Xia, Y., Bex, V., Midgley, P. M. (eds) Cambridge University Press, Cambridge, UK & New York, USA. pp 119-158.

Dansgaard, W., Johnsen, S. J., Clausen, H. B., Dahl-Jensen, D., Gundestrup, N. S., Hammer, C. U., Hvidberg, C. S., Steffensen, J. P., Sveinbjörnsdottir, A. E., Jouzel, J., Bond, G. (1993). Evidence for general instability of past climate from a 250-kyr ice-core record. *Nature,* 364, 218-220.

Davies, W.E. and Krinsley, D.B. (1960). Caves in Northern Greenland. *NSS Bulletin*, 22, 114-116.

Grootes, P.M., Stuvier, M., White, J. W. C., Johnsen, S., Jouzel, J. (1992). Comparison of oxygen-isotope records from the GISP2 and GRIP Greenland ice cores. *Nature*, 366, 552-554.

Johnsen, S.J., Clausen, H. B., Dansgaard, W., Fuhrer, K., Gundestrup, N., Hammer, C. U., Iverson, P., Jouzel, J., Stauffer, B., Steffensen, J. P. (1992). Irregular glacial interstadials recorded in a new Greenland ice core. *Nature*, 359, 311-313.

North Greenland Eemian Ice Drilling (NEEM) Community members. (2013). Eemian interglacial reconstructed from a Greenland folded ice core. *Nature*, 493, 489-494.

NorthGRIP project members. (2004). High-resolution record of Northern Hemisphere climate extending into the last interglacial period. *Nature*, 431, 147-151.

Gina E. Moseley
Institute of Geology, University of Innsbruck
Innrain 52
A-6020 Innsbruck
Austria
gina.moseley@uibk.ac.at

R. Lawrence Edwards
Department of Earth Sciences, University of Minnesota
310 Pillsbury Drive St.
Minneapolis
MN 55455-0231
United States
edwar001@umn.edu

Hai Cheng
Institute of Global Environmental Change, Xi'an Jiaotong University
West No. 1 Building
Quijang Campus
No 99 Yanxiang Road
Xi'an
China
cheng021@mail.xjtu.edu.cn

Christoph Spötl
Institute of Geology, University of Innsbruck
Innrain 52
A-602- Innsbruck
Austria
christoph.spoetl@uibk.ac.at

REPORTS

QRA ANNUAL DISCUSSION MEETING
QUATERNARY DRIVERS AND RESPONDERS

Royal Holloway, University of London, 6th to 9th January, 2016

The **2016 Annual Discussion Meeting** of the QRA was hosted by the Centre for Quaternary Research (CQR) at Royal Holloway, University of London, from 6th to 8th January, 2016, and followed on 9th January by a QRA-sponsored **Public Science Day**.

The ADM was co-ordinated by **Danielle Schreve**, **Ian Candy** and **John Lowe**, with support from **CQR** staff members and postgraduate students in the organisation, logistics and running of the event. The meeting attracted just over 150 registered participants (Figure 1), drawn from universities and other research organisations in the UK ranging from Southampton and Plymouth in the south to St. Andrews in the north, and from Aberystwyth and Belfast in the west, to York and Hull. Overseas participants attended from the Republic of Ireland, Finland, Denmark, The Netherlands, Norway, Sweden and Italy. Around one third of the attendees were postgraduate students.

Figure 1. The audience in a packed lecture theatre in the Boiler House Complex at Royal Holloway, University of London.

