AVALANCHE RELEASE AND SNOW CHARACTERISTICS

**Richard L. Armstrong
and Jack D. Ives, Editors**

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16. ABSTRACT

A methodology for the accurate prediction of snow avalanche occurrence has been developed through investigation of quantitative relationships among terrain, climate, snowcover properties and avalanche formation. An instrumentation network was established to measure air and snowpack temperatures, wind speed and direction, precipitation rate and amount, snow settlement rate, net all-wave radiation, and stratigraphic snow density values. Avalanche events were monitored by direct observation of 214 avalanche paths. Detailed investigations into the physical properties of the snow within the study area were carried out by stratigraphic studies at standard, level snow study sites, test slopes representative of avalanche release zones and actual avalanche fracture lines. Such studies allowed definition of a local snow climate. An "in-house" stability evaluation and avalanche forecast were prepared at daily intervals during three winters. Each forecast was evaluated the following day in terms of actual events subsequent to the initial forecast. A statistical forecast model based on discriminant function analysis of four years of data was developed.

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May 1976

Richard L. Armstrong and Jack D. Ives (Eds.)

San Juan Avalanche Project
Institute of Arctic and Alpine Research
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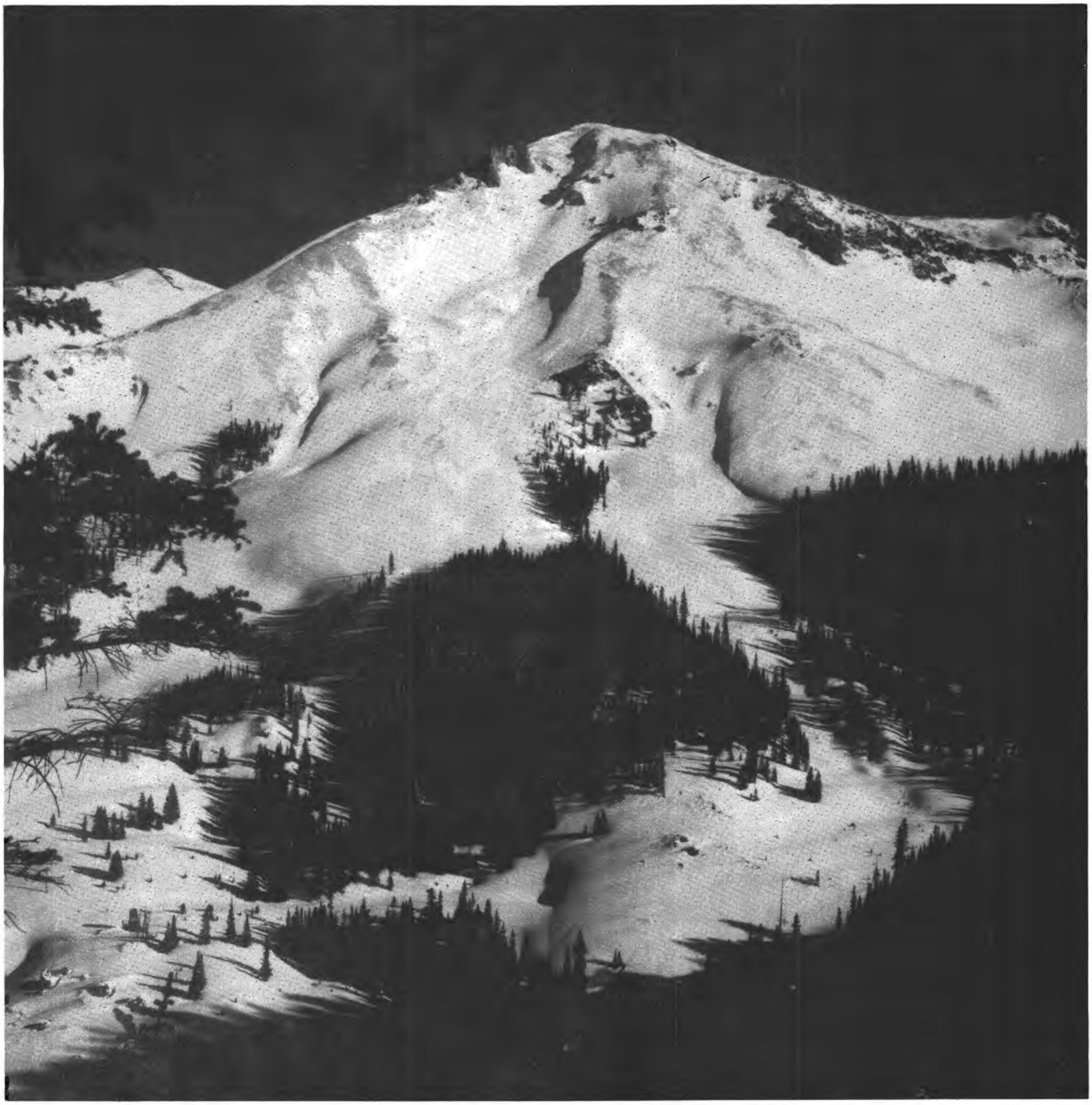

Looking across Red Mountain Pass onto the Red Mountain Group. INSTAAR's 12,325 weather station is situated along the skyline to the right.

PREFACE

This INSTAAR Occasional Paper represents the final report to the Division of Atmospheric Water Resources Management of the Bureau of Reclamation, United States Department of the Interior. An original three-year contract was signed in May 1971 that was subsequently extended to permit data collection during a fourth winter season (1974-75) and to facilitate data analysis and write-up during the current winter (1975-76). The report has also been designated as a contribution to the United States Unesco Man and the Biosphere (MAB) Program, especially since its objectives fall so naturally within the scope of US MAB Directorate 6A: study of the impact of human activities on mountain ecosystems.

During the course of the previous five years, the Silverton avalanche research project, as originally conceived, has evolved extensively and has undergone many changes. Personnel have changed, methods of study have been refined, and some of the original areas of investigation, especially those concerning seismic and infrasonic signals from avalanches, carried out under the direction of J. C. Harrison, were completed earlier. Nevertheless, this report has been prepared so as to ensure that the user has as complete an understanding as possible of the overall avalanche project. This has necessitated some duplication of data presentation and discussion. However, the report is intended to supersede all earlier interim publications and to stand as the final statement on work emanating directly from Bureau of Reclamation Contract No. 14-06-D-7155.

A few words about project organization and personnel should be of assistance to the reader. The initial contract, awarded to INSTAAR, designated Jack D. Ives, J. Christopher Harrison and Donald L. Alford as principal investigators, with Edward R. LaChapelle, Malcolm Mellor (snow mechanics) and Wilford Weeks (statistical analysis) as principal consultants. Christopher Harrison was responsible for the seismic and infrasonic studies. Donald Alford played a vital role in the setting up of the operational framework and by serving as Silverton Field Director during the first winter (1971-72). Subsequently, Richard Armstrong succeeded to the position of Field Director and became a principal investigator, and indeed carried the main burden of the project through to its completion such that he rightly deserves the first author position indicated here. The three consultants proved invaluable throughout and INSTAAR has been highly privileged to have such support. Edward LaChapelle, in particular, has de facto played the role of a principal investigator and, as a Research Associate of INSTAAR, has been a pivotal member of the research team throughout, making readily available his wealth of personal experience in snow and avalanche research.

Second only to the contributions of the principals have been those of the field team. These included Betsy Armstrong, Don Bachman, Juris Krisjansons, Gail Davidson, Bill Isherwood, Fred Johnson, Phillip Laird, Bill McClelland, Len Miller, Rod Newcomb and Imants Virsnieks. All played a vital role, often under exacting physical and mental conditions. It need not be stressed that four full winter seasons between 3,000 and 4,000 meters elevation in avalanche terrain is not entirely devoid of personal risk. That no accident was incurred is a tribute to each individual and to the team as a unit.

Administrative and clerical back-up has also been extensive. Claudia Van Wie acted as scientific assistant for the first three years and helped extensively with editing, preparation of interim reports and statistical analysis in particular, and in all other phases of the project. Her enthusiasm and critical faculty are especially acknowledged. Laura Osborn provided budgetary assistance and Marilyn Joel undertook all the drafting. Ann Stites, as administrative assistant to the INSTAAR Director, helped extensively, including organization of this report. John Clark, INSTAAR climatologist, assisted with the meteorological instrument site selection, calibration and maintenance, and, our remarkably good climatological data collection is largely due to his persistence and dedication.

Michael J. Bovis entered the project in a special capacity and at a relatively late stage, and made a major contribution by breaking through the mass of data and developing the statistical approach to avalanche forecasting. This is reflected in Chapter 5 of this report and Michael's separate publications which constitute a significant advance in the field of avalanche forecasting. In this he was assisted by Nel Caine of the INSTAAR faculty and consultant Wilford Weeks.

Our contacts with and assistance from persons outside of INSTAAR have been extensive. These are acknowledged separately immediately following this preface, although the special supportive role of Olin Foehner, contract monitor, Bureau of Reclamation, must be emphasized above all. The backbone of the project, however, was Richard and Betsy Armstrong and daughter Johanna, who entered this world as an avalanche baby. For some years Betsy and Richard had their second name substituted by "Avalanche" and people in Silverton came to regard them as decidedly odd since they were not like the other visitors to Silverton who came in the summer and departed with the first snows of autumn; they came with the bad weather and stayed through summer also.

Projects of this nature invariably induce scientific excursions in parallel and divergent directions. The intimately related projects include studies of snow temperature-gradient metamorphism, supported by US Army Research Office (Durham), Grant No. DAHCO 4-75-G-0028, assessment of alternate methods for artificial avalanche release, supported by grants from the Highway Departments of the states of Colorado and Washington, and the Federal Department of Transportation (University of Washington Subcontract No. 845043). A special project, funded in part from this project, and in part from NASA Office of University Affairs Grant No. NGL-06-003-200 and San Juan County, resulted in the publication of the San Juan County Avalanche Atlas as INSTAAR Occasional Paper No. 17. Support from the same sources also culminated in the publication of INSTAAR Occasional Paper No. 18 "A Century of Struggle Against Snow: A History of Avalanche Hazard in San Juan County" by Betsy Armstrong. Of major importance has been development of expertise in mapping areas subject to natural hazards in the northern tier of the San Juan Mountain counties as one of the major objectives of NASA Grant No. NGL-06-003-200, applications of space technology to the solution of land-use problems in mountain Colorado. Our thanks go to grant monitor Joseph Vitale for his guidance and extensive encouragement. This made it possible to interchange several key personnel amongst these major research projects. It also facilitated the staging of a very effective avalanche and natural hazards workshop in Silverton in June/July 1975 which included leading participants from Switzerland, Canada and several United States agencies.

It is perhaps fitting to end with the statement that although this report may represent completion of contractual obligations under the original contract, it is intended as a beginning of attempts to widen our understanding of environmental conditions and processes in the San Juan Mountains. This magnificent mountain area with its stalwart people and their attendant problems of natural hazard assessment, resource development and land-use policy requirements, is considered as a superb natural laboratory for the enlargement of an important segment of the United States Man and the Biosphere Program. This should be pursued in three forms: basic research, applied research and in training and education.

Jack D. Ives
Jack D. Ives
Director, INSTAAR and Professor of Geography
Chairman, United States MAB Directorate 6A

27 April 1976

Acknowledgments: to individuals and agencies for assistance and advice in many phases of the research project

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ABSTRACT

This final report covers research conducted by the San Juan Avalanche Project, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado for the period August 1971 to June 1975. The research was supported by Contract No. 14-06-D-7155 with the Division of Atmospheric Water Resources Management, U.S. Bureau of Reclamation, Department of the Interior, and has had as its purpose the study of the nature and causes of snow avalanches within the vicinity of Red Mountain Pass, Molas Pass, and Coal Bank Pass in the San Juan Mountains of southwestern Colorado. The ultimate objective of the project was to develop a methodology to accurately forecast avalanche occurrences through study of the complex relationship which exists among terrain, climate, snow stratigraphy, and avalanche formation. When the project was initiated, only a limited amount of climatological data was available for the study area. Recognizing that an avalanche prediction model relies heavily upon data gathered from highly accurate, reliable instruments installed on carefully selected sites, a network of fixed instrumentation was utilized to measure meteorological parameters, determine physical properties within the snowpack, and detect avalanche events.

The primary snow study site located at Red Mountain Pass (3400 m) included instrumentation to measure air temperature, temperatures within the snowpack, wind speed and direction, precipitation rate and amount, snow settlement rate, and net all-wave radiation at the snow surface. In addition an isotopic profiling snow gauge provided snow density and water equivalent values throughout the snowpack at 1.0 cm intervals. Seismic and infrasonic instrumentation for avalanche event detection was investigated during the first two winters, but neither of these systems proved feasible.

Detailed investigations into the physical properties of the snow within the study area were prompted by the fact that the San Juan Mountains exhibit climatic extremes not found in more northerly latitudes where most practical and scientific knowledge of snow avalanche formation has been accumulated. The combination of high altitude, low latitude and predominately continental climate produces a specific radiation snow climate. Generally, this condition is the result of two factors. First, the extreme nocturnal radiational cooling occurring on all exposures produces snowpack temperature gradients of a magnitude sufficient to cause significant recrystallization or temperature-gradient metamorphism. The second factor is the substantial amount of solar energy available to slopes with a southerly exposure. This daytime condition causes melt at the snow surface and subsequent freeze-thaw crusts. These two situations continue to influence the snowcover throughout the winter. The resulting stratigraphy is highly complex and often unstable.

During the second winter many snow pits were dug to collect data on snow stratigraphy. These snow pits were of three types. One type was located at standard, level snow study sites, while a second was located on test

slopes or avalanche release zones. Special emphasis was given to the third type associated with the actual avalanche fracture lines. The first two types are acquired as a series at fixed sites to determine changes in snow structure with time. During the third and fourth winters, these received the major emphasis with particular attention directed towards the temperature gradient process. Snow temperatures were measured throughout the depth of the snowcover on a daily basis at sites at three different elevations. Periodic snowpits at these sites demonstrated the relationship between the magnitude of the temperature-gradient and the type and extent of subsequent metamorphism.

As a part of the daily operational procedure during the 1972-73, 1973-74, and 1974-75 winters this project produced an "in-house" stability evaluation and avalanche occurrence forecast for the research area. Such forecasts were made for each 24 hour period and at more frequent intervals during storms. Each avalanche occurrence forecast was evaluated the following day in terms of actual conditions and events subsequent to the initial forecast. During the third winter the avalanche forecast procedure was further refined to give forecasts for specific groups of paths, as well as general area forecasts. Methods employed by the field observers to evaluate numerous meteorological and snowcover parameters in order to produce an avalanche forecast were isolated and described. Forecasting accuracies of 81 percent for the general area and 73 percent for specific path groups were achieved. On the completion of the third winter's data collection, work began on the development of a statistical model for the purpose of avalanche prediction.

Following the fourth winter's research, the statistical forecast model was further refined. During this final winter an unusually high level of avalanche activity prevailed, allowing twice the annual average number of avalanche events to be included in the statistical analysis. The stepwise discriminant function program allowed stratification of avalanche and non-avalanche days in terms of antecedent conditions described by ten variables over five, three and two-day periods prior to each avalanche or non-avalanche day. Analysis suggests that the two-day time step is most efficient, thus reducing the amount of computation, with no loss in forecasting precision. A clear difference is found between dry snow and wet snow avalanche conditions. The dry snow avalanche days are most clearly identified by reference to precipitation totals during the few hours prior to avalanche release and by air temperature over varying time periods according to the magnitude of event being considered. The wet snow avalanche days are best related to the mean and maximum two hour air temperatures in the 12 to 24 hour period prior to the avalanche event. While rapid temporary warming may often preceed cycles of small wet loose avalanches, a more prolonged period of warming is required for larger wet avalanche cycles to occur. A measure of the relative distance of a discriminant score from the discriminant index allows a more precise forecast than a simple "yes" or "no". This refinement enables the forecast to be stated in probability terms, an approach not previously attempted in numerical avalanche forecasting.

Evidence suggests that avalanche release within sub-freezing snow layers is primarily dependent on precipitation to trigger unstable layers deep within the snowcover. Delayed-action events are extremely rare. While avalanche frequency and magnitude are influenced by precipitation rates and amounts, they are thus determined primarily by the snow structure which exists within the release zone at the time precipitation-loading occurs. Avalanche magnitude is further affected by mechanical strength of all snow layers in mid-track, for this determines the penetration depth of sliding snow and the ultimate volume of the moving avalanche.

