Genesis and deformation of holocene shoreline terraces, Yellowstone Lake, Wyoming

by Grant Arnold Meyer

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Earth Science
Montana State University

Abstract:
Geodetic leveling over a 62-year period has revealed uplift averaging up to 15 mm/yr within the 0.6 Ma Yellowstone caldera. This historic uplift is most likely due to magmatic activity at shallow crustal levels, but the time of initiation, history, and significance of uplift is unknown. In this study, postglacial shoreline terraces (dating from ca. 9000 yr B.P. to present) around the north end of Yellowstone Lake are used to measure tilting and estimate net vertical deformation since their formation.

The study area lies within the southeastern caldera rim and contains a sequence of 6 or more discontinuous raised shoreline terraces. 106 profiles were surveyed by accurate leveling techniques across terrace sequences. Shoreline elevations were determined from profiles by extrapolation of the best-preserved wave-cut cliff and platform slopes. Individual terrace segments were correlated across gaps using morphology, vertical spacing, and extrapolation of shoreline tilts. Shoreline, elevation data show that the terraces are significantly and complexly deformed, with local tilt values of up to 6000 microradians (6 m/km). The overall pattern of deformation suggests that inflation somewhat similar to the historic form has occurred throughout the time- of shoreline formation. Uplift rates calculated from radiocarbon-dated shorelines are less than one-half of historic rates, suggesting episodic deformation or reversals in direction which result in lower long-term rates. Though uplift rates may be increasing at present, the terrace deformation does not suggest an overall trend of accelerating uplift.

Many deviations from the historic inflation pattern are observed in the form of strong local deformation, which may be due to local magmatic events such as dike or cupola injection, adjustments to surface distension accompanying inflation, or extension on regional tectonic trends.

Since vertical deformation of the lake outlet area directly affects lake level, it is likely that magma-related deformation has played a major role in controlling lake level fluctuations and terrace formation. Localized tectonic downwarping . of the outlet may also have been involved in lake level control. Further work, including extensive absolute dating, is necessary to understand the temporal relationships between individual lake level stands and episodes of deformation.

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APPROVAL

of a thesis submitted by

Grant Arnold Meyer

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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Date May 5, 1986

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ABSTRACT

Geodetic leveling over a 62-year period has revealed uplift averaging up to 15 mm/yr within the 0.6 Ma Yellowstone caldera. This historic uplift is most likely due to magmatic activity at shallow crustal levels, but the time of initiation, history, and significance of uplift is unknown. In this study, postglacial shoreline terraces (dating from ca. 9000 yr B.P. to present) around the north end of Yellowstone Lake are used to measure tilting and estimate net vertical deformation since their formation.

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INTRODUCTION

The Nature of the Problem

Surficial geologic mapping by Richmond (1973, 1974, 1977) and Richmond and Pierce (1972) has delineated a series of postglacial shoreline terraces around virtually the entire shore of Yellowstone Lake. The terraces were formed subsequent to the complete disappearance of the Pinedale icecap from the lake basin ca. 12,000 yr B.P. (Richmond, 1976a). They were identified by elevation above present lake level, implying undeformed horizontal shorelines. Radiocarbon dates on four terraces from widely spaced localities over the lake basin are consistent with a nearly constant rate of decline of lake level from about 9000 yr B.P. to present. Lake level decline was ascribed to downcutting of the lake outlet through glacial sediments (Richmond, 1969).

Precise geodetic releveling of benchmarks throughout Yellowstone Park has revealed that uplift comparable in rate to that measured at some active volcanic centers is presently occurring within the 0.6 Ma Yellowstone caldera (Pelton and Smith, 1982) (Fig. 1). First- and second-order level line benchmarks (first established in Yellowstone in 1923) were reobserved to determine relative vertical surface