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# Determining Patterns of Abrupt Climate Change during the Last Glacial-Interglacial Transition (LGIT) in the Southern Hemisphere

Marcus J. Vandergoes

*Principal Investigator; University of Maine, Orono, M.Vandergoes@gns.cri.nz*

Ann Dieffenbacher-Krall

*Co-Principal Investigator; University of Maine, Orono, annd@maine.edu*

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**Final Report for Period:** 11/2009 - 10/2010

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**Principal Investigator:** Vandergoes, Marcus J.

**Award ID:** 0502427

**Organization:** University of Maine

**Submitted By:**

Dieffenbacher-Krall, A. - Co-Principal Investigator

**Title:**

Determining Patterns of Abrupt Climate Change during the Last Glacial-Interglacial Transition (LGIT) in the Southern Hemisphere

### Project Participants

#### Senior Personnel

**Name:** Vandergoes, Marcus

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Dieffenbacher-Krall, A.

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

#### Post-doc

#### Graduate Student

**Name:** Chase, Brenda

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Chase prepared chironomid samples by sieving sediment and extracting chironomids, then mounting them on microscope slides.

#### Undergraduate Student

**Name:** Wilcox, Jennifer

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Wilcox prepared chironomid samples by sieving sediment and extracting chironomids, then mounting them on microscope slides.

**Name:** Hannington, Thomas

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Hannington prepared chironomid samples by sieving sediment and extracting chironomids, then mounting them on microscope slides. Hannington additionally participated in measurements of physical properties of sediment cores. Hannington's work was additionally supported by a federal work-study award.

**Name:** Nelson, Carla

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Nelson prepared chironomid samples by sieving sediment and extracting chironomids, then mounting them on microscope slides. Nelson's work was additionally supported by a federal work-study award.

**Name:** Palmer, Howard

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Palmer prepared chironomid samples by sieving sediment and extracting chironomids, then mounting them on microscope slides. Palmer's work was additionally supported by a federal work-study award.

**Name:** Francis, Lyle

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Francis prepared chironomid samples by sieving sediment and extracting chironomids, then mounting them on microscope slides.

**Name:** Shyderoff, Alex

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Shyderoff prepared chironomid samples by sieving sediment and extracting chironomids, then mounting them on microscope slides. Shyderoff's work was additionally supported by a federal work-study award.

**Name:** Spinney, Eileen

**Worked for more than 160 Hours:** No

**Contribution to Project:**

**Name:** Huffer, Heath

**Worked for more than 160 Hours:** No

**Contribution to Project:**

**Name:** Peter, Chillemi

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Extracted chironomid remains from lake sediment and mounted onto microscope slides.

**Name:** Bavaro, Dawn

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Bavaro prepared chironomid samples by sieving sediment, manually extracting chironomid head capsules, then mounting them onto microscope slides. Her work was supported in part by a federal work-study award.

**Name:** Hoffman, Maria

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Hoffman prepared chironomid samples by sieving sediment, manually extracting chironomid head capsules, then mounting them onto microscope slides. Her work was supported in part by a federal work-study award.

**Name:** Morgan, Jonathan

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Morgan prepared chironomid samples by sieving sediment, manually extracting chironomid head capsules, then mounting them onto microscope slides. Her work was supported in part by a federal work-study award.

**Name:** Snow, Anna

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Snow prepared chironomid samples by sieving sediment, manually extracting chironomid head capsules, then mounting them onto microscope slides. Her work was supported in part by a federal work-study award.

**Name:** McCann, Erin

**Worked for more than 160 Hours:** No

**Contribution to Project:**

McCann prepared chironomid samples by sieving sediment and extracting chironomids, then mounting them on microscope slides.

**Technician, Programmer**

**Other Participant**

**Name:** Marysdaughter, Karen

**Worked for more than 160 Hours:** No

**Contribution to Project:**

Non-professional community volunteer - assisted with subsampling sediment cores, extraction of chironomid remains, measuring physical properties of sediment, field collection of sediment cores.

