RADIAL INFLUENCE OF THE GAZ-EX ON A CONTINENTAL SNOWPACK GLORY BOWL SLIDE PATH, TETON PASS, WYOMING

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ABSTRACT

The study is centered on the GAZ-EX installations on Teton Pass, near Jackson, Wyoming, USA. Four GAZ-EX exploders are found on Mt. Glory (3074 m) which has several large slide paths crossing Wyoming State Highway 22. Transects of depth, snow-water equivalence and ram resistance were completed at GAZ-EX 1 on 16 March, 1993. After GAZ-EX 3 and 4 were installed, we completed several more transects encompassing units 1, 3 and 4 during the period 31 March through 2 April, 1994. Three different ram resistance calculations were used for each point; mean, maximum, and integrated ram number. Integrated ram number is the sum of the individual layer ram numbers multiplied by the depth of the corresponding layer. Results indicate that a shallow snowpack is maintained in the blast area relative to surrounding terrain, and a weak snowpack dominated by depth hoar exists in the blast region with increasing strength observed with greater distance from the blast area. The radius of influence for snow depth is about 10 to 40 m from the GAZ-EX legs, depending on year and direction, but may be greater in down-slope cases. The radius of influence for strength is about 10 to 35 m from the GAZ-EX legs, depending on year and direction of measurement. Although effective in removing new snow above the depth hoar before it gains strength after deposition, the GAZ-EX itself is not effective in removing the depth-hoar snowpack in the blast area.

INTRODUCTION

Wyoming State Highway 22 was relocated in 1970, crossing several paths that previously did not affect the road. The new route crosses the Glory Bowl slide path which was spanned by a bridge. In January of 1970 the bridge was damaged by a large avalanche and was subsequently removed. Avalanche forecasting and active control began in the winter of 1971-1972 and has continued to the present. Control devices included a 75 mm pack howitzer, avalauncher, and a 105 mm recoiless rifle. With diminishing reserves of military ammunition and a desire to reduce hazard to motorists on Teton Pass, the Wyoming Transportation Department (WTD) began searching for alternative methods of avalanche hazard mitigation. In 1992 WTD installed two GAZ-EX explodes on Mt. Glory, followed by two more in 1993. Cost of the exploders was approximately $517,000. One device is located in the South Twin slide path; the other three are in the Glory Bowl slide path starting zone. More information on the GAZ-EX itself can be found in Schippers (1992 and 1994),

The GAZ-EX was developed in France for the maritime climate of Europe. Most of the installations world-wide have been in the snow climates of maritime snowpacks, i.e. Europe and California. Based on observations in a continental climate from two seasons on Teton Pass, the radius of influence and the expected behavior may be different in this type of snowpack.

FIELD SITE

The study is centered on the GAZ-EX installations on Teton Pass, near Jackson, Wyoming, USA. The exploders are found on Mt. Glory (3074 m) which has several large slide paths crossing Wyoming State Highway 22 (Figure 1). The GAZ-EX installations that we studied are on the Glory Bowl path which runs from about 3050 m to about 2150 m. The climate is typical of intermountain areas where cold temperatures and clear weather periods lead to depth hoar development in the snowpack.

FIELD METHODS

Transects of depth, snow water equivalence (SWE) and ram resistance were completed at GAZ-EX 1 on 16 March, 1993. Snow water equivalence was measured with a Mt. Rose (Federal) sampler and ram resistance was measured with a standard Swiss ram. One transect was completed with nine measurements downslope from the installation over a 45 m distance. Another transect was completed cross-slope, centered on the GAZ-EX over about 70 m distance. After GAZ-EX 3 and 4 were installed, we completed several more transects encompassing units 1, 3 and 4 during the period 31 March through 2 April, 1994 (Figure 1). Only ram resistance and depth were recorded during this field season. In both years, distance between sampling points was somewhat arbitrary, but we made an attempt to sample at a greater frequency close to the blast areas (3-5 m apart) and further apart (10 m) as distance from the units increased. Two snow pits were excavated during the 1994 field work to check temperature and stratigraphy, primarily to insure that the snowpack was still cold and had not undergone melt. Both pits were located directly downslope from GAZ-EX 1, 6 m and 15 m below the anchor rods. A total of 28 ram profiles and SWE measurements were taken in 1993, and 81 ram profiles were completed in 1994. Because SWE was highly correlated with depth in 1993, the labor-intensive SWE measurements were not continued in 1994.

