LATE PLEISTOCENE DEGLACIATION OF THE CLEAR CREEK GRABEN, SAN JUAN MOUNTAINS, COLORADO

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Goals The goals of this study are:

1) to create a 1:12,000 map of the glacial and surficial deposits in the Clear Creek Graben
2) to determine ice extent at the last glacial maximum
3) to determine the chronology of deglaciation based on this information

Introduction and Field Area

This study examines the glacial geology of the Clear Creek Graben in the eastern San Juan Mountains, southwest Colorado. The mountain range covers 20,000 square kilometers, extending from San Luis Park on the east to within 50 miles of Utah on the west. Thirteen peaks exceed 14,000 feet, and over twenty others exceed 13,000 feet (Atwood and Mather, 1932, Carrara, 1984). The continental divide bisects the center of the range, with the Rio Grande River draining to the east and the Colorado River draining to the west. My research looks at the area where South Clear Creek and the Rio Grande River flow east out of confined valleys into the large Clear Creek Graben. This area is located within the USGS 1:24,000 topographic maps of the Hermit Lakes quadrangle and the Bristol Head quadrangle; 37°45' to 37°52' north latitude and 107°4' to 107°13' west longitude. Elevation ranges from 9500 feet in the south, to 10,400 feet along the eastern edge of the graben.

In this study, the most recent glaciation will be termed Pinedale, and the second most recent will be termed Bull Lake. Quaternary deposits in the San Juan Mountains have been correlated with glaciations defined in the Wind River Mountains, Wyoming (Blackwelder, 1915, Meierding and Birkeland, 1980). The Pinedale glacial maximum has been dated at 23,500 to 21,000 years BP in the Front Range, Colorado (Madole, 1986). The Pinedale glaciation erased many Bull Lake deposits, but some Bull Lake till outcrops in the eastern and southeastern portions of the study area. No deposits from glaciations older than Bull Lake were evident.

During the last glacial maximum, the San Juan range was covered by a complex of large regional ice fields, transection glaciers and valley glaciers (Carrara et al, 1984). This glaciation was not as extensive as the second most recent. Most major valley glaciers did not reach the foothills of the mountains, but left long valley trains of glacial debris extending downvalley from their former glacial termini. The Rio Grande glacier was formed by the confluence of ice flowing out of South Clear Creek Canyon, Crooked Creek Canyon, House Canyon, and Road Canyon. The Rio Grande Glacier was fed by cirques on Rio Grande pyramid along the continental divide. It was over 30 miles long and occupied over 375 mi^2, making it the second largest glacier in the San Juans (Atwood and Mather, 1932).

Methods Four techniques were used to achieve the goals of this study:

1) field mapping and air photo interpretation
2) relative dating methods using soils and weathering rinds
3) ice provenance studies
4) glacier modeling

The entire area was mapped using a combination of field mapping and stereoscopic aerial photograph interpretation. The small size of the study area made it possible to map by examining topography on foot, digging exposures in landforms to determine sediment composition, and walking the contacts between units. Air photographs were used as a means of examining topography and mapping out contacts.

Relative dating techniques were used to determine whether deposits in the study area were from the Pinedale or Bull Lake glaciation, and also to see whether any differentiation between Pinedale deposits was possible. Soil pits were dug in thirteen places either on moraine crests or the top of kame terraces. In the field, horizon depth, color, texture, structure, and percent gravel were noted at each site. In the lab, particle size analysis was performed on samples from each horizon and dry color was recorded. Mafic weathering rinds were measured on basalts or andesitic basalts at fourteen locations in the study area, generally moraine crests or the top of kame terraces. Rinds were also measured at ten locations near the Pinedale terminus of the Rio Grande Glacier to correlate the study area measurements with other known Pinedale deposits, and to determine a more complete chronology of deglaciation.

