Quaternary Science Reviews 27 (2008) 1–5

INTegration of Ice-core, MArine, and TErrestrial records (INTIMATE): refining the record of the Last Glacial–Interglacial Transition

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Received 3 October 2007; accepted 4 November 2007

Abstract

INTegration of Ice-core, MArine and TErrestrial records (INTIMATE) is a core project of the INQUA Palaeoclimate Commission, the primary goal of which is to synchronise records of the Last Glacial–Interglacial Transition (LGIT). Through a series of international workshops, INTIMATE has encouraged direct collaboration between scientists with interests and expertise in a wide range of palaeoenvironmental approaches. The workshops have focused on the dissemination of good practice in the dating, correlation and synthesis of diverse palaeoenvironmental records that span the LGIT. This special issue of *Quaternary Science Reviews* presents some of the outcomes of the 8th INTIMATE International Workshop held in Iceland in September 2005, and focuses on four themes considered vital to INTIMATE's long-term strategy. (1) An event stratigraphy approach, which uses the Greenland oxygen isotope record as a stratotype sequence, lies at the core of INTIMATE's operations. A revised event stratigraphy scheme for application to North Atlantic LGIT records is presented, which is based on the new GICC05 Greenland ice-core chronology. (2) New tree-ring data from Switzerland and the application of Bayesian-based procedures in the analysis of comprehensive radiocarbon data sets provide much potential for reducing the uncertainties in radiocarbon-based age models. (3) Three of the contributions present new evidence that helps to refine the tephrostratigraphy of the LGIT in the NE Atlantic and New Zealand regions. (4) Establishing the precise order and synchroneity of events during the LGIT is vital to understand the causes and effects of abrupt climate change. Data are presented from the Baltic region and Alaska, which vary in degree of compatibility with North Atlantic records. Two final papers consider the roles of Dansgaard–Oeschger events on thermokarst during the Middle Weichselian and of solar activity variations during the mid-Holocene; both illustrate how the INTIMATE event stratigraphy approach can apply to the study of other time intervals.

1. INTIMATE: a core project of the INQUA Palaeoclimate Commission

INTegration of Ice-core, MArine and TErrestrial records (INTIMATE) is a core project of the INQUA Palaeoclimate Commission, which was initiated during the XIVth INQUA Congress held in Berlin in 1995. The project's primary goal is to synthesise marine, terrestrial and ice-core evidence for the Last Glacial–Interglacial Transition (LGIT), initially defined as the period between ca 15 and 10 ka cal BP (but see below). The overall aim is to clarify the sequence, timing, nature and causes of abrupt environmental events during the LGIT. More information on the INTIMATE project, its activities and its outcomes can be found at http://www.geo.uu.nl/fg/INTIMATE.

To achieve its objectives, INTIMATE has organised a series of international workshops which have encouraged direct collaboration between the ice-core, marine and terrestrial scientific communities for the purpose of synchronising palaeoenvironmental records which span the LGIT (see e.g. Björck et al., 2001a). Precise correlation of the records has proved a difficult challenge, however,

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0277-3791/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.quascirev.2007.11.020

largely because of the limited precision and accuracy routinely achievable using available dating and correlation methods (Balter, 2006; Turney et al., 2006a). Hence the INTIMATE international meetings have tended to focus on issues of chronology and correlation and the development of procedures that can generate more secure age models for LGIT records. A key strategy to emerge from the meetings has been the adoption of an event stratigraphy approach for the correlation of LGIT records, the basis and strategic importance of which are outlined in Björck et al. (1998), Walker et al. (1999) and Lowe et al. (2001).

This special issue of *Quaternary Science Reviews* contains a selection of the papers presented at the 8th INTIMATE International Workshop, held in Mýrdalur, Iceland in September 2005. The meeting was organised by Jón Eiríksson, Arny Sveinbjornsdottir, Olafur Ingolfsson and Sigfus Johnsen and attended by 28 INTIMATE project members from eight different countries (see Lowe, J.J. et al., 2008, Appendix 1) including representatives from the ice-core, marine, terrestrial, tephrochronology, radiocarbon, tree-ring and climate modelling scientific communities. In line with previous INTIMATE international meetings, the dominant theme of the Iceland meeting was high-precision chronology, including assessments of Greenland ice-core records, dendrochronological data sets, age–depth modelling of sedimentary sequences, the distribution and origins of volcanic ash layers within sedimentary sequences and a revision of the INTIMATE event stratigraphy scheme. In essence, the meeting provided an opportunity for the INTIMATE group to review dating and correlation protocols in the light of recent, important methodological developments.