The theme of the meeting was '*Quaternary Drivers and Responders'*. The principal aim was to explore and to better understand the manner and rates of response of different Earth system components to key forcing factors, while noting the problems of establishing causal connectivity in the Quaternary record. To ensure breadth of focus, talks were arranged in five thematic sessions to consider different forcing factors operating over (1) long-term change, (2) interglacial and (3) glacial cycles, and (4) the Holocene period, while a fifth session was devoted specifically to aspects of geomorphological response to environmental forcing factors. The tone was set for each of the five sessions by the following invited Keynote Speakers: **Erin McClymont**, Durham University (long-term change), **Eric Wolff**, Cambridge University (interglacials), **Sune Rasmussen**, **Niels Bohr** Institute, Copenhagen (glacials), **Anna Hughes**, Bergen University (geomorphic response), and **Dominik Fleitmann**, Reading University (Holocene). Keynotes were followed by speakers presenting evidence of responses from a range of proxy records. **Sune Rasmussen's** contribution was sponsored by Wiley, publishers of *Journal of Quaternary Science*, as **the Annual Wiley Lecture**.

The organisers of the meeting wish especially to thank the following Chairpersons who not only kept the meeting to schedule in admirable fashion, but also orchestrated lively and engaging debates in each of the discussion intervals**: Derek Fabel**, SUERC, Glasgow (*Long-Term Change*), **Kirsty Penkman**, York University *(Interglacials*), **Christine Lane**, The University of Manchester (*Glacials*), **Clare Boston**, Portsmouth University (*Geomorphic Processes*) and **Pete Langdon**, Southampton University (*The Holocene*).

After **Erin McClymont's** keynote 'Evolution of sea surface and intermediate water temperatures through the Pleistocene: implications for the Mid-Pleistocene Transition' the *Long-term Change* session on Wednesday continued with **Anna Bird** (University of Hull) talking about the provenance of Chinese Loess Plateau since the Pliocene using isotopic signatures and **Dave Mattey** (Royal Holloway, University of London) who discussed the record of environmental change and regional climate change over multiple ice age cycles from speleothem archives of caves in Gibraltar. After lunch the session continued with **Luca Bellucci** (La Sapienza, Rome) presenting a review of Galerian fauna in the Italian peninsular and the implications for human settlement, then **Tim Atkinson** (University College, London), who took us through the isotopic composition of precipitation in Britain through glacial-interglacial cycles, **Jim Rose** (Royal Holloway, University of London), who considered the factors forcing mid-latitude Quaternary landscape change and **Rob Westaway** (University of Glasgow) completed the session with a talk about the feedbacks between climate change and landscape evolution in fluvial sequences. After half an hour of discussion on talks in this session, we broke for tea and coffee and poster perusal before a fully attended AGM in which we confirmed our four Honorary Memberships to Chris Caseldine, Rick Shakesby, Tony Stuart and David Sugden, and also awarded the QRA medals to Tom White (Lewis Penny Medal and Alayne Street-Perrot (Croll Medal).

Day 2 started with the *Interglacials* session and the keynote from **Eric Wolff** 'Interglacials – what, when and why?'. This was followed by **Tom White** (University of Oxford) presenting a review of the British Pleistocene through multiproxy reconstructions of interglacial climate; **David Horne** (Queen Mary, University of London), who looked at fossils in human occupation as a record of human dispersal in the European Middle Pleistocene; **Francis Rowney** (Plymouth University), who presented a new high-resolution, multi-proxy record for the Cromerian stratotype at West Runton, and a presentation by **Anna March** (Queen Mary, University of London) on the response of lacustrine fauna to climate change in MIS-11 at Marks Tey in Essex. The session continued after the tea and coffee break with **Barbara Mauz** (University of Liverpool) taking us to the eastern Mediterranean and the records of Last Interglacial sea-level oscillations recorded at the site of Hergla. **Alice Milner** (Royal Holloway, University of London) then spoke about sub-millennial variability in vegetation in the Mediterranean during the Last Interglacial, and **Anson Mackay** (University College London) presented research from Central Asia about abrupt cool events during the Holocene and Last Interglacial as recorded within isotopic evidence from diatoms. **Ian Candy** (Royal Holloway, University of London) closed the session, showing us records of abrupt climate events during MIS 11 from Britain and the North Atlantic.