Two techniques were used to determine ice flow direction from each small, confined valley: 1) the ratio of crystalline to volcanic rocks in glacial deposits, 2) the orientation of the long axes of rock drumlins. The crystalline source area is located along the continental divide to the southwest of the study area. A large ice field situated over this area fed all four of these glaciers. There is a significant decrease in the percentage of crystalline erratics from the

Conclusions. By matching up paleomagnetic data from glacial Lake Atwood with the Rosenbaum and Larsen study, we know the lake existed between 15,000 and 13,500 years B.P.. The age represents only the time during which the lacustrine sediments were deposited; some water must have existed in the basin during the glacial maximum, but the lake may have been too shallow or turbid for rhythmites to form. There is some question as to whether ice existed in North Clear Creek Park in the Pinedale. Scott McMillin and Alex Durst (both this volume) determined the ICSD at the mouth of the Continental Reservoir to be of Pinedale age (soil pit evaluation). This finding suggests ice began to emerge from North Clear Creek into the paleobasin during the Pinedale, and would account for the amount of outwash that exists in this end of North Clear Creek Park. The Pinedale glacial maximum occured around 23,500-21,600 years B.P. (Madole, 1986); it is during this time when ice would have most certainly existed in this northern section. There is no direct evidence to suggest sediment from this northern outwash affected the rhythmites at the delta or near the ice, and the outwash does not have any features suggesting it was graded to a lake level; it is difficult to determine when (during the existence of the lake) ICSD began to contain outwash and meltwater in North Clear Creek. Till does exist within the paleobasin (Figure 1) but its age is problematic.

Sedimentation in glacial Lake Atwood was dominated by underflow, both in the winter and the summer, although the presence of winter clay layers through suspension settling suggests that some type of stratification did exist (either thermal or sediment) and that turbidity probably decreased in magnitude during the winter months from ice cover. Coarser sediment was deposited in the rhythmites near the glacier, where no sediment traps existed between melting ice and the basin. Facies changes found within the stratigraphy of rhythmites near the glacier reveal possible fluctuations in sediment inflow over time. Sections with smaller percentages of sand and higher percentages of clay are representative of periods of low inflow, and sections with many cross-bedded and massive sand layers and a high silt percentage reflect increased turbidity. Because the identification of varve couplets is impossible from the complex rhythmicity, a precise longevity of the lake is not known. However, the considerable thicknesses and frequency of turbidity deposits suggests a fairly high rate of sedimentation, and paleomagnetic results indicate the rate is 1 meter every 714 years at the ice/lake contact.

Paleomagnetic data also helps to bracket the catastrophic drainage of the lake. Maria Panfil (this volume) has radiocarbon dated material from Ghost Lake in Santa Maria Canyon at 7,610 +/- 90 yrs. The date represents the youngest possible date for debris to have covered the lower spillway of glacial Lake Atwood, and therefore the absolute latest date for catastrophic drainage of the lake. The drainage thus occured at some time between 7,610 and 13,500 years B.P.. These dates are coherent with others findings for Pinedale deglaciation in the San Juans (Carrara et al, 1991, Gillam et al, 1984). The volume of water in glacial Lake Atwood at its maximum (lake level 10,150') was approximately 6,636,447 cubic meters: the lower spillway at 10,070 ft. would have been responsible for the catastrophic drainage of some 6,087,090 cubic meters of water.

The approximate size of glacial Lake Atwood in map view is consistent with the findings of Atwood and Mather. The use of paleomagnetics, surficial mapping, and consideration of glaciolacustrine sediments provides us with a more detailed understanding of glacial Lake Atwood. Paleomagnetics is especially helpful in placing the age of lacustrine sediments within the period of Pinedale deglaciation in the Colorado Rocky Mountains.