In conclusion, the claim is made that the Silverton Avalanche Research Project has been able to produce for the first time an approach to an operational real-time statistical forecast model. This model which, for major avalanche cycles during the dry and wet snow seasons, has an accuracy of 88% and 82% respectively, is also the first to be applied to groups of starting zones and individual paths, and to predict magnitude of avalanche occurrence.

Richard L. Armstrong and Jack D. Ives (Eds.)
Institute of Arctic and Alpine Research
University of Colorado, Boulder

27 April 1976

CHAPTER 1: INTRODUCTION

Richard L. Armstrong and Jack D. Ives

Objectives of the Study

An investigation into the nature and extent of snow avalanche activity was carried out during four consecutive winters (1971-1975) by the Institute of Arctic and Alpine Research (INSTAAR), University of Colorado. The research was undertaken through contractual arrangements with the Bureau of Reclamation, U.S. Department of the Interior (Contract No. 14-06-D-7155). The initial objective of the research was to identify and catalog those areas of significant avalanche activity within the study area and to acquire an understanding of the nature and type of its snow avalanche releases. The second step was to develop a methodology that would determine the specific causes of local avalanche activity and, finally, a third step was to construct a forecast model for the prediction of avalanche occurrence. This summary report contains a comprehensive analysis of all relevant meteorological, snowcover and avalanche data collected over the past four winters. The most comprehensive previous account, that includes the first serious attempt at statistical forecasting, is contained in Armstrong et al. (1974).

Definition of the Hazard

Information regarding the relationship between augmented winter precipitation and avalanche occurrence, that could in turn create economic and public safety problems, was considered a vital segment in analysis of the United States Bureau of Reclamation Project Skywater winter cloud-seeding experiment. In May of 1971, INSTAAR was awarded a contract to provide this information, with J. D. Ives, J. C. Harrison and D. L. Alford as the original principal investigators. During the period of the INSTAAR study, the Upper Colorado River Basin Pilot Project was involved in winter cloud-seeding experiments in the San Juan Mountains although the original target area was reduced so as not to include the northwestern sections of the mountains wherein practically all permanent human habitations were concentrated. Therefore, research was directed toward study of the relationships among avalanche activity and natural precipitation patterns and other environmental factors in this area. Observations of actual avalanche activity were concentrated within an area immediately adjacent to a 58 km section of U.S. Highway 550 between Coal Bank Hill and the town of Ouray, as well as 14 km of Colorado Highway 110 north of the town of Silverton and the environs of Silverton itself: the major avalanche hazard in San Juan County occurs within this area. While unknown numbers of avalanches occur in the San Juan Mountains each winter, only those that come into contact with man or his property constitute a hazard. One hundred fifty-six avalanche paths directly threaten the above mentioned highways and 13 affect property within the town of Silverton with varying frequency. The sections of highways 550 and 110 and the land immediately adjacent to them that are the objective of this study experience a higher degree of avalanche activity than any other section of highway in the United States (Figure 1). Present-day traffic within and through this area is light, so that the magnitude of the actual avalanche hazard is relatively low, although despite this, four deaths and considerable property damage have been caused by avalanches since 1950. Moreover, it is anticipated that traffic flow will increase in the years ahead. The mining industry, the original economic base of the region, has appreciable potential for growth as world shortages become more acute and prices rise. This must be viewed against the situation prevalent during the mining boom (1875-1918) when 89 avalanche-related deaths and extensive property damage occurred in San Juan County alone (B. Armstrong, 1976a). In addition, the comparatively new phenomenon of rapid acceleration in recreational use of mountain lands, dramatized by the mushroom growth of ski resorts such as Vail and Aspen, is gradually penetrating the San Juan Mountain area (Ives et al., 1976). The downhill ski resort of Purgatory, 20 km south of Coal Bank Hill, has doubled its lift capacity in the last five years while a steady growth is occurring in cross-country skiing, snowmobiling, winter mountaineering and other forms of back-country recreation.

In summary, therefore, avalanche hazard can be defined as the product of density of human usage, size of area affected by avalanche run-out and frequency of avalanche occurrence. The first variable, while highly relevant to determination of the degree of hazard, lies beyond the scope of this investigation. The second and third variables and the factors influencing them become of immediate concern.

Overview of Study Area Physical Geography

The San Juan Mountains are located in the southwestern quadrant of Colorado and their crest-line, forming the Continental Divide, runs in a great backward trending curve from the New Mexico state line turning more westerly to point roughly toward Silverton. Within 15 km of the town the Divide turns abruptly east-northeast for some 30 km and then northerly again. Fourteen peaks exceed 14,000 ft (4308 m) and numerous large rivers have dissected the major mountain mass into subranges and a complex system of ridges and valleys. The major rivers include the Rio Grande and the San Juan with a series of important tributaries including the San Miguel, Dolores, Animas, and Los Pinos. A central core of intrusive granite-gneisses and quartzites form the southern limits of San Juan County, including the Needles and Grenadier ranges. This central core is skirted by great accumulations of volcanic ashes and tuffs, agglomerates, basalts and dolorites, and metamorphosed sediments with subhorizontal stratification. Repeated growth of ice sheets and radiating valley glacier systems characterized the late-Cenozoic period and glacial sculpturing is responsible for much of the more rugged relief and deep, U-shaped valleys typical of the area today. In the immediate study area, this glacial widening and overdeepening has been important in shaping the spectacular East and North Animas Fork valleys and Ironton Park of the upper Uncomphagre drainage that form the main

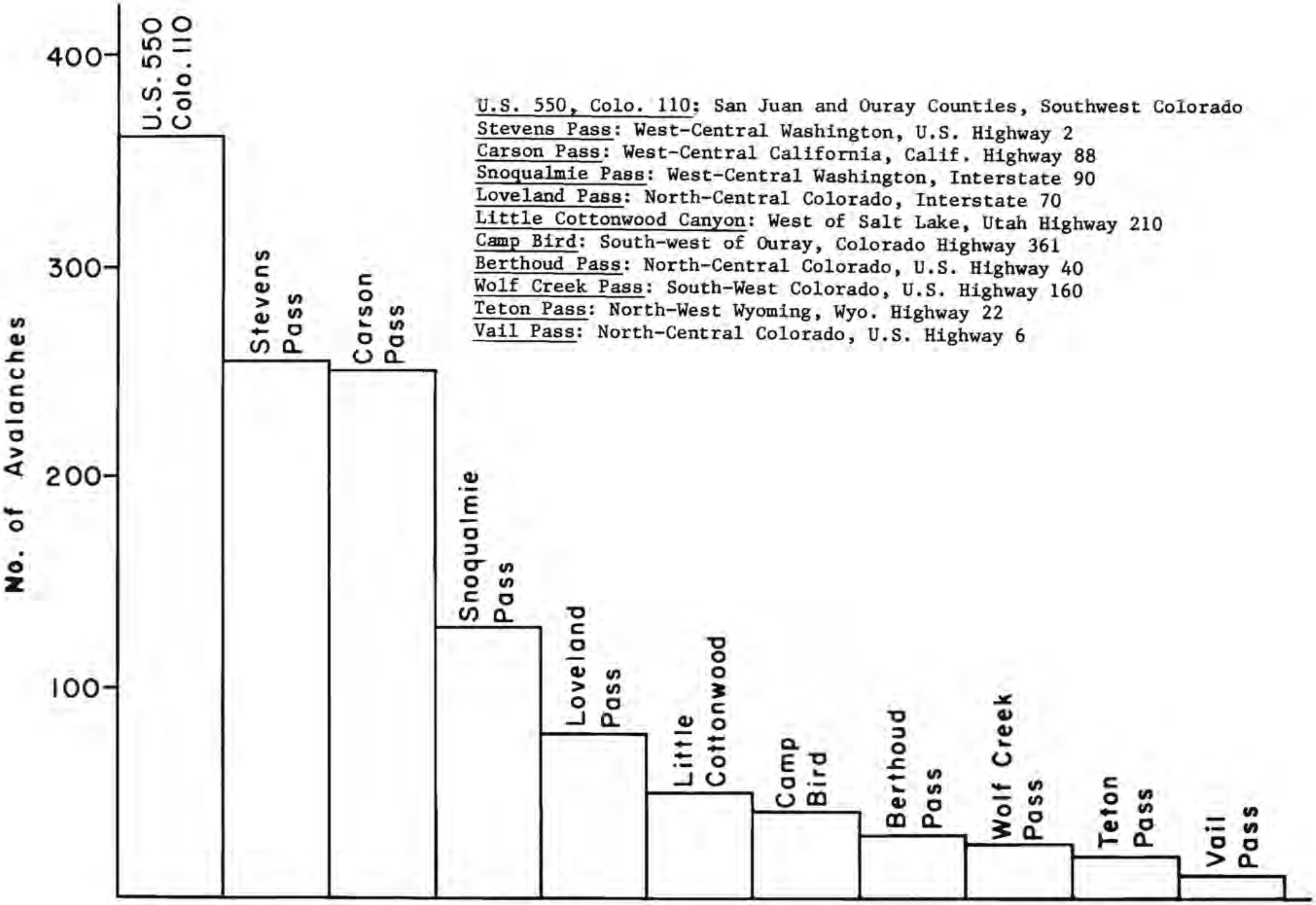

Figure 1. Total number of avalanches crossing major highways at eleven sites in the United States during the four winters 1971-1975. Data provided by U.S. Forest Service, Alpine Snow and Avalanche Project.

communication lines in the two counties of Ouray and San Juan. Local relief frequently exceeds 1300 m and even approaches 2000 m between Ouray and Mount Sneffels. Red Mountain Pass, the key locality for the present study, has an altitude of 3400 m and forms the col between the Animas North Fork above Silverton, and the Uncomphagre River which drains northwards through the Uncomphagre Gorge to Ouray and so on to the Gunnison River.

The treeline ecotone lies at approximately 3600 m with extensive local variation above which the great rolling and only infrequently pinnacled mountain summits rise, carrying cover types that include wet and dry tundra meadows, many small lakes, talus slopes and bare rock. Below timberline the uppermost forest belt includes pine (principally *Pinus flexilis* and *P. contorta*), spruce (mainly *Picea engelmanii*), subalpine fir (*Abies lasiocarpa*) and aspen (*Populus tremuloides*). Lower elevation forests contain Douglas fir, Blue spruce and Ponderosa pine, and finally an oak-piñon pine-juniper shrubland. However, since the study area lies primarily above the 3000 m level, we are only concerned with the uppermost forest belt. The position of treeline is extremely important for the avalanche study. Avalanche starting zones are located primarily above treeline, while the track and run-out zones generally lie below it. Thus the avalanche impact on the vegetation delineates all but the most infrequently active avalanche paths in a most dramatic manner (Figure 2).

The climate of the area is best described as a continental interior montane type with cool, relatively moist summers and cold winters characterized by long dry spells broken by periods with light snowfalls. Spring tends to produce a secondary precipitation maximum to summer while autumn experiences long periods of fine settled weather broken by intensive storms. Severe sustained winter cold waves are rare west of the Continental Divide and stationary high pressure systems frequently control winter weather with warm clear days and cold nights. Precipitation increases and temperature decreases fairly uniformly with elevation. As would be expected in a rugged mountain area, however, the climate is characterized by extreme variability both from place to place during the same season and from year to year. These climatic generalizations contain further limitations: at the beginning of the study period (1971) the only long-term climatological data was derived from the valley floor stations in Silverton, Telluride, Ouray and Durango and no data was available from above treeline. Annual precipitation and temperature patterns are provided for Silverton and Durango (Figures 3 and 4).

A companion study to the avalanche project, Ecological Impacts of Snow Augmentation in the San Juan Mountains, Colorado (Steinhoff and Ives, eds., 1976), contains a detailed analysis of all available historical climatic data (1874-1970) in the San Juan Region (Barry and Bradley, 1976). This historical summary discusses variations in precipitation and temperature over the last one hundred years and contains a wealth of data of importance to avalanche research.

In summary, several broad geographic factors have an important bearing on the characteristics of the snowpack in the San Juan Mountains highly relevant

Figure 2. The Battleship avalanche path has a vertical fall of 2700 ft. (823 m) and starting zones contained within three broad shallow basins. During the study period 36 avalanche events were recorded, 13 of which ran full-track.

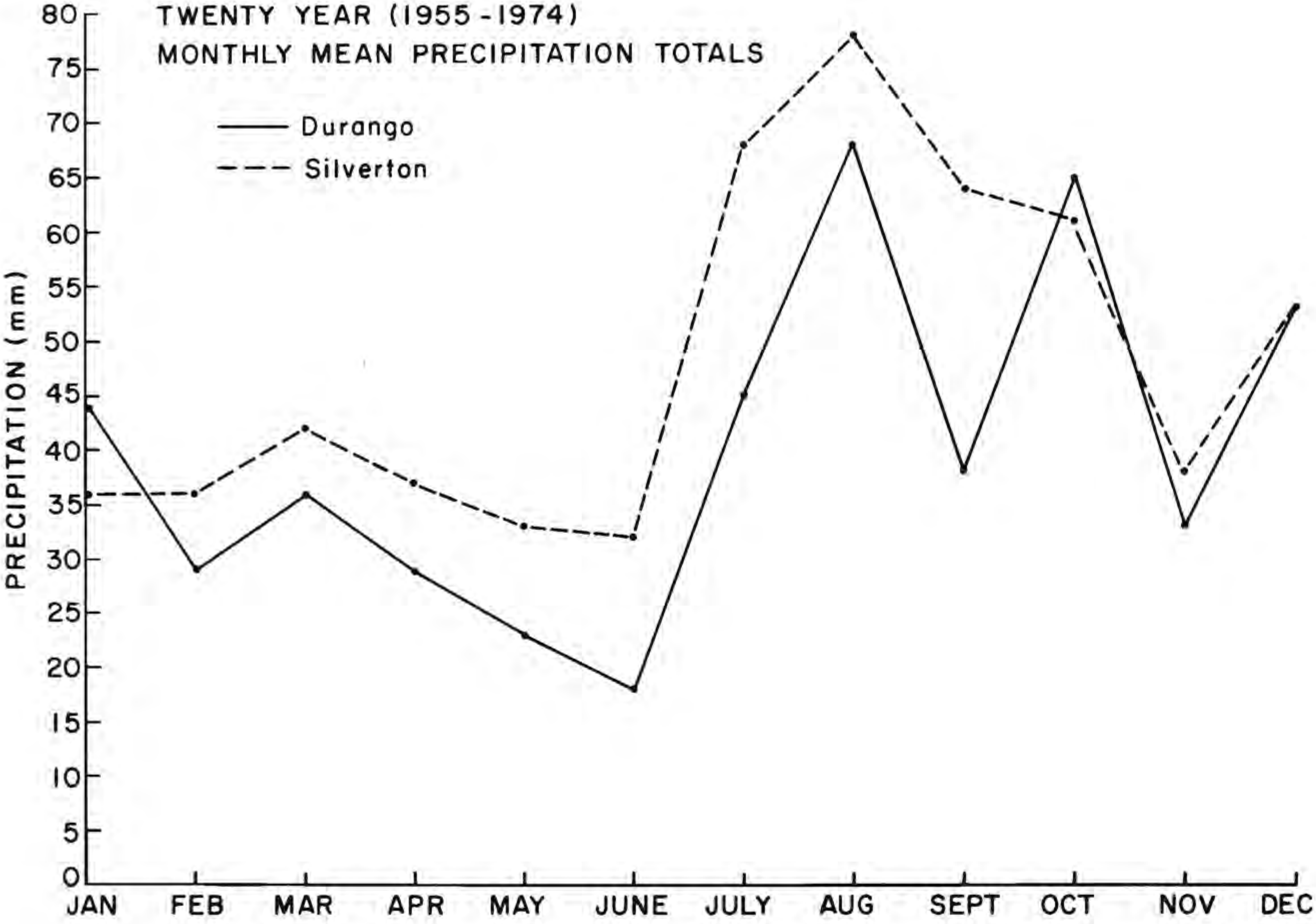

Figure 3. Twenty year monthly mean precipitation totals for Silverton and Durango, Colorado (1955-1974). Durango is located 85 km south of Silverton at an elevation of 2030 m.

