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Conference Reports

The 6 ka Workshop

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INTRODUCTION

In early May 1992, John Stone, Director of Environment Canada's Climate Research Branch, invited 45 participants to a Toronto workshop on Climate System Research. One of the outcomes of the Federal Green Plan initiative was that the government had expressed an interest in improving its ability to predict the magnitude, rate and spatial characteristics of climate change in Canada. To this end, the Canadian Climate Research Network was developed in January 1992 to help identify researchers who had expertise in this area, and to motivate collaborative interactions in the development of new climate models. Initial workshops to assist these goals were held in Victoria (on ocean circulation modelling) and in Saskatoon (on land surface modelling). The Toronto workshop was the third in the series, and emphasized potential interactions with researchers in the areas of thermodynamic and optical effects of clouds, and the transport and interaction of chemically and radiatively active gases and aerosols in the atmosphere. Some members of the proxy data community were also invited, because of their knowledge of atmospheric changes in the most recent geological past.

One of the recommendations of the Toronto workshop was that another workshop session be held later in 1992 to draw paleoclimatic expertise to bear on the question of verification of climate models. This meeting was held at the Talisman Inn, Ottawa, 21-23 November 1992. Because the purpose was to assist a proposed circulation model run on the mid-Holocene (a hind-casting model), the meeting was termed "The 6 ka Planning Session". However, the meeting went further than this, in that it focussed on how proxy data workers might interact and bring their different areas of expertise to bear on the analysis of other time frames.

Approximately 40 scientists were present at the 6 ka meeting. They represented a variety of research fields in proxy data across Canada and came from federal and provincial governments and universities. They joined a smaller number of colleagues from the Canadian Climate Centre, IMEP (Marseilles), the Lawrence Livermore National Laboratory, the National Geophysical Data Center, the Illinois State Museum, Brown U., and the U. of Lund (Sweden). The non-Canadian participants had been invited to illustrate how their programs could assist the proposed Canadian endeavors. All had participated in national programs involving models, extensive databases, and the use of proxy data.

THE SESSIONS

The workshop was sponsored jointly by the Canadian Climate Centre, the Geological Survey of Canada (GSC), and the Royal Society of Canada. All of the participants owe a special thanks to Hélène Jetté, John Matthews and Alice Telka, of the Terrain Sciences Division, GSC, who put so much into the organization of the workshop. Introductions were made by John Stone, who commented on studying past data to see if it could throw light on projected climate change due to CO_2 buildup, and especially in the uses of proxy data in test model runs for past time frames. He stressed the importance of climate modellers and proxy data workers co-operating in joint ventures. Brian Bornhold welcomed the representatives on behalf of the Royal Society of Canada's Canadian Global Change Programme, and similar sentiments were expressed by Jean-Serge Vincent from the GSC.

Following further introductions by John Matthews and Richard Peltier, the first session opened with a presentation by Norman McFarlane and Diana Verseghy on the Canadian Climate Model and Canadian LAnd Surface Scheme (CLASS). McFarlane stated that the current model used in Canada is run on the supercomputer at Dorval and is capable of generating sophisticated graphics output. The spatial resolution of the model represents grid squares about 4×4° of latitude and longitude (about 200×200 km). The temporal resolution is from days to years or decades. He said that the grid scale can be improved (at considerable computing costs) and the temporal resolution can also be allowed to run further. Most models tend to reach a "steady state" fairly quickly after the initial spin up, however, and the resolution does not appreciably improve with significantly longer runs. McFarlane pointed out that many physical processes are smaller than the resolved scales of the model, and the effects of such processes have to be parameterized, since they can be very important. He commented that the model has a number of altitudinal levels, usually with 30 km acting as the topmost level. All important physical processes are included in the model. A few of these include solar input, radiation travel in the atmosphere (in and out), optical properties of clouds, dynamics and behavior of clouds (parameterized), ocean-sea ice interactions, and soil and vegetation interactions. He pointed out that all models using CO_2 doubling illustrate that the maximum surface warming occurs at high latitudes and that the maximum warming in the tropics occurs in the troposphere. In such situations, there are some unexpected effects: tropical cloud cover increases, optical reflectance of clouds increases, radiation decreases, and moisture availability is higher. Obviously, cloud cover has important implications in climate models, particularly as one of the driving mechanisms of the tropical monsoon. The final question posed by McFarlane was which models should be used for the 6 ka run.