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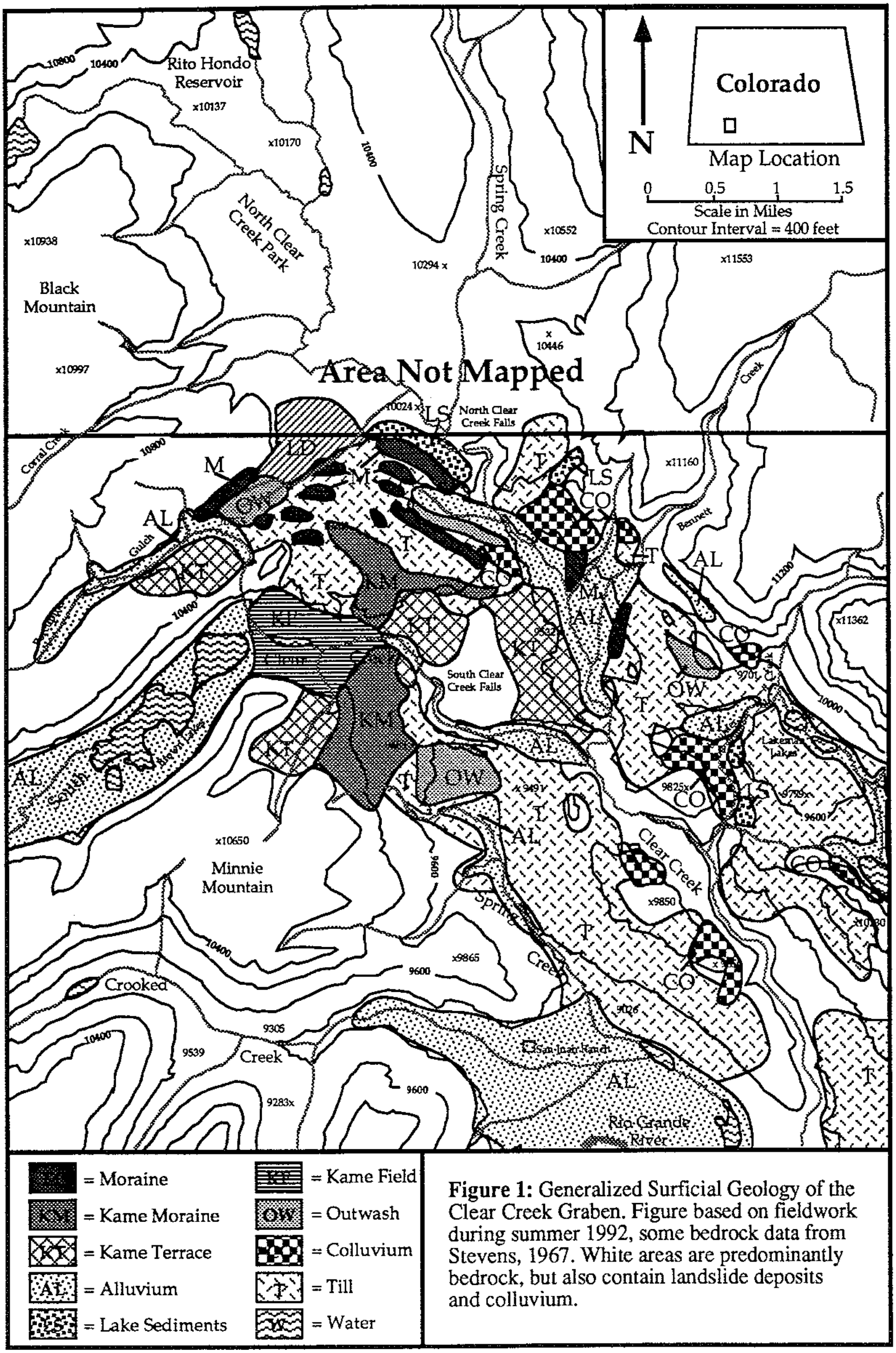

Figure 1: Generalized Surficial Geology of the Clear Creek Graben. Figure based on fieldwork during summer 1992, some bedrock data from Stevens, 1967. White areas are predominantly bedrock, but also contain landslide deposits and colluvium.

northernmost to southernmost valley. At thirty three locations, 100 clasts were sampled to determine the ratio of crystalline to volcanic rocks. These data help to identify which glacier is responsible for the deposits that contain a high percentage of crystalline erratics and the position of that glacier at the most recent glacial maximum. The long axes of rock drumlins are excellent indicators of ice flow direction and help to position the valley glaciers within the Clear Creek Graben at the most recent glacial maximum (Flint, 1971).