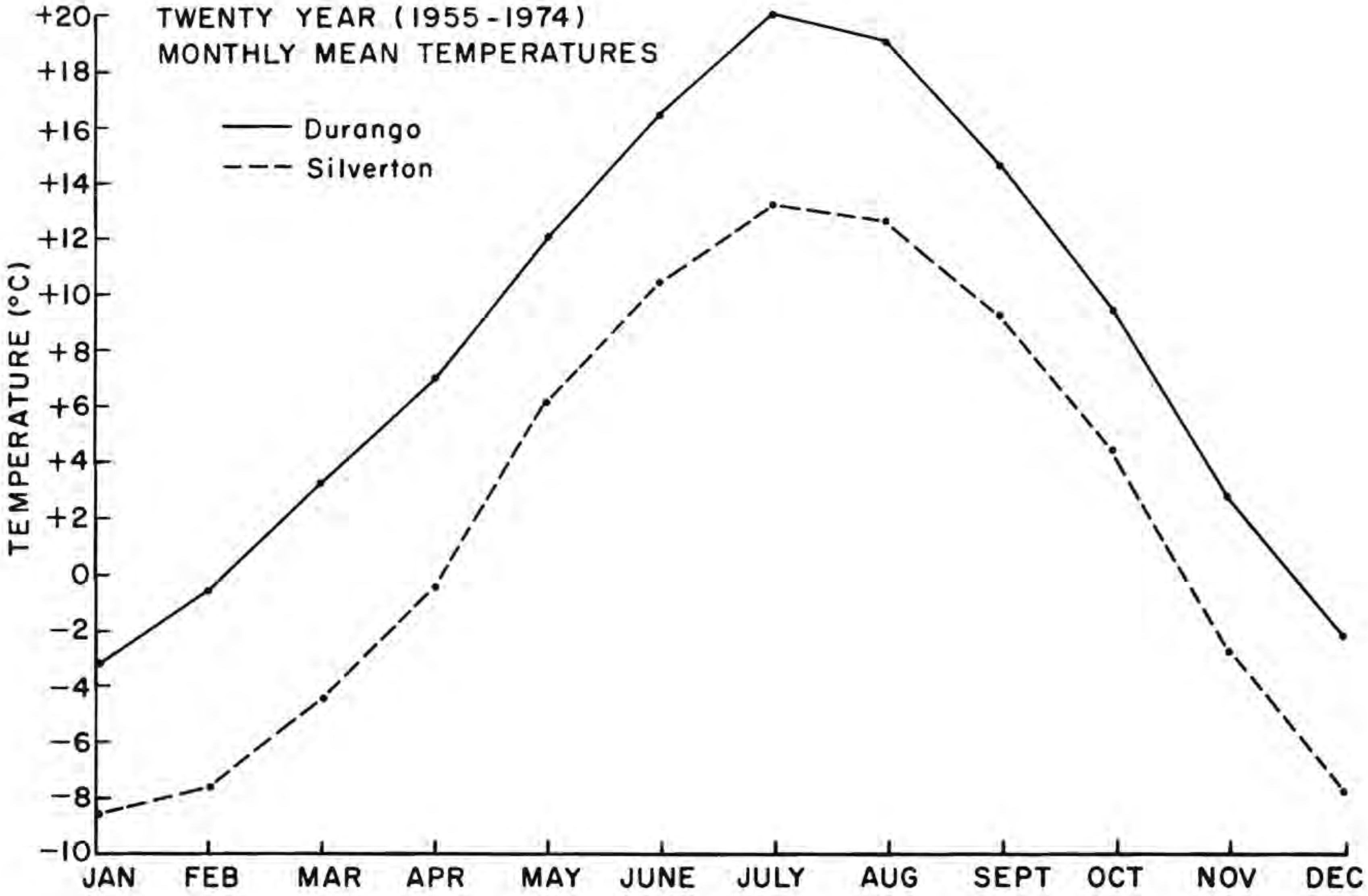

Figure 4. Twenty year montly mean temperatures for Silverton and Durango, Colorado (1955-1974). Durango is located 85 km south of Silverton at an elevation of 2030 m.

to avalanche occurrence. They are: relatively low latitude (37^{o}N), extremely varied relief with long slopes traversed by timberline and with all aspects represented, a continental winter climate with frequent light to moderate snowfalls interspersed with long dry periods, and great annual climatic variability. The early mining activity had an enormous impact on the forest cover and this, together with significant climatic change through time, makes it difficult to determine whether the frequency and magnitude of avalanche events during the recent period for which we have anything approaching consistent records (1950-1975) is representative of a longer period. Any precise determination of the future potential impact of snowpack augmentation through winter cloud-seeding must await resolution of this problem. This adds further justification to our decision to concentrate on studying snow processes directly.

Historical Data

An examination of historical data relating to avalanche activity in San Juan County was undertaken for the period 1875-1975 (B. Armstrong, 1976a) and a similar study is in process for Ouray County (B. Armstrong, 1976b). San Juan County was a booming gold and silver producing area, reaching its peak in population, mineral production and, correspondingly, avalanche deaths and destruction to property during the period 1880 through World War I.

Data were obtained from newspapers of the period and by interviews. Avalanche sites were plotted on USGS 1:24,000 scale maps and tabulations of avalanche frequency were presented, chronologically and by geographic location. A total of 95 avalanche deaths were recorded during the survey period. Of these, 69 percent occurred while the victims were in fixed positions, either in or near a building. The remaining 31 percent of deaths occurred while the victims were traveling in the mountains. One hundred properties were damaged by avalanches; of these, 89 were hit between one and three times and 11 were hit four or more times. The location suffering the most avalanche damage was the Iowa-Tiger Mill in Arastra Gulch, 4.3 km due east of Silverton. During a period of 23 years, it was damaged on eight occasions, being almost totally destroyed twice. Fifteen geographic locations were plotted where deaths and/or burial from avalanches resulted.

The major avalanche disasters occurred during heavy storm periods, March, 1884, and March, 1906. During the storm of March, 1906, 12 men were killed in the Shenandoah Mine boarding house above Cunningham Gulch, 7.0 km southeast of Silverton, and six deaths were recorded elsewhere during the storm period. However, avalanche deaths and destruction also occurred during periods of light snowfall or none at all. After the storm of February, 1891, when only 6 inches of new snow fell, one avalanche death was reported and three men were caught but escaped injury. The snowpack was reported to be "all granulated", most likely an example of the temperature-gradient snow described later in this report.

The avalanche hazard during this historical period was widespread and not concentrated in any particular area primarily because the mining operations were scattered throughout the county with diverse traffic routes. In contrast, the present-day communication pattern is almost entirely restricted to Highways 550 and 110, Silverton itself and a few large individual mines. The historical data is important because it gives us a measure of the past magnitude of avalanche hazard. It also shows the early growth in awareness of the avalanche hazard. In 1906, through an editorial in The Silverton Standard newspaper, there was an urgent call for State assistance in the establishment of an avalanche hazard zoning plan together with appointment of an authorized state officer to carry it out.

> The Standard has a suggestion to offer which it believes will be of great practical good to every mining camp in Colorado. . . Briefly, it is to have a state law enacted by which mining counties may appoint inspectors, or a commission, clothed with the power of protecting, as far as possible, lives and property from snowslides. . . Upon such a commission should the power be bestowed to decide whether sites for such buildings are safe or unsafe, and their licenses issued accordingly. . .
>
> (Silverton Standard, April 7, 1906)

Decline in mining activity after World War I, however, resulted in the reduction in the magnitude of the hazard and a corresponding loss of interest, or awareness. This situation has only changed significantly within the last decade and the need for avalanche hazard zoning laws is once more an important local and state-wide political issue.

The more recent avalanche occurrence data became available through the Colorado Department of Highways and records of avalanches which affect local highways are available for the period beginning 1951. More detailed information became available when the United States Forest Service Alpine Snow and Avalanche Project began data collection in this area in 1967. Finally, with the start of this project in 1971, the first complete data collection system was initiated thus creating the opportunity for development of a forecast methodology.

Research Methodology

In order to better understand the nature and causes of avalanches and to ultimately predict their occurrence within the study area, the following procedure was undertaken.

Collection of historical data: The collection of historical data on past avalanche activity summarized above was undertaken by the INSTAAR project and the findings are published in separate reports (B. Armstrong, 1976a and b). The information provided by this investigation of the magnitude and frequency of avalanches within the study area, over a time period much greater than that allowed for the current project, proved to be extremely valuable. However, the primary hazard relating to travel and fixed structures was located according to the demographic pattern of the period (1874-1938) and many of the sites are currently uninhabited and the travel routes used only infrequently in winter.

Identification of avalanche areas: The identification of pertinent avalanche-prone areas by field survey began immediately with initiation of the project. All avalanche paths which directly affected Highways 550, 110 or the town of Silverton, as well as those that could be easily observed while monitoring the primary group of paths were cataloged. The total number of paths involved in the initial study was 214. Each path was identified by a name and number and was delineated on low level, oblique air photographs as well as on USGS 1:24,000 scale topographic maps. Basic information regarding the distribution of avalanche release zone altitude, orientation, slope angle and terrain and vegetation features was compiled. Such comprehensive information for the release zone, track and run-out zone, as well as an historical record of occurrence for each avalanche path monitored within San Juan County is contained in a separate publication (Miller, Armstrong and Armstrong, 1976). An example of this material is found in Appendix 3. Most of the large avalanche paths originate above timberline (around 3500-3700 m) on slopes consisting of bare earth, bedrock outcrops or alpine tundra. Well developed trim-lines in conifer and aspen forests are characteristic of mid-track and runout zones for many of these paths. Release zone aspects for the research area are well-distributed around the compass with clear frequency maxima at 120° and 290° T (Figures 5 and 6).

Collection of climatic records: The compilation of local climate records was a brief step because, as is often the case in mountain environments, good climatic data were scarce. As previously noted, the only available data were from valley floor stations. Extrapolation of these data to the altitudes of the avalanche starting zones is a questionable practice. Temperatures cannot be extrapolated in terms of a linear lapse rate because of the strong night and early morning temperature inversions present on the valley floors during much of the winter. Such inversions usually disperse during the day causing valley floor sites to exhibit higher maximum as well as lower minimum temperatures compared to valley wall or ridge top sites. Extrapolation of wind or precipitation data to higher elevations is made difficult by the steering and orographic effect of the local mountain system.

Collection of current snow, weather and avalanche data: The adequate collection of snow, weather and avalanche information depends on data gathered from accurate, reliable instruments installed at carefully selected sites. In addition to remote sensing apparatus, accurate detailed observations by competent, properly trained field personnel on a daily basis and maintained at a high standard of reliability and consistency are essential. In most cases, such observations are the only source of technically adequate data for forecasting and analysis. Accessible observation sites representative of avalanche release zones must be sought, together with ridge-top sites for wind records.

Three primary instrument sites were selected in proximity of Highway 550 (Figure 7). The Molas site is located 271 m east of the highway at an elevation oi 3225 m, 9.6 km south of Silverton and 1.9 km north of Molas Divide. It sits on the level remnant of a lake bed in a large clearing surrounded by scattered forest. The Silverton site is at an elevation of 2830 m adjacent to the INSTAAR project headquarters at 824 Greene Street. The location of

Figure 5

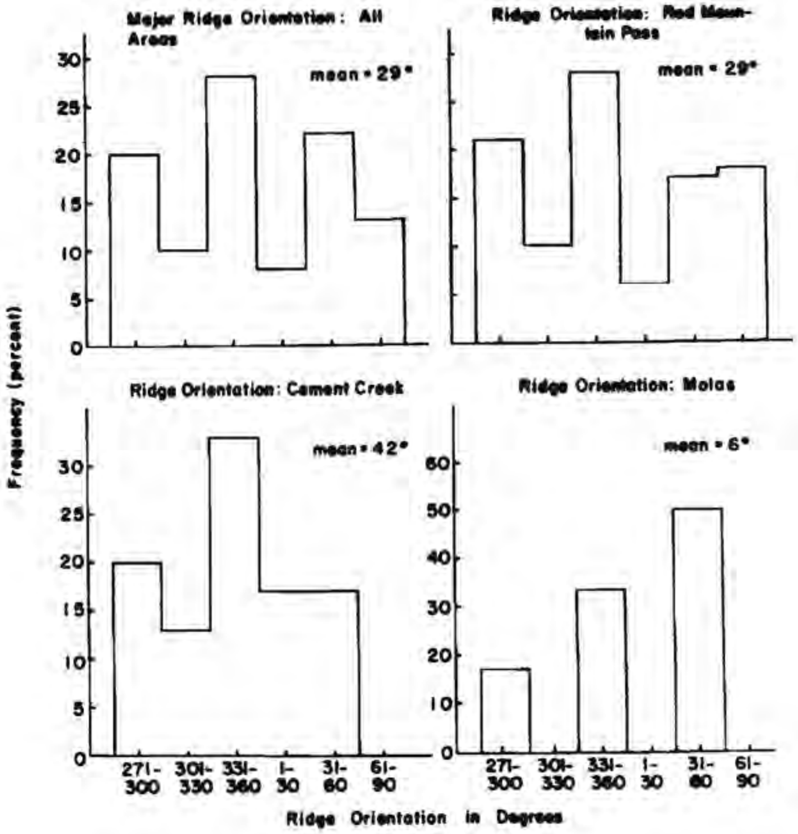

Figure 6

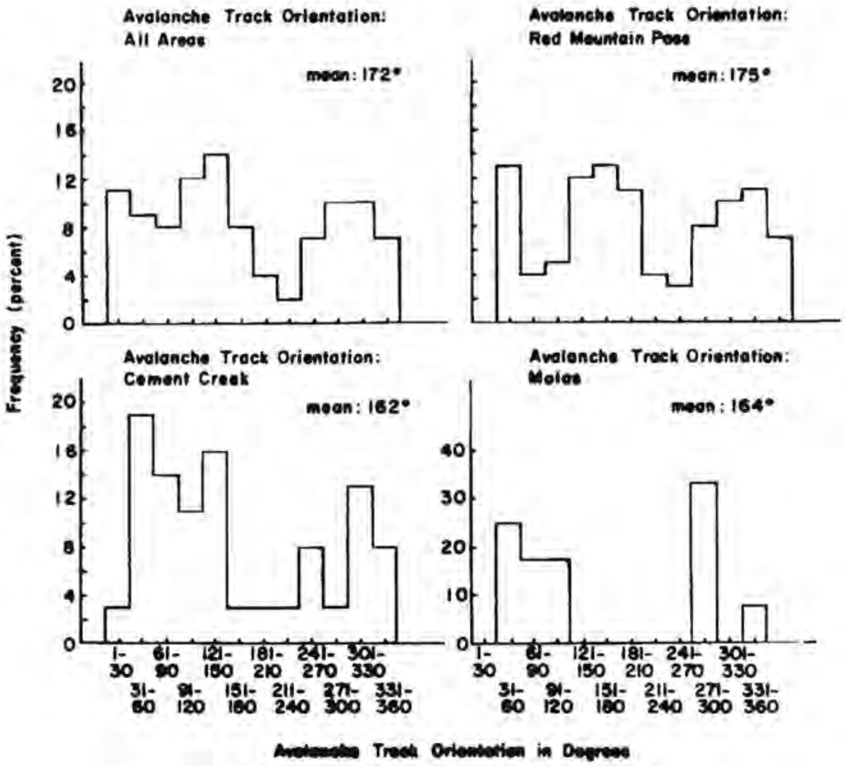

Figure 5. Histograms showing the orientation of the major ridge system for: a. the entire study area, b. the Red Mountain Pass portion of Highway 550, c. the Cement Creek road, and d. the Coal Bank Hill-Molas Pass portion of Highway 550. The ridge orientations have been calculated for 20 degree class intervals, and were measured toward the northern hemisphere (after Smith, unpublished manuscript, 1971).

Figure 6. Histograms showing the orientation of the upper portion of the avalanche tracks for: a. the entire study area, b. the Red Mountain Pass portion of Highway 550, c. the Cement Creek Road, and d. for the Coal Bank Hill-Molas Pass portion of Highway 550. The avalanche track orientations have been calculated for 20 degree class intervals (after Smith, unpublished manuscript, 1971).