The development of the CLASS-A for GCMs (General Circulation Model) was also outlined. In this process, heat and moisture transfers for snow-covered and snow-free areas are calculated with the energy-balance equation solved for surface temperature. A second procedure involves a vegetation model which includes energy and moisture fluxes from the canopy, as well as the radiation and precipitation through it. There is a thermal separation from the ground beneath. The model is also able to take into consideration seasonal variations in the canopy. These developments have allowed a far more accurate assessment of predicted temperatures and precipitation in the newer GCM-coupled runs.

Karl Taylor of the Lawrence Livermore Laboratory provided an overview of the Paleoclimate Model Intercomparison Project (PMIP). It was established to co-ordinate and encourage the systematic study of atmospheric general circulation models (AGCMs) and to assess the ability of the various models to recreate paleoclimatic conditions. Since experiments to simulate transient climate time frames — for example, interglacial to glacial conditions (or *vice versa*) — are not practical, PMIP will concentrate on times when the climate is believed to be "different", but more stable. The first two experiments will be run in a "snapshot" mode for time frames centred at 6 ka and 18 ka. These times were chosen because they are believed to represent climatic extremes (near maximum ice conditions at 18 ka and near climatic optimum conditions for the present interglacial intemperate latitudes at 6 ka) for which there is a fair amount of paleoclimatic data reconstructed from various proxies. Most parameters, except for insolation and possibly CO_2, will be retained at the modern values. It is hoped that variations in monsoonal patterns will emerge from the 6 ka time frame. The 18 ka time will have a newly modelled ice surface (developed by Peltier) and sea surface temperatures will be computed from models. One of the hoped-for results of the 18 ka time frame model is simulated changes in northern hemisphere storm track patterns.

Sandy Harrison of the Department of Physical Geography, U. of Lund, Sweden, gave an interesting presentation on the fundamental characteristics of GCMs and the interactive uses of paleoenvironmental data in model designs. She pointed out that the spatial scale of GCM design is coarse (see McFarlane's comments above) — they do not capture (or generate) localized data — and that patterns of comparison are best made on a continent-wide scale. Implicit in this realization is that proxy data should also be best synthesized on a continent-wide scale. Her second main point was that GCMs "spin up" rapidly, and that long-time runs can become extremely expensive. For example, a model run might be for six years, whereas in the real world climate statistics are averaged over 30-year periods. Such realities mean that model outputs tend to become averaged over adjacent cells (especially for highly variable processes such as those generated in the atmosphere), and this creates the tendency of coarser spatial predictions at any given point on the GCM grid. Certain outputs from the GCMs (wind direction and strength, or sea level pressure, for example) are more reliable than temperature or precipitation, which tend to be more local in position. GCMs are better at producing long-term conditions, whereas short-term events (floods, for example) are poorly suited to models. There are various reasons for this, including: spatial scale of the event *versus* cell grid size, gross simplification of local topography, and short run times. Finally, GCMs tend to concentrate more on simulating long-term climatic trends rather than shorter time events. Because of this, a limited number of geographically confined, high-resolution, proxy data sites are of less use than a large number of reasonably well-dated sites which cover a wide geographic area.

In her exposé on Quaternary proxy data, Harrison pointed out that different indicators react in different ways. An individual climatic signal for each proxy must be identified, and multiple indicators must be used. In their own ways, qualitative data can be as important as (or even more important than) quantitative data. Lake levels and dunes provide regional qualitative data about moisture balances and wind directions, but quantitative data, unless model deficiencies are fully understood, can create problems. The advantage of quantitative data sets is that the interpretations of complex records can be more readily understood. Perhaps the most important element is that individual sets from different proxies have to be determined independently.