DATA PREPARATION

The field site was considered one of the "off-limits" areas to backcountry travelers and recreationalists in the 1970's and early 1980's because of avalanche hazard. In the early 1990's it became one of the more popular skiing and snowboarding locations, particularly in the Glory Bowl and Twin Slide avalanche paths. The result is influence on the snowpack from skier stabilization. We will not make comment on how effective or prudent this activity is, but it requires mention as it affects the field data that we have collected. In 1993, there was less activity on Glory Bowl than in 1994, when it appeared to get a great deal of ski and snowboard attention. Because this activity leaves anomalously high values of snow strength where tracks have been left, it is necessary to look at trends in the data instead of single points. Ski tracks are impossible to identify once buried, therefore, it is impossible to locate measurement all points free from their influence. In examining the data we used a smoothing technique called "twicing" so that the occasional odd points would not mask the trends in which we are interested.

Three different ram resistance calculations were used for each point; mean, maximum, and integrated ram number. Integrated ram number is the sum of the individual layer ram numbers multiplied by the depth of the corresponding layer. It gives a good index of overall snowpack strength, much like mean ram number. The 1994 field work followed a clear, warm weather period that formed a strong crust on the surface. Because we were interested in the overall strength of the snowpack as its development may be affected by the GAZ-EX, we removed this surface layer when calculating ram numbers for this study. This method also removed the diurnal influence where we observed decreasing near-surface strength as the daily radiation warmed the snowpack. About 0.25 m were affected and removed from each profile.

RESULTS

Transects from both field seasons are plotted in Figures 2 through 7. Vertical lines represent approximate location of the support rods or legs of the GAZ-EX units, not the center of the blast area or the base or mouth of the unit. We chose this point because it was easy to measure in the field. Note that the Y axes have been maintained at a constant range so comparison between sites and years can be made. The X axes are variable and relative distances are not constant from one site or year to the next. The 1993 season was close to normal in snow accumulation for the region; the 1994 year was about 50% of normal.

From Figures 2 through 7, it is clear that the GAZ-EX has an undeniable influence on the snowpack, both in accumulation and in relative strength. One of our initial goals in the study was to determine the radius of influence of the GAZ-EX on snowpack properties. The figures show some variation, but generalizations can be made. Snow depth in the down-slope direction increases with distance from GAZ-EX 3 and 4 to a point 15-20 m away from the legs, then stabilizes (Figures 2 and 3). Strength follows a similar pattern for 4, but shows a distance of about 30-35 m for GAZ-EX 3. In both 1993 and 1994, GAZ-EX 1 down-slope snow depth increases beyond the distance we measured and mean strength follows this trend as we would expect (Figures 4 and 5). However, the 1994 data shows that the maximum ram resistance stabilizes at about 35 m, indicating that while the overall pack is gaining strength with greater depth down-slope, the strongest layers are not getting stronger. This result means that the weak layers must be gaining strength for the mean ram resistance to be increasing. Therefore, it may be that the GAZ-EX's influence is rapidly decreasing after 35 m distance at this site.

The cross-slope transect for GAZ-EX 1 in 1993 (Figure 6) shows unclear effects from the up wind direction, although depth does show a change at about 12 m. Down-wind directions shows an abrupt change in both depth and strength at about 10 m. In 1994, depth and strength show a large influence based on GAZ-EX 1 and 4 proximity (Figure 7). Depth is unaffected at distances greater than about 20 m and shows a lack of influence even between the two exploders. Strength is affected similarly, but the notable exception is the loss of strength between the two units, even though the depth increases. This result may indicate something about the appropriate spacing of the exploders for optimal operation. The area down-wind from the transect in Figure 7 (on the right side of the graph) shows a slight decrease in snow depth and a stronger decrease in snow strength. This portion of the transect is in the lower portion of the down-slope transect from GAZ-EX 3, and the result is probably due to removal of snow from this area by the GAZ-EX.