After lunch we moved to *Glacials* and in this session, **Sune Rasmussen** opened with his keynote on 'A high-resolution ice-core account of abrupt climatic changes during the most recent glacial period and a look at their governing mechanisms.' **Anna Bourne** (Queen Mary University of London) then presented a cyptotephra record from the Adriatic Sea that helps to unpick whether the drivers of environmental change are from regional or local forcing. This was followed by **Richard Staff** (University of Oxford) who assessed the concordance between the IntCal radiocarbon and Greenland ice-core timescales using new data from the Tenaghi Philippon peat core record. After tea and coffee we reconvened to hear about how refined chronologies using the Campanian Ignimbrite tephra and the addition of faunal data is helping to unpick the drivers of Neanderthal extinction in Europe from **Simon Blockley** (Royal Holloway, University of London). **Mark Hardiman** (University of Portsmouth) kept us on an archaeological theme, exploring the history of fire impacts in the landscape before and after the arrival of humans on the Californian Channel Islands. Next, **Sven Lukas** (Queen Mary University of London) presented a conceptual model of the different spatial and temporal scales of drivers of ice-marginal fluctuation as recorded in moraine sequences. The last talk of the *Glacials* session was by **Melissa Marr** considered the responses of British Mammals to climate change at the end of the last glacial from ecomorphological and population-level genetic data. In the evening we gathered for a lovely Conference Meal at Café Gondola.

Friday morning's session on *Geomorphic Response* began with *The CQR Lecture*, given by **Anna Hughes** (University of Bergen) on 'Ice sheets as drivers and

responders: Interpreting the glacial geomorphological and chronological record.' Then **Cianna Wyshnytzky** (Queen Mary University of London) presented a sedimentological study of minor moraines at Schwarzenstienkees, Austria and Silvrettagletscher, Switzerland. This was followed by **James Scourse** (Bangor University) showing the role of megatides in driving ice sheet collapse along the British-Irish Ice Sheet margin using glacial isostatic adjustment models. **James Lea** (University of Liverpool) continued with ice sheet margins, presenting an intercomparison of iceberg calving laws and highlighting that this is a source of uncertainty in simulating palaeo ice sheets. **Riccardo Arosio** (Scottish Marine Institute) led us into the first discussion session of the day with his exploration of ice sheet dynamics in south-western Scotland based on swath bathymetry data and continental shelf core sediments. After coffee **Paul Lincoln** (Royal Holloway, University of London) took us through the record of the Last Glacial-Interglacial Transition at the Vale of Pickering in north east England. **Trevor Faulkner** (University of Birmingham) presented deglacial speleothem records from the caves of Giggleswick Scar in the Yorkshire Dales. **Bethan Davies** (Royal Holloway, University of London) took us back to glacier-records, assessing the glacier-climate relationships on the Antarctic Peninsula during the past, in the present and into the future, using ice core and geological data and numerical climate model simulations. The talks in this session concluded with **Ann Rowan** (University of Sheffield) investigating the response of Himalayan glacier surfaces covered in debris to climate change between the Little Ice Age and AD 2200.

The final session focussed on *The Holocene* and began with **Dominik Fleitmann's** (University of Reading) keynote 'Chasing abrupt climatic events during the Holocene'. **Andy Smith** (NERC Isotope Geosciences Facility) then discussed speleothem records from the northern Iberian coastline and their records of moisture delivery from the north Atlantic to Europe throughout the Holocene. We continued with speleothem records with **Michael Deiringer** (University College, Dublin) identifying temporally coherent changes in oxygen isotope records within nine European speleothem records that link with ocean circulation in the North Atlantic. **Lai Comas-Bru** (University College, Dublin) investigated reconstructions of the North Atlantic Oscillation and the factors that influence its stationarity. Following a discussion and tea and coffee **Jonathan Hassall** (University of Southampton) kept us thinking about atmospheric circulation dynamics in the South Pacific as recorded in lake records from Samoa and Atiu, Southern Cook Islands. **Abi Stone** then took us into sandy desert regions to consider how and where hydrostratigraphies have been reconstructed, using natural chemical tracers within the pore moisture of sand-rich sediments above the water table. **Meighan Boyd** (Royal Holloway, University of London) returned to speleothem records and the climatic conditions in Alepotrypa Cave, Greece during inhabitation by humans between 8 and 5.2 ka. **Rob Wilson** closed *The Holocene* session and the conference with a tree-ring based reconstruction of the summer temperature for the Northern Hemisphere over the last millennium. The

