P1.4 THE INFLUENCE OF METEOROLOGICAL AND GEOLOGICAL PROCESSES ON THE FORMATION, DEVELOPMENT AND CHARACTERISTICS OF MONTANE LAKES

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1. INTRODUCTION

During the summer of 2002, 25 students, half Americans half Scots, participated in a field expedition to the Cloud Peak Wilderness Area of the Big Horn Mountains of Wyoming. The object of the program was to study a selected aspect of the area while gaining field experience. The areas of study included hydrology, meteorology, energy budget, botany, and mapping of the substantial geologic features of the area.

2. RATIONALE

The mapping data collected provides an idea of the processes involved in the formation of the moraines, and subsequently, the lakes. Kiilsgaard, Erikson, Patten and Bieniewski (1972) state that "glaciation during the last period (of the Pleistocene epoch) was widespread above an altitude of 9000 feet." If this was the case, then the area under study was at or near the ice front and most likely would have experienced minor advance and retreat with meso-scale changes and climatic fluctuation. The patterns in which the moraines are situated, their shape, and positioning relative to the valley walls suggests one possible route that a glacier had followed, as well as the glacier's advance and retreat tendencies.

Lake data from 2000 and 2002 were used in conjunction with the mapping data to determine the influence of the metorology and geomorphology of the valley on the formation and current characteristics of Long and Ringbone Lakes.

3. SITE DESCRIPTION

The area of study is a u-shaped valley that had been subjected to glaciation during the last two periods of the Pleistocene epoch (Figure 1). The cirque at the valley head just below Dartan Peak is indicative of such glacial activity. The valley head is at an elevation of 12275 feet, and is located at approximately N 44˚ 16'30", W 107˚ 06' 30". From there, it extends downhill in a southeasterly direction. Oliver Creek runs down the center of the valley, weaving through granite gneiss boulder fields and moraines, also indicative of glacial activity, and collecting in a series of lakes. Of these lakes, two were studied: Long Lake, and Ringbone Lake, Ringbone being situated uphill and to the northwest of Long. In a previous expedition in 2000, Long Lake was mapped in detail, and its meteorological and hydrological fluctuations were observed. In 2002, Ringbone was studied in a similar fashion.

Figure 1: Southwestern view of cirque, u-shaped valley and Long Lake.

A particular area of interest was the numerous, interconnected moraines, lying primarily lengthwise down the valley. These moraines are substantial features, revealed from under the tree cover by forest fires of 1946 and 1988. They are blocky in character and consist of large angular rock fragments; any silt content was removed by subsequent fluvial action. Five of these moraines were mapped in great detail in order to better understand their underlying formation, the sequence of deposition and to contribute to a holistic understanding of coincidental features – namely Ringbone and Long Lakes.

4. FIELD METHODS AND EQUIPMENT

Equipment utilized in the mapping of the moraines includes a magnetic compass, a clinometer, 50-meter tape measures, manual and electronic rangefinders, and a handheld global positioning system (accuracy up to 15 feet.) Measurements that were necessary for reconstruction of their shape, size and location were taken. The latitude and longitude coordinates, and the elevation of each point on the moraines were found via the

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GPS unit. The distances between these arbitrary points were measured, as were the vertical angles from one point to the next. The curvature of the moraine was determined by measuring the compass bearing from one point to the next. In order to develop an idea of the profile of the moraines, the distance down and angle from the horizontal of the distal and proximal slopes were found at each of the points (Figure 2). The moraines were mapped beginning at the uphill end of each one, then following the moraine down the valley. Relative distances from one designated point on a moraine to another were also measured in order to note the relationship among the interlaced moraines.

Figure 2: Mapping of M_3.

Also noted was the relationship between the moraines and the adjacent lakes, primarily Long and Ringbone Lakes. The studies conducted on Long Lake in 2000 and on Ringbone Lake in 2002 provided opportunity for comparison between themselves and with the moraine mapping data.

The data collected from the mapping of the moraines was plotted onto paper, developing a birds-eye view of each of the five moraines mapped, using a scale of 1 cm for every 5 meters. A cross section of the moraine at each individual point, and a lengthwise profile of the moraine were also constructed (Figure 3).