Investigations of the snowpack at the GAZ-EX installation in the Glory Bowl slide path on Teton Pass indicates that:

- a shallow snowpack is maintained in the blast area relative to surrounding terrain,
- the radius of influence for snow depth is about 10 to 40 m from the GAZ-EX legs, depending on year and direction of measurement, but may be greater in down-slope cases,
- a weak snowpack dominated by depth hoar exists in the blast region with increasing strength observed with greater distance from the blast area,
- the radius of influence for strength is about 10 to 35 m from the GAZ-EX legs, depending on year and direction,
- although effective in removing new snow above the depth hoar before it gains strength after deposition, the GAZ-EX itself is not effective in removing the depth-hoar snowpack in the blast area.

SUMMARY

If the objective of using GAZ-EX is to reduce the need for artillery control, then spacing of the GAZ-EX installations is critical for maximum effect in all types of layered snow conditions. Locating GAZ-EX units too far apart may leave areas of unstable snow that may release naturally with continued loading. If units are too close together, they may not be cost effective. Because the initial cost of the GAZ-EX installation is high relative to other methods of avalanche control, optimal placement and number of units should be determined for the maximum cost/benefit ratio to be obtained.

ACKNOWLEDGEMENTS

Robbie Fuller and Mark Newcomb helped with the field work in 1993. Ken Swedeen and Steve Kruse of the Wyoming Department of Transportation have generously provided information, photographs, and discussion regarding the GAZ-EX installations on Teton Pass. The work was supported by the American Avalanche Institute and Snowmetrics.

REFERENCES

Schippers, J., The GAZ-EX avalanche control system, *Proceedings of the International Snow Science Workshop*, 72-79, Breckenridge, Colorado, 1992.

Schippers, J., Artificial triggering of avalanches: GAZ-EX avalanche release system, *Proceedings of the International Symposium on Snow and Related Manifestations*, 297-299, Snow and Avalanche Study Establishment, Manali (HP), India, 1994.

Figure 1. Location of the GAZ-EX units in the Glory Bowl starting zone. Dotted lines represent locations of field transects in 1994. Numbers are located downslope from the corresponding GAS-EX.