A radical change for INTIMATE introduced at the Iceland meeting was a considerable extension of the project's period of study. Prior to that meeting, the INTIMATE project had focused mainly on developments during the LGIT in the North Atlantic region while confining its deliberations to the interval between 15 and 10 ka cal BP. A new Australasian INTIMATE group, inaugurated during the XVIth INQUA Congress held in Reno, Nevada in 2003, adopted the event stratigraphy approach introduced by the North Atlantic INTIMATE group but developed a regional scheme with application to the interval between 30 and 8 ka (Turney et al., 2006b; Alloway et al., 2007). This was considered necessary because significant climatic warming appears to have occurred considerably earlier (at around 28 ka) in some parts of the Southern Hemisphere than in the North Atlantic region. This extended interval also includes the early Holocene climatic perturbations, such as the Preboreal Oscillation and 8.2 ka event, which are increasingly becoming the focus of considerable scientific study (e.g. Björck et al., 2001b; Rohling and Pälike, 2005; Davis and Stevenson, 2007; Hoek and Bos, 2007). Since the ultimate goal of the INTIMATE project is to synchronise LGIT events at the global scale, the North Atlantic INTIMATE group has accordingly extended its focus of attention to cover this same interval. Consequently, a new event stratigraphy scheme has been developed for the North Atlantic region (see Lowe, J.J. et al., 2008).

2. Refining the record of the LGIT in the North Atlantic region

The papers presented in this special issue collectively address four key themes. These have dominated INTIMATE's scientific agenda because they are considered vital to the project's long-term strategy for synthesising records with greater precision and accuracy.

2.1. The new GICC05 timescale and INTIMATE event stratigraphy scheme

The recovery of the NGRIP ice-core and the publication of the new Greenland Ice Core Chronology (Rasmussen et al., 2006; Andersen et al., 2007; Svensson et al., 2007) have opened up the potential for refinement and extension of the INTIMATE Event Stratigraphy scheme of Björck et al. (1998) and Walker et al. (1999). Lowe, J.J. et al. (2008) report on the construction and definition of a new GICC05 chronology for the last 30 ka and on revised (GICC05) age boundaries for the isotopically defined climatic events that span the interval 30–8 ka. The results provide the North Atlantic INTIMATE group with a new and extended Greenland stratotype sequence to underpin the event stratigraphy scheme for the North Atlantic region. Lowe, J.J. et al. (2008) also outline other recent developments that may lead to improved synchronisation of LGIT records, such as improved protocols for reducing the uncertainties in radiocarbon-based age models and the widening potential for the use of volcanic ash marker beds for correlation purposes.

Rasmussen et al. (2008) report on correlations between the NGRIP, GRIP and GISP2 ice-core records, and on procedures for synchronising the records to produce the new GICC05 timescale. They present matching data for the period ca 32.45–14.9 GICC05 ka b2k (before 2000 AD), corresponding to the end of MIS-3 and MIS-2, which reveal differences in snow accumulation rates between the three Greenland core sites during selected intervals. They conclude that the differences reflect variations in atmospheric circulation patterns over Greenland, which in turn altered the precipitation gradients between the core sites. The paper illustrates the increasingly sophisticated analytical procedures that can now be brought to bear on the Greenland ice-core records, and the increasingly detailed palaeoenvironmental interpretations that can be attempted as a result.

2.2. Refining age models based on radiocarbon dating

Extension of tree-ring records beyond ca 12.4 ka is vital for reducing the age errors in radiocarbon-based age models derived for sequences that fall within the period of interest to INTIMATE. Schaub et al. (2008) show how fossil pine remains from sites in Switzerland provide the potential for extending the continuous tree-chronology back into the Allerød (GI-1c to 1a) period. The data they present also contain important palaeoclimatic implications, for they indicate consistency in the timing and duration of short-term events, such as the Gerzensee Oscillation (GI-1b) and the abrupt climate shift at the start of the Younger Dryas (GS-1), inferred from the Swiss tree-ring, NGRIP ice-layer thickness and Cariaco Basin varve records.