**Research Experience for Undergraduates****Organizational Partners****GNS Science, Wellington, New Zealand**

We are cooperating with GNS Science on pollen and chironomid analyses of Quagmire Tarn and Kettlehole Bog. GNS has provided logistical support for field work, while GNS science Rafter radiocarbon laboratory has provided some additional financial support for radiocarbon analysis and methodological expertise to identify and resolve site specific problems with radiocarbon dating.

**Other Collaborators or Contacts**

Drs Klaus Zink (GNS Science), Kai Mangelsdorf, GFZ Potsdam, Germany, Lorenz Schwark University Kiel, Germany, have collaborated on analysis of microbial lipids from modern and late glacial sediments to develop a preliminary lipid MBT temperature inference model.

Dr. Rewi Newnham, Department of Geography, University of Plymouth, United Kingdom, now Victoria University of Wellington, New Zealand, has collaborated on pollen analysis of Boundary Stream Tarn sediment and assisted with coring of Quagmire Tarn.

Thomas Whittaker and Jeremy Cole-Baker, graduate students of Waikato University, Hamilton, New Zealand, participated in coring of Quagmire Tarn.

Dr. Matt McGlone and Janet Wilmshurst, Landcare Research, Lincoln, New Zealand, have provided existing core and sediment samples from Kettlehole Bog.

Aaron Putnam and Alice Doughty, graduate students of University of Maine, participated in lake coring and collection of surface sediment samples.

Scott Travis, Comer Science and Education Foundation, participated in lake coring.

Karen Marysdaughter, a volunteer laboratory assistant at the University of Maine, participated in lake coring and collection of surface sediment samples.

Craig Woodward, Queensland University, Australia, and Ian Boothroyd, Kingett, Mitchell, and Associates, Auckland, New Zealand, collaborated on standardization of New Zealand subfossil chironomid taxonomy.

**Activities and Findings****Research and Education Activities: (See PDF version submitted by PI at the end of the report)**

Pdf file attached.

**Findings:**

A comprehensively AMS-dated, pollen and chironomid stratigraphy from Boundary Stream Tarn provides the first chironomid derived temperature reconstruction to quantify temperature change during late-glacial times (17,500-11,000 cal yr BP) in the Southern Alps, New Zealand. The records indicate a disruption to the late glacial warming trend lasting about 1000 years during the Antarctic Cold Reversal (ACR) with a summer temperature depression of ~2-3oC lasting about 700 years. Following this, both proxies indicate generally warmer but fluctuating temperatures during the Younger Dryas chronozone. These results provide unambiguous evidence of cooling during the time of the

ACR, highlighting a direct linkage between Antarctica and mid-latitude terrestrial climate systems and the largely asynchronous nature of the interhemispheric climate system during this period of abrupt climate change. A major discovery of this research is the differences in the magnitude of the cooling signal reconstructed from the two proxies, pollen and chironomids. The greater magnitude of temperature change shown by the chironomids are attributed to the influence of seasonal climate variations, with chironomids reflecting summer temperature and vegetation more strongly controlled by duration of winter or by minimum temperatures. These differences imply stronger seasonality at times during the deglaciation, which may explain some of the variability between other paleoclimate records from New Zealand and have wider implications for understanding differences between paleo-indicators for abrupt climate change, in particular when seasonality may be an important factor.

Similarities to these results are also seen at Kettlehole Bog (despite dating issues), although the reconstructed temperature changes are more subtle. Using the original age model derived for the site by McGlone et al. (2004), pollen and chironomid assemblages indicate a reorganization to cooler climate flora and fauna that lasts approximately 1300 years during the late-glacial. This disruption of the warming trend is estimated to reflect a summer temperature depression of ~3-4°C, beginning some 400 years earlier than indicated at Boundary Stream Tarn, but still within the time of the ACR. Both proxies indicate generally warmer temperatures during the Younger Dryas chronozone, but with chironomids and the modelled temperature reconstructions showing minor fluctuations. Differences in the timing of changes between Boundary Stream Tarn may be a result of inconsistencies in the current age model of Kettlehole Bog or may reflect realities of the regionally different response of flora and faunal change to climate at the end of the last glaciation.