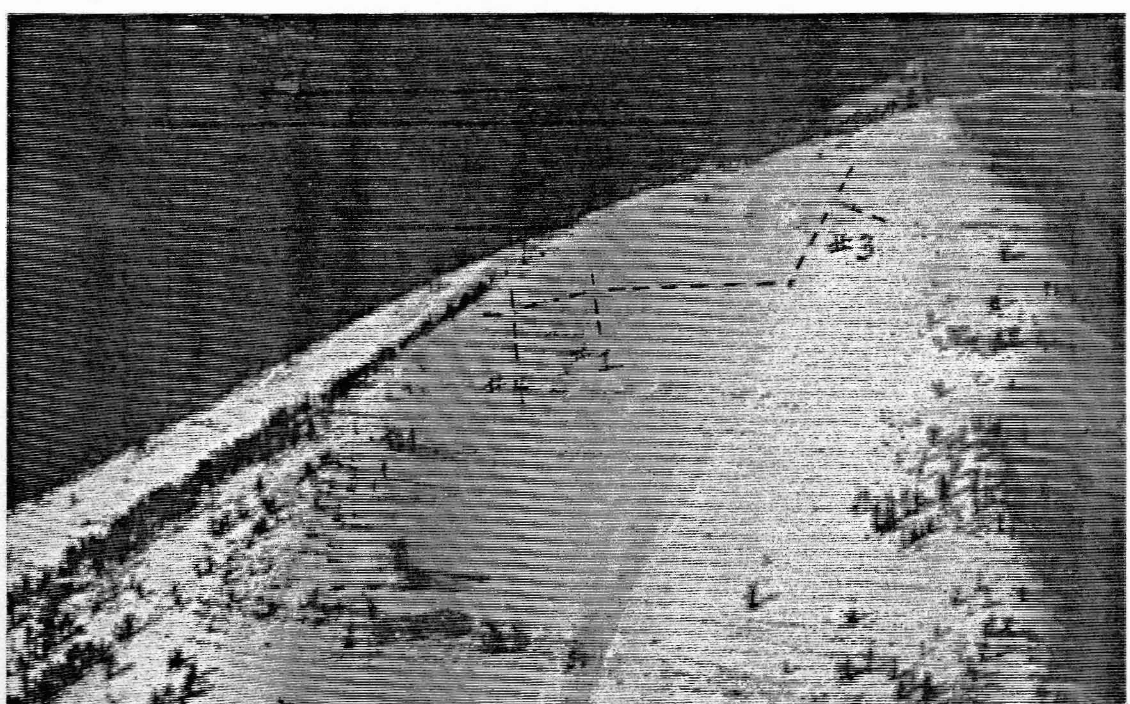

Figure 2. Depth, mean, integrated and maximum ram resistance numbers for the down-slope transects at GAZ-EX 3, completed in 1994.

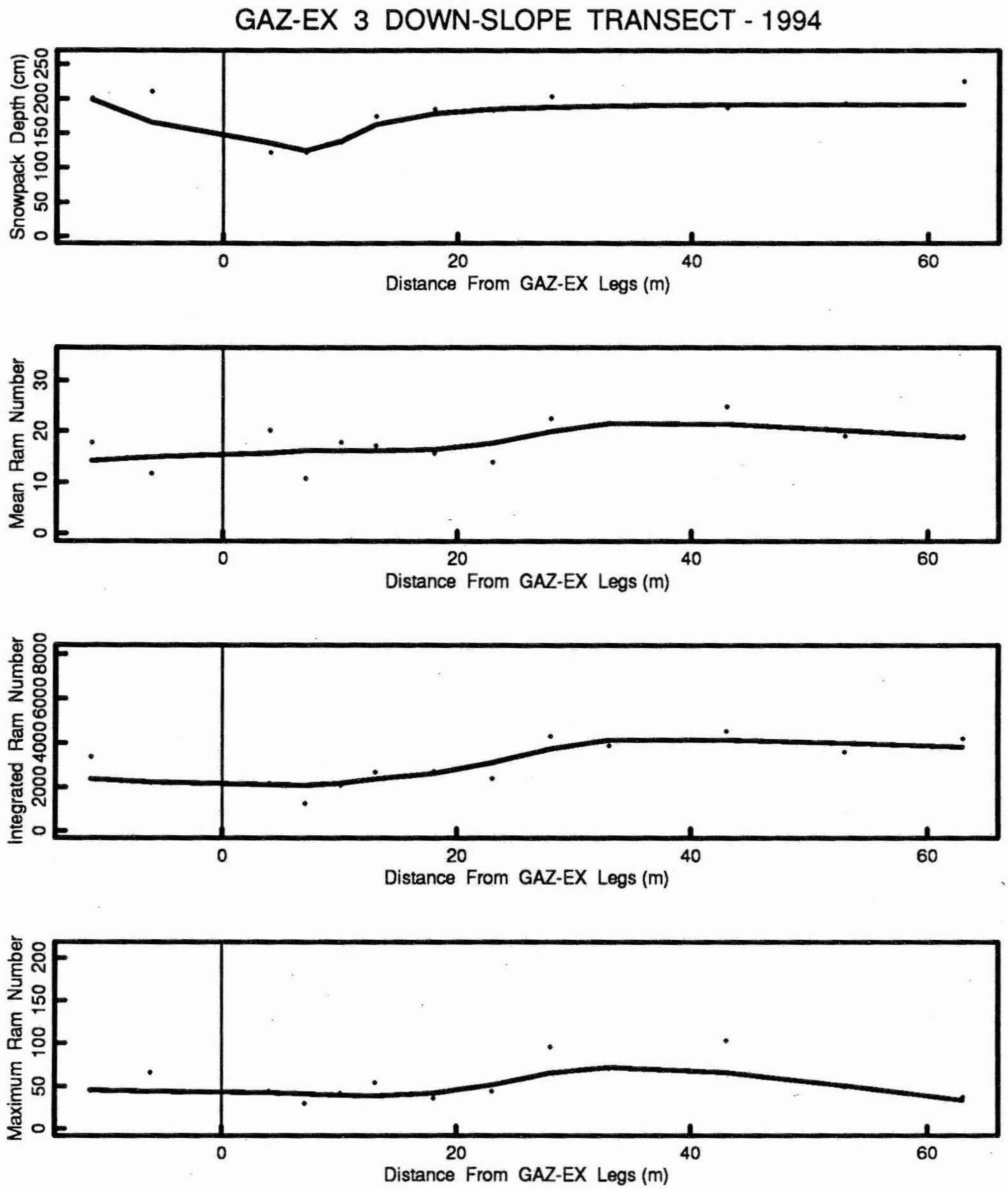

Figure 3. Depth, mean, integrated and maximum ram resistance numbers for the down-slope transects at GAZ-EX 4, completed in 1994.

