Ice Flow Dynamics of the Anastomozing Rio Grande
Glacier System, San Juan Mountains, Co.

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INTRODUCTION

At least two major glaciations in the San Juan Mountains occurred during the Pleistocene. In 1932 Atwood and Mather published an exhaustive paper on the Quaternary Geology of the San Juan Mountains with a map detailing the extent of the last glaciation. Their map indicates that ice thicknesses in the east central San Juans were so great that ice spilled out of the Rio Grande and North Clear Creek valleys. The spillover ice filled adjacent valleys which would not have had sufficient accumulation areas to sustain glaciers of their own.

Using field data based on mapping the extent of the last glaciation in North Clear Creek, the Rio Grande valley, and the valleys in between (figure 2), this study examines the feasibility of ice overflow in this area by testing the field data with theoretical ice profile modelling equations based on fundamental laws of physics.

FIELD METHODS

The primary method of field work consisted of mapping glacial depositions, extent and distribution of glacial erratics, and orientations of glacial landforms such as striae and whalebacks. To differentiate between the last glaciation and the penultimate glaciation, I employed relative dating techniques. The principal technique was measurement of weathering rinds on mafic clasts. Rind measurement technique consisted of finding 6-20 mafic rocks at 14 different locations on moraines or glacially polished slabs. On the exposed surface of a smashed open rock the mean weathering rind thickness was measured to the tenth of a millimeter using a comparador. The results were compared using techniques from Coleman and Pierce, 1981.

Weathering rind data were augmented by examining soil development in various glacial deposits. Eight soil pits were dug on moraines and ice contact stratified drift. Soil pits were described in the field and sampled by horizon using methods from Birkeland, 1984.

ICE FLOW DYNAMICS

Ice will begin to flow significantly when subjected to shear stress on the order of 80 to 100 kPa. The shear stress experienced by basal ice in a glacier is a function of glacier thickness, surface slope, and valley shape according to a formula derived by Nye, 1952:

$\tau = Frgh \sin \alpha$ (equation 1)

From Paterson, 1981.

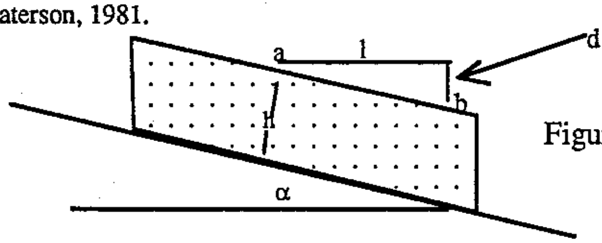


Figure 1

Where τ is the basal shear stress, angle of the slope is α, glacier thickness is h, and F is the shape factor of the valley. The shape factor is dependent on the width, depth, and form (e.g. parabolic, semi-ellipse) of the valley. The equation can be rewritten to determine the drop in elevation (the height d)between points a and b.

$$d=\left(\mathrm{Tan}\left(\frac{\tau}{F\rho\, gh}\right)\right) l \quad \text{(Equation 2)}$$

If basal shear stress of a paleoglacier is assumed to be approximately 80-100kPa, then it is possible to model the surface profile of the paleoglacier from one or several ice thickness points using equation 2 to solve for incremental drops in glacial surface slopes. This approach provides a theoretical test for the results of the field data.