The comprehensively-dated sequence from Quagmire Tarn suggests the ecological changes at this site occurred earlier in the last glacial transition. Pollen and chironomid assemblages indicate a disruption to the late glacial warming trend and a reorganization from warmer to cooler climate flora and fauna that occurred between c. 16,600 and 15,500 cal yr BP. This event is estimated to reflect a summer temperature depression of ~3-4°C, predating the ACR, indicative of climate fluctuations occurring at the termination of the last ice age. The cooling period identified in this record corresponds well with recently dated moraine evidence of ice advance in the area. Beryllium ( $^{10}\text{Be}$ ) surface exposure age dates on the Prospect Hill Moraine indicate that ice advanced to within one km of the site at c. 16,400 cal yr BP (Putnam et al unpublished data). The combined evidence from Quagmire Tarn and Prospect Hill provide the first well dated evidence of climate cooling pulses during the last glacial transition that predated the ACR. Evidence suggesting the possibility of such events have been displayed in some pollen records in Southern New Zealand (Vandergoes et al. 2005; Vandergoes et al. unpublished data), but has yet to be accurately quantified or dated.

Comparison of climate events between sites separated by 180 km (Boundary Stream Tarn and Kettlehole Bog) suggests temporal differences between the onset and termination of climate change events. These events are likely to be the result of local climate-influencing factors and microclimate effects including site topography, aspect, and relation to prevailing moisture sources. The current chironomid-temperature reconstruction model may not, in some instances, identify minimal temperature changes that occur at some sites. New sites are being added to the training set to improve reconstruction resolution.

Preliminary results from microbial lipid analysis has shown that Branched Isoalkane Tetraethers (BIT) have been identified in high abundance in both modern and glacial sediments of New Zealand, South Island freshwater lakes comprising a wide range of altitudes (101?2000 m). Similarly to isoprenoid Glycerol Dialkyl Glycerol Tetraethers (GDGTs) they provide excellent potential of temperature assessment. For this study, their distribution patterns (MBT: Methylation ratio and CBT: Cyclisation ratio of BIT) have been successfully used to develop an initial temperature calibration for the study area and to provide first (paleo)environmental interpretations. MBT data from modern lake sediments correlate well with measured air temperatures ( $r^2 = 0.75$ ) enabling a local calibration to reconstruct paleotemperatures for fossil samples. MBT-derived paleotemperatures, calibrated against mean summer temperature, were determined for several last- and late-glacial-age sediment samples. Compared to the modern temperature level the MBT data indicate a decrease of ~ 4.5°C to ~ 2.1°C respectively during this time. Modern and past MBT-derived temperatures correspond extremely well with chironomid-based temperature reconstructions in this area. These findings have been published in a special issue of *Organic Geochemistry* and will provide the basis for future research projects (Zink et al. 2010). Research in this area will be continued through a collaborative relationship with GNS Science.

Interest in the Boundary Stream Tarn paleoclimate record has led to the initiation of research on the early-Holocene portion of these cores in collaboration with Peter Langdon, University of Southampton, UK. Development of the New Zealand chironomid training set has led to collaborative study of late-Holocene, human impact studies on New Zealand lakes with Cathy Whitlock, Montana State University (paper in review). Success of the New Zealand chironomid climate-inference model for Southern Hemisphere reconstructions has led to collaborative research in late-glacial climate reconstructions in South America with Patricio Moreno, University of Chile, and Julieta Massafiero, CONICET, Argentina, published in 2009 (Massafiero et al. 2009), and collaborative development of a similar inference model for Patagonia with Julieta Massafiero and Steve Brooks, Natural History Museum, London, UK.