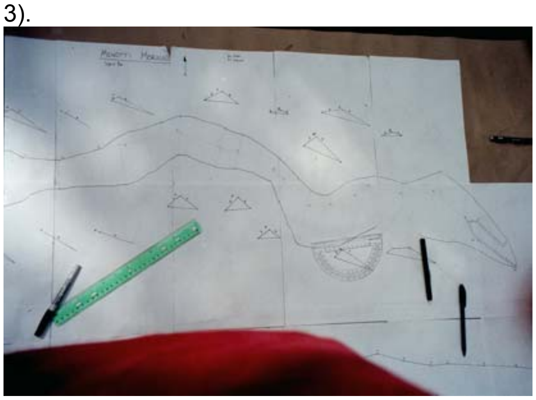

Figure 3: First draft of map of M_3.

5. DATA AND ANALYSIS

Upon measuring and mapping the moraines, the relative dimensions and locations of the moraines became evident. By plotting the coordinates of each of the individual points, classification of the moraines as push, lateral or medial became possible. Table 1 a sample of recorded measurements of one of the moraines.

Table 1: See Apendix A

This particular dataset describes a moraine (M_2) that extends out across most of Ringbone Lake in a direction nearly parallel with the walls of the valley. (Figure 4.) There is a trend, evident in this data and in the data from the other four moraines, in that the distance down the distal slope of the moraine (side further from the glacier) is nearly always longer than the proximal slope (the side adjacent to the glacier.) This occurrence, typical of moraines, results from the force of the glacier to cause the debris to spill over the top of the moraine and down the other side, thereby depositing more material on the moraine's proximal face. It should also be noted that, while the vertical angle of the moraine may fluctuate between positive and negative values, the total angle is a negative number, consistent with the tendency of the moraine to slope downhill overall.

Figure 4: Southeastern view of Long and Ringbone Lakes

Lake data from Long and Ringbone Lakes were derived either from the lake studies team of 2000 or from 2002. Comparison of the data was possible since there were only very slight variations in the meteorological elements between the two years. These two adjacent basins exhibit several key differences. Not only is Long Lake considerably deeper than Ringbone, the lake bottom of Ringbone is primarily scree from nearby slopes and silt deposits along the margins, whereas the bottom of Long is littered with large boulders. Long is also at a lower elevation than Ringbone, thus Ringbone provides a source of water for Long, the flow being filtered through a boulder field from the outflow of Ringbone down to the inflow of Long.

6. COMPARISON TO LAKE STUDIES

Initially a lake study was designed for a location in the Gallatin Mountains. A preliminary scouting of this site revealed the area to be inhabited by several Grizzly bears and forced the team to move to an alternative study site. After being relocated to the Big Horn Mountains, the focus of the Ringbone lake study assumed the research design employed for the study of Long Lake by the field team in 2000. After mapping the perimeter of Ringbone Lake (Figure 5), mapping the lake bottom, completing the chemistry studies, and deploying a technique for determining changes in lake level over time, it became apparent that the data sets for Ringbone and Long Lake were substantially different.

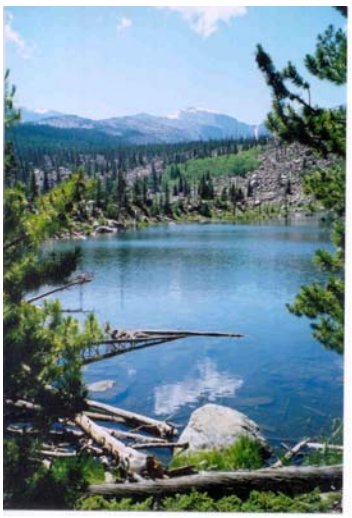

Figure 5: Ringbone Lake

Ringbone Lake is significantly larger than Long Lake in surface area and shallower. Temperature measurements were warmer than those measurements taken from Long Lake. This discrepancy was hypothesized to be related to differences in depth. In addition, several of the chemistry parameters for Ringbone differed significantly from those of Long Lake. Again it was hypothesized that the increased temperature of Ringbone Lake in comparison to Long Lake might influence the differences of the observed conductivity, pH, and other ion concentrations. To test this hypothesis, chemical properties of the inflow and outflow for Ringbone were also determined. (Figure 6)

Figure 6**-** Conducting outflow chemistry test

Data from both teams is now being analyzed and will be reported at the annual meeting.(Table 1)

Avg. Lake Properties	Long Lake	Ringbone Lake
pH	8.1	8.6
conductivity	10 ms	20 ms
Surface Temperature	13.8 °C	18.6 °C
Depth (center transect)	3.8 m	1.9m

Table 1

These lakes are greatly affected by geological and meteorological processes. Both processes have the possibility to induce many of the differences observed between the two lakes. Therefore, it is critical to the holistic understanding of the entire area that we gather a sense of their origin and how that process might have induced some of the observed differences.