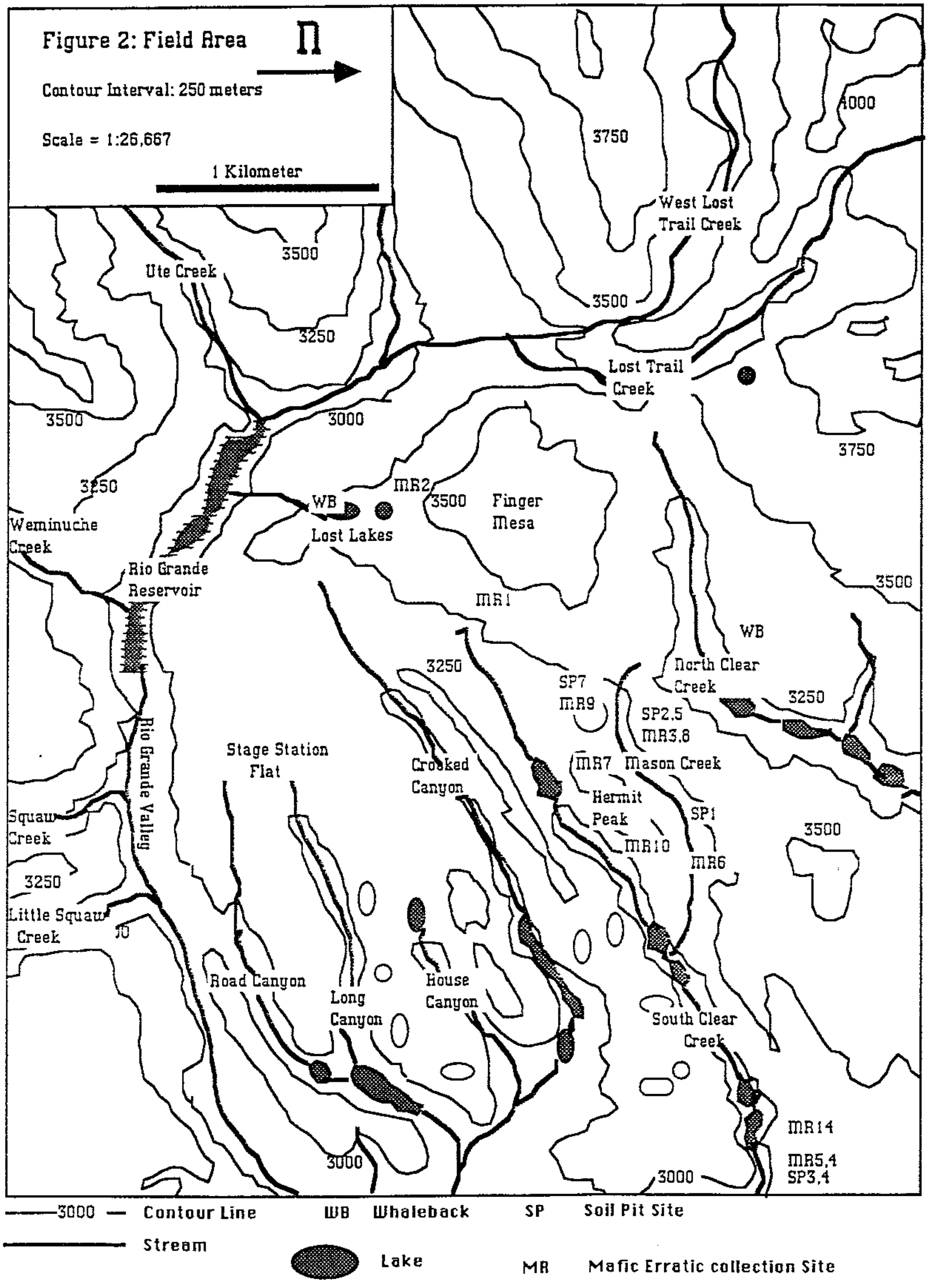


Figure 2: Field Area

RESULTS

At the Lost Lakes area young ice contact stratified drift lies close to striae and whalebacks oriented toward the small adjacent valleys to the North of the Rio Grande valley. This evidence proves that during the last glaciation at least 100 meters of ice spilled out of the Rio Grande valley into the smaller valleys. On the divide between North and South Clear Creek and in Mason Creek there are young glacial deposits indicating ice had been there during the last glaciation. Consequently, 90 meter thick ice flowed either North or South in between North and South Clear creeks. Rind data in and near South Clear Creek dictates minimum and maximum ice thicknesses. Field data shows a slightly thicker and greater extent of ice than Atwood and Mather had mapped in the field area.

