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Climate of the Past Discussions

Interactive comment on "A 350 kyr record of climate change from Lake El'gygytgyn, Far East Russian Arctic: refining the pattern of climate modes by means of cluster analysis" *by* U. Frank et al.

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Summary Cores from Lake El'gygytgyn, a meteorite impact crater lake in Siberia, are important because they contain the longest continuous terrestrial paleoclimatic record from the arctic. Core PG1351 is a 1291-cm-long percussion core collected in 1998 and is dated to 280 cal ka, The results of a multidisciplinary study of this core were presented in a special issue of the Journal of Paleolimnology in 2007 (v. 37, no. 1) that defined the characteristics of four climate modes. Core Lz1024 is a 1660-cm-long percussion core collected in 2003 and is dated to 350 cal ka. Results of a multidisciplinary

study of this core and of core PG1351 are the subject of the present Frank et al. paper. Samples from these two cores were analyzed for magnetic susceptibility (MS), major-element inorganic geochemistry, and biogeochemistry including total organic carbon (TOC), total nitrogen (TN), total sulfur (TS), and biogenic silica (opal; BioSi). These results confirmed the four climate modes defined for core PG1351, extended them to core Lz1024, and added a fifth climate mode based on very high concentrations of BioSi (up to 40 wt. %) in the bottom of the core. Results from the study of these two cores are really pilot studies for core ICDP 5011-1, which is 315 m long taken in 2011 with the GLAD800 drilling system modified for cold conditions and will hopefully extend the El'gygytgyn paleoclimatic record back to the time of the impact (3.6 Ma). The present Frank et al. paper, along with other papers presented in the 2007 Journal of Paleolimnology volume, paint a picture of relatively warm conditions (ice-free in summer) that were dominant during the past 350 cal ka alternating with colder conditions (perennial ice cover) that were either dry or moist. The age model for the two cores (Nowaczyk et al. 2002; Forman et al., 2007) is based on AMS radiocarbon dates of the younger sediments, luminescence dating of the rest of the core, and the whole record tuned to northern hemisphere insolation. The water column during the warm intervals was oxic and well-mixed. The surface waters were relatively productive (high % BioSi), but the sediments deposited during these warm intervals (most of the core) were structureless and contained poorly preserved organic matter (low % TOC and % TN). However they did have well-preserved magnetite (high MS). Cold climate modes were either dry with perennial ice cover and low snowfall that permitted enough light penetration through the ice to support relatively high productivity (high % BioSi) or moist with thick ice and snow cover that limited productivity (low % BioSi). Sediments deposited during cold-dry conditions had the highest concentrations of TiO2 due to dilution of lithogenic material with biogenic material (mostly diatom debris). Bottom waters were anoxic under all cold conditions with laminated, S-rich sediments and poor preservation of TOC, N, and magnetite (low MS). The present Frank et al. paper applies cluster anlaysis to the magnetic, geochemical, and biogeochemical data to objectively define groupings of samples with like characteristics that are related to climate modes. Six clusters are illustrated by colored dots on downcore plots of selected variables. I would have preferred to see scatter plots clusters or, better yet, as down-core plots of cluster distances (0-1). The authors then try to relate climate modes in the El'gygytgn cores to marine isotope stages (MIS) in the stacked benthic foraminiferal record of Lisiecki and Raymo (2005). All substages of MIS back to MIS 10 can be recognized, particularly in the varibility of the minerogenic component, expressed as a chemical index of alteration (CIA) defined as [(Al2O3/Al2O3+CaO+Na2O+K2O) * 100]. A major exception is the lack of agreement of the period of peak warmth at 125 cal ka with MIS5.5, the Eemian (about 130 cal ka), which is the peak warm phase before the Holocene. Because of the high latitude location of Lake El'gygytgn it is very sensitive to temperature changes such that small changes in summer temperature can greatly effect the duration of summer ice-free conditions and, therefore, biogenic productivity, water-column mixing, and dissolution of organic matter and magnetite.

Specific Comments First of all the illustrations are too small, especially Figures 2, 3, and 4. I could enlarge them on the screen but I needed a magnifying glass to read the paper copies. The text talks about mixing lines in Figure 5; where are these mixing lines? The relations between oxic and anoxic conditions; cold and warm climatic intervals; moist and dry climatic intervals; and high and low productivity are not well spelled-out in this paper. Redox : high or low TOC, high or low TS, and laminated or bioturbated sediments (redox-sensitive trace elements would help here); Productivity: high or low BioSi and with or without ice cover. Detrital input: high or low Ti. Cold-warm vs cold dry: $\pm$snow cover. Perhaps a figure such as Figure 3 of Melles et al. could be added, or perhaps a table. By a combination of this paper the papers by Melles et al. (2007) and Nowaczyk et al. (2007) I get the following interpretations: Biogeochemical analyses (TOC, TN, TS, BioSi) of core PG1351 were made "in steps of 2 cm". For Lz1024 BioSi and TOC were by infrared spectroscopy "in steps of 1 cm". How about N and S? Why were different methods used? Inorganic geochemical analyses (XRF) of core Lz1024 were made "in steps of about 5 cm". What was the sampling inter-

val for inorganic geochemistry in PG1351 (5 cm?)? What are the precisions of these analyses? For the cluster analyses, all parameters "were re-sampled in steps given by the sampling intervals of the inorganic geochemistry samples" (i.e., 5 cm). What does "in steps of" mean? One cm every 5 cm? Continuous 5-cm samples? Why different sampling intervals? Why are results of major inorganic elements (other than Ti) and N and S not discussed? Were any trace elements analyzed? Tell us a little more about the S-ratio and what it's telling us just like the CIA tells us about weathering. These are both important properties but are derived from primary measurements. The primary measurements of Ti and BioSi tells us about detrital input and productivity, what does the IRMBF/SIRM ratio tell us? Tell us a little more about ICDP core 5011-1. When was it taken? How was it taken? Who took it? Results of the cluster analyses are not really shown in terms of numbers (measure of similarity, 0-1). They are simply shown as different colored symbols on the down-core plots of each parameter. I would like to see down-core plots of the cluster results. Also, there should be a key for each symbol, not just described in the figure caption and text. Statements like the blue square cluster, the red triangle cluster are al right but a graphic would be better. This makes it difficult for the reader to see how the results of the cluster analysis match the climate zones. For example the caption for Figure 4 says "the different symbols and colours denoting the five (six) clusters..." what are the symbols and colours? Show in a key; I had to make one. And show it in each figure. The TiO2 scales in figure 6 are backwards. I can see why but this should be pointed out in the caption.

Interactive comment on Clim. Past Discuss., 8, 5109, 2012.