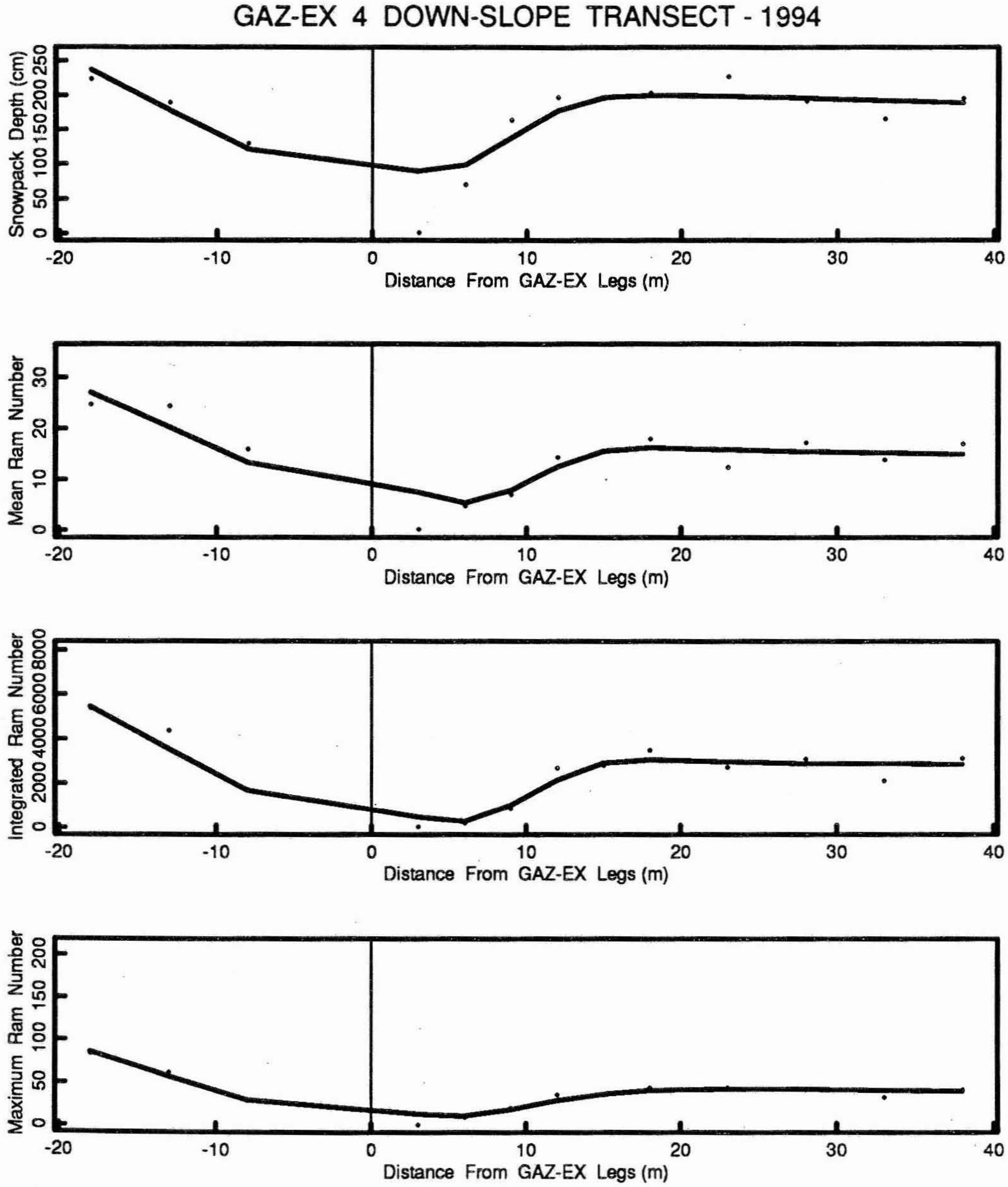

Figure 4. Depth, mean, integrated and maximum ram resistance numbers for the down-slope transects at GAZ-EX 1, completed in 1993.