#### Related References

Vandergoes, M.J.; Newnham, R.M.; Preusser, F.; Hendy, C.H.; Lowell, T.V.; Fitzsimons, S.J.; Hogg, A.G.; Kasper, H.U.; Schluechter, C. 2005. Regional insolation forcing of Late Quaternary climate change in the Southern Hemisphere. *Nature*, 436(7048): 242-245

**Training and Development:**

A total of one graduate and 13 undergraduate students have assisted with laboratory work, gaining research skills and valuable experience. Two New Zealand and two University of Maine graduate students gained field experience in lake and peatland coring and collection of surface samples.

**Outreach Activities:**

The objectives and methods were presented to a group of grade 4-8 students, who spent a day in the laboratory gaining hands-on experience sampling sediment cores, sieving to extract plant and insect remains, and examining their finds microscopically. We conducted eleven tours for grade 4-12 groups. Students came from an approximately 32,000 km<sup>2</sup> area around the University of Maine. This economically-depressed region includes many public schools where students have no access or limited access to microscopes. We hosted a group of high school science teachers, leading field and lab exercises. We provided a tour for Senior College (senior citizens) and a day-long program for middle and high-school students in which we presented objectives of the research and assisted participants with microscopic examination of chironomid remains. We presented the project objectives to faculty from other disciplines, Maine state biologists, conservation professionals, and private consultants during a December 2005 Paleocology Research Laboratory open house. A non-professional, community volunteer has been assisting with this project since September 2005.

Results have been presented at the American Geophysical Union Meeting in December 2005; a public seminar at GNS Science, Wellington, New Zealand, in June 2006; the Southern Connections Conference in January 2007 and March 2010, the International Union for Quaternary Research Congress in August 2007 and the AUS-INTIMATE meeting in June 2008 and October 2009.

**Journal Publications**

Dieffenbacher-Krall, A.C., M.J. Vandergoes, and G.H. Denton, "An inference model for mean summer air temperature in the Southern Alps, New Zealand, using subfossil chironomids", *Quaternary Science Reviews*, p. 2487, vol. 26, (2007). Published,

Vandergoes, M.J., A.C. Dieffenbacher-Krall, R. Newnham, G.H. Denton, and M. Blaauw, "Cooling and changing seasonality in the Southern Alps, New Zealand during the Antarctic Cold Reversal", *Quaternary Science Reviews*, p. 589, vol. 27, (2008). Published,

Zink, K. G., M. J. Vandergoes, K. Mangelsdorf, A. C. Dieffenbacher-Krall, L. Schwark., "Application of bacterial glycerol dialkyl glycerol tetraethers (GDGTs) to develop modern and past temperature estimates from New Zealand lakes.", *Organic Geochemistry*, IMOG 2009 Special Issue., p. 1060, vol. 41, (2010). Published,

Massaferro, J.I., P.I. Moreno, G. Denton, M. Vandergoes, and A. Dieffenbacher-Krall, "Chironomid and pollen evidence for climate fluctuations during the Last Glacial Termination in NW Patagonia", *Quaternary Science Reviews*, p. 517, vol. 28, (2009). Published,

Vandergoes, M.J., A.C. Dieffenbacher-Krall, G.H. Denton, M. Blaauw, "Deglacial chironomid temperature reconstruction from Quagmire Tarn South Island, New Zealand", *Quaternary Research*, p. , vol. , (2011). in prep,

Vandergoes, M.J., A.C. Dieffenbacher-Krall, and M. Blaauw, "Late-glacial climate reconstructions for eastern South Island, New Zealand, using pollen and chironomid fossils", *Palaeogeography, Palaeoclimatology, Palaeoecology*, p. , vol. , (2011). in prep,

Dieffenbacher-Krall, A.C., M.J. Vandergoes, C. Woodward, and J. Shulmeister, "An expanded chironomid inference model for mean summer air temperature in southern New Zealand", *Quaternary Science Reviews*, p. , vol. , (2011). in prep,

Vandergoes, M.J., A.C. Dieffenbacher-Krall, R.M. Newnham, G.H. Denton, and M. Blaauw., "New Zealand-Antarctic climate connections during the last Termination", *Quaternary Science Reviews*, p. , vol. , (2011). in prep,

**Books or Other One-time Publications****Web/Internet Site**

**URL(s):**

<http://www.climatechange.umaine.edu/Research/facilities/perl/nzguide.html>

**Description:**

A standardized taxonomy of New Zealand subfossil chironomids was developed from modern lake sediment under an earlier project funded by the Comer Science and Education Foundation, and from late-glacial-age lake sediment under the current NSF-funded research.

