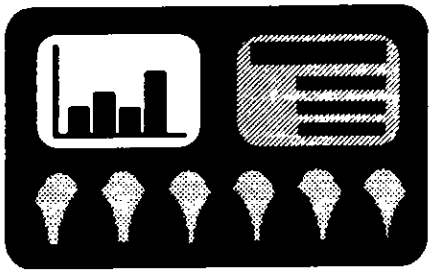

LIGA II

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BACKGROUND

The organization called LIGA (the Working Group on the Last Interglacial in the Arctic and Subarctic) was created in 1990 and first met at a NATO Advanced Research Workshop in Hantsholm, Denmark. The primary objectives of the group were to reconstruct high-latitude paleoenvironments and paleoclimate for Sangamonian (Eemian/Ipswichian) time *sensu lato*, with special attention being paid to the 5e time frame (Sangamonian, *sensu stricto*). The Hantsholm meeting resulted in a compilation of data for high latitudes in the northern hemisphere which was published as special issue of *Quaternary International* (Rutter *et al.*, 1991). The LIGA Working Group agreed to a number of secondary objectives which involve the creation and compilation of databases pertaining to sites within the time frames mentioned above and generally above 50°N latitude. Furthermore, the scientists involved have attempted to liaise between Quaternary field workers, paleoecologists and climate modellers in order to refine the specific reconstructions for different portions of Marine Isotope Stage 5.

The second LIGA meeting was held at the Université de Québec à Montréal (UQAM) Field Station at Saint-Michel des Saints, north of Joliet, Quebec, 4-7 May 1993. The primary purpose of the meeting was to make recommendations and to define protocols for the creation of databases essential for the quantitative reconstruction of climatic and environmental conditions during the last interglacial interval. The 34 attending scientists came from Canada (16), the United States (8), Norway (3), France (2), Denmark (2), Sweden (2) and Iceland (1). University researchers (27) heavily outweighed the number of government researchers (7) and there were no industrial representatives.

THE PLENARY SESSION

The first plenary session was chaired by John Matthews (Geological Survey of Canada, Ottawa) who briefly welcomed the participants to the Second LIGA Meeting. The initial introduction was made by Anne de Vernal (UQAM) who welcomed the participants to the Université de Québec à Montréal Field Station. She explained that all were there because of their interests in the last interglacial. She then went on to elaborate on the problems of this time frame (the difficulties of accurate dating, the boundary conditions which prevailed, and the dilemma of producing accurate chronostratigraphic maps for the northern Hemisphere). This subject of Sangamonian chronostratigraphy was to be the first of the topics which needed to be discussed at length by one subset of the working group.

The second major thrust would involve the development of a database. This working group was presented with three objectives.

1) To look at the question of the format of the database (to ensure that it was amenable for data input and output by all participants) and to ensure the methodology of data (would it be primary or interpreted data?).
2) What amount of standardization was necessary (or essential) on laboratory protocols and in material being prepared for contribution to the database?
3) What modifications needed to be made in the preliminary compilation of sites presented in the initial documentation from the Hantsholm meeting? Could a revised listing be compiled?

The third working group was charged with examining data-model comparisons. The group was asked to examine the relationships between the scientists providing the proxy-data (since this information input sets up some of the boundary conditions on the models) and the climate modellers (who are responsible for the model validation and output). It was suggested that some clear guidelines should be provided to the proxy-data researchers on the needs and constraints of the models.

Gifford Miller (U. of Colorado) provided an interesting background on the establishment of LIGA as an extension of CELIA (Brigham-Grette *et al.*, 1991), and the relationship of LIGA to other programs which involved high (and, principally northern) latitudes (PALE, PANASH, PASH, PEP, PONAM; see Table 1). Miller explained that LIGA was initiated as a result of the large number of (likely) Sangamonian sites at high latitudes in formerly glaciated regions. These were of interest because sensitivity studies indicate that the greatest changes will occur in high latitudes as a result of atmospheric CO_2 buildup. He pointed out that besides the Late Pleistocene-Early Holocene maxima at *ca.* 11-9 ka BP, the last interglacial is the most recent extreme warming event in which it is possible to study the climate system. He also stated that Marine Isotope Stage 5 has three periods for which the summer insolation forcing is higher than the Holocene. Miller then explained more about the PALE Program since it was aimed at different temporal resolutions and scales (the last 2,000 years at annual resolution; the last 20,000 years at centennial resolution, and the last 150,000 years at millennial resolution). He pointed out that a series of protocols have been developed during the last year to assure that individual records can be stored and compared in a common database, one of the problems that LIGA will have to deal with.