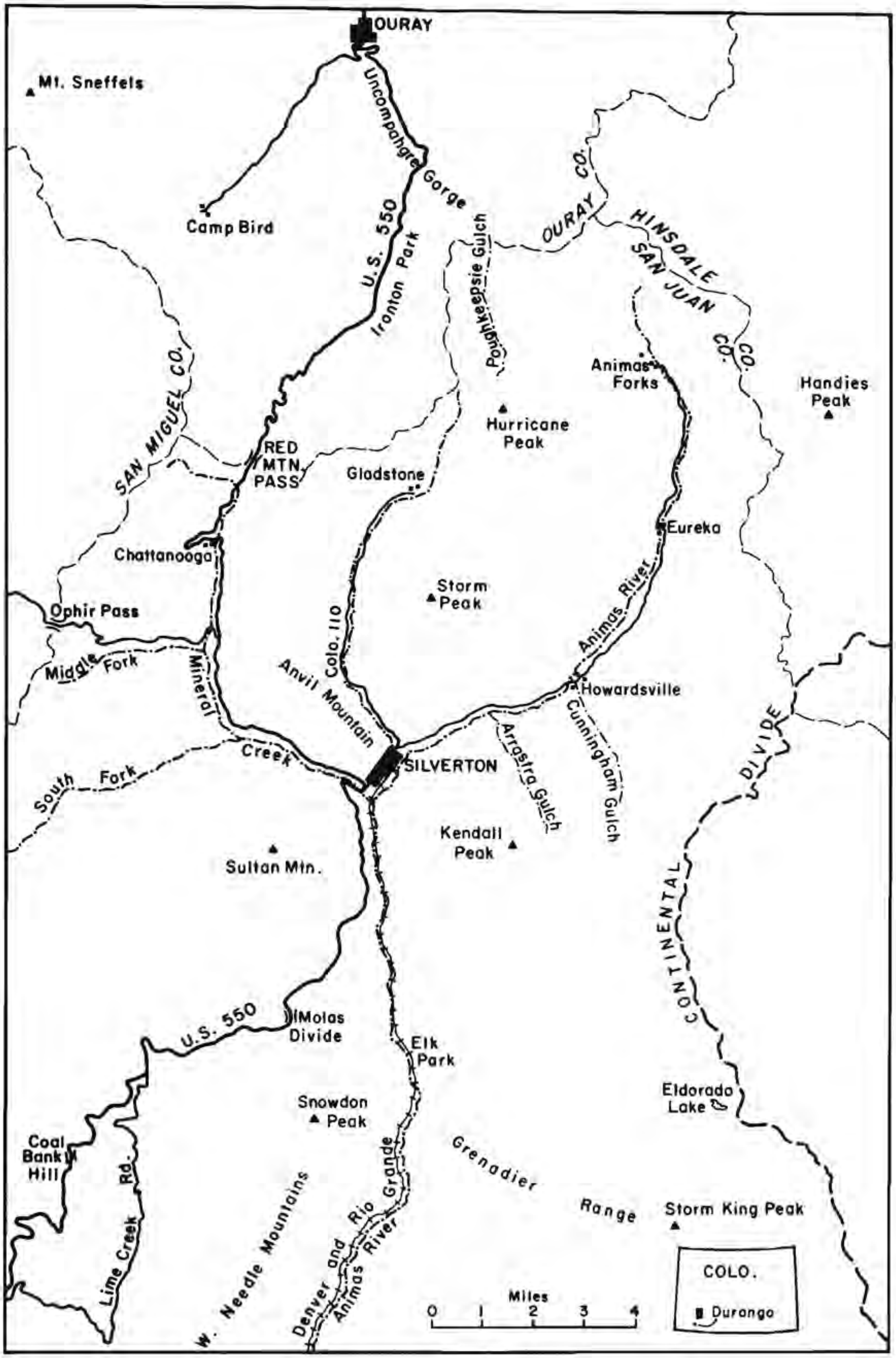

Figure 7. Location map of San Juan County, Colorado, 1975.

the town is in a high park surrounded by mountain peaks of 3660 m to 3965 m elevation. The observation program has been centered at the Red Mountain Pass Site (Figure 8) which is located at 3400 m, 0.8 km south of the Pass and 275 m east of the highway. It is reached by skis or oversnow vehicle from the top of the Pass. The study site is in a clearing in medium heavy forest. The Red Mountain Pass site incorporates areas of undisturbed snow extensive enough to serve in snow morphology studies involving continuing pit analyses.

Wind measuring sites are grouped in the general vicinity of Red Mountain Pass: (1) the Rainbow site is located 387 m above the highway, 3600 m south of the Red Mountain Pass snow study site at an elevation of 3490 m. The location is on an open site directly above the starting zones of several medium-sized avalanches (Brooklyns) that frequently cross the highway below; (2) the Carbon site is 450 m east of the Red Mountain Pass snow study site at an elevation of 3587 m in a clearing surrounded by scattered forest; and (3) the Pt. 12,325 site is on an exposed ridge, well above timberline on the northwest shoulder of McMillan Peak at an elevation of 3759 m. It is 1525 m east southeast of the Red Mountain Pass snow study site.

Table 1 contains a listing of meteorological parameters collected at the various stations. Table 2 contains the dates for which these data were collected. Daily road patrols provided continuous avalanche occurrence observations which were augmented by observations from the various meteorological sites and the town of Silverton. Electronic trip-wires were also utilized in conjunction with certain active avalanche paths in order to obtain more accurate occurrence times.

<u>Observation of internal snowpack evolution</u>: These observations take place both as a series of snow pit studies at fixed observation sites to determine changes in the snowpack (time profile), and as single observations at widely dispersed sites (release zone and fracture-line profiles). The essential observations are those of density, temperature, crystal types, stratigraphy and strength properties as a function of snow depth. In addition to the continuous stratigraphic studies at fixed sites, that were level and well sheltered from strong winds and accessible under almost all weather conditions, work was carried out on test slopes or avalanche release zones that possess an elevation and a slope angle and orientation comparable to actual avalanche paths but were relatively free of hazard to the observer. The fracture-line profile is associated with the actual avalanche release, whether natural or artificial. This type of investigation provides data with the closest approximation to the idealized research objective, that of relating internal structural changes of the snowpack to avalanche release mechanisms.

The San Juan snowpack observations were centered at the Red Mountain Pass site, with subsidiary time profiles taken from lower altitudes. During three winters, time profiles were also collected from north, south and west aspects of release zones on Carbon Mountain near Red Mountain Pass. A total of 103 snowpack profiles, 53 fracture-line profiles and 104 release zone profiles were collected over a wide range of altitudes and aspects. On the basis of these observations plus the recorded weather, snow and avalanche data, a

Figure 8. Part of the snow study plot at Red Mountain Pass. From right to left instrumentation includes: recording precipitation gauge with Alter shield; standard meteorological screen; "zig-zag" isotopic snow profiler (immediately behind screen); snow settlement gauge; isotopic snow profiler (4 upright posts and connecting limbs); fixed thermocouple array. The three snow boards, master stake and data read-out shack are off the picture to right.

TABLE 1. METEOROLOGICAL INSTRUMENTATION NETWORK AND DATA REDUCTION PROCEDURE

STATION	ELEVATION (m)	INSTRUMENT	PARAMETER	DATA REDUCTION		
				reduced data available	time interval	increment of measurement
Pt.12,325	3759	thermograph	temperature (°C)	monthly	daily max, min mean	0.5°C
		wind system	wind speed (m/sec)	weekly	hourly	0.5 m/sec
			wind dir. (degrees)	weekly	hourly	nearest 10°
Carbon	3587	wind system	wind speed (m/sec)	monthly	2 hr means	0.5 m/sec
			wind dir. (degrees)	monthly	2 hr means	nearest 20°
Red Mountain Pass snow study site	3400	recording precipitation gauge	snow-water equivalent (mm)	weekly	2 hr increments	0.5mm
		hygrothermograph	air temperature (°C)	weekly	2 hr	0.5°C
			relative humidity (%)	not reduced		
		thermocouple	snow temperature (°C)	daily	daily at intervals of 10.0cm	0.5°C
		isotopic profiler	snowpack density (g/cm^3 or Mg/m^3)	daily	daily at intervals of 1.0 cm	$0.005\ Mg/m^3$
			snowpack water equivalent (mm)	daily	daily at intervals of 1.0 cm	1.0 mm
		net radiometer	net all-wave radiation (cal/cm^2)	weekly	daily net value	$0.05\ cal/cm^2$
		settlement gauge	snow settlement (cm)	daily	daily	0.25cm
		master snow stake	total snow depth (cm)	daily	daily	1.0cm

		24 hr snow board	24 hr new snow depth(cm) 24 hr new snow density (Mg/m^3)	daily daily	daily daily	0.5cm 0.005 g/cm^3
		interval snow board	3 hr interval new snow depth (cm) 3 hr interval new snow density (Mg/m^3)	3 hr 3 hr	3 hr 3 hr	0.5cm 0.005 Mg/m^3
Rainbow	3490	recording precipitation gauge	snow-water equivalent (mm)	weekly	2 hr increments	0.5mm
		hygrothermograph	air temperature (°C) relative humidity (%)	monthly not reduced	daily mean	0.5°C
		wind system	wind speed (m/sec) wind dir. (degrees)	monthly monthly	2 hr mean 2 hr mean	0.5 m/sec nearest 20°
Silverton	2830	hygrothermograph	air temperature (°C) relative humidity (%)	weekly not reduced	2 hr	0.5°C
		recording precipitation gauge	snow-water equivalent (mm)	weekly	2 hr increments	0.5mm
		microbarograph	air pressure (mb)	not reduced		
		master snow stake	total snowfall (cm)	daily	daily	1.0cm
		24 hr snow board	24 hr new snow depth(cm) 24 hr new snow density (Mg/m^3)	daily daily	daily daily	0.5cm 0.005 Mg/m^3
Molas	3225	hygrothermograph	air temperature (°C) relative humidity (%)	weekly	2 hr	0.5°C
		master snow stake	total snowfall (cm)	weekly	weekly	1.0cm
		24 hr snow board	24 hr new snow depth(cm) 24 hr new snow density (Mg/m^3)	daily daily	daily daily	0.5cm 0.005 Mg/m^3

TABLE 2

1971-1975 INSTRUMENTATION NETWORK

Winter 1971-1972

Site		
Pt. 12,325		
	wind system	Nov.-April
	thermograph	annual
Carbon		
	wind system	Oct.-March
RMPsss		
	precipitation gauge	Nov.-April
	hygrothermograph	Nov.-April
	thermisters-snow temp.	Nov.-March
	isotopic profiler	Dec.-April
	settlement gauge	Feb.-April
	master snow stake	Nov.-March
	24 hour snow board	Nov.-March
	storm board	Nov.-March
	interval snow board	Nov.-March
Rainbow		
	wind system	Oct.-March
	hygrothermograph	Oct.-March
Silverton		
	hygrothermograph	Oct.-April
	precipitation gauge	Oct.-April
	microbaragraph	Aug.-May
	master snow stake	Nov.-March
	24 hour snow board	Nov.-March
Molas		
	hygrothermograph	Nov.-April
	master snow stake	Nov.-March
	24 hour snow board	Nov.-March

Winter 1972-1973

Pt. 12,325		
	wind system	Nov.-May
	thermograph	annual
Carbon		
	wind system	Oct.-April

	Site	
RMPsss		
	precipitation gauge	Oct.-May
	hygrothermograph	Nov.-May
	thermisters-snow temp.	Feb.-May
	isotopic profiler	Nov.-May
	net radiometer	Feb.-June
	settlement gauge	Jan.-April
	master snow stake	Oct.-May
	24 hour snow board	Oct.-May
	storm board	Oct.-May
	interval snow board	Oct.-May
Rainbow		
	wind system	Oct.-March
	hygrothermograph	Nov.-May
	precipitation gauge	Nov.-May
Silverton		
	hygrothermograph	Nov.-May
	precipitation gauge	Nov.-May
	microbaragraph	Nov.-May
	master snow stake	Nov.-May
	24 hour snow board	Nov.-May
Molas		
	hygrothermograph	Nov.-May
	master snow stake	Nov.-April
	24 hour snow board	Nov.-April

Winter 1973-1974

Pt. 12,325		
	wind system	Nov.-April
	thermograph	annual
Carbon		
	wind system	Nov.-Feb.
RMPsss		
	precipitation gauge	Nov.-April
	hygrothermograph	Nov.-April
	thermocouple array	Nov.-April
	snow surface temperature	Nov.-April
	isotopic profiler	Nov.-April
	net radiometer	Mar.-May
	settlement gauges	Dec.-April
	RSG Isotopic total water gauge	Nov.-April
	master snow stake	Nov.-May
	24 hour snow board	Nov.-May
	storm board	Nov.-May
	interval snow board	Nov.-May

Site		
Rainbow		
	wind system	Nov.-March
	hygrothermograph	Nov.-May
	precipitation gauge	Nov.-May
Chattanooga		
	hygrothermograph	Dec.-April
	master snow stake	Dec.-April
	24 hour snow board	Dec.-April
	thermocouple array	Nov.-March
Silverton		
	hygrothermograph	Nov.-April
	precipitation gauge	Nov.-April
	microbaragraph	Nov.-April
	master snow stake	Nov.-April
	thermocouple array	Nov.-March
	24 hour snow board	Nov.-April
	Winter 1974-1975	
Pt. 12,325		
	wind system	Nov.-April
	thermograph	annual
RMPsss		
	precipitation gauge	Oct.-May
	hygrothermograph	Oct.-May
	thermocouple array	Oct.-May
	snow surface temperature	Oct.-May
	isotopic profiler	Oct.-June
	net radiometer	April-June
	settlement gauges	Nov.-June
	RSG Isotopic Total Water Gauge	Oct.-June
	24 hour snow board	Oct.-May
	storm board	Oct.-May
	interval board	Oct.-May
Rainbow		
	wind system	Nov.-March
	precipitation gauge	Nov.-March
Chattanooga		
	hygrothermograph	Oct.-May
	master snow stake	Nov.-May
	24 hour snow board	Nov.-May
	thermocouple array	Nov.-April
Silverton		
	hygrothermograph	Oct.-May
	precipitation gauge	Oct.-May
	microbaragraph	Oct.-May
	master snow stake	Nov.-May

radiation snow climate was identified in the San Juan Mountains (LaChapelle, in Ives et al., 1973 and Chapter 2 of this report). The winter snowpack in this area is characterized by relatively light snowfalls, very wide diurnal swings in snow surface temperature related to intense daytime insolation and nocturnal radiation cooling at this latitude and altitude, extensive temperature-gradient metamorphism typically involving some 70 percent or more of the snowcover, and a highly differentiated stratigraphy with very low mechanical strength on all slope exposures. Over 80 percent of the observed fracture-line profiles exhibited a climax avalanche structure wherein slab failure took place in older snow layers deposited and metamorphosed prior to the triggering precipitation event.

Establish a program of operational avalanche forecasting: The above five sections provide an outline of the preliminary observational and data analysis steps required before the primary objective of development of an avalanche forecasting system can be approached. The primary test of understanding weather, snow and avalanche conditions in a given area is the ability to evaluate current slope stability and, given adequate weather forecasts, predict possible avalanche occurrences. It was not possible to develop any type of forecast model based on statistical correlations between historic climatological data and avalanche occurrences due to the lack of appropriate meteorological data as mentioned above. The recently available record of avalanche activity within the study area was intermittent and contained only those events that interfered significantly with highway traffic.

Conventional avalanche forecasting techniques have been applied on a formal basis as part of the San Juan Avalanche Project (LaChapelle, in Armstrong et al., 1974). A systematic evaluation procedure has shown that daily forecasts for the entire winter averaged 81 percent accurate and were 89 percent accurate for severe hazard conditions. Conventional techniques for area forecasts were also extended to the much more difficult task of forecasting occurrence time and magnitude for the specific avalanche paths that most actively affected Highway 550. An overall accuracy of 73 percent was achieved for this pioneering effort. Analysis of the conventional forecasting technique is contained in Chapter 3 of this report.

Utilization of accumulated data and experience to develop a numerical avalanche forecasting scheme: For regional forecasting where a large data base can be established, statistical analysis of the relationship between contributory factors and avalanche occurrence becomes feasible. This can provide an objective basis for developing improved avalanche forecasts, although the complexity of the avalanche phenomena and the imperfect state of knowledge about it probably precludes an exclusively numerical forecast, especially for small areas or individual avalanche paths. In order to acquire the highest level of accuracy with a numerical method, it is likely that an essential ingredient may continue to be the subjective input of a trained field observer, well versed in the general concepts of the physical and mechanical properties of snow, and especially as to how these properties are influenced by the local snow climate. This implies the need for training and support of highly skilled forecasters with extensive local knowledge.

Other than those associated with the relatively limited geographic confines of a downhill ski area, persons possessing such qualifications in the United States, or anywhere else in mountainous areas throughout the world, are extremely limited. It could be said that there are currently no more than 10 or 20 persons in the United States who would possess a high degree of expertise in the area of avalanche occurrence forecasting.

Accumulated meteorological and avalanche data for the winters 1972-1973, 1973-1974, and 1974-1975 in the San Juan research area have been subject to discriminant function analysis (Bovis, 1976; and Chapter 5 of this report). The stratification of avalanche versus non-avalanche days has been examined in the light of 13 different meteorological variables considered over varying lengths of time prior to each test date. A clear difference is found between wet snow and dry snow avalanche conditions. The dry snow avalanche days are most clearly identified by reference to precipitation and six-hour wind averages during the 24 hours prior to the avalanche event. The wet snow avalanche days are best related to the mean and maximum two-hour air temperatures in the 12 to 24-hour period prior to the avalanche event. Forecasting by discriminant function analysis appears feasible in the San Juan Mountains and the accuracy can be improved as an extended body of data becomes available.