Dieffenbacher-Krall, A.C., M.J. Vandergoes, C.A. Woodward, and I.K.G. Boothroyd. 2008. Guide to Identification and Ecology of New Zealand Subfossil Chironomids Found in Lake Sediment. Climate Change Institute, University of Maine, Orono, ME.

### Other Specific Products

**Product Type:****Instruments or equipment developed****Product Description:**

In collaboration with the Advanced Manufacturing Center, University of Maine, we have designed a new poundable, piston corer for improved collection of lake cores in dense sediment. The prototype was successfully tested and new systems have been produced for coring projects in Maine, New Zealand, and South America.

**Sharing Information:**

Design for this corer has applications for all paleolimnological studies requiring sediment recovery.

**Product Type:****Physical collection (samples, etc.)****Product Description:**

We have expanded the New Zealand chironomid reference collection for the University of Maine with the addition of 11,482 fossil specimens from 391 stratigraphic levels from Boundary Stream Tarn, Quagmire Tarn, Galway Tarn, and Kettlehole Bog, and expect the collection to increase further as a consequence of this project. This subfossil collection is currently the largest and most taxonomically extensive collection of New Zealand chironomids in the world and plans are underway to make it publically available via an internet searchable database including photographs of specimens. We have provided 384 photographs of subfossil chironomids in response to requests.

**Sharing Information:**

The reference collection has been used to create a standardized guide to New Zealand subfossil chironomids (in collaboration with Craig Woodward and Ian Boothroyd). The guide is now available on the internet.

### Contributions

**Contributions within Discipline:**

This study provides some of the first chironomid inferred temperature reconstructions for the Late Glacial-Interglacial Transition (LGIT) in New Zealand, an area where quantifiable reconstructions of terrestrial temperature change are currently lacking. The study provides new proxy data to help constrain models of past climate change and therefore contributes to the development of more accurate models for prediction of future change. This study provides comparable data for independent temperature proxies from speleothem, marine core, beetle, ice core and mountain snowline records to assess the relative timing and magnitude of LGIT climate change in these proxy records. It contributes to understanding the detail of global climate change, suggesting the effects of mechanisms responsible for cooling in Antarctica in the past have also influenced parts of southern New Zealand. The project provides refined paleoclimate data from southern New Zealand which greatly enhances our ability to assess and understand local and regional climate change in New Zealand and the Southern Hemisphere.

**Contributions to Other Disciplines:**

The project significantly expands the knowledge of subfossil chironomid taxonomy from New Zealand the changes in abundance and distribution of these organisms in the past, improving knowledge of chironomid ecology for this region.

**Contributions to Human Resource Development:**

Thirteen undergraduate students and one graduate student have obtained experience in laboratory research in geology and paleoecology, and 4 graduate students obtained field experience.

**Contributions to Resources for Research and Education:**

Our new design for a piston corer will make collection of dense sediment significantly easier.

The New Zealand subfossil chironomid webpage will insure taxonomic consistency between our studies and future studies conducted by various researchers. The publication of the first chironomid-based, quantitative inference model for North America and Europe led to an explosion of research studies involving subfossil chironomids. However, the unavailability of a standardized taxonomy or subfossil chironomid keys for these regions until recently inhibited comparison of studies across each continent until researchers conducted a series of taxonomic workshops. The publication of our New Zealand subfossil chironomid key (Dieffenbacher-Krall et al. 2008), should preclude the need for a series of taxonomic workshops and promote comparisons between future studies.

