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COLLABORATIVE RESEARCH: Southern Andes Paleoclimate; A Testof Abrupt Ocean-Atmosphere Reorganizations in Glacial Cycle

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Project Participants

Senior Personnel

Name: Denton, George
Worked for more than 160 Hours: Yes
Contribution to Project:

Post-doc

Graduate Student

Undergraduate Student

Technician, Programmer

Other Participant

Research Experience for Undergraduates

Organizational Partners

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Activities and Findings

Research and Education Activities:

Rationale:
In the late 1980s, Broecker and Denton prepared papers on the concept that glacial-to-interglacial transitions involved global reorganizations of the ocean-atmosphere system (Broecker, W. S. and Denton, G. H., 1989. The role of ocean-atmosphere reorganizations in glacial cycles. Geochimica et Cosmochimica Acta, 53, 2465-2501; Broecker, W. S. and Denton, G. H., 1990, What drives glacial cycles? Sci. American, 262, 49-56). These reorganizations were thought to constitute jumps of Earth's climate systems between stable modes of operation, and they featured changes in the greenhouse-gas content or reflectivity of the atmosphere. In that concept, switches in thermohaline circulation, resulting from changes in ocean salinity, drive the abrupt mode flips. A key test of this notion of ocean-atmosphere reorganizations involved the timing and magnitude of climatic changes in the Southern Hemisphere. The fundamental question addressed in this research is whether climate changes in the Northern and Southern Hemispheres were synchronous and of similar magnitude during the last glacial/interglacial transition. The answer to this question requires detailed paleoclimatic records from key localities in the Southern Hemisphere. As outlined below, in the course of this research we retrieved such records from the Chilean Andes in middle latitudes of the Southern Hemisphere.

Activities:

To address the issue of interhemispheric paleoclimatic changes, we carried out glacial geologic and palynologic investigations between 1993 and 1997 alongside the Chilean Andes in the area of the southern Lake District, Seno ReloncavÝ, and Isla Grande de ChiloÚ, Chile. An extensive radiocarbon-dating program provided the essential detailed chronology. The tasks accomplished are outlined below and described in detail in the listed publications.

1. Detailed glacial geomorphic maps were produced in color for moraines and outwash plains of the former Andean piedmont glacier lobes that filled Lago Rupanco, Lago Puyehue, Lago Llanquihue, Seno ReloncavÝ, Golfo de Ancud, and Golfo Corcovado. All these water bodies lie just west of the Andes in the southern Chilean Lake District. These maps are the basis for tying glacial geologic sections and pollen stratigraphies to former ice margins.

2. The stratigraphy of glacial deposits revealed in sections within the moraine belts was worked out in detail. The position of these stratigraphic sections was placed on the glacial geomorphic maps. This procedure allowed the radiocarbon chronology to be tied to former ice-marginal fluctuations of the Andean piedmont glacier lobes.

3. A detailed chronology of ice-marginal fluctuations and former glacial maxima was established from more then 500 new radiocarbon dates obtained during the course of the research. These dates came from three sources of samples. The first source was organic horizons situated in the stratigraphic sections revealed in the moraine belts. The second source was organic matter from the base of mires on moraine systems. The third source was peat clasts reworked into moraines.

4. Cores for pollen analysis were collected from mires and small lakes situated on the moraine belts. Fifteen of these cores were studied and extensively radiocarbon dated. Cores at Canal de la Puntilla, Fundo Llanquihue, Huelmo, and Taiquemo were analyzed at one-centimeter intervals and dated by numerous radiocarbon analyzes. The first three of these cores extended back in time to 17,000-21,000 14C yr B.P., whereas the base of Taiquemo is > 49,000 14C yr B.P.

5. From these data, the paleoclimate was established for the last glacial maximum and for the last termination. These results were compared with similar data sets from the Northern Hemisphere. The resulting conclusions were then presented in the publications listed below.

Findings:

Findings:
The following conclusions concern the character and timing of the last glacial maximum and the last termination in the Chilean Andes in the middle latitudes of the Southern Hemisphere, as derived from this research.

1. The last glacial maximum began with a massive ice advance into the outer Llanquihue moraine belt at 22,500 14C yr B.P. Piedmont glacier lobes remained at or near their maximum extents until 14,700 14C yr B.P.; 17,700 14C yr B.P.; 16,000 14C yr B.P.; and 14,800 14C yr B.P. These advances are registered in a number of individual lobes. Relative to today's values, snowlines were lowered 800-1000 m during the last glacial maximum.

2. Pollen records show that the landscape of the southern Chilean Lake District during the prolonged interval of the last glacial maximum was dramatically different from today's dense Valdivian and North Patagonian Rain Forests. Rather, the vegetation was an open Subantarctic Parkland marked by small clumps of Nothofagus set in an open grassland developed on outwash plains. The presence of Magellanic Moorland species indicates a wet environment. Relative to today's values, treeline was lowered about 1000 m. Mean summer temperatures at sea level were + 6oC, representing a depression of 6-8oC below today's values.

3. In both the vegetation and glacial records, the last termination began very close to 14,600 14C yr B.P., just after the youngest ice advance of the last glacial maximum. Glacier recession was rapid and extensive. By 13,850 14C yr B.P., ice had receded deep into the Andes. At the same time, thermophilous trees invaded the landscape for the first time since before 49,000 14C yr B.P. A North Patagonian Rain Forest was established throughout the southern Chilean Lake District. The climatic change that marked the termination was certainly the most important of the last 49,000 years and probably of the entire last glacial cycle.