Glacier modeling was performed to determine whether the ice from South Clear Creek Canyon formed the ice dam of Glacial Lake Atwood or whether the ice from the four southernmost valleys could have flowed up the valley gradient and dammed Glacial Lake Atwood. Glacier modeling also facilitated determination of the ice extent in the Clear Creek Graben at the last glacial maximum.

Chronology of Deglaciation

At the last glacial maximum, ice flowed out of South Clear Creek Canyon with a surface elevation of between 10,400 and 10,500 feet. As the ice spilled into the Clear Creek Graben, it spread slightly upvalley to the north and flowed extensively downvalley to the south and across the graben to the east. The surface elevation of the ice decreased as it spread out and reached 10,150 feet where the ice contacted the far eastern wall of the graben. The ice dammed several streams, forming Glacial Lake Atwood. (Figure 2) The lake had a maximum surface elevation of 10,150 feet which has been correlated with a delta graded to that level in the southwestern corner of the lake and a spillway along the eastern edge of the graben. The lake volume at this stage was 6,636,500 cubic meters (MacGregor, this volume).

The ice retreated from the Clear Creek Graben in four major stages. In the first stage, the spillway was lowered from 10,150 feet to 10,070 feet. This drop in the lake level caused catastrophic flooding downstream as evidenced by large boulder lag deposits at the mouth of Santa Maria Canyon, and flood deposits found farther down the canyon. The lake volume at this level would have been 550,000 cubic meters (MacGregor, this volume). The ice remained at the 10,070 level long enough for the spillway to erode a channel into a bedrock plateau along the eastern edge of the graben. This level, however, was not as long-lived as the 10,150 level because there are no large scale deltaic features graded to it.

The ice then began its second stage of retreat, depositing moraines on the floor of the Clear Creek Graben at 9670 feet and 9600 feet. (Figure 1) The main body of ice remained pinned against the eastern wall of the graben, maintaining the lake level at 10,070 feet. The drainage, however, no longer flowed into Santa Maria Canyon, but flowed around the edge of the glacier back onto the floor of the graben and into the present Clear Creek Canyon.

As the ice retreated for the third time, the ice dam was breached and Glacial Lake Atwood drained completely. This drainage was probably catastrophic, but the water flowed down the present day North Clear Creek into Clear Creek and any deposits have been obscured by modern alluvium. The volume of this flood would have been much smaller than when the lake drained from 10,150 to 10,070 feet. At this stage, the glacier left four arcuate moraines near the contact between the ice and the former lake. (Figure 1) The final stage of deglaciation occurred when the ice stagnated in the mouth of Clear Creek Canyon leaving a hummocky complex of kames and kettles (Small, this volume).

Paleomagnetic data indicate that Glacial Lake Atwood rhythmites were deposited beginning 16,380 years BP, and continued until approximately 13,500 BP (MacGregor, this volume). Although this does not extend back to the Pinedale glacial maximum at 22,000 years BP, the lake was most likely present at that time, but the sediment input was too high for the silt and clay to settle out as rhythmites.

