Dry Climate Disconnected the Laurentian Great Lakes

Recent studies have produced a new understanding of the Holocene history of North America’s Great Lakes, showing that water levels fell several meters below lake basin outlets during an early postglacial dry climate in the Holocene (younger than 10,000 radiocarbon years, or about 11,500 calibrated or calendar years before present (B.P.)). Water levels in the Huron basin, for example, fell more than 20 meters below the basin overflow outlet between about 7900 and 7500 radiocarbon (about 8770–8290 calibrated) years B.P. Overflow rivers, including the Niagara River, presently falling 99 meters from Lake Erie to Lake Ontario (and hence Niagara Falls), ran dry. This newly recognized phase of low lake levels in a dry climate provides a case study for evaluating the sensitivity of the Great Lakes to current and future climate change.

The Laurentian Great Lakes

Collectively, these Great Lakes constitute one of the largest surface reservoirs of freshwater on Earth. The lakes contain 21,000 cubic kilometers of water, of which less than 1% is replenished annually by precipitation. Situated in the eastern central part of North America and shared by the United States and Canada (Figures 1a and 1b), the five lake basins and their ecosystems support a population of more than 33 million people (in 1990–1991) and host well-developed industries for shipping, fishing, recreation, and power production, as well as water supply and wastewater disposal for municipalities. The overall range of monthly water levels in lakes during the past century has varied by less than 2.1 meters, and thus lake levels appear to be relatively stable; yet even this amount of variation causes economic stress.

The interplay of three air masses (Figure 1c) currently controls climate and water levels in the Great Lakes watershed, most of the moisture originates from humid air masses arising in the Gulf of Mexico and reaches the Laurentian Great Lakes by the moist air mass from the Gulf of Mexico.

New Understanding of Great Lakes History

Previous interpretations of past Great Lakes water levels lacked key information on the altitudes of outlets during lowstands. Consequently, evidence for lowstands below the present level was taken to indicate that lakes overflowed more northward than一般 ice jams were densely populated with animals, and the sedimentation rates in those areas were high. Microfossil evidence and other paleontological records suggest that at least some of the lowstands began with an abrupt increase in water levels, followed by a gradual decrease. This pattern is consistent with the theory of isostatic rebound, which suggests that the Great Lakes region was still rebounding slowly after the last glacial period. The rebound is thought to have caused the water levels to rise and fall several times over the past 10,000 years.

Explanation of the Lowstands

Lakes without overflow, such as these lowstands in the GLB, can only be explained by a dry climate in which water lost through evaporation exceeded water gained from direct precipitation and catchment runoff. The dry regional climate that forced the lakes into hydrologically closed conditions must have been substantially drier than the present climate. Hydrologic modeling of the GLB shows that current mean annual precipitation would have to decrease by about 25% in the Superior basin and by about 42% in the Ontario basin, in conjunction with a 7°C mean temperature increase, to achieve lake closure.

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Widespread Secondary Volcanism Near Northern Hawaiian Islands

Hot spot theory provides a key framework for understanding the motion of the tectonic plates, major volcanism and composition, and magma genesis. The age-progressive volcanism that constructs many chains of islands throughout the world’s ocean basins is essential to hot spot theory. In contrast, secondary volcanism, which follows the main edifice-building stage of volcanism in many chains including the Hawaii, Samos, Canary, Mediterranean, and Kerguelen islands, is not predicted by hot spot theory. Hawaiian secondary volcanism occurs hundreds of kilometers away from the main shield volcanism, which follows the main stage, and has generated more than 50% of the volume of the volcano’s mass (Macdonald et al., 2005). Diamond Head, in Honolulu, is the first and classic example of secondary volcanism.

To determine the where, when, and what of secondary volcanism on and near the northern Hawaiian Islands (Figure 1), the U.S. National Science Foundation (NSF) recently sponsored a multidisciplinary investigation (volcanology, marine geology, geophysics, geochronology, magnetism). A 4-week marine expedition, called D2C10, was conducted in August 2007. The focus of the Hawaiian R/V Kilo Moana and using the JASON2 submersible, revealed several features of offshore volcanic and lava flows, including several geothermal areas and more than 70,000 cubic kilometers of new island material. Secondary volcanism well away from the islands themselves raises many questions about hot spot evolution and magma genesis in general.

Seafloor Mapping

The seafloor around the islands of Kā‘aihau, Ni‘ihau, and Ka‘ula (Figure 1) is the focus of the marine expedition because Kā‘aihau has the most voluminous (≤5 cubic kilometers) and young (≤2.5 million years old (C. E. Gaudette et al., 2007)) volcanic features. The volume of Kā‘aihau’s volcano is the origins of Hawaiian rejuvenated volcanism, submitted to Geology, 2007; secondary volcanism of Hawaii’s main islands and because this seafloor had not previously been completely mapped. For comparison, the volumes and interior of Hawaiian shield volcanoes are slightly less than the entire island was surveyed, yielding the first detailed bathymetry, acoustic backscatter maps of Kā‘aihau and the Middle Bank volcanoes, and confirming that

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secondary volcanism is widespread offshore rather than focused on the islands.

Extensive Secondary Volcanism

The new acoustic imagery map (Figure 2) highlights areas of extensive secondary volcanism around the islands of Ka‘ula and Ni‘ihau. More than 100 secondary submarine volcanic structures surround these islands, most of which have a distinctive pancake shape (steep-sided and flat-topped) similar to some venturian volcanoes (Smith, 1956). To form flat-topped cones, sustained but

Hawaiian Islands  cont...on next page

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