lation both from data and modeling perspectives were considered first. This was followed by an examination of the role of millennial-scale variability as an intrinsic feature of the past five terminations. Marine and ice core data from MIS 5e and 11 were presented next, along with a general consideration of Antarctic variability within interglacial periods. After a discussion of new simulations of Last Interglacial climates, the presentations ended with an examination of interglacial climate oscillations in speleothem and long pollen records from southern Europe.

Two major themes were identified during discussions, and these will now form the focus of two separate projects. One will emphasize the importance of rigorous statistical treatment of intra-interglacial variability and its relationship to mean global state. The other will examine the role of higher frequency variability in orbital-scale changes such as deglaciations (or interglacial inceptions).

The third PIGS workshop will be hosted by Jerry McManus and take place later this year in the U.S. (exact place and time to be appointed). This workshop will focus on the duration of interglacials.

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Understanding future sea level rise: The challenges of dating past interglacials

PALSEA

PALSEA workshop, Woods Hole, USA, 20-25 September 2009

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The aim of the joint PAGES-IMAGES Working Group "Paleo-constraints on sea-level rise" (PALSEA; www.climate.unibe.ch/~siddall/working_group.html) is to extract information about ice sheet response to temperature change from the history of sea level over the Quaternary, particularly interglacial periods, within a range of temperatures bracketing the modern. A better understanding of the relationship between global temperature and sea level is crucial for projections of future sea level rise expected from global warming. Currently, substantial uncertainty exists for such projections, primarily due to a lack of understanding about ice sheet dynamics. The 2nd PALSEA workshop focused on challenges in uranium-thorium (U-Th) coral dating, with discussions centered on three themes: technical issues in U-Th mass spectrometry, open-system behavior of U-series nuclides, and development of a Quaternary sea level database.

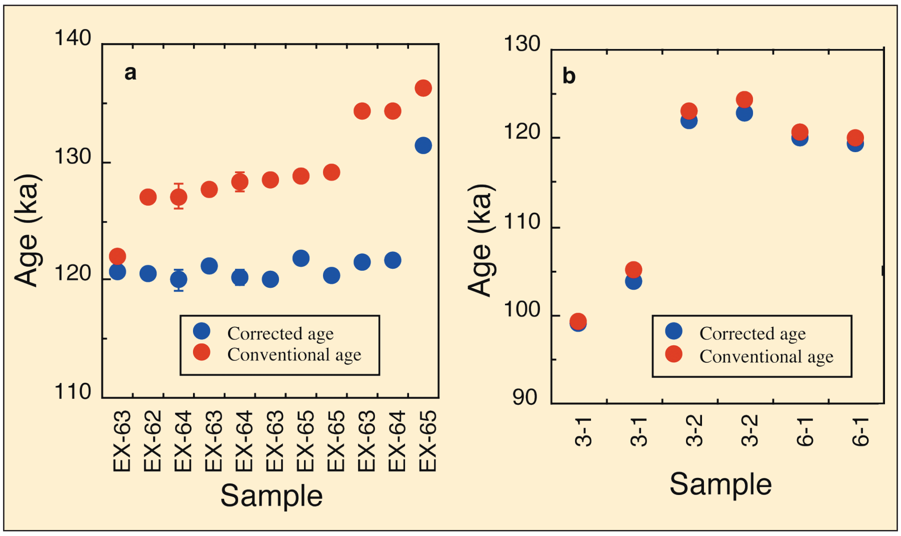

*Figure 1: The impact of open-system processes on coral ages (Thompson, unpublished data): **a**) Discrete sample replicates from a single large Western Australian head coral. Conventional ages range from 122 to 136 ka. Corrected ages cluster tightly at 121 ± 1 ka (mean and 2 SD), with the exception of one age at 131 ka. **b**) Ages from a Caribbean Last Interglacial reef outcrop (3 corals; 2 replicates each). Initial uranium isotope ratios fall between 1.147 and 1.151, satisfying a 'strictly reliable' screening criterion. However, one coral age is ~ 20 ka younger than it should be and reproduces poorly, due to late uranium addition. These two examples illustrate that neither rigorous screening criteria nor correction methods succeed in producing accurate ages in every case, highlighting the importance of replicating ages from discrete pieces of the same coral and comparing ages with stratigraphic observations from the field as an additional means of excluding erroneous ages.*

Analytical developments

Developments in mass spectrometry continue to improve coral age precision and extend the range of the U-Th geochronometer (Andersen et al., 2008). As a result, assuring comparability of ages reported by different labs is crucial. Ideally, all measurements should be traceable to the same set of reference standards. Unfortunately, internationally recognized standards are not currently available. A widely used U/Th uraninite reference standard, HU-1, is now in short supply and may no longer be suitable as a reference standard, as different aliquots have different isotope ratios when measured at current levels of precision and the assumption of radioactive equilibrium no longer appears valid. The time is ripe for the development of new standards. As a result of workshop discussions, a strategy for their production and distribution has been initiated in collaboration with the National Environment Research Council's Geosciences Laboratory, UK, drawing on the experiences of the EARTHTIME project (www.earth-time.org). As part of the workshop, an informal U-Th dating inter-lab comparison involving 14 labs was run. This exercise provided extremely useful information for the participants and a more comprehensive intercomparison is being planned.