In a lengthy afternoon session chaired by Paul Egginton, ten researchers explained how their areas of expertise had been used to assist in paleoenvironmental reconstructions in different regions of Canada. Roy (Fritz) Koerner (Terrain Sciences Division, GSC) outlined how ice cores are analysed (stable isotopes providing information on annual temperatures; particulates, on airmass trajectories and turbidity; major ions, on atmospheric transport; and pollen, on local- and long-distance transport). Although the Canadian ice core work has concentrated largely on Arctic island ice caps, there are sufficient data to discuss much of Holocene time at 50-year means, and volcanic horizons (marked by acidity spikes) can provide many checks when cross-correlated with absolute dates on tephra horizons in Greenland and Iceland. Transfer functions involving stable isotopes can be derived from a number of variable factors, and reconstructions show that the main climatic warming in this region is early Holocene in age. They do not reflect a mid-Holocene Hypsithermal interval at, or approximately at, 6 ka.

John Smol (Queen's U.) presented information on diatoms and chironomids as paleolimnological indicators in different regions of Canada. He mentioned that diatoms are particularly useful in high latitudes because of extreme environmental conditions, and that lake water temperature, depth, dissolved inorganic carbon and organic carbon and silica account for statistically significant variations in the floras. In more extreme conditions, diatoms can also shed light on the extent of ice cover on high-Arctic lakes. In the drier regions of western Canada, salinity tolerances can be used to infer lacustrine salinity (and throw light on paleo lake levels). Water temperatures can be inferred from chironomid head capsules, and this technique has been used to some success in the Younger Dryas fluctuations of eastern Canada by Ian Walker and co-workers.

Denis Delorme (National Water Research Institute, Canada Centre for Inland Waters) continued the paleolimnological theme by discussing the potential of ostracodes in reconstructing past environments. He pointed out that a considerable database exists, centred on the Prairies, but extending elsewhere in Canada, and that many ostracode species have quite specific preferences for water chemistry and for temperatures and depths, which can be used to provide information about past climatic changes.

Anne de Vernal (GEOTOP, U. de Québec à Montréal) described her research on dinoflagellates in the North Atlantic and in the Arctic and sub-Arctic basins, such as Hudson Bay and the Labrador Sea. Considerable interest was elicited by her explanation that dinoflagellate cysts have a close relationship with sea surface temperatures, seasonality and salinity. She demonstrated examples which linked dinoflagellates to sea surface salinity and temperature in February and August and to the seasonal extent of sea ice cover. She was also able to illustrate the results from several cores demonstrating post-glacial changes in sea surface conditions in Hudson Bay, the Gulf of St. Lawrence, and the Labrador Sea.

Steve Zoltai (Northern Forestry Centre, Forestry Canada, Edmonton) dealt with the topic of peat. He pointed out that sections of peat can be analysed to indicate plant communities, and that these reflect changes in local environmental conditions (hydrology and water quality) and, frequently, regional climatic changes. Zoltai commented on the growth of peat after 6 ka in the northern Prairies, an interpretation which invokes the onset of cooler, moister conditions; a similar development of peat in the Boreal region between 4 and 5 ka; and the development of permafrost in northwestern Alberta peatlands *circa* 3.5-4 ka, possibly reflecting the onset of cooler conditions. Similarly, the cessation of peat deposition in the high Arctic between 7 ka and 6 ka may be due to the commencement of colder and drier conditions. Zoltai also pointed out the potential for the use of bryophytes (mosses) in reconstructing detailed information on growth position (height above the local water table), pH and regional climate.

James Syvitski (Atlantic Geoscience Centre, GSC, Halifax) outlined the potential of marine process studies in resolving past environments. One interesting concept was that tides existed in nearshore regions after 6 ka as the amphidromal points moved onto the shelf areas with sea-level rise. Syvitski's presentation concentrated on hind-casting techniques in resolving paleoclimatic conditions from the accumulation rate of organic carbon in sea-floor samples. The organic carbon concentration is inversely proportional to the total suspended load arriving in Canadian Arctic basins from runoff. The organic carbon measured downcore can be used in the calculation of absolute sedimentation rates. A transport model can be used to indicate discharge conditions and loads, ice accumulation and ablation, and summer thermal conditions which control ice storage balance. A number of examples were cited from Baffin Island fjords.