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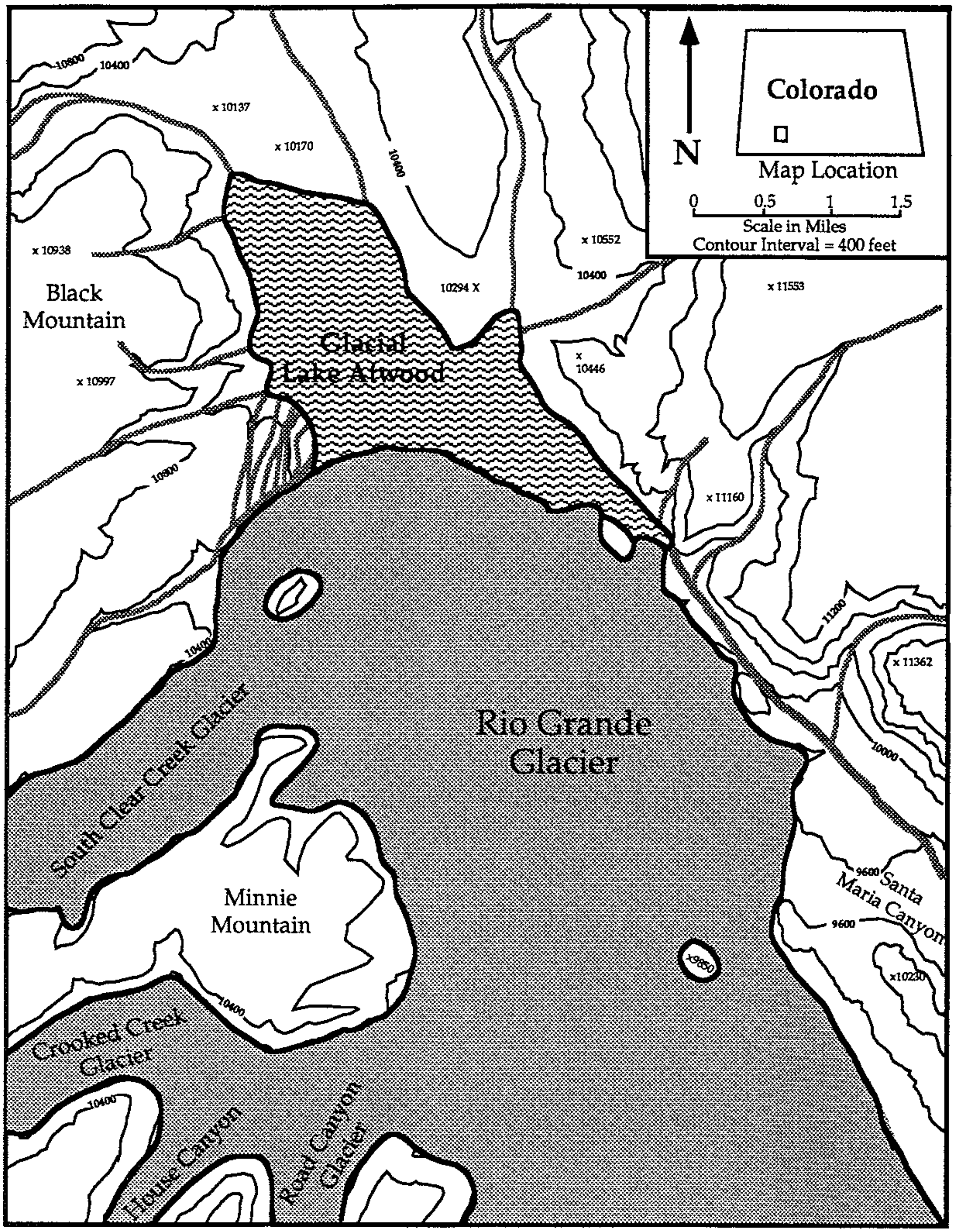

Figure 2: The Clear Creek Graben at the last glacial maximum. The Rio Grande Glacier is formed by the confluence of ice flowing out of South Clear Creek Canyon, Crooked Creek Canyon, House Canyon and Road Canyon. The ice dammed off several streams causing Glacial Lake Atwood to be formed (surface elevation 10,150 feet). At its maximum extent Glacial Lake Atwood had a volume of 6,600,000 cubic meters. The lake drained around the eastern edge of the glacier along the wall of the graben, then down through Santa Maria Canyon.