five sessions were supported by over 35 excellent posters that were on display for the duration of the meeting.

The public science event on 9th January, '*Out of the Ice Ages: Our Past, Present and Future*', was based around a series of keynote lectures, interspersed with practical sessions and hands-on demonstrations provided by CQR staff and students, with contributions from colleagues from Aberystwyth, Sheffield, Leeds, Oxford and UCL. The programme was designed to complement the Geography and Biology A level syllabi, as well as to appeal to the general public. **Ian Candy** set the scene with an exploration of anthropogenic contributions to global warming and the evidence from past interglacials, followed by **Bethan Davies** on glaciers and climate change, with reference to the changing face of Antarctica (Figure 2A). **Danielle Schreve** and **Alice Milner** then presented the past, present and future picture of flora and fauna in Britain, linking the evidence from palaeoecology to contemporary questions of rewilding, before **Simon Blockley** discussed the interplay of climate change, human evolution and adaptation.

Figure 2. (A) Bethan Davies giving a public lecture at the Public Outreach Day, (B) members of the public grappling with glaciers.

The practical sessions included an interactive "Glacier Goo" model with moving ice sheet (**Bethan Davies, Alison MacLeod, Luke Parker, Sylvia Kwong, Julian Martin**), together with the 'Vanishing Glaciers of Everest' display (Figure 3A) from the 2015 Royal Society Summer Science Exhibition (**Ann Rowan**, Sheffield, **Neil Glasser, Mike Hambrey** and **Morgan Gibson** from Aberyswyth and **Scott Watson**, Leeds). Further exhibits were provided on sea level change (**John Lowe**), varves (**Richard Clark-Wilson, Chris Francis, Alice Carter-Champion, Josh Pike**), megafloods (**Jacob Bendle, Jo Hornsey, Chris Francis**) and tephra (**Ian Matthews, Rhys Timms, Paul Lincoln, Dorothy Weston**). Displays of Pleistocene mammal bones and rewilding (**Danielle Schreve, Pierre Schreve, Neil Adams, Angharad Jones**), insects (**Scott Elias**), pollen (**Alice Milner, Roseanna Mayfield**), diatoms (**Poppy Harding, Rebecca Kearney**) , Palaeolithic stone tools (**Simon Blockley, Lucy Turner**) and early hominin

dispersal through the 'Green Sahara' (**Simon Armitage**) were complemented by demonstrations of 3D laser imaging of fossils (**Melissa Marr**) and the evidence from stable isotope analysis of biological materials (**Amy Jeffrey, Emma Loftus**).

Figure 3. (A) Visitors at the Vanishing Glaciers of Everest display and (B) Explaining and demonstrating varve records at the Public Outreach Day.

The day was attended by over 300 participants including teachers and school students from around the south-east, members of regional geological societies and the general public. Participants were invited to submit questions when registering, and a "Question Time" session with panel members wrapped up the day's proceedings.

The organisers of the ADM and Public Science Day wish to record their gratitude to the QRA for allowing the CQR to host the 2016 ADM and associated Public Science Day, as well as providing start-up funding towards operational costs. We are also indebted to John Wiley & Sons for providing financial support to enable us to host the annual Wiley Lecture, and to Beta Analytic for their financial contribution to the conference. Staff members from the Royal Holloway Conference Office, Schools Liaison and Communications and External Relations offices are thanked for their assistance. Finally, very warm thanks are extended to the postgraduate students (members of the MSc Quaternary Science cohort 2015-16) who volunteered their help to ensure the seamless conduction of both meetings.

