The Late Paleozoic Ice Age Revisited

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The Late Paleozoic Gondwanan ice age (LPGIA), which spans the late Carboniferous through early Permian, marks Earth’s last complete transition into, and out of, ‘icehouse’ conditions, and corresponds to peaks in the diversity and extent of paleotropical wet forests [Gastaldo et al., 1996]. Studying the LPGIA therefore has the potential to provide valuable information for understanding the Earth’s transition out of the current ‘greenhouse’ conditions, and corresponds to peaks in the late Carboniferous, sea surface temperature, and tropical climate, which correspond to interglacial intervals recognized in late Paleozoic, high-latitude deposits. In addition, new, high-resolution paleontological records indicate rapid fluctuations in climate at low and high latitudes that are not consistent with the traditional view invoking prolonged glacial episodes.

A recent two-day workshop brought together about 40 researchers from the various subdisciplines of the geosciences to (1) assess the current understanding of the timing, duration, and character of the LPGIA and how it influenced Earth’s climate, sea level, depositional systems, and biota; (2) begin integrating the growing body of knowledge into a holistic framework that includes all aspects of studies of the LPGIA, including sedimentological, paleontological, and geochemical data; and (3) devise plans for future integrated research.

Participants included university faculty and researchers, state and government scientists, and graduate students. In addition, representatives from three U.S. National Science Foundation (NSF)-funded initiatives—Chronics (based at Iowa State University, Ames), Geo-systems (based at the University of Oklahoma, Norman), and PALEOSTRAT (based at Boise State University, Idaho)—were on hand to provide overviews of these initiatives and describe their potential roles in future research efforts.

Glacial Episodes: Protracted or Short-Lived?

Traditionally, the LPGIA has been regarded as a single protracted glaciation during the late Paleozoic era that spanned the Carboniferous and Early Permian periods, between approximately 320 and 265 million years ago [e.g., Frakes, 1979; Crowell, 1999]. Coal-bearing, low-latitude ‘cyclothems’ of late Paleozoic age preserved in Europe and North America have long been attributed to the waxing and waning of Gondwanan glaciers [Wanless and Shepard, 1936; Weevers and Powell, 1987]. Estimates of sea level change based on lithology and fossil variations in cyclothems have been used to suggest world-wide sea level changes of 100 meters or more, implying the presence of an immense, long-lived ice sheet that covered much of southern Gondwana. This view has been perpetuated in numerous paleogeographic reconstructions and paleoclimatic simulations for the Carboniferous and Permian.

It was clear from workshop presentations and discussions that the long-held paradigm of a single, prolonged ice age is being modified by the emerging view of a dynamic climate regime in which multiple glacial episodes of short duration (less than five million years) alternated with longer intervals characterized by warmer interglacial, or perhaps ice-free, nonglacial conditions. This interpretation is supported by new isotopic records suggesting associated fluctuations in atmospheric carbon dioxide partial pressures (pCO₂), sea surface temperature, and tropical climate, which correspond to interglacial intervals recognized in late Paleozoic, high-latitude deposits. In addition, new, high-resolution paleontological records indicate rapid fluctuations in climate at low and high latitudes that are not consistent with the traditional view invoking prolonged glacial episodes.

Keynote Talks

Nine keynote talks provided workshop participants with overviews of the current understanding of icehouse climates and the LPGIA as viewed from various disciplinary perspectives. Rob DeConto (University of Massachusetts, Amherst) presented an overview of the principal outcomes from modeling studies of icehouse periods in general. Peter Sheehan (Milwaukee Public Museum, Wisc.) reviewed the early Paleozoic glaciations, to pref ace a series of reviews of specific aspects of the LPGIA.

A series of presentations then reviewed the geological evidence for the timing, duration, and character of Carboniferous and Permian glaciation in component parts of Gondwana. John Isbell (University of Wisconsin, Milwaukee) reviewed occurrences of glacial strata in Antarctica and provided some interesting calculations of plausible south polar ice volumes based on geological evidence, as opposed to ice volumes required to generate sea level changes of varying magnitude such as those postulated mainly from fair-field records in the Northern Hemisphere. Geologically reasonable estimates of possible ice volumes are considerably smaller than those necessary to force sea level changes of 100 meters or more, raising an issue that cannot at present be resolved. Chris Fielding (University of Nebraska at Lincoln) reviewed the distribution of glacial strata in eastern Australia, and Noel James (Queen’s University, Kingston, Ontario, Canada) reviewed occurrences of polar Permian limestones from both Southern and Northern hemispheres.

A second set of keynote presentations reviewed Carboniferous and Permian far-field records in the Northern Hemisphere. The cyclical Pennsylvanian stratigraphy of the North American midcontinent was summarized by Phil Heckel (University of Iowa, Iowa City), and that of northern Europe was summarized by Sarah Davies (University of Leicester, U.K.). Bob Gastaldo (Colby College, Waterville, Maine) presented a review of patterns of vegetational response to deglaciation events in the late Paleozoic, and Isabel Montañez (University of California, Davis) provided a summary of geochemical proxy records of the LPGIA and its transition into the subsequent greenhouse world.

A strong theme that emerged from these presentations and ensuing discussions was that there is a close, persuasive correlation between the timing of Southern Hemisphere glacial events determined from the near-field rock record in Gondwana and those of events recognized from proxy records of paleotemperature and pCO₂ from fair-field sites in Europe and North America. This pattern provides some exciting opportunities for future research.

Breakout Sessions

A series of breakout sessions was held in the areas of (1) lithostratigraphy and sedimentology, (2) geochemistry and proxy records, and (3) paleobiological records. Discipline groups were asked to formulate strategies for future research, including methods and approach, funding sources, and potential collaborations. Each discipline group presented a report of their discussion at a subsequent full-group session.

To better understand the LPGIA and its impact on global systems, participants agreed that future research should focus on several key issues, namely, (1) the conditions responsible for the onset of glaciation, (2) the internal pacing and environmental drivers of glacial maxima and minima, and (3) conditions that led to final deglaciation and transition into greenhouse climate conditions. Investigation of these issues will ultimately allow for the identification of critical thresholds contained within natural systems that, once exceeded, drive the initiation or termination of widespread glaciation. Future research efforts should be interdisciplinary and should yield results at both high resolution, participants agreed. The favored approach involves focused, multidisciplinary study of key time slices along latitudinal transects that span both hemispheres.
Despite the vulnerability of society to climate change associated with increasing atmospheric CO₂ levels, the links between greenhouse gases, climate, and polar ice volume remain poorly constrained. Improved understanding of the LPGIA will aid in predicting the global changes that will occur with global warming. To maintain the momentum created by the workshop and to increase the visibility of the LPGIA, participants plan to (1) create working groups of interested scientists with an associated Web site to be hosted by Geosystems, (2) develop a synthesis paper that summarizes current understanding of the LPGIA and publish versions in scholarly journals and popular science magazines, and (3) publish a special volume based on workshop outcomes and the associated topical session.

The workshop, The Late Paleozoic Gondwanan Ice Age: Towards a More Refined Understanding of Timing, Duration and Character, was held 20–21 October 2005 in Salt Lake City, Utah, immediately following the 2005 Annual Meeting of the Geological Society of America.

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References


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