Late Pleistocene glacier dynamics of southwestern Montana and adjacent Idaho and paleoclimatic implications
by Donald R Murray

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

Abstract:
Application of glacial flow theory to reliable reconstructions of paleoglaciers allows calculation of the dynamics of these glaciers. Effective basal shear stresses calculated along the longitudinal profiles of these glaciers can be used to estimate the component of mass flux due to internal deformation. Assuming basal slip to be zero at the point where deformation mass flux is a maximum, minimum net accumulation and ablation gradients can be calculated. Using the continuity equation, minimum mass flux at the ELA can be estimated. Also, net winter accumulation can be calculated by dividing the mass flux at the ELA by the accumulation area. Because local climate, in part, controls the mass balance and dynamics of a glacier, this model provides information on the climatic setting of paleoglaciers.

The model also allows estimation of basal slip as a factor in point estimates of glacial flow. Application of the continuity equation above and below the ELA generates additional estimates of mass flux at discrete points along each glacier. The difference between calculated deformation mass flux and continuity flux at these points yields a first approximation of basal slip, which can be highly variable along the length of a glacier.

The . model was developed on the late Pleistocene Big Timber glacier of west-central Montana and tested on five other paleoglaciers in the Northern Rocky Mountains of southwestern Montana and adjacent Idaho. Sensitivity analysis performed on Big Timber glacier shows that the results are accurate within 20%. Low ablation gradients, ranging from 1.9 to 5.4 mm/m for five of the six glaciers, suggest a cold, dry environment in this region during the late Pleistocene. Calculated average annual net accumulation for these glaciers is 20-75% below modern maximum snowpack values, indicating a drier climate during the full glacial period. Basal sliding accounts for most (> 90%) of the glacial flow near the terminus of each glacier, but is variable along the rest of the glacier. While the mass balance values are minima, they are assumed to be reasonable approximations of the actual values, unless very high basal slip rates occurred along the entire length of each glacier.

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APPROVAL

of a thesis submitted by

Donald Richard Murray

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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INTRODUCTION

The Problem

There is an intimate relationship between climate and glaciation (Fig. 1), such that the dynamics (thickness, rate of flow and length) of a glacier are controlled to a large extent by changes in climate (Meier, 1965; Andrews, 1975). Climatic changes during the late Pleistocene (79,000 to 10,000 years ago) have been characterized by several global glacial advances and retreats. Evidence that late Pleistocene glaciers existed in some valleys of the Northern Rocky Mountains, which do not have glaciers at present, suggests that the paleoclimate must have been different from the present. The existence of glaciers does not, however, provide an actual measure of temperature or precipitation, but certain features of glaciers may be used as proxies to these climatic variables. Because the dynamics of a glacier are controlled in part by climate, reconstructed dynamics of paleoglaciers can be used as proxies to climate. In this study, a model is developed to interpret the ice dynamics of paleoglaciers. Although this project concentrates on the development of the model, the application of this model to six paleoglaciers that existed in southwestern Montana and adjacent Idaho during the last glacial maximum (20,000 years ago) suggests the magnitude and direction of late Quaternary changes in precipitation.