Prepared by Danielle Schreve and John Lowe, on behalf of the organising committee, Royal Holloway University of London

Danielle Schreve
Department of Geography
Royal Holloway, University of London
Egham
Surrey
TW20 0EX
danielle.schreve@rhul.ac.uk

John Lowe
Department of Geography
Royal Holloway, University of London
Egham
Surrey
TW20 0EX
j.lowe@rhul.ac.uk

20TH ANNUAL POSTGRADUATE SYMPOSIUM

2-4th September, 2015, Scott Polar Research Institute, University of Cambridge

The 2015 postgraduate symposium of the Quaternary Research Association (QRAPG 2015) was held at the Scott Polar Research Institute, University of Cambridge (Figure 1). It was attended by 46 students from all over Britain (Scotland, England and Wales), and from Ireland and Germany, in addition to two senior research scientists, our keynote speakers, **Prof Robert Mulvaney** (British Antarctic Survey) and **Dr Babette Hoogakker** (University of Oxford). We consider the large number and diversity of the student group to be a sign of the success of this year's symposium, with attendance from several students from outside the UK. There were 24 oral and 18 poster contributions which resulted in a long and successful poster session. This year's QRAPG Symposium covered a large variety of topics - Quaternary climate reconstructions in the UK, tropical regions, Asia and the polar regions.

Figure 1. The symposium attendees outside the Scott Polar Institute, Cambridge (Photo credit Jack Lacey).

The backgrounds of our student delegates ranged from Geochemistry, Geophysics, Botanics, Geoecology, Glaciology, Palaeoceanography and Palaeolimnology. There was a stronger representation of ocean-related Quaternary Sciences than during

previous symposia. The variety of topics at this year's events was valuable and enriching for all attendees. The symposium made it possible to gain an update on Quaternary Research in the UK and worldwide. Besides the fascinating presentations by our keynote speakers on new advances in Antarctic ice core science and Palaeoceanography, one of the highlights of QRAPG 2015 was an insightful talk by **Lucy Gonzalez** (Anglia Ruskin University) on funding for postgraduate opportunities beyond the PhD. Many attendees found this presentation extremely useful, relevant and informative. We congratulate **Alwynne McGeever** (Trinity College Dublin) for her prize for best presentation for her excellent talk on modelling tree populations in Europe and **Francesca Falcini** (Aberystwyth University) for the best poster, which used 3D images to showcase research into the roughness imparted onto surface by past ice streams.

Another highlight of QRAPG 2015 was a tour of British Antarctic Survey on the first day of the meeting that every delegate was invited to. It offered our delegates from different research areas a unique opportunity to experience what research on Antarctica involves (i.e. visiting the cold store and examining recently drilled ice cores, getting to know Antarctic animals in the aquarium of the institute, etc.). The British Antarctic Survey is not open to the public, making this especially worthwhile and enriching for our attendees. Also, with our choice of the conference and icebreaker venue, the Scott Polar Research Institute/Museum and the Sedgwick Museum of Earth Sciences respectively, we have put emphasis on important locations in Cambridge that are strongly associated with the Quaternary Sciences. During breaks or the icebreaker event, the delegates had the opportunity to make the most of this, by visiting the exhibitions or discovering and discussing about fossil samples etc., which we believe was one of the successes of QRAPG 2015 in Cambridge.

One the strengths of this conference, which we advise following year's to consider is the focus on advertising the symposium via social media, in particular via Twitter (@QRAPGSymposium). We believe that strengthening the representation of the QRAPG Symposium in social media helped to improve outreach, build a larger QRAPG community and facilitate communication with students for future events.