Ernie Walker (Department of Anthropology and Archaeology, U. of Saskatchewan) addressed the question of human habitation in the northern Great Plains in the period from 7.5 ka to 5 ka. This early middle prehistoric period is poorly understood, largely because of a lack of studied sites in the Canadian portion of the Plains. Walker felt that the reasons given for the apparent absence of sites (warmer and drier conditions around 6 ka) may be partially a function of the difficulty of site location in this time frame. He outlined the discovery and excavation of several sites of this age in Saskatchewan and pointed out that humans have the ability of concentrating many elements of the "natural" environment in site occupation levels. Such information can be used in regional climatic reconstructions.

Alan Morgan (Quaternary Sciences Institute, U. of Waterloo) summarized the use of fossil insects in reconstructing paleoclimates. He mentioned that fossil Coleoptera (beetles) have been recovered from more than 260 sites of Quaternary age in North America. Of these, only 16 can be matched to the period from 7 ka to 5 ka, and only four are centred at 6 ka. Past methodologies of climate analysis using Coleoptera have ranged from simple comparisons of species ranges to climate, to analytical comparisons of species to floral zones in Scandinavian mountains, to biogeographical range representations based upon species assemblages, and to the Mutual Climatic Range (MCR) method developed for Europe by Atkinson, Briffa and Coope. A comprehensive beetle database has been compiled for the North American fauna, which will be matched with climate stations to provide methods of climatic analysis that can be checked against GCM runs.

Glen MacDonald (Department of Geography, McMaster U.) addressed the problem of treeline movements in northern Canada. He pointed out that using fossil pollen to reconstruct climate involves various assumptions, including whether pollen (vegetation) changes are synchronous with climate change or whether there are lag effects, whether observed changes reflect regional changes rather than local conditions, and whether the sampling grid accurately reflects spatial variations in climate in a given temporal interval. His assertion is that in the period centred at 5 ka, at treeline in central Canada, there is no lag in pollen compared with diatoms or isotopes. He also pointed out, however, that later changes are asynchronous, and that the position of the treeline in Canada has fluctuated in time depending whether the western, central or eastern sectors of the country are considered.

The last person to address this section of the workshop was Hélène Jetté (GSC, Ottawa). Jetté provided participants with an outline of the main features of the GSC paleoecological database (pollen counts, fossil wood, and macrofossils) and illustrated this with samples of output from a linked geographical information system (GIS) database. She presented a paleovegetation map which divided Canada into 13 phytogeographic regions for the period 6 ka. Recognizing that deficiencies are present in the full spatial dataset, Jetté requested that participants contribute to refining the model. This engendered a fair amount of discussion in regard to certain areas of the country, and particularly for Nouveau Québec where workers from the Centre d'études Nordiques (U. Laval) and the U. de Montréal have established that a residual ice mass was still present at 6 ka.

The second day of the workshop saw a number of talks on transfer functions and other methods of quantification. The preliminary session was chaired by Glen MacDonald, and the first section was led by Joël Guiot (Laboratoire de botanique historique et palynologie, CNRS, Marseilles). Guiot addressed the question of paleobioclimatological analogues for the determination of climatic parameters using fossil pollen. The technique uses a distance method to find the closest modern analogues to a fossil assemblage, and a weighted average of the climate variables is then calculated to provide the paleoclimatic reconstruction. Unfortunately, the "no-analogue" situation arises in certain cases, and the resulting problems have to be addressed by the use of other paleoclimatic indicators. These have involved fossil insects (which seem to respond faster than pollen) and lake levels (which provide a different signal for precipitation levels). Percent organic matter is believed to represent an indicator of biomass at a site. Guiot illustrated several of these concepts and reconstructions with data from pollen and insects at Grand Pile (Massif Central, France) and with European pollen and lake data for assemblages from the 6 ka time frame.

