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Atmospheric Dust: Impacts on Climate and the Critical Need for Geologic Data

by DeAnne Pinney

Introduction

With financial support by INQUA (International Union for Quaternary Research), Division of Geological & Geophysical Surveys (DGGS) Quaternary geologist DeAnne Pinney attended a workshop titled *"The Role of Mineral Aerosols in Quaternary Climate Cycles: Models and Data,"* sponsored by the INQUA Commission on Loess, that was held in Jena, Germany, October 7 through 11. The city of Jena (population 99,779) is located in the former East Germany in the middle of the Saale Valley of east Thuringia. It is home to more than 30 scientific institutes, including the Max Planck Institute for Biogeochemistry, which hosted the workshop.

This international meeting of scientists from the fields of geology, climate modeling, and computer databases was convened to initiate the synthesis of loess (windblown dust deposited on land) data and to facilitate interactions between the dust modeling and data collection communities. Twenty-five scientists worldwide were selected for invitation to the workshop, and it was a great honor for a State of Alaska employee to have been chosen as one of only five representatives of the United States. This conference offered DGGS a valuable opportunity to expand its knowledge of current geologic thought regarding the Quaternary geology of Alaska and its relation to global climate events, a forum to actively discuss current problems and questions with some of the foremost geologists and climatologists in the world, and to take an active role in the ground-level development of a global system of loess data collection and documentation. Workshop discussion revolved around the importance of windblown dust and its impacts on climate change models, the significance and availability of existing regional terrestrial dust records, and proposed refinements to a prototype loess database that was presented at the workshop.

The meeting was organized into a series of plenary presentations, discussion sessions, and working sessions. The plenary sessions served to introduce the current state of modeling of dust processes in the climate system, to present an overview and creative approaches to interpreting the geologic record of dust, and to address specific questions and problems pertinent to individual loess regions. Discussion sessions focused on key issues such as the types of information that should be included in the database, how to organize a regional database of loess information, and how to maximize the utility of this information for all users. The working sessions built on the discussion sessions by providing a practical opportunity to test the data synthesis procedures and database structure, and to begin the input of regional data.

Background

The Quaternary period spans approximately the last two million years of the Earth's history, an interval with frequent changes in global climate characterized by a succession of glacial (colder) and interglacial (warmer) periods. The study of environmental change is a strongly interdisciplinary one, and Quaternary research involves a broad range of specialists in fields such as anthropology, climatology, geochronology, geography, geology, glaciology, isotope geochemistry, paleoceanography, paleoecology, paleontology, palynology, and soil science. Working collaboratively, Quaternary scientists interpret the changing world of the glacial ages, their impact on the planet's surface environments, and their possible role in human evolution. Quaternary paleoclimatic investigations play a key role in the understanding and evaluation of possible future climate change on our planet. By studying the complex environmental changes of the glacial ages and interpreting them using analogies to present-day processes and environments, Quaternary scientists document the pattern and timing of past climatic changes to understand the causes of changing climate. Understanding the causes and feedback effects of climate change is becoming increasingly critical as scientists have come to realize that the Earth, possibly influenced by human activities, may be entering a time of unusually warm climate in which significant and potentially rapid environmental changes could pose major challenges for human habitability. Because much of Alaska is situated within a geographic zone that would be profoundly affected by any significant global climate change, it is important to develop a comprehensive understanding of the work that is being conducted to quantify both the timing and magnitude of change that might take place. Future policy decisions will be based on this knowledge.

INQUA, the International Union for Quaternary Research, was founded in 1928 by a group of scientists seeking to improve understanding of environmental change during the glacial ages through interdisciplinary research. INQUA's primary goal of promoting improved communication and international collaboration in basic and applied aspects of Quaternary research is achieved mainly through the activities of its commis-

(continued on page 2)

sions and committees. Current INQUA commissions include Glaciation, Sea-level Changes and Coastal Evolution, Global Continental Palaeohydrology, Human Evolution and Palaeoecology, Palaeoclimate, Neotectonics, Tephrochronology and Volcanism, and Loess. The INQUA Commission on Loess has identified as an important goal the synthesis of available data on loess accumulation, provenance, and transport that could be useful for climate model evaluation. This identified need was the impetus behind the convening of the Jena loess workshop.