Other related research undertakings: The very presence of an avalanche research team based in Silverton during four winters led to development of other related research activities for which funding was obtained beyond the limits of this Bureau of Reclamation contract. This included: (1) a detailed evaluation of snow stratigraphy with emphasis on the recrystallization process associated with temperature-gradient metamorphism (supported by United States Army Research Office-Durham Grant No. DAHC04-75-G-0028 1974-76). Specific temperature and vapor pressure gradients required to cause recrystallization within various snow types over varying time periods are being studied (LaChapelle and Armstrong, in preparation); (2) development of methods alternate to conventional explosives for the purpose of artificial avalanche release. Some of the methods currently being tested include the inflation of air bags to dislodge cornices, pneumatic vibratory devices and various oxygen-acetylene gas-fired exploder systems to cause snow failure within the starting zones. All systems are designed to be activated remotely. This work is being performed under contract to the Colorado State Highways Department and the Washington State Highways Department (LaChapelle et al., 1975); (3) mapping of areas county-wide subject to avalanche and other geophysical, or natural hazards, such as landslides, rockfall, debris flows, etc., supported by a grant from the National Aeronautics and Space Administration Office of University Affairs and performed in conjunction with county response to Colorado State House Bill 1041 (NASA-PY Grant No. NGL-06-003-200).

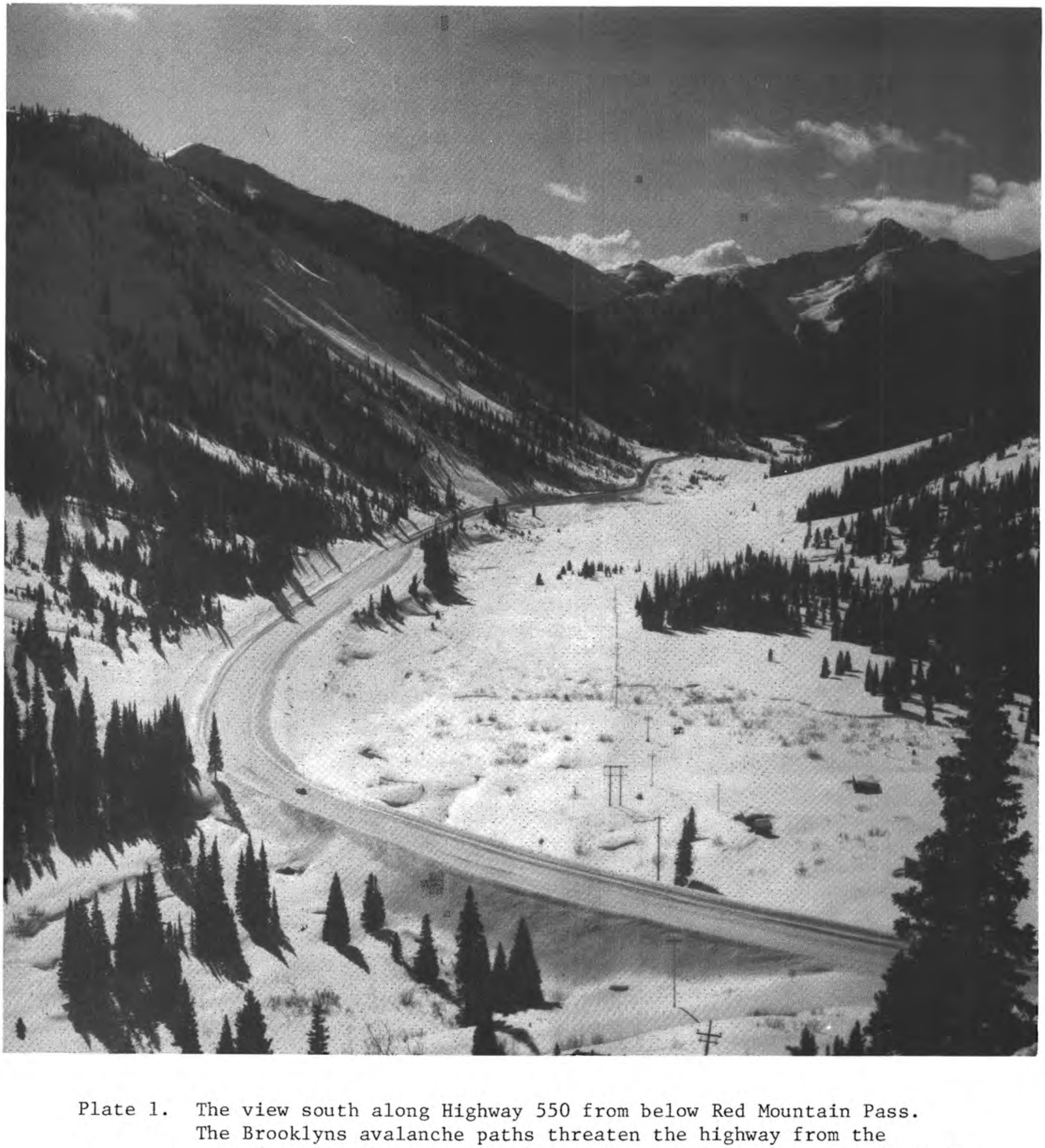

Plate 1. The view south along Highway 550 from below Red Mountain Pass. The Brooklyns avalanche paths threaten the highway from the east (left). From the opposite side several major paths, including Imogene, Bismark, and Battleship, cross the highway and damage timber on the reverse slope when they run full-track.

Plate 2. In contrast to the major avalanche paths, the linear vegetation shown here indicated repeated small scale wet snow avalanche activity. The derelict North Star Mill buildings in the center ground were not damaged by avalanche activity.

Plate 3. An entirely different avalanche setting. Wind-loading amongst broken topography on Molas Pass sets the stage for many small scale responses. While the avalanche debris shown here is insignificant in terms of highway communications, it is enough to endanger an unwary ski tourist.

CHAPTER 2: NATURE AND CAUSES OF AVALANCHES IN THE SAN JUAN MOUNTAINS

Edward LaChapelle and Richard L. Armstrong

General Characteristics of Snow Structure and Slab Avalanche Formation

As new snow accumulates on the ground, a complex matrix develops composed of a delicate cellular material, only 5-10 percent of which is ice grains, the remainder being vacant pore space. Upon initial observation, the stratigraphy may appear homogeneous but even at this stage a distinct layered structure is developing as the result of variations in certain parameters during the storm, such as crystal type and size, amount of crystal riming, wind speed and direction, and temperature. During the period between precipitation events the development of a layered system within the snowcover continues as settlement rates vary and metamorphic processes begin, both producing variations in structure and density. The layered structure is further enhanced by weathering actions at the snow-air interface such as freeze-thaw crust formation, surface hoar development, and densification due to wind action. The primary significance of this layered structure to the avalanche phenomenon is the wide range of strengths associated with the respective layers and the wide variations in inter-layer bonding.

In order to provide the conditions for an avalanche, this snow structure must be developing on a slope and the same processes are at work here that occur at a level site. The situation becomes more complex as each point on a slope is responding according to specific orientation and slope angle. In mountainous regions, climate and terrain interact to produce a distinct topoclimate which in turn establishes the local snow structure. Slopes facing the noon sun and inclined so that the sun's rays are essentially normal to the surface receive maximum solar energy. Depending upon the intensity of insolation, enhanced sintering may stabilize these slopes, surface crusts resulting from diurnal freeze-thaw cycles may form, or, if the temperatures are high enough, free water may be produced in sufficient quantities to destroy the intergranular bonding with a consequent reduction in strength. North-facing slopes and those which are topographically shaded much of the time receive relatively little direct short-wave radiation. These areas are characterized by lower surface temperatures which inhibit sintering and favor the formation of cohesionless snow deposits or depth hoar. Specific conditions in the San Juan Mountains are often considerably more complex, as will be described later in this report.

When snow lies on a slope, the relationship between stress and strength becomes of prime importance. The vertical force of gravity is resolved into two components, one normal to the slope and tending to hold the snow on the slope and one parallel to the slope, the shear force, causing the snow to move downslope (creep and glide). The snow also gradually densifies under compressive bulk stress (settlement). Generally, deformation rates depend on the structure and temperature of the snow and the body forces. Elastic strain energy is stored in the snow when irregularities of settlement, creep and glide introduce tensile, compressive and shear stresses. In most cases this stored energy is slowly dissipated through viscous deformation of the snowcover (relaxation). But in some instances the stresses, particularly in tension and shear, may exceed the mechanical strength of snow layers or inter-layer bonds and failure can then occur, either spontaneously or through an external initiation (triggering). When this failure takes place on a sufficiently steep slope, a slab avalanche may be released as one or more snow layers slide away.

Summary of the Stratigraphic Character of the San Juan Snowcover

In the second INSTAAR Interim Report, 1973, E. R. LaChapelle, in his description of the physical causes of avalanches within the study area, identified what he called a predominately radiation snow climate. After two winters of snow structure analysis, it had become apparent that the local stratigraphy exhibited properties which differed greatly from the more northerly latitude of U.S.A., Canada, Europe and Japan where most practical and scientific knowledge of snow avalanche formation had been obtained. The latitude of the Red Mountain Pass snow study site is 37° 54'N, some 1200 km closer to the equator than the Swiss Alps. The avalanche release zones within the research area range in altitude from 2800 m to 4000 m with a mean altitude of 3400 m. This combination of high altitude, low latitude and a continental climate produces what is described as a radiation snow climate.

A substantial amount of solar energy is available to slopes with a southerly aspect, even at midwinter, and this increases as spring approaches. This slope aspect includes a majority of the avalanche release zones in the study area. At the same time, the combination of high altitude and low atmospheric moisture leads to the intense nocturnal radiation cooling of all exposures. The annual snow accumulation within the release zones generally amounts to depths from 1.5 to 3.0 m and is not sufficient to suppress the development of significant temperature gradients. While the mean internal temperature gradients of north- and south-facing slopes do not differ to a significant extent, such values being a function of long-term mean daily air temperatures, it is within the near surface layers that the radical contrast exists. Slopes with a southerly exposure experience subsurface warming due to the penetration and absorption of solar radiation. At any time during the winter season this warming can be sufficient to cause the snow temperature to reach the melting point with the eventual formation of a freeze-thaw crust. Even at the warmest point in the diurnal temperature cycle, when melt is occurring 1.0-3.0 cm beneath the surface, the temperature of the snow-air interface, due to radiation cooling, often remains well below freezing, creating an extremely steep temperature gradient within this uppermost layer. This combination provides optimum conditions for temperature-gradient recrystallization; mean snow temperatures at or near freezing providing maximum water vapor supply and snow structure of low density allowing maximum vapor diffusion with a temperature gradient as high as several degrees per centimeter. The large diurnal fluctuations in the radiation-determined temperature of the near surface snow layers continue throughout the winter and a highly complex stratigraphy develops, characterized by large variations in structure and strength. Layers of relatively homogeneous, stronger snow, comprising the individual precipitation increments, are separated by thin layers of temperature-gradient snow and freeze-thaw crusts that have developed during clear weather periods between storms (Figure 9). Poor layer bonding is prevalant in these situations and the snowcover can be described as conditionally unstable, i.e. highly susceptible to load-induced or thaw-induced avalanche release. The general concept of the stabilization of southerly slopes associated with the effect of solar radiation simply is not applicable in the San Juan Mountains. A more detailed analysis of the effect of near-surface temperature gradients can be found in LaChapelle and Armstrong (in preparation). The identification of a local radiation snow climate may be as much a result of the detailed snow structure studies undertaken by INSTAAR as a consequence of any unique climatic situation. Similar snow properties may well be associated with other high altitude continental sites but these areas have not been studied in sufficient detail so as to identify this condition. Such additional studies are needed in order to better understand relationships between climate and snow structure.

Snowcover data from the first two years of the INSTAAR project revealed a persistent pattern of lower average mechanical strength of the snowcover in avalanche release zones than in the level study sites. Following subsequent data analysis, LaChapelle suggested that this difference was in large part due to variations in compressive metamorphism between level ground and the inclined avalanche slopes. The component of body force acting perpendicular to the ground - the component which provides the compressive loading - declines with the cosine of slope angle for a given snow layer thickness. Comparison of mean snowcover ram resistance with total loading perpendicular to the ground showed a consistent correlation between these two parameters (Figure 10). The overall results confirm the conclusion that the distribution of snowdepths commonly found in the San Juan research area is such that compressive load values associated with higher snow strengths appear early in the winter on level ground but do not appear until much later in the winter on slopes steeper than 30° which are characteristic of avalanche release zones.

Avalanche Event Record

Snow avalanches were observed within the study area as early as October 29, and as late as May 30 during the 4 season period. The length of each of the four avalanche seasons studied is shown in Table 3. Table 3 also includes the snow depths at the Red Mountain Pass snow study site at the time when the first significant avalanching was recorded. Although the sample is small, it is worth noting that there is little deviation from the average depth of 76.3 cm. "Significant avalanche activity" was defined

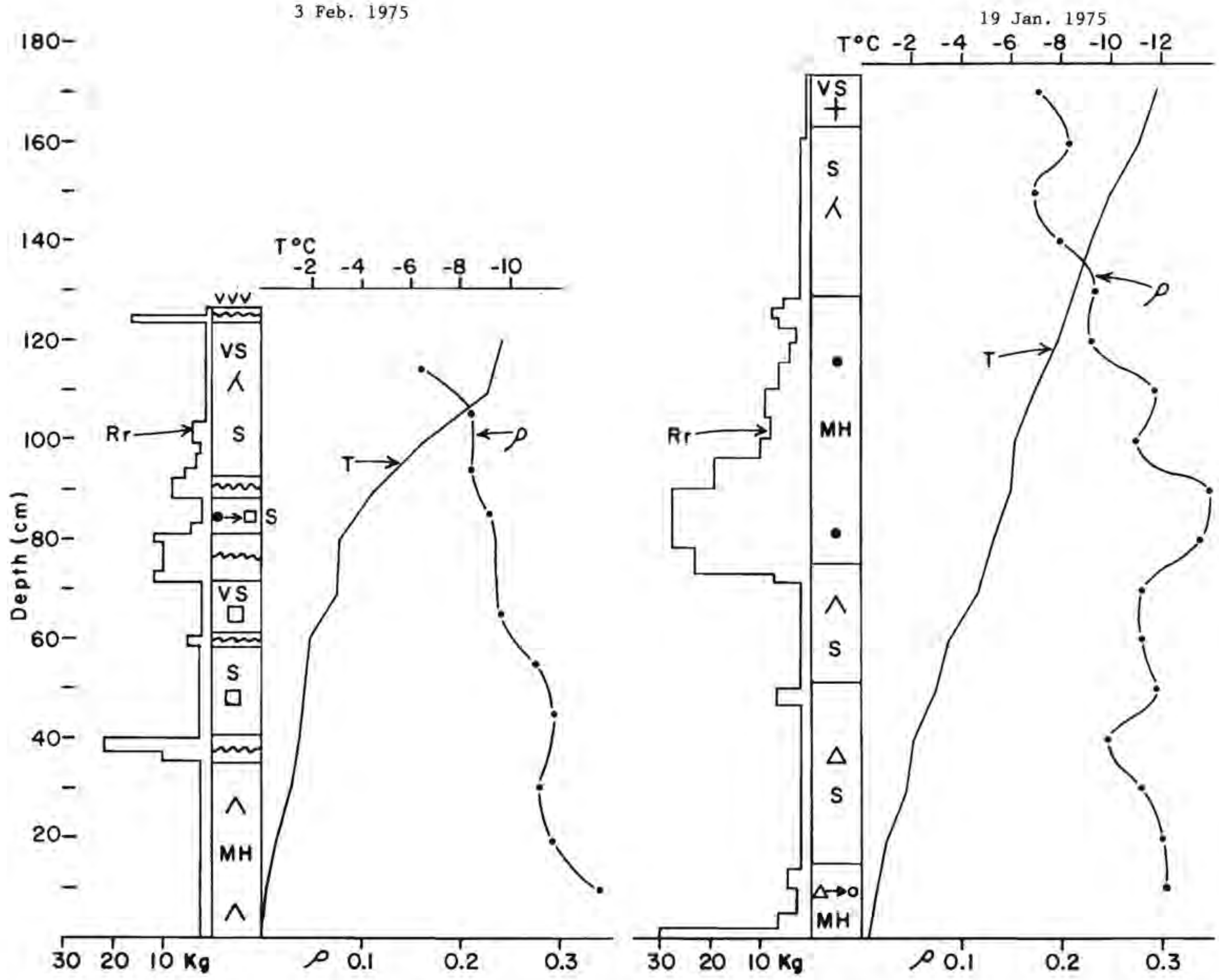

Figure 9. Two examples of typical San Juan snow stratigraphy. The profile on the left of the figure is from a south-facing slope and on the right is a north-facing slope. Both profiles are from the Red Mountain area at an elevation of 3550 m. See page 223 in Appendix 4 for symbol explanation.