While the new INTCAL04 calibration data set (Reimer et al., 2004) provides a more secure basis for radiocarbon calibration back to ca 26 ka than its precursor, INTCAL98, nevertheless the calibration uncertainties remain rather large for the interval beyond the limit of dendro-based calibration (12.4 ka). Significant improvement in this position must await incremental refinement of the INTCAL calibration data set, such as may be achieved by the successful extension of dendro records. On the other hand, considerable progress is being made in the generation of sophisticated statistical procedures for testing the coherency of radiocarbon-based age models and for matching the results to calibration data sets. Bronk Ramsey (2008) explains how Bayesian-based procedures facilitate these procedures and outlines a series of routines that can be implemented through the freely available OxCal software to build comprehensive age–depth models for a variety of depositional contexts. These enable the age–depth plots to be assessed in the light of different assumptions concerning the mode and rate of sedimentation. The routines offer the potential to integrate information between different site records and to test for coherency in chronological and correlation assumptions.

The application of Bayesian-based age models is tested by Blockley et al. (2008) on an annually laminated sediment record from Lake Soppensee in Switzerland. By sequentially introducing a series of stratigraphical constraints during the construction of the age models, Blockley et al. were able to test for degree of coherency and optimal probability distributions in the results. This contribution and that of Bronk Ramsey (2008) together illustrate the increasing versatility and sophistication of the statistical tools that are becoming available for the analysis and comparison of comprehensive radiocarbon data sets.

2.3. *Enhancing the tephrostratigraphy of the LGIT*

The use of volcanic ash layers for the correlation of LGIT records has played an increasingly influential role within the North Atlantic INTIMATE project in the wake of discoveries that they are more numerous and more widely dispersed in the region than previously appreciated (Davies et al., 2002, 2005; Turney et al., 2004). However, a note of caution is advised by Pyne-O'Donnell et al. (2008), since the employment of volcanic ash layers for this purpose requires that individual ash layers are geochemically distinct. Pyne-O'Donnell et al. present results, which show that several stratigraphically discordant tephra layers of Icelandic origin have virtually identical geochemical signals when analysed using conventional methods. Unless more exacting geochemical discriminant methods are employed, therefore, miscorrelations are eminently possible.

Koren et al. (2008) describe a new volcanic ash layer, discovered in a sequence from Norway, which they have named the Dimna Ash. It has a very similar chemistry to the Vedde Ash, which occurs higher in the same sequence and is dated to the middle of Greenland isotopic event GS-1 (the Younger Dryas). The Dimna Ash is clearly stratigraphically much older, having been dated by Koren et al. to before 12.8 ^{14}C ka BP or 15.1 ka cal. BP, placing it within isotope event GS-2. Very few tephra layers have been attributed to GS-2 thus far, and hence the Dimna Ash may represent an important new marker horizon for the correlation of LGIT sequences in the North Atlantic region.

New Zealand has been volcanically very active during the last 30,000 years, and a number of facets of the study of tephrochronology have been pioneered in New Zealand (Alloway et al., 2006). In the paper by Lowe, D.J. et al. (2008), 22 discrete tephra layers identified from records spanning the last 30 ka are examined for their potential for precise correlation between records and hence for underpinning the event stratigraphy scheme for the New Zealand region. The individual tephra layers can be dated by a variety of methods and some can be identified in laminated sediment sequences. There is evident potential for refining the age estimates of a number of the tephras, and hence for the more precise correlation of sequences of Last Termination age in the New Zealand region.

2.4. *Inter-regional comparison of abrupt climatic events and their effects*

Stanèikaitė et al. (2008) have reconstructed Late Weichselian (Late Wisconsinan/Late Devensian) terrestrial and aquatic environmental changes in Lithuania and argue that the key climatic events in that region can be correlated precisely with equivalent events in the North Atlantic region. This suggests that North Atlantic climatic signals extended quite far into the European continent during the Last Termination. By contrast, Yu et al. (2008) suggest, on the basis of a multi-proxy study of a sediment sequence from a site in Alaska, that an early Holocene climate oscillation possibly had a much greater magnitude in the North Pacific region than did the GS-1 (Younger Dryas) climatic perturbation. This suggests the possibility of a clear discordance in the sequence and/or amplitude of climatic events between the North Pacific and North Atlantic regions during the Last Termination. The possibility of such inter-regional differences underlines the need for an objective approach to the inter-regional correlation of records, an approach which avoids assumptions of contemporaneity of climatic transitions (see Lowe J.J. et al., 2008).