Climatic Impacts and Implications: Mineral Aerosols, Dust, and Loess

Mineral aerosols have significant impacts on the climate system, and a major recent focus of global change research is the development of earth system models that predict the impacts of dust on climate change. The geologic record of dust is thus an important tool to help analyze the mechanisms and timing of past global climate change. It is clear that airborne dust and climate change are interrelated and have feedback effects on each other: climate affects wind and potential sources of dust, which in turn affects the dust record; and dust affects radiative forcing, atmospheric chemistry and biogeochemistry, and thus climate. We know that there are large glacial-interglacial changes in dust deposition, with different characteristics of deposition depending on location with respect to source emphasizing that spatial patterns of deposits need to be considered.

The geologic record of dust is preserved in ice cores, marine sediment cores and, in the terrestrial environment, loess deposits. Research on polar ice cores in particular has recovered much data that is valuable to the study of the relationship of dust and climate change. Long-term changes in the dust record can be compared to δD and $\delta^{18}O$ (chemical characteristics of ice which are indicators of temperature) and scientists can thus track changing dust concentrations in relation to changes in climate. The Vostok core from Antarctica shows that dust deposition increases when climate is colder, but the relationship is not direct in either magnitude or timing. Preliminary research into polar ice core dust provenance (source areas) utilizing mineralogy, isotopic data, and rare earth elements (REE) has also yielded some promising results, but there is a critical need for more baseline data on the materials characteristics of potential dust source areas around the globe. Marine sediment cores have also proven fruitful for recording and preserving data that correlates dust accumulation rates and climate change, and have been collected from ocean floors all over the world.

Even a cursory examination of the global distribution of dust data points makes it very clear that the continents stand out as huge data gaps (see figure). Terrestrial dust records have remained largely undocumented, especially with respect to the kind of information that is critical for validation of earth system model simulations. This fact notwithstanding, one of the best-studied terrestrial dust records is that of the Chinese loess plateau, where loess deposits over 280 m thick have been accumulating for more than 6 million years and characteristics such as magnetic susceptibility and relative proportion of coarse quartz grains in the deposits have been correlated to temperature by comparison with $\delta^{18}O$ curves. Thick loess deposits in central Alaska also comprise a valuable record of past climatic changes in high latitudes, but much less work has been done on Alaskan loess sites than in China or Europe. Magnetic susceptibility of interior Alaska loess has also been correlated to temperature by comparison with $\delta^{18}O$ curves, but many trends are different or even completely contrary to trends observed in Chinese loess. One of the goals of the loess workshop is that a more rigorous, complete, and regionally representative collection of observations and data may ultimately lead to a greater understanding of how to interpret the global significance of information preserved in a local loess record.

DIRTMAP Database

Climate models that are to be used to understand or ultimately predict climate change need to be evaluated using relevant global validation datasets to see how well they reproduce not only modern or historical dust loadings, but also the observed changes in the dust cycle through time. Paleodata thus have a key role to play in the evaluation strategy for models of the dust cycle. One of the aims of the INQUA Commission on Loess is to incorporate loess data in the **D**ust **I**ndicators and **R**ecords of **T**errestrial and **MA**rine **P**alaeoenvironments (DIRTMAP) database.

The DIRTMAP database has been designed to record diverse classes of dust data. These include: eolian accumulation rates; provenance indicators, including clay minerals, radioactive isotopes, heavy minerals, and trace metals; grain size; chronological data; and documentation, including such information as site location and references. Although individual loess sites may be dust sources, areas of dust transport, dust depositional sinks, or a combination of these, scientists are able to calculate general mass accumulation rates (MAR) that are critical to dust modeling efforts. Mass accumulation rates give scientists a measure of how much dust is accumulating relative to time, and require well-constrained data regarding the age, thickness, and physical characteristics of the deposits. MAR values are a key component required to validate dust and climate change models designed to simulate past conditions.