Open-system effects

The impact of open-system behavior of U-series isotopes on the quality of coral ages is well documented, and both sample screening (Gallup et al., 1994) and age correction (Thompson et al., 2003) methods are employed to alleviate this problem. While practices for sample screening and/or age correction are still keenly debated, workshop participants agreed on a number of key points: 1) It is clear that many corals yield ages that do not agree within the analytical uncertainty when several individual pieces of the same coral are measured, thus age replication is crucial to establish the level of age uncertainty associated with sample heterogeneity; 2) The stratigraphic context of corals provides a key constraint on relative ages that has been largely underutilized. Publications should include this information, rather than just sample elevations; 3) Both sample screening and age correction approaches rely heavily on the $^{234}U/^{238}U$ ratio of seawater; yet the history of ocean uranium isotopic composition is not well known. Furthermore, $^{234}U/^{238}U$ values for screening and correction are not consistent between different lab groups. It is important to adopt a uniform history of ocean $^{234}U/^{238}U$ for quality and correction criteria, and to incorporate seawater $^{234}U/^{238}U$ uncertainty into error estimates for the ages.

Compilation

A key goal of PALSEA is to establish a comprehensive Quaternary sea level database. This data is presently scattered across the scientific literature with widely varying reporting formats, screening and correction criteria, and decay constants. Stratigraphic information is often incomplete, and elevations are not tied to consistent benchmarks. It is highly desirable to compile existing data in a uniform format that can be made available to the wider community, and to adopt a uniform set of standards for future data reporting. Thus PALSEA is currently compiling existing data, which will be available on the PALSEA website. Data management software, that processes raw ICP-MS data, produces publication quality data tables, and links seamlessly with the EarthChem database developed through the EARTHTIME project, and discussions are underway to adapt this software for the U-Th chronometer.

Ice sheet recommendations

Relative sea level histories permit the reconstruction of former ice sheets—a fundamental boundary condition for modeling past climate. PALSEA suggests the following ice sheet guidelines for the Paleoclimate Modeling Intercomparison Project (PMIP): 1) Alternative ice sheet boundary conditions, generated by independent glacial isostatic adjustment (GIA) models must be considered. 2) An existing database (Dyke et al., 2002) that uses evidence of ice-sheet extent should be used. 3) GIA models use different relative sea level databases, many with inconsistent or outdated reconstructions. To address this problem PALSEA aims to develop an open-access, quality-controlled database of relative sea level using consistent age estimates for use in isostatic models. This will allow improvements in isostatic models in the future, which should be incorporated into PMIP simulations.

Public outreach

The meeting included a public outreach event: "Where land and sea meet: Managing shoreline change over the next 100 years", funded by the Woods Hole Oceanographic Institution Morss Colloquium. This event brought together PALSEA scientists with economic, legal, and policy experts for a series of brief presentations and a panel discussion responding to audience questions.

Acknowledgements

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High- to mid-latitude northern atmospheric circulation changes during the last climate cycle

1st ADOM Workshop, Hyères-les-Palmiers, France, 1- 4 November 2009

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How dusty was the world during the last climate cycle? Modeling efforts are performed focusing specifically on the role of dust in driving past climate changes. At the first workshop of the PAGES Working Group "Atmospheric circulation Dynamics during the last glacial cycle: Observations and Modeling" (ADOM), presentations were given on paleodust records from ice core, terrestrial and marine eolian archives, on process studies of dust emission and transport, and on modeling dust as an environmental agent.

When summarizing the presentations of this meeting, a question immediately comes to mind: How can loess sequences be related to dust records from ice cores? Due to the importance of small-scale transport and deposition processes of dust, loess sequences are difficult for modelers to apprehend. Loess series can provide information on dust sources because a close connection can be established between deposit and source(s). On the other hand, in ice cores one only observes the result of long distance transport, making attribution to a specific source area more difficult. Up to now, there is no precise information on the geological characteristics for precisely identifying key source regions. What are the meteorological and geological features that control dust emission processes in the different source locations (Fig. 1)? What are the properties of the emitted dust particles? How is dust transported from its source localities? These questions are as yet unsolved. However, due to their ability to record long-distance dust transport, ice cores may help clarify these issues, all of which address the critical questions of the origin of dust and the processes involved in dust emission and transport towards the deposition location.

How dust affects the climate is another key question that was raised during the meeting. Observational data provide information on actual deposition, while models, which address the radiative forc-