The potential value of applying the INTIMATE event stratigraphy approach to the study of other time intervals is underlined by the contributions by Bohncke et al. (2008) and Plunkett and Swindles (2008) in their respective studies of Middle Weichselian and late Holocene sequences. Bohncke et al. (2008) assess the possible role of Dansgaard–Oeschger cycles on permafrost degradation in the eastern part of Germany during the early Middle Weichselian. Chironomid and palaeobotanical data provide evidence for a rapid warming event that, although of short duration, appears nevertheless to have been of sufficient magnitude to form thermokarst lakes within permafrost. Plunkett and Swindles (2008) examine the influence of solar activity on Holocene bog development in Ireland and find evidence for spatial gradients in the timing of climate events triggered by solar forcing at the Subboreal–Subatlantic transition. Their final conclusion neatly epitomises the aspirations of the INQUA-INTIMATE project: 'Only by obtaining palaeoclimate records with high chronological precision can researchers expect to identify subtle spatial and temporal patterns that may lead to a better understanding of the mechanisms that alter climate'.

Acknowledgements

The North Atlantic INTIMATE project group is extremely grateful to Jón Eiríksson, Arny Sveinbjornsdottir, Olafur Ingolfsson, and Sigfus Johnsen for organising the Iceland Workshop in 2005 and associated field visits. We thank all the workshop participants for their contributions and participation in the ensuing fruitful discussions. Finally, we record our deep gratitude to all those who kindly agreed to review articles for this special issue. This is a contribution to INQUA Palaeoclimate Commission core Project 0408, the North Atlantic INTIMATE Project.

References

Alloway, B., Larsen, G., Lowe, D.J., Shane, P., Westgate, J.A., 2006. Tephrochronology. In: Elias, S.A. (Ed.), Encyclopaedia of Quaternary Science, vol. 4. Elsevier, Amsterdam, pp. 2869–2898.

Alloway, B.V., Lowe, D.J., Barrell, D.J.A., Newnham, R.M., Almond, P.C., Augustinus, P.C., Bertler, N.A.N., Carter, L., Litchfield, N.J., McGlone, M.S., Vandergoes, M.J., Williams, P.W., NZ-INTIMATE Members, 2007. Towards a climate event stratigraphy for New Zealand over the past 30,000 years (NZ-INTIMATE Project). Journal of Quaternary Science 22, 9–35.

Andersen, K.K., Svensson, A., Johnsen, S.J., Rasmussen, S.O., Bigler, M., Röthlisberger, R., Ruth, U., Siggard-Andersen, M.-L., Steffensen, J.P., Dahl-Jensen, D., Vinther, B.M., Clausen, H.B., 2007. The Greenland Ice Core Chronology 2005, 15–42 ka. Part 1: constructing the timescale. Quaternary Science Reviews 25, 3246–3257.

Balter, M., 2006. Radiocarbon dating's final frontier. Science 313, 1560–1563.

Björck, S., Walker, M.J.C., Cwynar, L.C., Johnsen, S., Knudsen, K.-L., Lowe, J.J., Wohlfarth, B., INTIMATE members, 1998. An event stratigraphy for the Last Termination in the North Atlantic region based on the Greenland ice-core record: a proposal by the INTIMATE group. Journal of Quaternary Science 13, 283–292.

Björck, S., Lowe, J.J., Walker, M.J.C. (Eds.), 2001a. Integration of ice core, marine and terrestrial records of Termination I from the North Atlantic region. Quaternary Science Reviews 20, 1169–1274.

Björck, S., Muscheler, R., Kromer, B., Andresen, C.S., Heinemeier, J., Johnsen, S.J., Conley, D., Koç, N., Spurk, M., Veski, S., 2001b. High-resolution analyses of an early Holocene climate event may imply decreased solar forcing as an important climate trigger. Geology 29, 1107–1110.