POST-GLACIAL HYDRAULICS, MORPHOLOGY, AND LONG PROFILE ADJUSTMENT OF THE RIO GRANDE RIVER, SAN JUAN MOUNTAINS, COLORADO

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INTRODUCTION:

A flight of unpaired late Quaternary terraces comprised of fluvio-glacial deposits flanks the Northern Rio Grande River for nearly ten miles along the upper Rio Grande valley. Terminal moraines equivalent to Pinedale and Bull Lake Stages of ice advance occur at the upstream origin of these terraces. More than three fluvial terraces extend at least twelve kilometers downvalley from the moraines. These terraces, which converge downstream, cut into sediments deposited by braided streams flowing from the terminus of valley glaciers that flowed down the Rio Grande valley. (see Figure 1 for sequence of terrace remnants). The coarsest terrace sediments were deposited during a catastrophic outburst flood (after the failure of an ice dammed lake) that produced rates of discharge at least as great as 11,092 m3/s.

METHODS AND PURPOSE:

A variety of research methods were useful in gathering pertinent data for this project. A Lietz total geodetic station provided coordinate and elevation data to correlate the terraces, determine channel geometry through cross sections, and construct longitudinal profiles of the individual terrace surfaces. Measurements of the lenghts of the intermediate axes of the ten largest boulders on both terrace tread surfaces and exposures within the terrace deposits were used to reconstruct paleoflow hydraulics. (If the boulder was not fully exposed, the apparent intermediate axis was measured). Determining the origin of the terrace fill material, and correlating the complex flight of terraces, as well as estimating paleohydraulic conditions of the Rio Grande is the objective of this study.

LOCAL GEOLOGY:

The San Juan Mountains are an area of high relief and rugged terrain carved into a two kilometer thick sequence of middle-to-late Tertiary lavas and pyroclastic rocks. The vlocanic rocks unconformably overlie metamorphosed sediments, volcanics, and intrusive rocks of Precambrian age, as well as sedimentary rocks of Paleozoic, Mesozoic, and Cenozoic age.

Although no glaciers exist in this area today, evidence of late Pleistocene glaciation is present throughout the range. Atwood and Mather (1932) mapped glacial deposits in the region and identified three episodes of glacial advance. Although Atwood and Mather inferred that the bulk of glaciers were valley glaciers, aerial photographs and topographic maps reveal evidence of broad regional ice fields and transectional glaciers as well (Carrara et al, 1984; U.S. Forest Service Aerial Photographs 684-175-180 and 684-205-209; Spar City, Creede, Bristol Head, and Workman Creek 71/2' USGS Quadrangles).

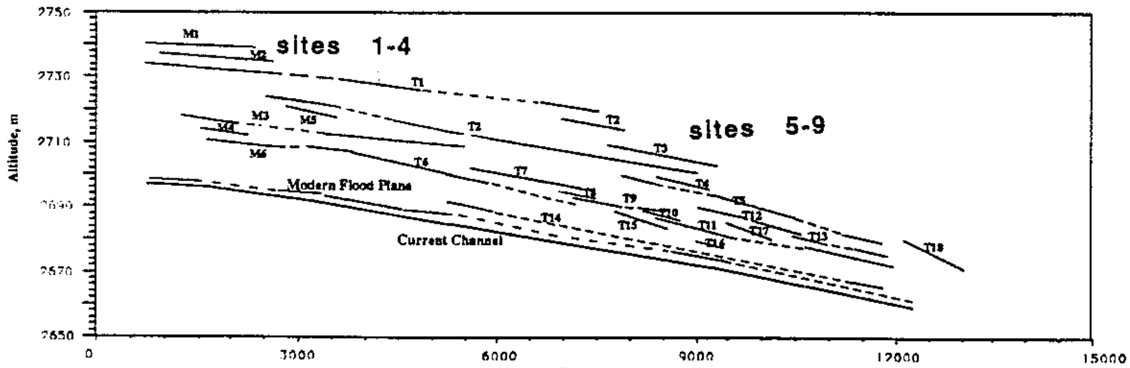

Figure 1: Longitudinal Profiles of terrace sequences along the northern Rio Grande River, San Juan Mountains, Colorado
(M=Moraine, T=Terrace, S=Surface)