We thank our sponsors (Quaternary Research Association UK, Van Walt Monitoring, British Antarctic Survey, Beta Analytic, University of Cambridge, Scott Polar Research Institute) and all attendees who made this event so enjoyable and enriching.

Jenny Roberts
Department of Earth Sciences
University of Cambridge
Madingley Road
Cambridge CB3 0EZ

ABSTRACT

IMPACT AND SIGNIFICANCE OF TEPHRA DEPOSITION FROM MOUNT MAZAMA AND HOLOCENE CLIMATE VARIABILITY IN NORTH WEST USA

The mid-Holocene climactic eruption of Mount Mazama in Oregon, USA (Volcanic Explosivity Index, VEI-7) was among the largest eruptions globally during the Holocene. Despite evidence for possible hemispheric climatic impacts, the age of the eruption is not well-constrained and little is known about environmental impacts of distal tephra deposition with previous studies showing no clear consensus. Further, the eruption occurred during a time of global climatic warming, raising questions about the impacts of tephra deposition in the context of longer-term change. Thus the aim of this thesis is to investigate the terrestrial and aquatic impacts of distal tephra deposition from the climactic eruption of Mount Mazama approximately 7700 years ago, and to reconstruct Holocene environmental change in the Pacific northwest of North America. The Mazama tephra forms an important isochronous marker horizon. A refined age of 7682-7584 cal. years BP (95.4% probability range) for the eruption was acquired through Bayesian statistical modelling of 81 previously published radiocarbon age estimations. Through high resolution palaeoecological and statistical analyses (stratigraphy, tephra geochemistry, radiocarbon dating, pollen, diatoms and ordination) aquatic and terrestrial impacts of tephra deposition is assessed. Records were examined from the centre and fringe of Moss Lake, Washington to elucidate regional and local effects on vegetation and to determine whether the observed aquatic impacts were consistent throughout the lake, or whether the diatoms were responding to other factors, such as climate or catchment changes. Tephra deposition from the climactic eruption of Mount Mazama caused a statistically significant local terrestrial impact with changes to open habitat vegetation (Cyperaceae and Poaceae) and changes in aquatic macrophytes (*Myriophyllum spicatum, Equisetum*) and alga (*Pediastrum*), but there was no significant regional impact of distal tephra deposition. Statistical testing suggests the regional changes observed were climate-driven, evidenced by longer-term, underlying environmental change. Tephra deposition had a statistically significant impact on the aquatic system with decreases of epiphytic taxa (*Fragilaria brevistriata* and *Staurosira venter*) and increases of epipelic (*Brachysira brebissonii*) and tychoplanktonic taxa (*Aulacoseira* sp.) indicating a change in habitat and an increase of the Si:P ratio, lasting approximately 150 years. Variance partitioning demonstrated tephra to be a significant environmental variable; however, directional change exerted most influence and interactions between variables are evident. This study clearly demonstrates that there are complex interactions between drivers of change

which is evidenced through time series analysis of the diatom Holocene record, revealing periodicities of approximately 2000 years, 1300 years, and 450 years attributed to solar variation and ocean-atmosphere interactions. Overall, tephra had a significant local effect on the environment, but no significant impact on the region independent of underlying environmental changes. More studies of similar nature are needed to replicate and evaluate the wider regional occurrence of localised impacts shown at Moss Lake.

Joanne Egan
Geography
School of Environment, Education and Development
The University of Manchester

Current address:
Department of Geography
Edge Hill University
Ormskirk
Lancashire
L39 4QP
joanne.egan@edgehill.ac.uk

QUATERNARY RESEARCH ASSOCIATION

The Quaternary Research Association is an organisation comprising archaeologists, botanists, civil engineers, geographers, geologists, soil scientists, zoologists and others interested in research into the problems of the Quaternary. The majority of members reside in Great Britain, but membership also extends to most European countries, North America, Africa, Asia and Australasia. Membership (currently *c*. 1,200) is open to all interested in the objectives of the Association. The annual subscription is £20 with reduced rates (£10) for students and unwaged members and an Institutional rate of £35.