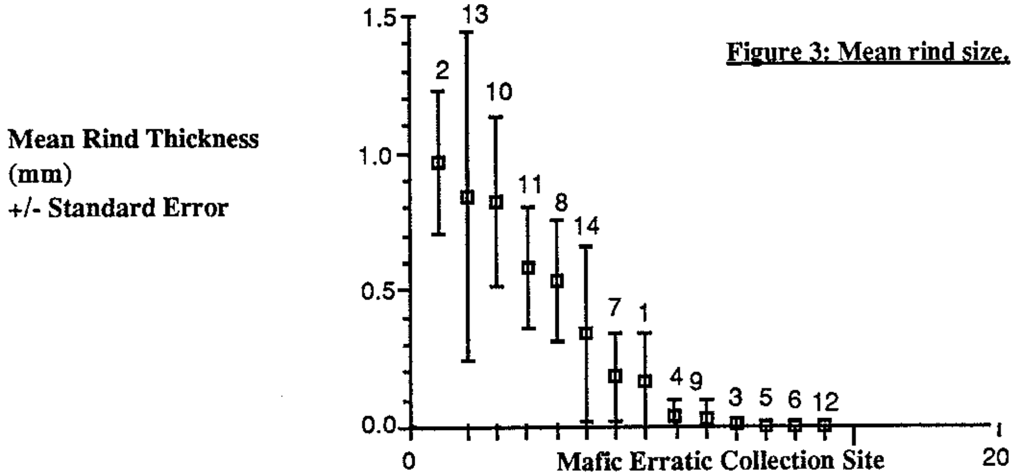
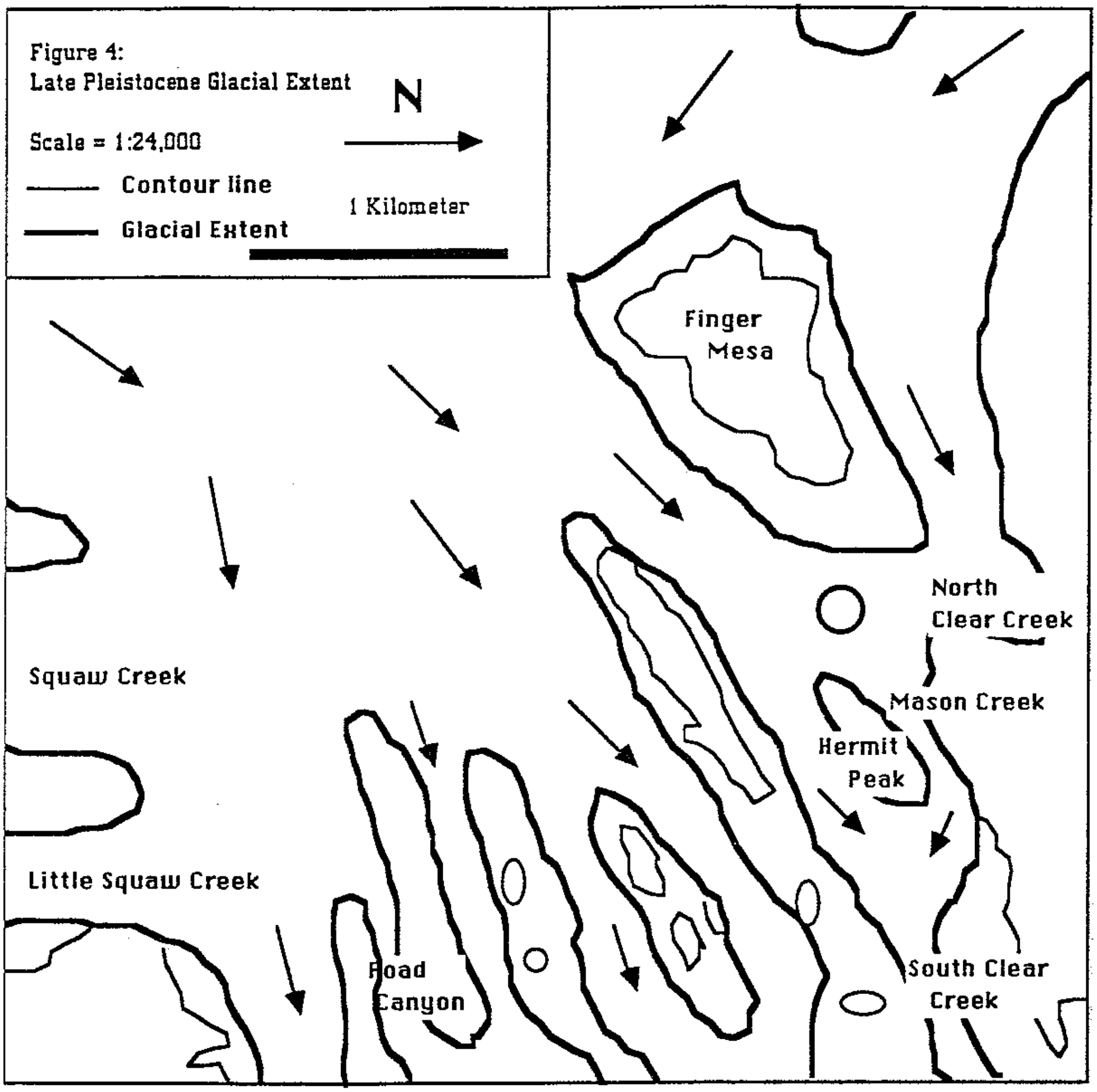


Figure 3: Mean rind size.

When glacier profiles based on field data were compared to theoretical profiles derived from ice flow modelling, both significant discrepancies and congruencies appeared. In both the Rio Grande and South Clear Creek valleys, theoretical ice profiles slope much steeper than the field data predicts. In South Clear Creek theoretic ice models predict that ice would end 4 kilometers before the end of the valley. The field data shows that there was at least 100 meters of ice at the end South Clear Creek. In order for ice to reach the downvalley positions in the Rio Grande and South Clear Creek valleys shown in figure 4, theoretic calculations show that ice would have to be quite a bit thicker upvalley. Atwood and Mather's map is equally incongruous. On the other hand, in North Clear Creek the field data and Atwood and Mather's mapping fit very well with calculations.

DISCUSSION

Both field evidence and theoretic calculations show that ice spilled out of the Rio Grande and North Clear Creek valleys. However, quite clearly there is a discrepancy with the field data and calculations based on simple laws of physics. To make ice flow further down valley into the Rio Grande and South Clear Creek ice would have to be about 200 meters thicker at Lost Lakes than mapped in figure 4. Doing this though would negate quite a bit of data in South Clear Creek and at Lost Lakes. It is possible that assuming a basal shear stress 80-100 kPa is invalid. A lower shield stress would yield a lower slope angle, and the glacier would be able to reach downvalley. Glaciers have been measured with shear stresses as low as 50 kPa (Birkeland, 1984). A third possible explanation is a mechanism such as soft sediment in valley bottoms which deforms as the glacier slides over it thereby allowing the glacier to slide further downvalley.



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