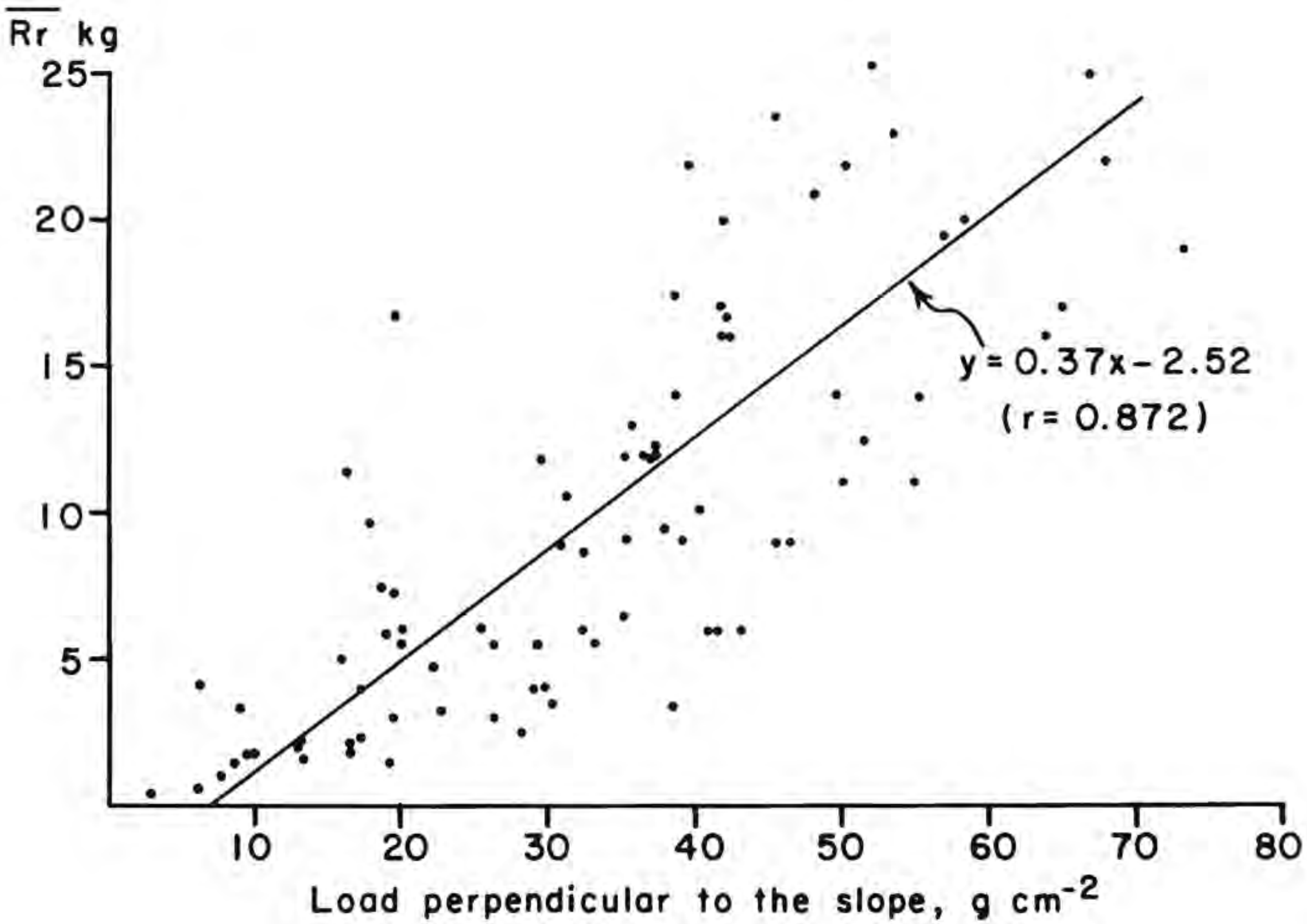

Figure 10. Mean snowcover ram resistance as a function of total compressive loading perpendicular to the ground surface at the base of the snowcover for 84 release zone profiles in the Red Mountain Pass area.

TABLE 3

AVALANCHE SEASON CHARACTERISTICS

Winter	Snow depth at Red Mountain Pass snow study site at start of avalanche season (cm)	Length of avalanche season
1971-1972	79	Nov 15-March 13
1972-1973	77	Oct 30-May 19
1973-1974	75	Nov 23-April 21
1974-1975	74	Oct 29-May 30

TABLE 4

AVALANCHE OCCURRENCES BY MONTH HIGHWAY 550, SIZE 1-5

Winter	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
1971-1972	0	30	193	34	15	29	0	0
1972-1973	2	88	70	41	64	93	87	131
1973-1974	0	4	39	96	29	92	27	0
1974-1975	6	73	234	269	238	305	155	26
Total	8	195	536	440	346	519	269	157

for this purpose as the occurrence of at least two slab-type avalanches with at least one reaching the highway. A tabulation of avalanche occurrence by month for the 1971-1975 period is contained in Table 4. A breakdown of avalanches by size and type, as well as their effect on highways is found in Table 5.

The division of total events by type reflects the following general regime: soft slab events present a consistent ratio and dominate during midwinter; hard slab events are a function of the number of storms accompanied by strong winds; wet slab frequency is dependent on spring snow structure and air temperature conditions; wet loose events show a somewhat consistent ratio and are related to higher snow and air temperatures during periods of unconsolidated surface snow conditions; dry loose events show a consistent percentage and are primarily made up of size one events, occurring as a result of minor instability within new snow. The annual percent of total events reaching the highway is remarkably consistent, showing an approximate ratio of 1:4. Within the portion of the table showing events by type reaching the highway, it is obvious that hazard caused by wet snow avalanches varies greatly from only 7 percent of the total in 1971-1972 to 45 percent in 1972-1973. The character of the wet snow avalanche season is described in Chapter 4.

The most significant type of avalanche in terms of both frequency and potentially destructive character to be recorded while the snow was at subfreezing temperatures was a load-induced, soft slab type, where slab failure took place in older snow layers deposited and metamorphosed prior to the triggering precipitation event (climax type). A load-induced avalanche is defined in the following terms: while a slope may contain sufficient weak layers to be described as marginally unstable, internal processes are not sufficient to cause spontaneous slab avalanche release; eventual failure is the result of the addition of new load to the snowcover in the form of a direct precipitation event or by wind transport. The amount of additional load required to cause failure on a given slope is then a function of the strength of the underlying snow structure. This condition may vary from relatively large amounts of new snow falling on a stable substructure without causing failure, to light snowfalls causing a significant avalanche cycle due to the predominately low mechanical strength and poor layer bonding of the old snow. Specific examples of these extremes appear in Chapter 3 of this report. A soft slab condition exists when the initial slab has a rammsonde strength of less than 10 kg/cm. In cases where this measurement was not obtained, the designation depends on the observers' subjective appraisal of the degree of disintegration of the initial slab material during the event. The second most prevelant type of release was thaw-induced and is the result of the introduction of melt water to subsurface snow layers, normally by thaw, causing a reduction in intergranular cohesion and mechanical strength leading to failure. A detailed analysis of this process is contained in Chapter 4.

Table 30 in Appendix 2 contains a listing of avalanche event frequency by path along Highway 550 for the four winters 1971-1972 through 1974-1975.

TABLE 5

OBSERVED AVALANCHE EVENTS 1971-1975

Total Number: 2470

A. Size: percent

1	2	3	4	5
14	57	23	5	1

B. Type: percent

	ss	hs	ws	dl	wl
Mean:	52	8	4	20	16
1971 - 1972	47	13	1	24	15
1972 - 1973	39	3	13	23	22
1973 - 1974	59	2	2	13	24
1974 - 1975	58	11	1	19	11

See Table 31 Appendix 2 for explanation of Type and Size designation.

C. Percent of Total Recorded Events Reaching Highway 550 by Year

1971 - 1972: 21
1972 - 1973: 22
1973 - 1974: 25
1974 - 1975: 25

D. Percent Reaching Highway 550 by Size

1	2	3	4	5
6	49	31	12	2

E. Percent Reaching Highway 550 by Type

	ss	hs	ws	dl	wl
Mean:	63	7	5	9	16
1971 - 1972	79	10	0	4	7
1972 - 1973	41	2	20	12	25
1973 - 1974	70	2	0	7	21
1974 - 1975	63	12	2	14	9

TABLE 6

20 Most Frequent Avalanche Paths Reaching Highway 550

Colorado Highway Department data 1951-1971				San Juan Avalanche Project data 1971-1975			
avalanche path number	avalanche path name	frequency	average no. of events per year	avalanche path number	avalanche path name	frequency	average no. of events per year
015-029	Brooklyns	106	5.3	015-029	Brooklyns	57	14.25
097	Blue Point	102	5.1	097	Blue Point	56	14.0
064	East Riverside	70	3.5	101	Rockwall	24	6.0
069	Mother Cline	61	3.05	104	Eagle	20	5.0
104	Eagle	35	1.75	064	East Riverside	20	5.0
144	Champion	30	1.5	069	Mother Cline	20	5.0
105	Telescope	26	1.3	065	East Riverside Left	17	4.25
095	Willow Swamp	24	1.2	105	Telescope	12	3.0
099	Snowflake	20	1.0	095	Willow Swamp	10	2.5
101	Rockwall	19	0.95	155	Henry Brown	10	2.5
156	Coal Bank	19	0.95	149	East Lime Creek	9	2.25
154	Swamp	18	0.9	144	Champion	8	2.0
010	Cement Fill	17	0.85	070	Silver Point	8	2.0
100	Silver Ledge Mine	15	0.75	096	Blue Willow	8	2.0
106	Muleshoe	15	0.75	062	East Riverside South	7	1.75
140-141	Jennie Parker	15	0.75	100	Silver Ledge Mine	7	1.75
061	Slippery Jim	12	0.6	142	Peacock	5	1.25
157-158	Coal Creek	12	0.6	150	West Lime Creek	5	1.25
074	West Riverside	11	0.55	010	Cement Fill	5	1.25
150	West Lime Creek	11	0.55	140-141	Jennie Parker	5	1.25

Table 6 provides a comparison of the frequency of the 20 most active avalanche paths during the period of the INSTAAR study and the preceding 20 years. All avalanche events, both natural and artificial, are included. The frequency of certain paths, such as the Eagle, will be a function of varying control procedures, but the data are intended to demonstrate magnitude of hazard regardless of other factors. Figure 11 provides a comparison of full-track events with the total number of releases for several of the most active paths, indicating a consistent ratio of approximately 1:3. Table 7 indicates magnitude of avalanche debris which directly affected travel along U.S. Highway 550 during the four year period.

TABLE 7

AVALANCHES REACHING HIGHWAY 550
SIZE 1-5

Winter	Total Length Covered (feet)	Average Length per Event (feet)	Average Depth (feet)
1971-1972	12,177	169.1	6.2
1972-1973	8,512	71.5	4.6
1973-1974	5,576	94.5	5.3
1974-1975	16,510	127.9	5.7

Fracture-Line Profile Analysis

Data which eventually allowed the description of the radiation snow climate of the study area was primarily made available from time-series stratigraphic investigations at release zone sites and actual fracture-line profiles. Over the past four winters, 157 snowcover profiles were collected over a wide range of aspects and altitudes. All fracture-line profiles collected during the 1972-1973 and 1973-1974 winter seasons are presented in Appendix 4 of this report. These stratigraphic studies show that a large percentage of the snowcover is composed of layers in some stage of temperature-gradient metamorphism. An analysis of typical snow-layer types in avalanche release zones is found in Table 8. Table 9 contains statistics from 53 fracture-line profiles.

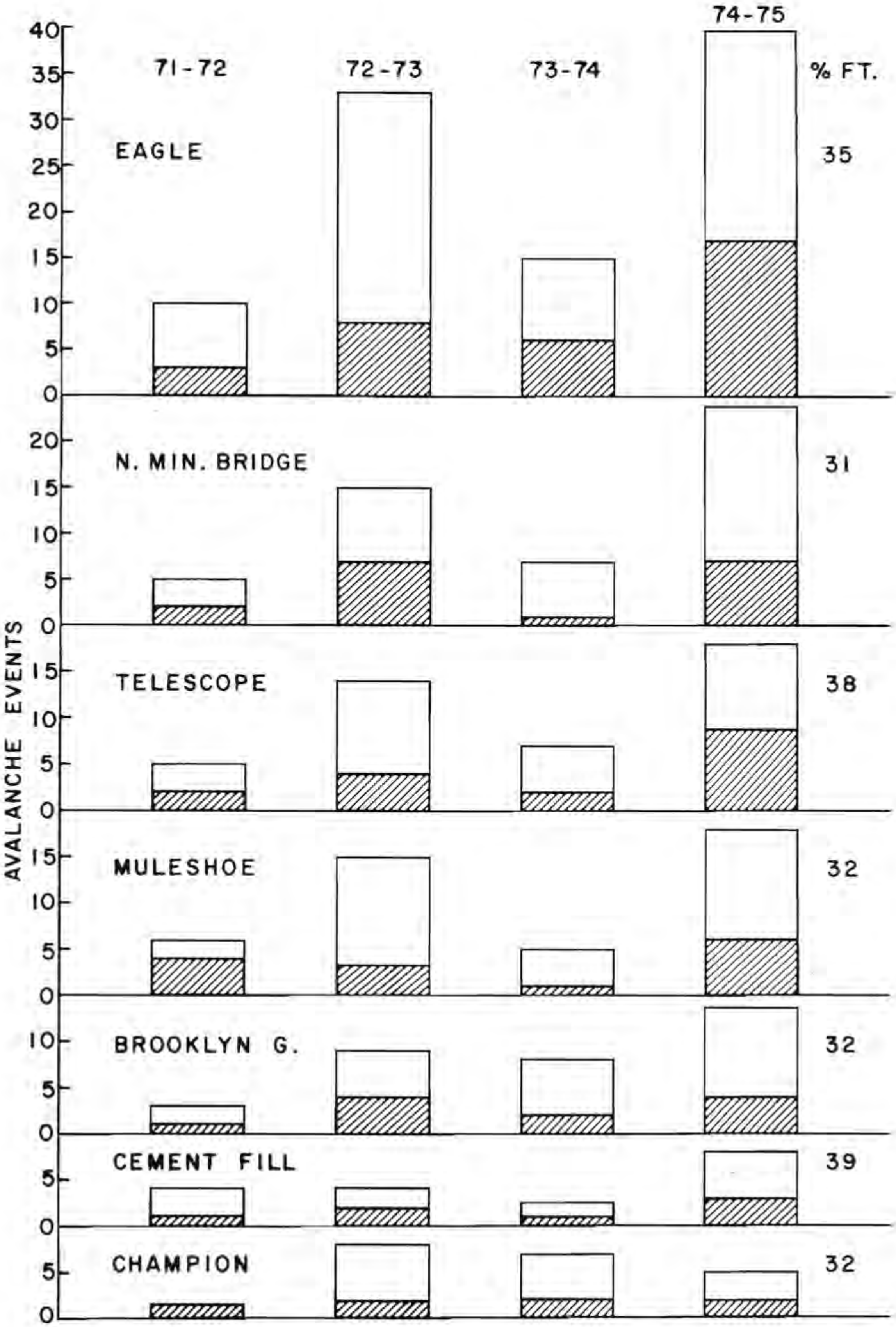

Figure 11. Relationship between the number of avalanche events reaching full track and the total number of observed events larger than size one for seven of the most active avalanche paths directly affecting Highway 550.

TABLE 8

DISTRIBUTION OF SNOW TYPES BY LAYER THICKNESS IN RELEASE ZONE PROFILES FOR THE WINTERS 1972-1973, 1973-1974 and 1974-1975

Total Layer Thickness (cm)	∧	□	•O	+λ\	Total
To end February	2122	3182	1694	2427	9425
After March 1	2295	1642	2678	1130	7745
Total of 3 winters	4417	4824	4372	3557	17,170
Percent					(No. of Profiles)
To end February	23	34	18	25	(69)
After March 1	30	21	34	15	(36)
Total of 3 winters	26	28	25	21	(105)

Temperature Gradient Snow		Equi-Temperature Metamorphism	New and Partially Metamorphosed Snow
Beginning	Advanced	(Increasing Grain Size)	(Decreasing Grain Size)
□	∧	•O	+λ\

Table 9 contains statistics from 53 fracture-line profiles.