The main meetings of the Association are the Field Meetings, usually lasting 3–4 days, in April, May and/or September, a 2-3 day Discussion Meeting at the beginning of January. Short Study Courses on techniques used in Quaternary work are also occasionally held. The publications of the Association are the *Quaternary Newsletter* issued in February, June and October; the *Journal of Quaternary Science* published in association with Wiley; and the QRA Field Guide and Technical Guide Series.

The Association is run by an Executive Committee elected at an Annual General Meeting held during the Annual Discussion Meeting in January. Current officers of the Association are:

President: ***Professor P. Coxon***, Department of Geography, Museum Building, Trinity College, Dublin 2, Ireland (email: pcoxon@tcd.ie)

Vice-President: ***Professor D. Bridgland***, Department of Geography, University of Durham, South Road, Durham, DH1 3LE (e-mail: d.r.bridgland@durham.ac.uk)

Secretary: ***Dr M. Frogley***, Department of Geography, Chichester 1, University of Sussex, Falmer, Brighton, BN1 9QJ (e-mail: m.r.frogley@sussex.ac.uk)

Publications Secretary: ***Dr J. Lee***, British Geological Survey, Keyworth, Nottingham NG12 5GG (e-mail: jrlee@bgs.ac.uk)

Treasurer: ***Dr T. White***, 59 Beechwood Avenue, Melbourn, Cambridgeshire SG8 6BW (e-mail: tsw29@cam.ac.uk)

Editor, Quaternary Newsletter: ***Dr A. Stone, Geography,*** School of Environment, Education and Development, The University of Manchester, Oxford Road, Manchester, M13 9PL. (e-mail: abi.stone@manchester.ac.uk)

Editor, Journal of Quaternary Science: ***Professor Geoff Duller***, Institute of Geography and Earth Sciences, Aberystwyth University, Aberystwyth SW23 3DB (e-mail:editor@qra.org.uk)

Publicity Officer: ***Dr Bethan Davies***, Department of Geography, Royal Holloway University of London, Egham Hill, Egham TW20 0EX (email: bethan.davies@rhul.ac.uk)

All questions regarding membership are dealt with by the **Secretary**, the Association's publications are sold by the **Publications Secretary** and all subscription matters are dealt with by the **Treasurer**.

The QRA home age on the world wide web can be found at: http://www.qra.org.uk

Registered Charity: 262124

JUNE 2016 No. 139

QN

Contents

Page

1 **EDITORIAL**

2 **QRA50:** Top 50(80) Quaternary Sites – Spotlight on a site

3 **OBITUARY**
3 Herb Wright *John Birks*

15 **NEW RESEARCHERS AWARD SCHEME**
15 Reinterpreting the pattern and style of last Cordilleran ice sheet retreat on the Thompson Plateau, BC, Canada
20 Developing a cryptotephra framework for North America: Trace element characterisation of Holocene tephra from northwestern sources
24 Building a new climate change record from MIS10 until the Holocene for the Italian Peninsula
27 Multiple mechanisms of minor moraine formation at an alpine valley glacier, Silvrettagletscher, Switzerland

31 **QUATERNARY RESEARCH FUND**
31 Quaternary glaciers and climate in the Peloponnese, Greece *Phil Hughes*
35 Northeast Greenland caves project: Constructing a speleothem-derived record of climate change for the Arctic *Gina Moseley*

39 **REPORTS**
39 QRAADM: Quaternary Drivers and Responders. Royal Holloway, University of London, January 6th-9th, 2016
46 20TH Annual Postgraduate Symposium

48 **ABSTRACTS**
48 Impact and significance of tephra deposition from Mount Mazama and Holocene Climate Variability in north west USA *Joanne Egan*

ISSN 0 143-2826