7. DISCUSSION

From the constructed maps and a topographic map of the area, careful observation of the orientations and shapes of the moraines and the characteristics of the lakes, and acquired knowledge of glaciation and geomorphology, a possible scenario for the formation of the system of moraines and lakes was developed. Based on this evidence, it was determined that the glacier receded and melted into an increasingly narrower tongue, receding in towards the center of the valley, and leaving impressions and indentations where the mass of the glacier scoured the valley floor during each period of stagnation. The possible position of the glacier at certain points is outlined by the positioning of the topographic contour lines. The impact of the glacier is possibly what lead Long Lake to be deeper than Ringbone, the glacier having spent more time in the Long Lake area than it did in Ringbone, since it peeled away from the Ringbone area first as the glacier was shrinking. Thus it can be concluded that M_1, the west-most moraine, located the furthest up the valley, is most likely the youngest of the five moraines. Its curved end point suggests that this lateral feature marks the position of the final and most substantial event. M_2 (moraine extending into Ringbone) and M_3 are coalesced and divide the lake basins of Long and Ringbone. It might be suggested, due to their proximity, that at one time this was a unified feature but a glacial advance, perhaps with the push recessional feature resulting in M_5 (eastern-most moraine, located at the tail of M_4), supra glacial medial depositions, M_3, were dumped alongside a smaller lateral type feature, M_2. This subsequent deposition thereby reinforced the effect of the Ringbone basin's first entrapment, M_2.

Figure 7 – Identification of Moraines

The divided end point of M_3 is a distinctive feature perhaps resulting from crevassing of the ice surface as it passed over the rock step below Long Lake. If the ice was near stationary as is suggested by the moraine M_5, then the crevasses would have filled with debris, and subsequent melt and deposition would leave a confused pattern. M_5 is different compared to the other moraines, being oriented at right angles to the ice flow. This marks some form of ice stationary period but we cannot be certain to its exact formation.

The fine silt found at the margins of Ringbone Lake can be attributed to its location right alongside the valley wall. This infill is debris, eroded and fallen off these walls and caught by the Ringbone basin. This silt remains in Ringbone and is not carried into Long Lake; any suspended debris is filtered out of the water while en route through the boulder field to the inflow of Long. Evidence of this was observed while studying the outflow channel from Ringbone.

8. SUMMARY

The impact of glacial activity on this region is phenomenal. It is this crucial series of events in the history of the valley that has sculpted the distinct geologic features of the moraines and the lake basins. An understanding of the processes involved in the geomorphology of the area provides enhanced appreciation for and awareness of how each aspect of the geological, hydrological, meteorological and biological environments are interconnected and how fluctuations in one will be felt in all other aspects of the environment.

To improve further upon this understanding, a final copy of the mapped moraines should be constructed. Also, additional studies will be conducted before the February conference involving comparison between Long and Ringbone Lakes based on their chemical characteristics, and on the evaporation rate versus the drainage rate.

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Apendix A: Sample of moraine mapping data

Point	**Altitude (feet)**	**Latitude (degrees)**	**Longitude (degrees)**	**Distal Distance (m) and Angle (degrees)**		**Proximal Distance (m) and Angle (degrees)**		**Distance (m)**	**Bearing (degrees)**	**Vertical Angle (degrees)**
0	8995	44 N 16.473'	107 W 1.809'							
								15.5	103	-20
1	9005	44 N 16.431'	107 W 1.798'	45	9.9	40	10			
								39.6	115	-6
2	9002	44 N 16.418'	107 W 1.777'	66	9.5	68	11			
								42	98	-2
3	8999	44 N 16.410'	107 W 1.749'	62	11	65	11			
								35.7	90	-2
4	9001	44 N 16.404'	107 W 1.722'	55	12	58	14			
								37.5	75	1
5	9000	44 N 16.405'	107 W 1.696'	54	12	56	18			
								42.7	76	-5
6	9000	44 N 16.406'	107 W 1.673'	21	25	55	19			
								31.5	72	5
7	8981	44 N 16.401'	107 W 1.649'	30	8.7	60	22			
								34.2	74	-1
8	8978	44 N 16.404'	107 W 1.621'	9	22	52	14			
								36	74	3
9	8972	44 N 16.405'	107 W 1.595'	0		56	19			

Table 2