Claude Hillaire-Marcel (UQAM) provided an excellent summary of the chronostratigraphic problems involved in dating supposedly last interglacial sites. He stated that the only precise dating technique is by Th/U using a TIMS technique which is capable of ±1 ka to 2 ka at 2 sigma in the time frame involved. The next best technique was probably Ar/Ar (using step heating by lasers on potassium feldspars) and this was probably good to 5% at 100 ka However, both techniques have significant drawbacks in the lack of suitable materials. Th/U could be used on speleothems (which might have open or closed radioactive systems); or samples could be contaminated by detrital Th. In the case of Ar/Ar, volcanic ejecta were needed. Hillaire-Marcel went on to describe other methods which could be of more general use. These involved U-series isotopes; ESR; OSL; AA "dat-

ing" which lacked time precision, but which could be useful for local stratigraphic correlation; geochronological correlation with marine isotope stratigraphy; secular magnetic variations (particularly the Blake event, an 110° oscillation, which could be of some importance in the time frame); tephra-stratigraphy (useful in eastern Siberia, the north Pacific, western North America and parts of the North Atlantic region), and coastal palynology, for example, the *Osmunda* fern peak which is clearly seen in some Labrador Sea cores (another way of linking with the marine record). All of these techniques were illustrated with specific examples. His presentation concluded with recommendations on how to reduce the uncertainties in the physical and chemical dating techniques principally, perhaps, by detailed searches for materials for precise Th/U dating, for ash horizons; and for high resolution coring sites.

The working sessions commenced in the late afternoon with various people being assigned to one of the three working groups outlined above. The working groups were chaired by Nat Rutter (U of Alberta) and Gifford Miller (U of Colorado) – Chronostratigraphy; Alan Morgan (U of Waterloo) – Database; and Sandy Harrison (U of Lund, Sweden) – Data-Model Comparison. The groups worked well into the evening and met again the following afternoon. The results of these working groups will be mentioned later.

The Second and Third Plenary Sessions

Day 2 commenced with rain, but also with an enthusiastic response to the food (excellent) and scientific rapport (even better)! The high calibre of the sessions was maintained throughout the day with the commencement of the second plenary session (chaired by Richard Peltier, U of Toronto). John Kutzbach (U of Wisconsin) provided an excellent overview on climate modelling of the last interglacial. He illustrated the orbital changes and axial tilt changes that have taken place over the last interglacial to present interglacial cycle, emphasizing that the models indicate radiation peaks at 125 ka, 110 ka, 83 ka, and 10-9 ka. The radiation peaks when combined with tilt at 125 ka and 10-9 ka are particularly pronounced, and allowed substantially warmer summer months (perhaps up to 5°C warmer) and somewhat cooler winters (about 2°C cooler than present). The land heating during such peaks is optimized in August, while the high-latitude water bodies see a heating peak which is delayed to late September and early October. Kutzbach then commented on the NCAR model resolution and some of the model results. Based on a 25° tilt, which is slightly more than presumed values for 125 ka (23.9°), and using present CO_2 levels, he pointed out that at 80°N during June, July and August at 125 ka,

Table 1 List of acronyms used in this report.

AFTP	Anonymous File Transfer Protocol (also known as FTP)
CELIA	Climate and Environment of the Last Interglacial in Arctic and Subarctic North America
CNRS	National Research Council (France)
COHMAP	Cooperative Holocene Mapping Project
ESR	Electron Spin Resonance
GCM	Global Climate Model (may also mean Global Circulation Model or General Circulation Model)
GISP	Greenland Ice Sheet Project (United States); GISP2 drilling terminating July 1993.
GRIP	Greenland Ice-core Project (European)
ICSU	International Council of Scientific Unions
IGBP	International Geosphere-Biosphere Project (an initiative of ICSU)
INQUA	International Union of Quaternary Research
NCAR	National Center for Atmospheric Research (United States)
NGDC	National Geophysical Data Center (Boulder, Colorado, United States)
NOAA	National Ocean and Atmospheric Administration (Boulder, Colorado, United States)
OSL	Optically Stimulated Luminescence
PAGES	Past Global Changes (a core project of IGBP)
PALE	Paleoclimate from Arctic Lakes and Estuaries
PANASH	Paleoclimate of the Northern and Southern Hemispheres (proposed pilot project of PAGES)
PASH	Paleoclimates of the Southern Hemisphere
PEP	Pole-Equator-Pole (paleoenvironmental transect)
PONAM	Polar North Atlantic Margins
PMIP	Paleoclimate Modelling Intercomparison Project
SST	Sea Surface Temperatures
TIMS	Thermal Ionization Mass Spectrometry