TABLE 9

FRACTURE-LINE CHARACTERISTICS 1971-1975

Characteristics	Percent
soft slab	76
hard slab	22
wet slab	2
release in new snow	14
release within old snow structure	86
lubricating layer comprised of temperature-gradient snow	75
sliding surface identified as a crust	69
range of slab thickness	19 - 232 cm
mean slab thickness	88 cm
mean slab rammsonde strength	7.3 kg

The basic pattern of avalanche release mechanics has been similar over the four-year period. Soft slab events incorporating old snow layers (climax type) and failure associated with layers of temperature-gradient snow predominate. When measurements are made in the field, particular attention is paid to the zone of shear failure, the surface on which the slab slides and the weak or lubricating layer often located just above. The principal sliding surfaces have been crust layers and this pattern has remained consistent throughout the sample period. These are most often very thin fragile freeze-thaw crusts in close association with a layer of temperature-gradient snow, a condition that may develop throughout the winter on all but the most northerly-facing slopes. Occasional sliding surfaces have been identified as wind crusts. On all exposures, persistent steep temperature gradients tend to disintegrate crusts with time. This can lead in time to part or all of the crust serving as a lubricating layer for slab release.

Clearly defined lubricating layers are more difficult to identify in the profiles. In most cases poor adhesion between the slab layer and the sliding surface appears to contribute towards the failure, rather than a separate and distinct layer of snow grains with low shear strength. Temperature-gradient metamorphism within near-surface layers, occurring when the potential sliding surface is exposed to the atmosphere between precipitation events, is most likely the cause of poor adhesion. Although the specific lubricating layers may not always be clearly identifiable, Figure 12 shows the strong relationship between the average density of the layer (5.0 cm) just above the sliding surface and calculated shear stress prevailing at the time of failure. Figure 13 contains a plot of the Coulomb-Mohr relationship (internal friction) for the fracture-line data. The r value of 0.942 and the y value of 1.346 x indicate that while at the time of failure the shear and normal stress values were similar, a slightly greater normal (perpendicular) stress prevailed. This relationship indicates the consistent presence of a layer weak enough to allow failure even when normal stress exceeds shear stress.

Data from various studies throughout the world have tended to define the most favorable slope angles for slab type avalanche releases (U.S. Forest Service Avalanche Handbook, revised edition, in press). Although large slab avalanches may release on slopes varying from 25^{o} to 55^{o}, there is a pronounced peak of avalanche occurrence between 35^{o} and 40^{o}. This pattern is further supported by INSTAAR data with 49 percent of the 53 fracture-line profiles located on slopes between 34^{o} and 41^{o} and 72 percent located between 30^{o} and 45^{o}. The range of the total sample was 25^{o} to 48^{o}. The relationship between slab avalanche frequency and slope angle appears independent of climate or avalanche type and is likely determined by the basic strength properties of snow.

Mechanical Properties of Temperature-Gradient Snow

The prevalence of temperature-gradient type metamorphism in the San Juan snowcover and the dominant association of this crystal type with zones of

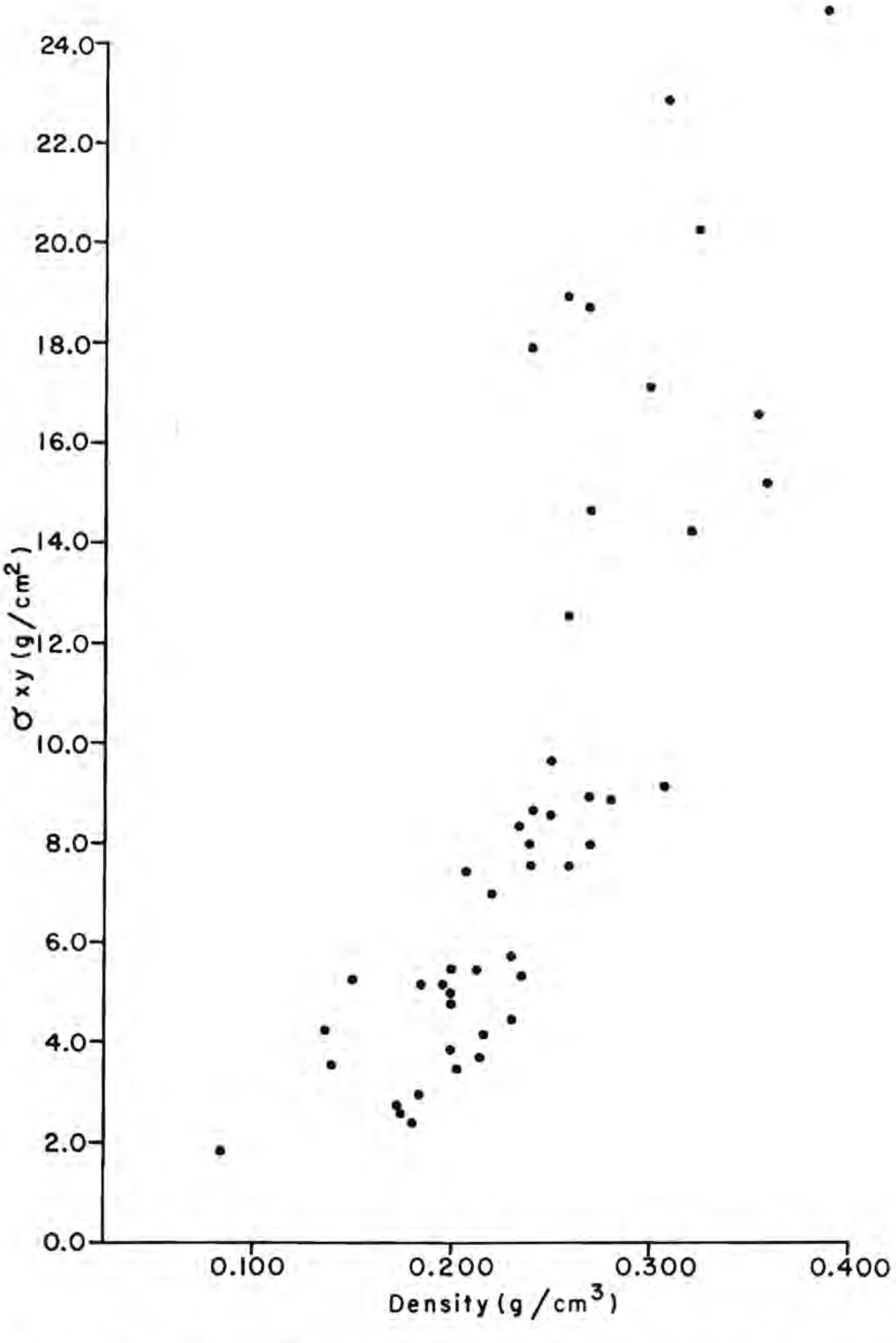

Figure 12. The relationship between snow slab shear stress at the point of failure (fracture line) and the density of the 5.0 cm layer (lubricating layer) at the base of the slab for 46 fracture line profiles.

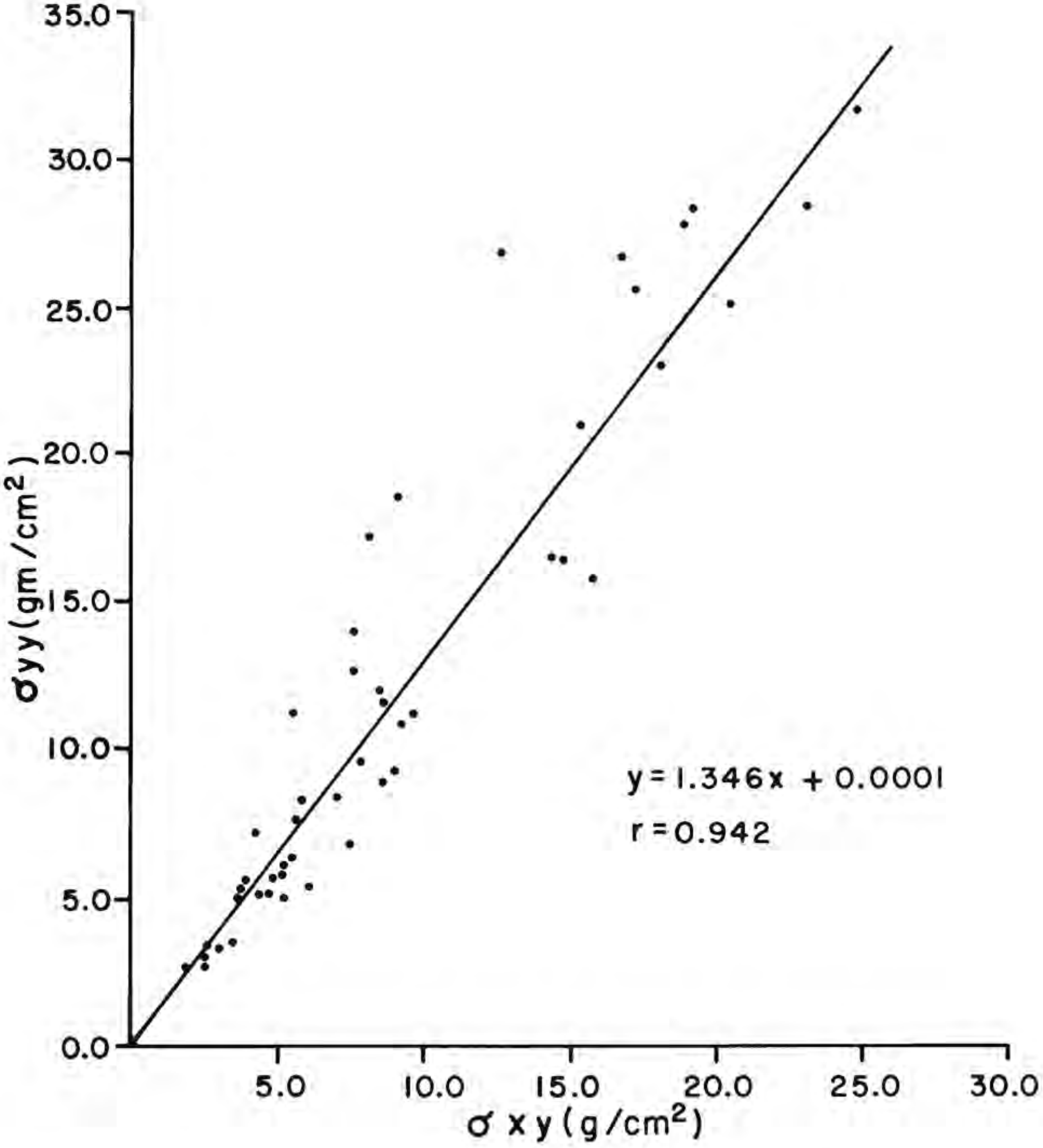

Figure 13. The Coulomb-Mohr relationship of shear stress vs. normal stress (internal friction) for 47 fracture line profiles.

shear failure in fracture-line profiles has already been emphasized. It is appropriate, therefore, to discuss some of the mechanical properties of this snow type.

The densification with time is a basic characteristic of the snowcover that relates directly to avalanche formation through effects on snow strength. Densification rates are dependent on climate and on the type of metamorphism involved (LaChapelle, 1974). When snow is resting on a slope the settlement, or densification, resulting from the forces of gravity and metamorphism is resolved into two components, one promoting shear stress and the other causing normal stress. It is true that the shear resistance of a given layer can be strengthened by increasing the normal pressure across the layer, as when new snow accumulates. However, it has been noted (Mellor, 1968) that this situation is complicated by the fact that shear resistance is improved not so much by normal pressure *per se*, but by irreversible structural changes induced in the snow layers by that pressure. Under compressive bulk stress most snow densifies and creates new bonds and shear strength increases. Under fixed bulk stress, shear strength then becomes a function of time and if the bulk stress is relaxed, the improved shear strength gained by its application does not disappear. However, temperature-gradient snow, the type most frequently found within the shear failure zone of the San Juan fracture-line profiles, does not behave in this fashion. Snow structure studies conducted by INSTAAR (LaChapelle and Armstrong, in preparation) as well as other research (Akitaya, 1974) have indicated that while temperature-gradient snow is quite weak in shear, it retains a relatively high compressive strength and once the initial changes in the new snow have taken place, temperature-gradient metamorphism tends to severely inhibit the densification process. Even under the loading effect of the majority of the winter snowcover, temperature gradient layers near the ground densify only slightly (Figure 14) compared to layers not influenced by temperature-gradient metamorphism. Very little new intergranular bonding occurs and even after an initially steep temperature gradient is removed from the layer, only insignificant increases in strength occur. Generally the large, coarse, cohesionless grains continue to exhibit very low mechanical strength throughout the winter and remain weak in shear strength.

Conclusion

It was the intention of this project at the outset to stress snowcover as well as meteorological parameters in the development of an avalanche forecast methodology. Although no comprehensive snow or avalanche studies had previously been conducted in the San Juan Mountains, the local snow structure had been recognized as one which, due to its complex stratigraphy, would consistently involve slab avalanche releases within old snow layers (LaChapelle, 1965). However, it was the inadequate correlation between precipitation factors and avalanche release encountered during the initial period of research which placed further emphasis on the need for a detailed investigation of local snow structure. The need to extrapolate from a level study site to the slopes of the avalanche release zones led to a comparison of the general physical and mechanical properties associated with

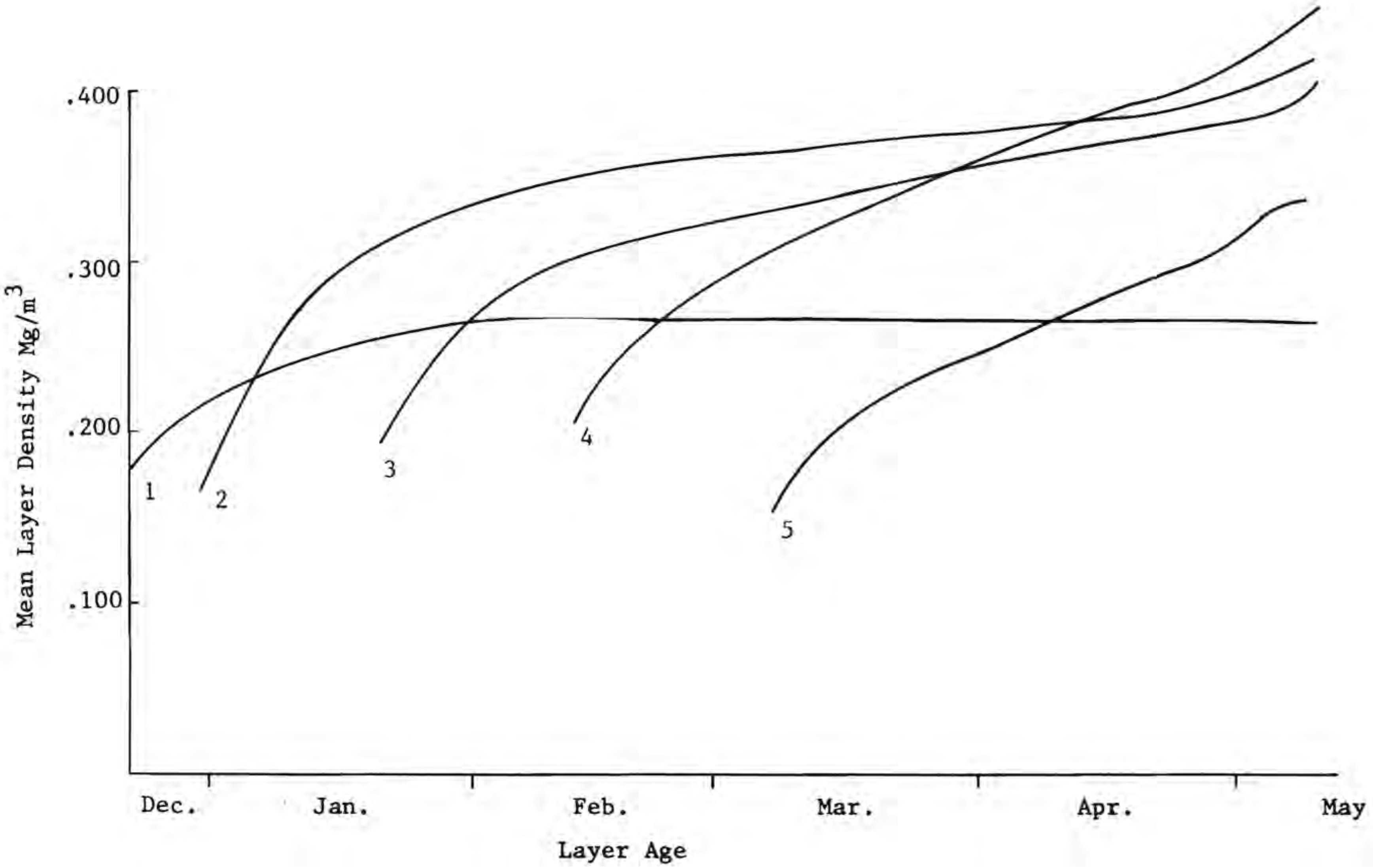

Figure 14. Snow layer densification rates at the Red Mountain Pass study site, 1973-1974. Layer number one is composed entirely of temperature-gradient snow. The remaining layers did not experience significant temperature-gradient metamorphism.

the snow structures of the two locations. The next step was to identify the particular stratigraphic snow structure patterns of various slope orientations and to analyze the meteorological conditions which created them. In summary, a predominately radiation snow climate, the result of a very wide range in snow surface temperature related to intense daytime insolation and nocturnal radiation cooling, was identified which produced extensive temperature-gradient metamorphism of the snowcover. This metamorphism in turn created conditions of predominately low mechanical strength and a highly differentiated stratigraphy on all slope exposures. The local snow structure was characterized as being conditionally unstable throughout the major portion of a winter season. By this, it is meant that at any given time while the snowcover is at sub-freezing temperatures, it is only marginally unstable with respect to spontaneous slab release due to internal causes, but it remains throughout each winter highly susceptible to load-induced avalanche release. The critical point to be made here is that in terms of precipitation-triggered avalanche events, the most important factor in occurrence forecasting may often not be the amount of precipitation provided by the storm, but rather the mechanical strength of the old snow structure on which the new snow load is accumulating. Over 80 percent of the observed fracture-line profiles exhibited a climax avalanche structure wherein slab failure took place in older snow layers deposited and metamorphosed prior to the triggering precipitation event. Accurate avalanche forecasting in the San Juan Mountains must rely heavily on an adequate understanding and continuous monitoring of the metamorphic processes contributing to the development of the snow structure. This point is further emphasized in the following chapter.