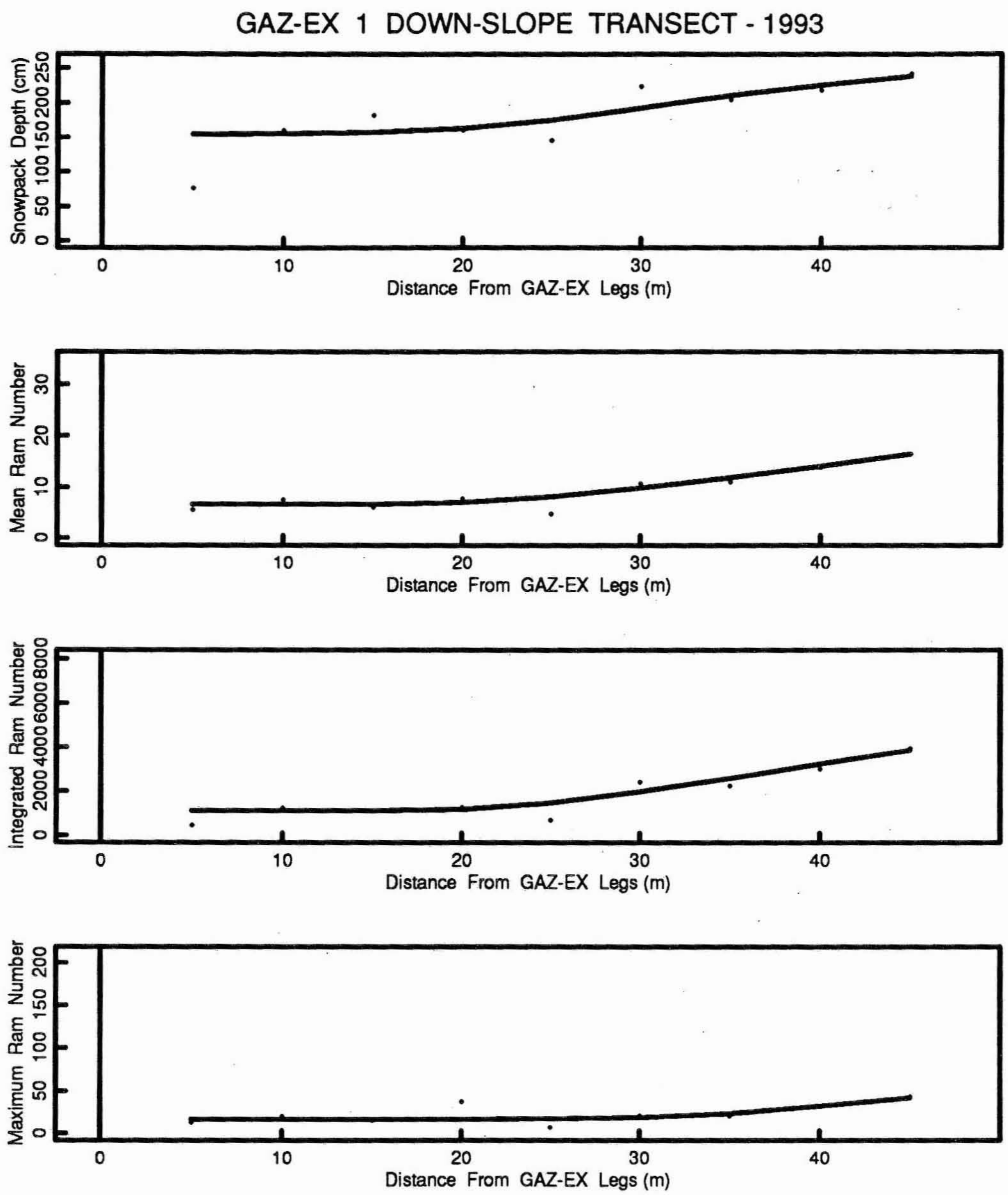

Figure 5. Depth, mean, integrated and maximum ram resistance numbers for the down-slope transects at GAZ-EX 1, completed in 1994.