Konrad Gajewski (Département de géographie, U. d'Ottawa) also dealt with the complex matter of reconstructing past climates from pollen using various statistical treatments. He concentrated on illustrating examples from the boreal forest region of Canada, and concluded that the modern analogues of boreal pollen taxa illustrate pollen-climate relationships, but that the late glacial/early Holocene assemblages indicate "no-analogue" situations.

Jock McAndrews (Department of Botany, Royal Ontario Museum, Toronto) spoke on the topic of the 6 ka July temperature reconstructed from pollen transfer functions. As a basis for discussion, he used Bartlein and Webb's (1985) paper which divided eastern Canada into 11 calibration regions. He had applied the calibration equations to 41 pollen diagrams from the same region (eastern Prairies to Newfoundland, including parts of the adjacent United States), and found the results in general agreement with the conclusions postulated by Bartlein and Webb. He drew some further insights, however, which suggested that the modern (cold) Lake Superior was warmer at 6 ka because regional temperatures were about 3°C higher than today. He suggested that prairie temperatures at 6 ka were also warmer than indicated by earlier reconstructions because ragweed had not been used. Finally, he suggested that the "no-analogue" high beech pollen anomaly in southern Ontario be investigated further with new transfer functions based on lake surface samples.

The final presentations were made in the afternoon of the second day. In a session chaired by Nat Rutter, a number of contributors outlined some of the methods and protocols involved in the handling of paleoclimatic data.

Robert Webb (National Geophysical Data Center, Boulder, Colorado) presented information on aspects of the paleoecological databases held by NOAA. In terms of availability, there are no specific restrictions on the use of data; data are flagged as published or unpublished. With respect to integrity, original counts are presented, together with the original taxonomic identifications. The responsibility for the original data rests with the data contributors. Database files stored by NOAA are open to all researchers, and there is co-operation with the European database users. Information can be downloaded to remote computers *via* telephone lines.

Eric Grimm (Research and Collections Center, Illinois State Museum) provided a specific example on how the NOAA pollen database had been managed. He pointed out that the data are in a relational database requiring approximately 9.5 megabytes (MB), containing about 315,000 records which take up approximately 4.5 MB. The database software, chosen for ease of use and friendliness, as well as ability to link files as needed, is Borland's "Paradox". The database is divided into a number of distinct areas (ARCHIVAL = Basic data; LOOKUP = Code numbers and names; RESEARCH = Interpretive or Subjective; SYSTEM = Database integrity, and VIEWS = Information derived from other tables).

These presentations led to a great deal of discussion, particularly concerning the merits and/or needs of establishing a distinct Canadian database. Most participants were of the opinion that a Canadian national database should be established, most likely at the GSC, with programmers funded, if necessary, from NSERC funds. (There were other workers who took the opposite view, that creating a Canadian database would be an unnecessary duplication of the efforts at Boulder. It was pointed out that many Canadian workers (Gajewski, Richard, Ritchie and others) have contributed to the pollen databases already housed at NOAA, and are key players in the advisory board for the NOAA database). With the ability of Canadian researchers to retrieve Canadian data contributed to NOAA, perhaps a "national" database is not required.

The final presentation of the day was a proposal generated by Richard Peltier to submit a Collaborative Special Project to NSERC on "Climate System History and Dynamics: A Canadian Contribution to the IGBP Core Projects PAGES and GAIM". This is a proposal to look at three time frames (6 ka, 18 ka, and 125 ka) by using proxy data, and by matching this to computer simulations for those time frames. The funding level requested would be considerable by NSERC standards, and would closely follow the amounts provided by NSERC to ODP and LITHOPROBE.