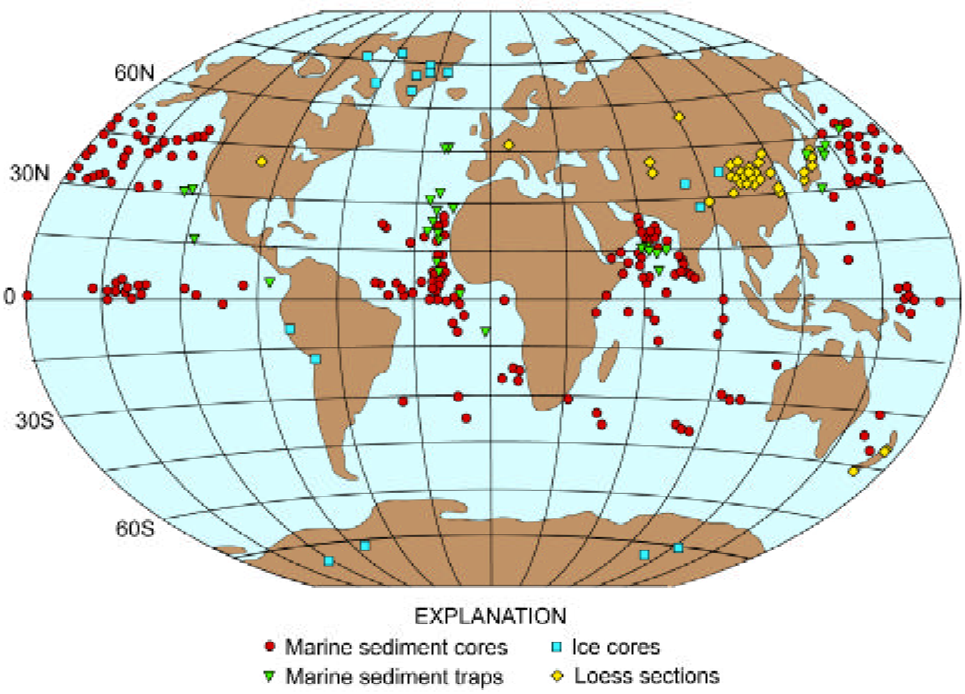
MARs calculated using the DIRTMAP data in its current state, which includes very little terrestrial data, nevertheless show a number of significant features. An expected late Holocene (the end of the last glacial period and beginning of the modern, warmer climate of the present) peak of airborne dust from Africa and Saudi Arabia is seen, as well as a smaller peak from Asia. The last glacial maximum (LGM) shows an additional dust peak from North America. Comparison of dust patterns from the LGM with those of the Holocene show an overall increase in MARs during the LGM, with greater increases over the poles, the Indian Ocean into the Pacific Ocean, and in Australia. The results also highlight the necessity of acquiring more and better data, especially in the form of reliable dates, measured dry bulk densities, grain size distributions, and indicators of the eolian component within a deposit. Another critical need is better mapping of the distribution and thickness of loess deposits, not only to document the deposits themselves, but also to relate dust to potential source areas and to help distinguish local, regional, and global influx of material at a given site.

The Future of DIRTMAP

"The Role of Mineral Aerosols in Quaternary Climate Cycles: Models and Data" workshop ended with a call for participants to commit themselves to compiling loess data from their respective parts of the world and making it available to the DIRTMAP database team, headquartered in Jena. DeAnne Pinney will be working with Jim Begét of the University of Alaska Fairbanks to compile data from Alaska and oversee its input into the revised DIRTMAP database. The workshop conveners plan to publish a report that will contain a brief description of the loess data from key regions, summaries of each workshop session, a summary of the basic conclusions about the regional database setup that was proposed, and recommendations for future work. This dynamic, productive technical gathering highlights the benefits that can be realized from the international collaboration that scientific organizations such as INQUA strive to achieve, and that is critical to the understanding of our world as a unified system.

Reference

Kohfeld, K.E., and Harrison, S.P., *in press*, DIRTMAP: The geological record of dust; Earth Science Reviews.



Data points contained in the current version of the DIRTMAP database. A total of 426 sites includes 253 from marine sediment cores, 56 from marine sediment traps, 18 from ice cores, and 99 from terrestrial loess deposits (principally in China). Note the comparative lack of data on the continents. Numerous loess sites in Alaska will be a valuable addition to this database and substantially expand the terrestrial coverage in the western hemisphere. (Modified from Kohfeld and Harrison, in press*)*

Dear Readers:

Global climate change debates feature opinions that range from those who cite critically reviewed historical weather records and conclude there is no incontrovertible evidence that global climate change is taking place to those who passionately assert that there is not only a rapid climate change underway, but that it is largely human induced. Geology provides hard data necessary to find the truth in this controversy and in so doing helps guide policy makers in making valid decisions. Those decisions are likely to have a major impact on everyone's future. DGGS has been called to participate in the debate. I am pleased that we have the critical professional skills of DeAnne Pinney to guide our contribution.

Sincerely,

Milton A. Wiltse

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Director and State Geologist

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