**Contributions Beyond Science and Engineering:**

Preparation for future climate changes requires a comprehensive understanding of the world's climate system. The prospect of abrupt climate changes in addition to or as a consequence of climate warming is less well understood than the potential for gradual warming. The research documents temporal and spatial extent and magnitude of climatological phenomenon. Better understanding of the rate and magnitude of abrupt climate change in the Southern Hemisphere mid-latitudes tests the viability of several hypotheses about climate forcing mechanisms, and contributes to numerical models predicting future climate and sea level changes. This base-line understanding is important for identifying and estimating the possible economic, environmental, and social costs associated with possible future climate change scenarios.

**Conference Proceedings**

**Categories for which nothing is reported:**

Any Book

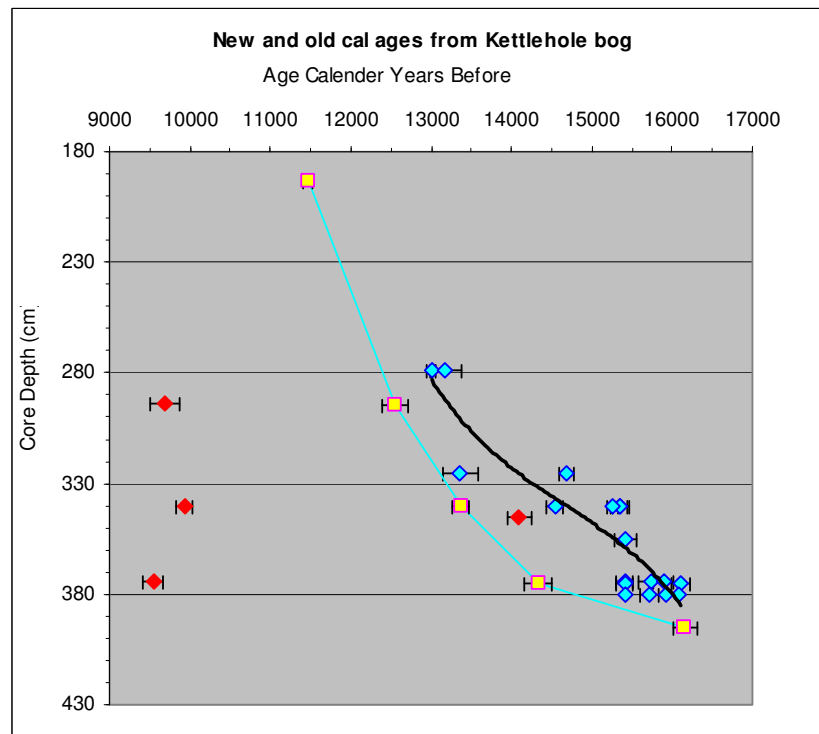
Any Conference



**Objective 1: Determine the precise timing and duration of deglacial climate change for the eastern Southern Alps, New Zealand.**

*Intent:* To obtain a comprehensive, precise radiocarbon chronology for the timing of deglacial climate changes and determine any spatial and temporal variability over the region.

*Results and Progress:* More than 80 Accelerator Mass Spectrometry (AMS) radiocarbon samples have been submitted for this project through the National Ocean Sciences Accelerator Mass Spectrometry (NOSAMS) facility at Woods Hole, MA, and the GNS Science Rafter Radiocarbon Dating Laboratory, Lower Hutt, New Zealand. For one site (Boundary Stream Tarn) these samples provide unprecedented age control, often with sub-centennial resolution, for critical periods of identified climate change between 10,000-17000 years ago. However construction of a robust age model for two other sites (Quagmire Tarn and Kettlehole Bog, see figure 1) was delayed due to dating inconsistencies and the possibility of natural or laboratory contamination in the samples. These inconsistencies seem to be resolved for Quagmire Tarn but remain problematic in Kettlehole Bog regardless of efforts to identify their cause.



**Figure 1.** Dating inconsistencies evident in Kettle Hole Bog. Yellow squares represent the original age model from the site (McGlone et. al. 2004). Blue diamonds indicate successive dating efforts to add to and refine the chronology. Red diamonds indicate efforts to replicate the original ages.