solar radiation amounted to about 57 $W \cdot m^{-2}$, whereas it was about half this figure (30 $W \cdot m^{-2}$) at 6 ka. By comparison, the December, January and February radiation was about 5 $W \cdot m^{-2}$ for both 125 ka and 6 ka (approximately 2% below present-day values). Using the model at 125 ka, the northern oceans tended to be up to 8°C warmer than present during the winter months, the United Kingdom had an annual temperature that was approximately 4°C warmer than present, while the annual temperature for southern Ontario was approximately 9°C (approximately 2°C warmer than present). Following his presentation, there was considerable discussion about what parameters were used in the model and what had been omitted. Charlie Schweger (U of Alberta) pointed out that permafrost, with its attendant feedbacks, has a very important role in vegetation growth. Kutzbach mentioned that it is assumed that the basic data input is correct, and that the model may be correct, however, it is best to assume that the model is incorrect until it agrees with the data. The model results will change a) as the models improve, and b) as one compares different models. Researchers should tend to believe the direction of model change, and they should believe in the broad-scale patterns exhibited in the models.

The afternoon (third) plenary session was chaired by Hans-Petter Sejrup (U of Bergen). Sandy Harrison (U of Lund) made a fine presentation on the BIOME simulation. She started by pointing out that Quaternary data tells us what has happened in the past, but not why. The GCMs can provide mechanistic explanations for the observed changes preserved in the geological record. The BIOME model predicts the equilibrium response of vegetation to climate at the scale of regional to global patterns using a variety of parameters. These include plant functional types, physiological constraints and bio-climatically effective variables. The BIOME model run at Lund recreates full seasonal cycles for all seasons for 20 years at 125 ka. A stable state is reached after 15 simulated years, and generally the last five to ten years of the run are used. She pointed out that it was essential to have a) raw data, b) that the proxy data be separated, and c) that the ecological constraints be described (where known).

Sigfus Johnsen (U of Copenhagen) gave a fascinating talk on recent drilling results from the European core in the Greenland Ice Sheet. Unfortunately (but realistically), the gathered scientists were asked to keep the information confidential until the formal release of the scientific papers describing the results, so readers should keep tuned to *Nature* and *Science* and other periodicals. Suffice to say that the results are most interesting. The GRIP Summit Core reached a depth of 710 m in 1991, 2.32 km in 1992, and terminated just above the base of the Ice Sheet at just about 3.03 km in 1993 (note that GISP2 terminated at 3.053 km at bedrock on 1 July 1993).

For those who are familiar with the never-ending interstadials of western Europe, I have been intrigued with the changing ages during the last 30 years or so. The current terminology and ages imply that the Denekamp is 34 ka; the Hengelo is 41-43 ka; the Glinde is 50 ka; the Oerel (of northern Germany) is 55 ka; the Odderade is 83 ka (and probably the prime candidate for Stage 5a), while the good old Brørup has aged even more rapidly than I. In 1970, it was assumed to be approximately 63 ka, and it is now placed at 100 ka. Johnsen's talk concentrated on some of the results of the Sangamonian section of the core, and rapid climate changes which occur within it. The implications of the work bode well for a far better understanding of this time frame in the northern Hemisphere.

Joël Guiot provided a most interesting presentation on transfer functions and how they are used in de-convoluting marine and terrestrial records. He explained the various approaches that are used to try to derive quantitative climatic data from various paleoecological studies, and qualified these by reference to vegetation and insect comparisons from the Grande Pile site in Central France.

Guiot's talk ended the formal presentations for the second day and the working groups reconvened for further discussion of their respective topics. (This discussion and a great deal more interaction continued throughout the third day of the workshop).

The Fourth Plenary Session

The results of the Working Group deliberations were given by the respective chairpersons during the fourth plenary (chaired by Eiliv Larsen of the Geological Survey of Norway, Trondheim).