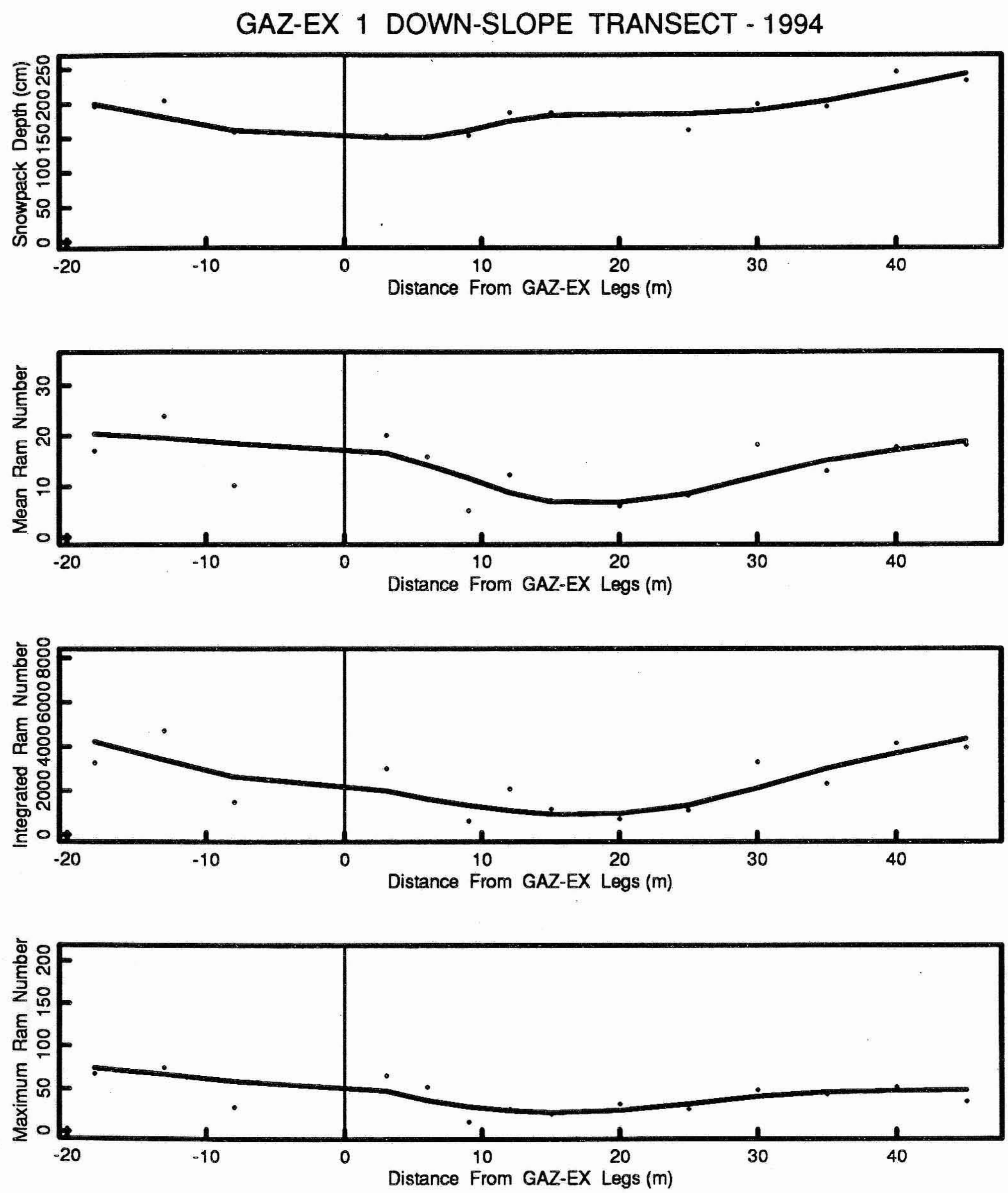

Figure 6. Depth, mean, integrated and maximum ram resistance numbers for the cross-slope transects at GAZ-EX 1, completed in 1993.