Blockley, S.P.E., Bronk Ramsey, C., Lane, C.S., Lotter, A.F., 2008. Improved age modelling approaches as exemplified by the revised chronology for the Central European varved Lake Soppensee. Quaternary Science Reviews 27, this issue, doi:10.1016/j.quascirev.2007.01.018.

Bohncke, S.J.P., Bos, J.A.A., Engels, S., Heiri, O., Kasse, C., 2008. Rapid climatic events as recorded in Middle Weichselian thermokarst lake sediments. Quaternary Science Reviews 27, this issue, doi:10.1016/j.quascirev.2007.09.017.

Bronk Ramsey, C., 2008. Deposition models for chronological records. Quaternary Science Reviews 27, this issue, doi:10.1016/j.quascirev.2007.01.019.

Davies, S.M., Branch, N.P., Lowe, J.J., Turney, C.S.M., 2002. Towards a European tephrochronological framework for the Last Termination and early Holocene. Philosophical Transactions of the Royal Society of London, Series A 360, 767–802.

Davies, S.M., Hoek, W.Z., Bohncke, S.J.P., Lowe, J.J., Pyne O'Donnell, S., Turney, C.S.M., 2005. Detection of Late-glacial distal tephra layers in the Netherlands. Boreas 34, 123–135.

Davis, B.A.S., Stevenson, A.C., 2007. The 8.2 ka event and Early-Mid Holocene forests, fires and flooding in the Central Ebro Desert, NE Spain. Quaternary Science Reviews 26, 1695–1712.

Hoek, W.Z., Bos, J.A.A., (Eds.), 2007. Early Holocene climate oscillations—causes and consequences. Quaternary Science Reviews 26, 1901–2030.

Koren, J.H., Svendsen, J.I., Mangerud, J., Furnes, H., 2008. The Dimna Ash—a 12.8 ^{14}C kyr old volcanic ash in western Norway. Quaternary Science Reviews 27, this issue, doi:10.1016/j.quascirev.2007.04.021.

Lowe, D.J., Shane, P.A.R., Alloway, B.V., Newnham, R.M., 2008. Fingerprints and age models for widespread New Zealand tephra marker beds erupted since 30,000 years ago: a framework for NZ-INTIMATE. Quaternary Science Reviews 27, this issue, doi:10.1016/j.quascirev.2007.01.013.

Lowe, J.J., Hoek, W.Z., INTIMATE group, 2001. Inter-regional correlation of palaeoclimatic records for the Last Glacial–Interglacial Transition: a protocol for improved precision recommended by the INTIMATE project group. Quaternary Science Reviews 20, 1175–1187.

Lowe, J.J., Rasmussen, S.O., Björck, S., Hoek, W.Z., Steffensen, J.P., Walker, M.J.C., Yu, Z., INTIMATE group, 2008. Synchronisation of palaeoenvironmental events in the North Atlantic region during the Last Termination: a revised protocol recommended by the INTIMATE group. Quaternary Science Reviews 27, this issue, doi:10.1016/j.quascirev.2007.09.016.

Plunkett, G., Swindles, G.T., 2008. Determining the sun's influence on Late-glacial and Holocene climates: a focus on climate response to centennial-scale solar forcing at 2800 cal BP. Quaternary Science Reviews 27, this issue, doi:10.1016/j.quascirev.2007.01.015.

Pyne-O'Donnell, S., Blockley, S.P.E., Turney, C.S.M., Lowe, J.J., 2008. Distal volcanic ash layers in the Lateglacial Interstadial (GI-1): problems of stratigraphic discrimination. Quaternary Science Reviews 27, this issue, doi:10.1016/j.quascirev.2007.02.019.

Rasmussen, S.O., Andersen, K.K., Svensson, A.M., Steffensen, J.-P., Vinther, B., Clausen, H.B., Siggaard-Andersen, M.L., Johnsen, S.J., Larsen, L.B., Dahl-Jensen, D., Bigler, M., Röthlisberger, R., Fischer, H., Goto-Azuma, K., Hansson, M., Ruth, U., 2006. A new Greenland ice core chronology for the last glacial termination. Journal of Geophysical Research 111, D06102.