Geochronology *(Gifford Miller)*

The primary purpose of the group was to find a means of assigning an absolute age to a specific site. It was recognized that the duration of the interval was important, and that it was also essential to see if synchroneity of deposition could be established in geographically close sites. Failing the above, it is important to try to define the portion of the "interglacial" being examined: is it 5a or 5e? Such resolution should be provided on evidence that is independent of climate. The group then provided a table of techniques used for dating, giving range, precision, accuracy and materials ranked in order from most to least useful. They provided a narrative for each technique, focussing on a) assumptions and pre-requisites pertinent to conditions and types of materials in Arctic and subarctic sites; b) an evaluation of the potential of dating sites of last interglacial age; c) a tabulation of materials which might be found, ranked by potential, with a brief rationale of their usefulness; d) specific examples; and e) key references. The group also discussed various strategies (collecting samples, the usefulness of multiple methods, limiting maximum and minimum ages and techniques to establish synchroneity in sites in geographic proximity). The last topic they discussed was the evaluation of results (how confidence limits can be assigned for deposits supposedly of the last interglacial).

The Database Group *(Alan Morgan)*

This group reported that, because of its size, it had split into three sub-units, although all members participated in the overall discussions. The first subunit (chaired by Lou Maher, U of Wisconsin) had looked at database format and handling. The principal recommendations were that the data input must be simple; second, that the database must be easily accessible; and third, and perhaps most important, it should be useful to many researchers. Furthermore,

- The format of preference was ASCII, and diagrams could be scanned in; the data was to be made available by E-Mail using Internet and its affiliated networks.
- There was the possibility that there could be a later, second-stage com-

pilation on CD-ROM disks.

- The original forms (generated at LIGA I in Hantsholm) were to be revised and information on new sites would be added. All of this data would be placed on the NOAA database, and on geology.wisc.edu for anonymous file transfer protocol (AFTP).
- The references to all entries made to date will be fixed by assignation to the Quaternary International text brought out after the Hantsholm conference.
- The references to new sites (discovered or re-assigned after the Hantsholm conference) would be prepared for a new publication to come from LIGA II.

The data-standardization sub-unit (chaired by Karen Knudsen, Arhus U, Denmark), decided that raw data and not results should be provided. However,

- Interpretation(s) should be provided as additional comments to explain the site context.
- A general descriptor of the full stratigraphy should be provided with special amplification on Stage 5.
- The boundaries of the units believed belonging to Stage 5 should be included in the data set.

The sub-unit updating the preliminary compilation (chaired by Jacques-Louis de Beaulieu, CNRS, Marseilles), developed a series of forms to be used in the revision of the sites described in the Hantsholm summary, as well as for the new sites mentioned above. The group recommended that preparation methods for individual techniques should be described, and, rather than "re-inventing the wheel", the protocols developed for the PALE initiative should be followed wherever possible. Failing this, the Berglund book on Paleoecological techniques should be followed (Berglund, 1985). If deviation took place from either (because of special local conditions), these exceptions should be clearly stated.

Data Modelling *(Sandy Harrison)*

This group decided that they should "go for the big signal" and "go global". Several questions had been posed, and the first of these was: What proxy-data is needed for the reconstruction of accurate paleoclimate maps? The group suggested that we need to refine what we know about boundary conditions, especially high-latitude SSTs, seasonal sea-ice margins, land ice margins (and heights), and sea levels. Such compilations of global boundary conditions are being stored at the NGDC. In terms of the question: How can validation of data-sets be established? it was advised that information should be derived from pollen, insects, lake extents, $\delta^{18}O$, marine microfossils and former permafrost distributions. The group stated that it was:

- important to provide primary data (not interpreted);
- that individual proxies be considered separately;
- that the LIGA organization tap into all available expertise; and that
- there should be an assessment of the quality of the dating control.

It was important to improve modern calibration of the data-sets (this emphasizes the significance of modern collections of biological organisms, *i.e.*, Coleoptera, Mollusca, Ostracoda, which can be used as baseline criteria); core-top materials were essential in palynological and marine studies, while modern surface samples (*i.e.*, from wetlands) are also of considerable value.

In response to the question on the sampling strategy, the group decided that it would recommend that:

- sampling should be improved in "good" regions (areas which were known, or suspected, to contain last interglacial deposits), however, that
- there should be no huge "gaps" in hemispheric sampling sites;
- concentrated attempts should be made at sampling in areas where the models show a big signal, and in areas where the models show a counter-intuitive signal;
- all the site investigators should strive for high temporal resolution.