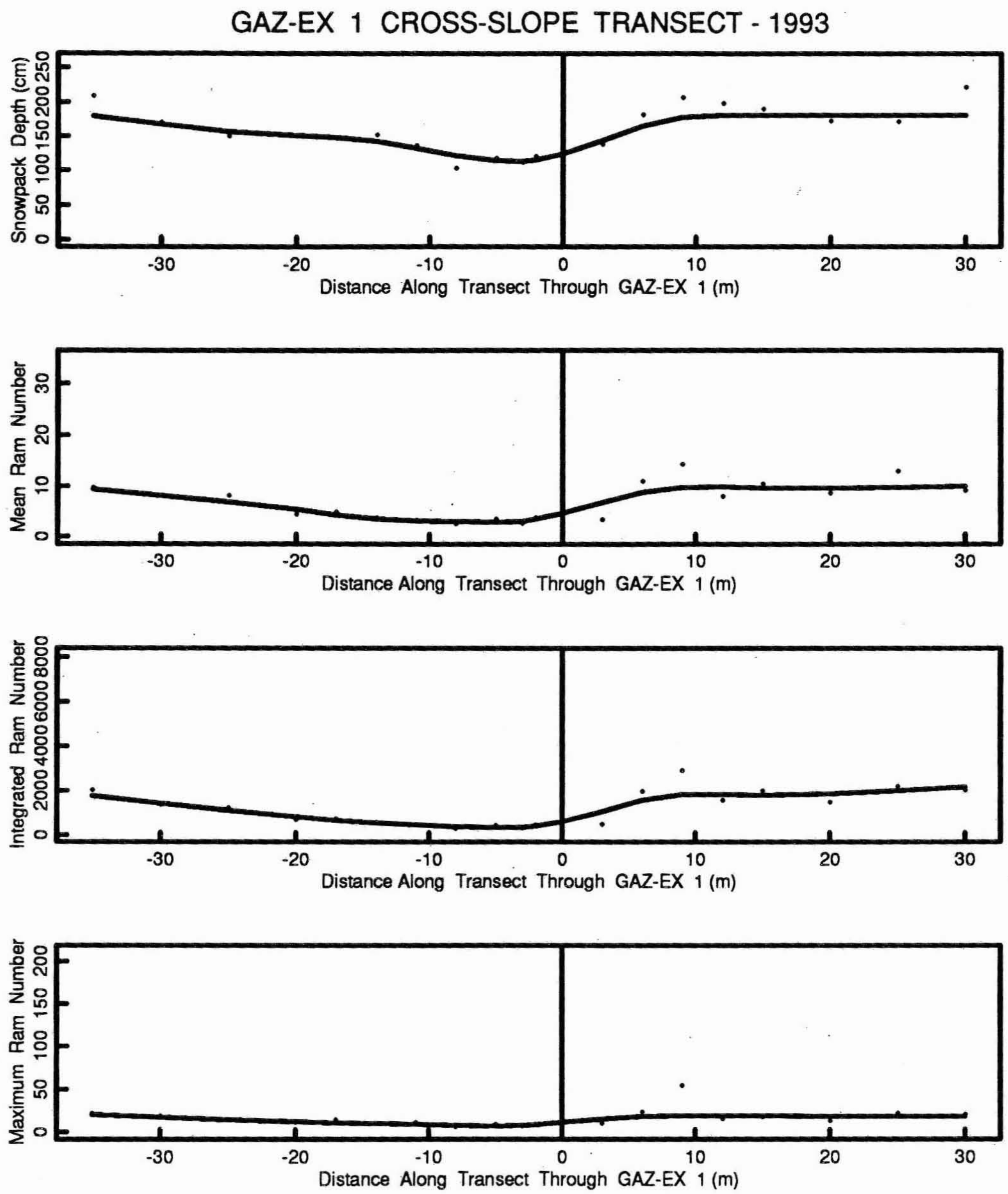

Figure 7. Depth, mean, integrated and maximum ram resistance numbers for the cross-slope transects at GAZ-EX 1 and 4, completed in 1994.