4. The timing of the last glacial maximum in the Chilean Andes matches that in the Great Lakes area of central North America, which is based on 400 radiocarbon dates of wood embedded in moraines. Moreover, the snowline and treeline lowering in Chile is of comparable magnitude to that in the western Cordillera of North America.

5. The timing of the last termination in the Chilean Andes matches that of the Northern Hemisphere, as follows. The Northern Hemisphere contained more than 90 percent of the excess ice volume on the planet at the last glacial maximum. The benthic oxygen-isotope ratios from deep-sea cores register changes in this excess ice volume. The most detailed of these oxygen-isotope records comes from high-sedimentation-rate cores from the eastern Pacific Ocean. Here the isotope change that marks the beginning of the last termination occurred

at 14,500 14C yr B.P. This value is identical, within dating error, to that obtained for the beginning of ice collapse in the southern Chilean Lake District.

6. Conclusions 4 and 5 above imply that both the last glacial maximum and the last termination were synchronous in the two polar hemispheres, again within dating limits. In particular, the critical switch between the two events occurred at close to 14,500-14,600 14C yr B.P. in both hemispheres. Finally, the magnitude of temperature lowering was about the same in both hemispheres. These findings have important implications. They indicate that paleoclimatic changes were of the same timing and magnitude in the middle latitudes of the two polar hemispheres, despite the fact that Milankovitch orbital forcing was out of phase at the two opposing middle latitudes. This means that the sequence of events driving ice ages must be as follows: Milankovitch orbital forcing produces an effect that forces simultaneous cooling in both polar hemispheres in order to produce the synchronous last glacial maximum. This effect must be a change either in the trace gas content or in the reflectivity of the atmosphere, or both. Milankovitch forcing of atmospheric carbon dioxide is a prime candidate for causing much of the ice-age cooling recognized in both hemispheres.

Training and Development:

Outreach Activities:

Educational Activities:
Moreno, Patricio, I., Ph.D., University of Maine, 1997. Dr. Moreno's dissertation concerned the paleovegetation of the Lago Llanquihue region during the last glacial maximum. He is now the equivalent of an Associate Professor at the University of Chile in Santiago.

Turbek, Susan E., M.S., University of Cincinnati. Susan Turbek's thesis concerned the development of ice-contact slopes alongside Lago Llanquihue.

Dubois, Mark, B.S., University of Maine. Field Assistant.

Ladorre, Claudio, B.S., Catholic University, Santiago, Chile. Field Assistant.

Silva, Arturo, B.S., Catholic University, Santiago, Chile. Field Assistant.

Journal Publications

Anderson,B.G.,Denton,G.H., and Lowell, T.V., "Glacial geomorphological maps of Llanquihue drift in the area of the southern Lake District, Chile", Geografiska Annaler, p. 155, vol. 81A, (1999). Published

Denton, G.H., "Glacial and Vegetational History of the Southern Lake District of Chile.", Special Issue of Geografiska Annaler, p. 105, vol. 81A, (1999). Published

Denton, G.H., Heusser, C.J., Lowell, T.V., Moreno, P.I., Andersen, B.G., Heusser, L.E., Cchluchter, C., and Marchant, D.R., "Interhemispheric linkage of paleoclimate during the last glaciation.", Geografiska Annaler, p. 107, vol. 81A, (1999). Published

Denton, G.H., "Glacial and Vegetational History of the Southern Lake District of Chile", preface to special issue of Geografiska Annaler, p. 105, vol. 81A, (1999). Published

Denton, G.H., Lowell, T.V., Heusser, C.J., Schluchter, C., Andersen, B.G., Heusser, L.E., Moreno, P.I., and Marchant, D.R., "Geomorphology, stratigraphy, and radiocarbon chronology of Llanquihue drift in the area of the southern Lake District, Seno Reloncavi and Isla Grande de Chiloe, Chile", Geografiska Annaler, p. 167, vol. 81A, (1999). Published

Heusser, C.J., Heusser, L.E., and Lowell, T.V., "Paleoecology of the southern Chilean Lake District - Isla Grande de Chiloe durng the middle-late Llanquihue glaciation and deglaciation", Geografiska Annaler, p. 231, vol. 81A, (1999). Published

Lowell, T.V., Heusser, C.J., Andersen, B.G., Moreno, P.I., Hauser, A., Heusser, L.E., Schluchter, C., Marchant, D.R., and Denton, G.H., "Interhemispheric correlation of late Pleistocene glacial events", Science, p. 1541, vol. 269, (1995). Published

Moreno, P.I., Lowell, T.V., Jacobson, G./L., Jr., and Denton, G.H., "Abrupt vegetation and climate changes during the last glacial maximum and the last termination in the Chilean Lake District: a case study from Canal de la Puntilla (41 S)", Geografiska Annaler, p. 285, vol. 81A, (1999). Published

Schluchter, C., Gander, P., Lowell, T.V., and Denton, G.H., "Glacially folded outwash near Lago Llanquihue, southern Lake District, Chile", Geografiska Annaler, p. 347, vol. 81A, (1999). Published

Turbek, S.E., and Lowell, T.V., "Glacial deposition along an ice-contact slope: An example from the southern Lake District, Chile", Geografiska Annaler, p. 325, vol. 81, (1999). Published

Books or Other One-time Publications

Web/Internet Site

Other Specific Products

Contributions

Categories for which nothing is reported:

Organizational Partners

Activities and Findings: Any Training and Development

Any Book

Any Web/Internet Site

Any Product

Any Contribution