Under "techniques", the group resolved that process models should be used to translate climate to response. This would be achieved by BIOME models, by lake models, by permafrost models, by ice sheet models, by upwelling models, and by geochemical models. They recommended the analogue approach (preferably the restrained analogue technique) and the use of multi proxies, and suggested that both qualitative and quantitative estimates could be used.

As a result of their discussion, the group had a number of concerns. They recognized that the network is sparse, and that the chronologies are poor, and, furthermore, that it is difficult to do a COHMAP style interpretation. This led them to suggest some new strategies that involved a range of comparisons along longitudinal gradients (*i.e.*, from *ca.* 30°N, north to high latitudes), as well as changes in direction as well as magnitude for different proxies. In this way zonal or sectoral comparisons could be provided.

Finally, there was some discussion about what modelling might be conducted for the Stage 5 time frame.

The Fifth Plenary Session and Conclusions

The final, and fifth, plenary session was chaired by Nat Rutter (U. of Alberta) and held on the fourth day of the meeting. A large number of topics were covered that can only be broadly described as proposed activities and research priorities. A new LIGA Committee was restructured retaining A. Velitchko (Russia) and J.V. Matthews (Canada) as the old members. (Alice Telka, Geological Survey of Canada, would be retained also, since the secretariat would remain in Ottawa). New members would be P. Anderson (United States) and S. Harrison (Sweden). N. Rutter remains as an *ex-officio* member because of his contacts with PAGES, and as Past President of INQUA. Stein-Erik Lauritzen is overseeing the next compilation report.

In terms of research priorities, it was generally recognized that there were large gaps in the LIGA coverage. More importantly, there was a growing recognition that the "A" in LIGA is, perhaps, inappropriate in terms of looking at Global Climate Models. There was a deal of tepid, sometimes approaching heated, discussion over whether LIGA should become LIG, and Rutter suggested that the Berlin INQUA (in 1995) might be an appropriate place to convene such a meeting. Because of the north-south transects (see Data Modelling, above), there was a recognition that groups should be involved whose interests were in mid-latitude Sangamonian/Eemian events, and there was a suggestion that Canadian workshops should be held for groups interested in the last interglacial in southern Ontario, Quebec and Manitoba and in the northern tier of the United States.

There was considerable discussion of "time-frame" techniques that might more accurately date selected sections

(for example, by using tephra as marker horizons). It was suggested that a high priority should be placed on research protocols for sampling and processing, on the notification to the community of sites which needed study, and on the potential division of site materials. It was also recognized that there should be standardization of the synthesis of data.

The group felt that there should be a focus on Stage 5e (Sangamonian *sensu stricto*) since it is this time frame that illustrates the optimum development of the interglacial. It was suggested that there were a number of critical repositories (and regions) where there was a high likelihood of a good last interglacial record. These would include the Greenland Ice Sheet, the Grande Pile record, Speleothems, many sections in Alaska, Denmark and the Netherlands, and substantial tracts of the Labrador Sea. Following some extremely interesting "mini-presentations" by a number of individuals, certain members of the group were given various responsibilities for different tasks. These included the preparation of a LIGA report for *Episodes*, for *Geoscience Canada*, for a special issue of a scientific journal with a topic on the structure of the last interglacial (these would be individual LIGA contributions), and a LIGA contribution to a large audience journal on data-model comparisons.

I would be remiss to close this account without acknowledging the sponsoring agencies for LIGA II. These include the National Science Foundation (USA); the Natural Sciences and Engineering Research Council of Canada; the International Geological Correlation Programme, the Université de Québec à Montréal, the Geological Survey of Canada, the Centre de recherche en géochimie isotopique et en géochronologie; the Chaire de Recherche en Environnement (Hydro-Québec) and the Canadian Climate Centre. Furthermore, since none of this happens without an Organizing Committee to safely oversee the arrangements, sincere thanks are due to Anne de Vernal, John Matthews and Alice Telka, who have now organized two excellent Quaternary Workshops in less than six months (Morgan 1992). Thanks are also due to the staff of the UQAM Field Station at Saint-Michel des Saints. They were always responsive and courteous, and greatly enhanced our pleasure at being at the Centre. Finally, thanks to all the participants. It was a delight to see scientists from so many disciplines and countries coming together to try to resolve one aspect of the pressing problems of rapid change on this planet. If anything good is to come from the sorry story of anthropogenic change it is the new alliances that are being forged between groups, which, under different circumstances, may never have met. I look forward to LIGA III!

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