Monday morning was devoted to two different topics: a discussion of items not covered on the previous days, and a working plan for implementing the 6 ka study. The former revolved around further debate of the proposed GSC database, and the latter broached some of the methodologies that might be used in understanding the 6 ka time frame. Two of these involved taking the output of the newest GCM and comparing it with the Canadian Eco-regions Map, and comparing the 6 ka GCM output to the 6 ka GSC vegetation map (prepared independently from the GSC Paleoecology database). At the same time, the 6 ka GSC map will be refined by careful comparison of data acquired from regional proxy indicators, such as peat and ostracodes, and specific point data from sites with multiple proxies, such as plant macrofossils, insects, molluscs and vertebrates. This effort will take about four years of co-ordinated work.

CONCLUSIONS

Was the 6 ka Workshop worthwhile? I think the answer should be a qualified yes. It served to outline (again) the range of experience and expertise of Canadian proxy data workers, who are among the best in the world in their respective disciplines. It was extremely encouraging to have members responsible for the GCMs sitting in the same room and listening to the comments and concerns of proxy data workers. At the same time, it was an eye-opening experience for the researchers working in data gathering from the recent past to see the limitations and promises of the GCMs. Such interaction is quite rare, and in the experience of many in the room, something which usually takes place at the end (rather than the start) of a long consultative process. We can only hope that this augurs well for newly forged links between the two areas in coming years.

Unfortunately, the meeting also highlighted some of the schisms which exist between the various sub-disciplines and working groups in Canada. Some of these are the result of natural geographic isolation within the huge Canadian landmass. The interests and concerns of those from Quebec universities working in Nouveau Québec are quite different, in terms of processes, from those of a new combination of researchers coming together to study the Palliser Triangle IRMA (Integrated Research and Monitoring Area) in western Canada. Nonetheless, both are connected by a need to better understand the global circulation which was taking place at approximately 6 ka. The same can be said for groups on the west coast, in the Great Lakes region, or along treeline in the Yukon and NWT. The most promising aspect is that with each meeting people are starting to realize the advantages of positive interactions with other disciplines, and collaborations are emerging which would have been unimagined a decade ago. It is time to take these interactions one stage further by linking them to "external" agencies, such as the Canadian Climate Centre, to produce new insights. Natural systems do not operate in isolation: it is time for Quaternary workers to realize that co-operation on local, national and international levels is necessary to understand the big picture. Global change is upon us; we have too little time to provide big results, and such co-operative ventures have to be undertaken as soon as possible. The 6 ka Workshop may have forced us a little further along that road.

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Penrose Conference: Tectonic Evolution of the Coast Mountains Orogen

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A Penrose conference on the "Tectonic Evolution of the Coast Mountains Orogen" was held 17-22 May 1992 in southwestern British Columbia. The conveners were Maria Luisa Crawford, George Gehrels and James Monger. The conference consisted of two parts: a two-day field trip (led by Monger and Murray Journeay) which focussed on the geology and crustal structure of the southern Coast Mountains, using new seismic reflection data; followed by three-and-a-half days of informal discussions and poster displays at Bowen Island Lodge, which is situated within the southwestern Coast Mountains.

Most discussions during the conference concerned the nature, age and significance of the tectonic boundary that trends acutely across the Coast Mountains, from the eastern side at its south end (latitude 49°N) to the western side north of the British Columbia-Alaska boundary (latitude 54°N). This feature was examined in light of: 1) stratigraphic and magmatic characteristics of terranes that can be traced into the Coast Mountains and are juxtaposed along the boundary; 2) the structural, stratigraphic, metamorphic and magmatic features associated with their juxtaposition; and 3) the linkages between formation of the Coast Mountains orogen, tectonic events elsewhere in the Cordillera, and Mesozoic-Cenozoic plate reconstructions. The latter suggest that >13,000 km of lithosphere may have been subducted beneath western North America in the last 150 million years. This subduction may have occurred close to the present continental margin, may be recorded in the Cretaceous-Tertiary accretionary complexes (*e.g.*, Chugach terrane and equivalents), and may be partly accommodated/concealed by the complex structures of the Coast Mountains orogen.

Features of the North Cascades and contiguous southern Coast Mountains were