The one year research extension of this project was used to further investigate the Kettlehole Bog dating problem. We have worked with both the NOSAMS and Rafter radiocarbon laboratories to address and resolve the problem with the remaining dating funds. We used refined microfossil extraction techniques to isolate specific organic material from possible contaminants (i.e., separate pollen from charcoal fragments in the samples) and carried out inter-laboratory sample preparation comparisons to eliminate the possibility of laboratory processing inconsistencies. Additional radiocarbon dating from Kettlehole Bog has yet to provide results consistent with the initial age model derived from the site by McGlone *et al.* (2004). We are continuing attempts to refine dating techniques of macro and microfossils to achieve a consistent and reliable chronology from this site. Age determinations from Quagmire Tarn are showing strong internal consistency but are dating several prominent pollen changes to an older time period than is shown by most other pollen sites in the region.

As a result of the delays associated with radiocarbon dating, we have taken the opportunity analyse additional pollen and chironomid samples from Kettlehole Bog and Quagmire Tarn to increase resolution and refine the existing records.

#### *Related References*

McGlone, M.S., Turney, C.S.M., and Wilmshurst, J.M. 2004. Late-glacial and Holocene vegetation and climatic history of the Cass Basin, central South island, New Zealand. *Quaternary Research* 62, 267-279.

### **Objective 2: Develop paleotemperature estimates for the last deglaciation from Southern New Zealand.**

*Intent:* Determine paleovegetation changes in the region during the deglacial transition using pollen analysis to assess the extent of paleoclimate change and estimate paleotemperatures using high-resolution chironomid analysis

*Results and Progress:* We have completed pollen and chironomid analysis for the two sites Kettlehole Bog and Quagmire Tarn and for the additional site Boundary Stream Tarn. Boundary Stream Tarn, located in the Mount Cook region close to the margins of the Southern Alps, has proven to be particularly sensitive to climate change.

### **Objective 3: Investigate the New Zealand-Antarctic-global climate connection during a period of significant climate change 17,000 – 10,000 years ago.**

*Intent:* Determine the presence or absence of Antarctic or Northern Hemisphere paleoclimate signals in Southern New Zealand to identify climate linkages and likely drivers of New Zealand climate change.

*Results and Progress:* The records indicate disruption to the deglacial warming trend and periods of overall cooling, one of which is consistent with the Antarctic Cold Reversal (ACR, 14,500-12,500 years ago). Following this cooling event, pollen and chironomid proxies indicate warming to near modern temperatures during the Northern Hemisphere Younger Dryas cool period (13,000–11,500 years ago). Overall, these results highlight a direct linkage between Antarctica and mid-latitude terrestrial climate systems and the largely asynchronous nature of the interhemispheric climate system during the last glacial transition.

#### *Additional Activities resulting from this project*

During collection of lake cores for this project, we obtained additional surface sediment samples to cover a poorly represented altitudinal range for our modern chironomid training set, and are combining our training set (Dieffenbacher-Krall et al. 2007) with the warmer temperature-range training set of Woodward and Shulmeister (2006) to expand the latitudinal range of the mean summer air temperature inference model.

We also conducted preliminary microbial lipid analysis of sediment samples to develop a new temperature reconstruction technique and apply it to late-glacial-age sediments. This method may increase precision of paleoclimate estimates in the Southern Hemisphere, especially New Zealand. Recent studies on several lipid types from unicellular organisms (archaea, algae) have been extended from the ocean into freshwater systems to develop a more precise temperature reconstruction method for the terrestrial realm. However the accuracy of these temperature indices (TEX86: ratio of lipids from archaea, Uk37: ratio of lipids from algae) are often hampered by low abundance of the respective primary producers in lakes. Our preliminary research using lipids from bacteria (MBT: ratio of methylbranched tetraethers) as a temperature indicator in modern New Zealand lakes provides more reliable estimates because of their high and ubiquitous abundance in terrestrial sediments. The modern MBT-temperature relationship enables us to reconstruct more precise paleo-temperatures than the TEX86 method from last-termination and late-glacial-age sediments.