Rasmussen, S.O., Seierstad, I.K., Andersen, K.K., Bigler, M., Dahl-Jensen, D., Johnsen, S.J., 2008. Synchronization of the NGRIP, GRIP and GISP2 ice cores across MIS2 and palaeoclimatic implications. Quaternary Science Reviews 27, this issue, doi:10.1016/j.quascirev.2007.01.016.

Reimer, P.J., Baille, M.G.L., Bard, E., Bayliss, A., Warren, B.J., Chanda, B.J.H., Blackwell, P.G., Buck, C.E., Burr, G.S., Cutler, K.B., Damon, P.E., Edwards, R.L., Fairbanks, R.G., Friedrich, M., Guilderson, T.P., Hogg, A.G., Hughen, K.A., Kromer, B., McCormac, G., Manning, S., Ramsey, C.B., Reimer, R.W., Remmele, S., Southon, J.R., Stuiver, M., Talamo, S., Taylor, F.W., van der Plicht, J., Weyhenmeyer, C.E., 2004. IntCal04 terrestrial radiocarbon age calibration, 0–26 cal kyr BP. Radiocarbon 46, 1029–1058.

Rohling, E., Pälike, H., 2005. Centennial-scale climate cooling with a sudden cold event around 8200 years ago. Nature 434, 975–979.

Schaub, M., Büntgen, U., Kaiser, K.F., Kromer, B., Talamo, S., Andersen, K.K., Rasmussen, S.O., 2008. Lateglacial environmental variability from Swiss tree rings. Quaternary Science Reviews 27, this issue, doi:10.1016/j.quascirev.2007.01.017.

Stanèikaitė, M., Sinkunas, P., Seiriene, V., Kisieleine, D., 2008. Patterns and chronology of the lateglacial environmental development at Pamerkiai and Kasuciai, Lithuania. Quaternary Science Reviews 27, this issue, doi:10.1016/j.quascirev.2007.01.014.

Svensson, A., Andersen, K.K., Bigler, M., Clausen, H.B., Dahl-Jensen, D., Davies, S.M., Johnsen, S.J., Muscheler, R., Rasmussen, S.O., Röthlisberger, R., Steffensen, J.-P., Vinther, B.M., 2007. The Greenland Ice Core Chronology 2005, 15–42 ka. Part 2: comparison to other records. Quaternary Science Reviews 25, 3258–3267.

Turney, C.S.M., Lowe, J.J., Davies, S.M., Hall, V., Lowe, D.J., Wastegard, S., Hoek, W.Z., Alloway, B., SCOTAV and INTIMATE Members, 2004. Tephrochronology of Last Termination Sequences in Europe: a protocol for improved analytical precision and robust correlation procedures (a joint SCOTAV-INTIMATE proposal). Journal of Quaternary Science 19, 111–120.

Turney, C.S.M., Roberts, R.G., Jacobs, Z., 2006a. Progress and pitfalls in radiocarbon dating. Nature 443, E4 (doi:10.1038/nature05214).

Turney, C.S.M., Haberle, S.G., Fink, D., Kershaw, A.P., Barbetti, M., Barrows, T., Black, M., Corrège, T., Hua, Q., Hesse, P.P., Johnston, R., Moss, P., Morgan, V., Nanson, G., van Ommen, T., Rule, S., Williams, N.J., Zhao, J.-X., Cohen, T.J., D'Costa, D., Feng, Y.-X., Gagan, M., Mooney, S., Xia, Q., 2006b. Integration of ice-core, marine and terrestrial records for the Australian Last Glacial Maximum and Termination: a contribution from the OZ INTIMATE group. Journal of Quaternary Science 21, 751–761.

Walker, M.J.C., Björck, S., Lowe, J.J., Cwynar, L.C., Johnsen, S., Knudsen, K.-L., Wohlfarth, B., INTIMATE group, 1999. Isotopic 'events' in the GRIP ice core: a stratotype for the late Pleistocene. Quaternary Science Reviews 18, 1143–1150.

Yu, Z.C., Walker, K.N., Evenson, E., Hajdas, I., 2008. Late glacial and early Holocene climate oscillations in the Matanuska Valley, south-central Alaska. Quaternary Science Reviews 27, this issue, doi:10.1016/j.quascirev.2007.02.020.