CHAPTER 3: AVALANCHE FORECAST METHODS

Richard L. Armstrong and Edward LaChapelle

Developmental Background

At the beginning of the project, two parallel techniques were proposed for development of a method for forecasting avalanches in the San Juan Mountains. The first was an operational, in-house, forecasting program initially based on established forecasting techniques, but to be continually upgraded on the basis of experience and empirical evidence obtained as the investigation of the local snow climate continued. The second would be based on acquisition of sufficient snow, weather and avalanche data to allow a statistical analysis of the relations between avalanche occurrence and contributing snow and weather factors. Direct investigation of snowcover structure and the physical causes of avalanches as determined by after-the-fact analysis would augment both approaches. A detailed account of the procedure adopted for the first approach by LaChapelle is in Armstrong et al. (1974) and is reproduced for the current report at the conclusion of this chapter. Following the third winter's study, initial statistical analysis was undertaken, the results being reported by Bovis (1976). The updated results of this work, including the unusually large sample of avalanche events from the 1974-1975 winter, are contained in Chapter 5 of this report.

Data providing the basis for conventional avalanche forecasting is generally available from two sources; direct evidence, where the condition of snow stability is obtained from direct examination of snowcover structure, and indirect evidence, that utilizes meteorological data only. The respective application of these techniques is related to the type of slab avalanche anticipated (LaChapelle, 1965). Direct snowcover data are required when the avalanche is caused primarily by weak layers that have developed within the old snowcover. By means of stratigraphic investigations, such incipient structural development can usually be detected well in advance of the actual avalanche release. Indirect, or meteorological evidence can be relied on more heavily when forecasting involves avalanches which release primarily as a result of instability within the newly-fallen snow. This condition is often associated with very rapid, widespread hazard development and therefore does not readily lend itself to systematic, time-consuming examination of snow structure. Empirical evidence indicates that a number of weather factors determine the stability of newly-fallen snow but the subjective weighing of the individual importance of each factor is the critical ingredient in an accurate forecast (U.S. Forest Service, 1961; Perla and Martinelli, 1976; and the last section of this Chapter). The first systematic effort directed towards avalanche forecasting in the San Juan Mountains was based on indirect or meteorological evidence (Rhea, 1970).

The application of physical models to the problem of avalanche release has to date been avoided due to the general lack of quantitative information regarding the complex nature of snow as a material. The inhomogeneity of a natural snowpack has thus far prevented any comprehensive detailed analytical treatment of the physical, mechanical and thermodynamic properties of snow. Such basic properties as the strength (tensile, shear and compressive), elasticity and viscosity of snow are highly dependent on temperature and structure and therefore experiments done in the laboratory regarding such properties are valid for only one set of conditions. Problems also arise in attempting to relate strength values obtained from relatively small laboratory samples to stress patterns associated with the much larger volumes comprising the avalanche release zones within a natural snowpack. Consequently, there is no universally accepted set of failure criteria for snow as a material and therefore no currently well established body of scientific knowledge to calculate quantitatively the causes of avalanches in general.

Snow Structure and Forecasting

As INSTAAR proceeded to develop an avalanche forecast methodology, it soon became apparent that emphasis would be directed toward the "direct evidence" described above. The decision to devote a significant effort towards a better understanding of the relationship between snowcover, climate and avalanche formation in the San Juan Mountains came partly as a result of the identification of the unusual snow structure conditions prevalent in the area, but also as a result of the initial attempt to apply indirect or meteorological evidence to avalanche forecasting. Attempts to relate precipitation rates and amounts, within varied time frames, to specific avalanche releases were not successful. Avalanche events were sub-divided according to size and/or type, time increments were varied from one hour precipitation rates and amounts to storm and winter totals but such efforts continued to produce r values in the .346 to .438 range. Relationships between total winter precipitation and avalanche events can be found in Figures 15 and 16. In Figure 16, the upper data points include all avalanches larger than size one to the end of March and the lower data points include only avalanches larger than size two to the end of March. It is of interest to note that while the sample including all avalanches larger than size one shows a direct relationship between precipitation and avalanche events, this sample would include many size two loose snow events (Table 5) and proportionally fewer large slab-type events. The second sample, which indicates a poor, in this case inverse relationship, would primarily be made up of large, destructive slab-type avalanches, again indicating the need for snow structure data in order to forecast this type of release with any degree of precision.

It became apparent that avalanches within the study site were primarily triggered by precipitation; over 90 percent of the mid-winter events occur during storm periods. Therefore, they are classified as direct-action, climax type avalanches because older snow layers are incorporated into the avalanche. This does not include events occurring in spring which result from the loss of internal strength due to the increasing free-water content of the snow. Recommended forecasting procedures for wet snow avalanches are reported in Chapter 4 of this report. However, even though the trigger was new-snow loading, an adequate understanding of conditions leading to

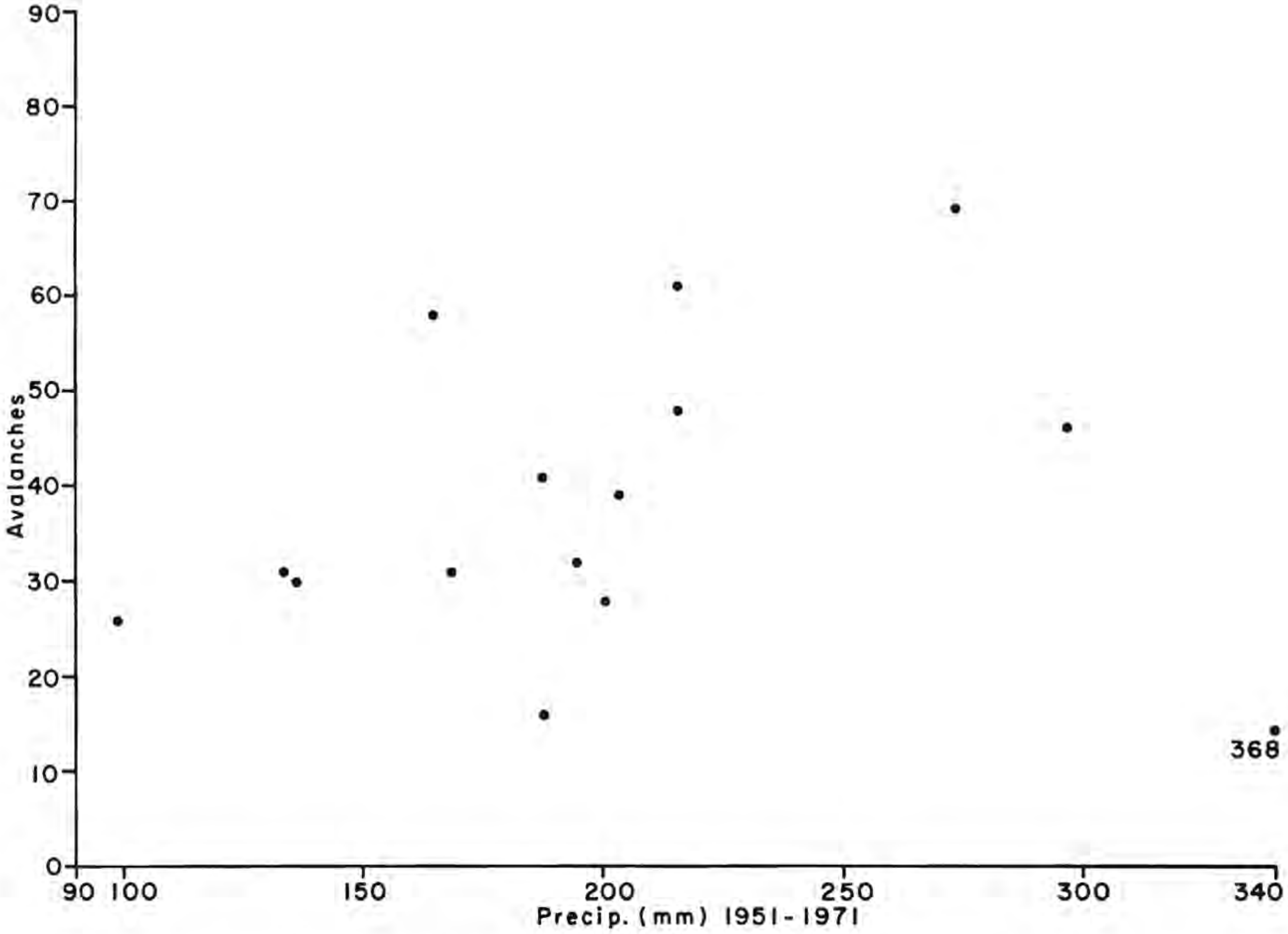

Figure 15. Relationship between the total number of avalanches reaching Highway 550 and total winter precipitation (mm water equivalent) for fifteen winter seasons within the period 1951-1971. Precipitation data is from the Soil Conservation Service, Red Mountain Pass site; avalanche data from Colorado Department of Highways.

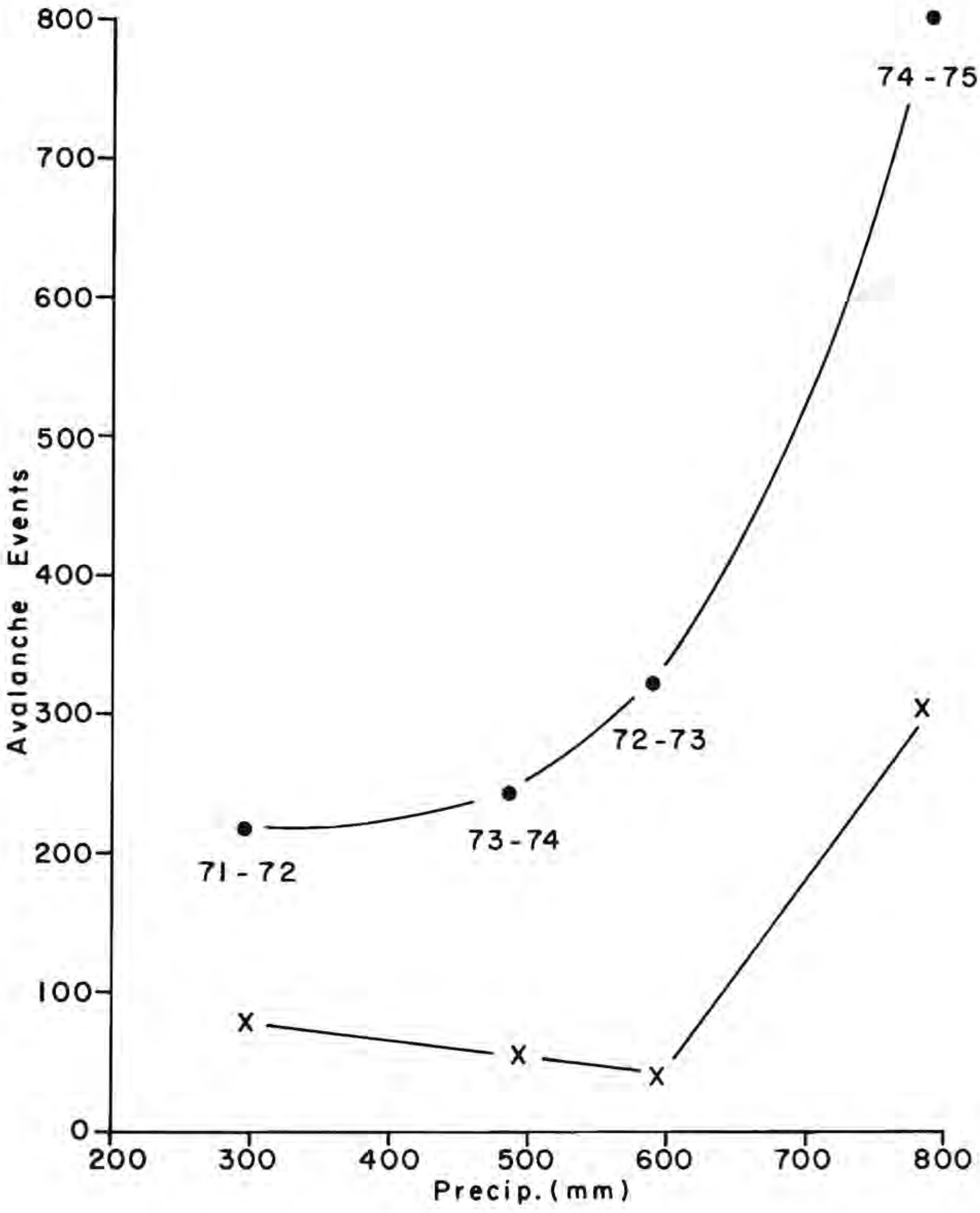

Figure 16. Relationship between total winter precipitation (mm water equivalent) to March 31, and total number of avalanches observed during the four winter seasons 1971-1975. Upper data points include all avalanches larger than size one; lower data include only events larger than size two.

failure was not possible without knowledge of the snow structure within the release zone as it existed prior to the onset of each new precipitation episode. An excellent example of the necessity for this type of analysis can be found in the snow structure - avalanche event chronology of the 1974-1975 winter season. Figure 17 shows the typically poor relationship between avalanche events and individual storm precipitation totals (r value .08). However, when the season is divided into four parts according to the intensity of the (temperature-gradient-driven) recrystallization process acting within the snowcover, the precipitation versus avalanche event data tends to conform to a systematic pattern (Figure 18). The periods are subdivided by date based on four temperature-gradient regimes as measured within the snowcover at the Red Mountain Pass study site. The mean temperature gradients for each period appear below the appropriate dates in Figure 18. The period November 1 to December 16 indicates the steepest temperature gradient and while the general snow structure is weakening in response to this condition, it is not until the period December 17 to January 12, that the weakness attains a maximum, creating the pattern of large numbers of avalanches resulting from relatively little precipitation. Figure 19 contains an example of a fracture-line profile obtained during this period: it shows the extremely weak structure of the old-snow. The strength data were recorded with a light weight (0.1 kg) rammsonde. The period January 13 to March 5 represents a period of transition with the snowcover gaining strength as the temperature-gradient decreases. The final period indicates the snowcover condition as it approaches an isothermal condition.

The deviation of data points A in Figure 18a, B in Figure 18c and C in Figure 18d can be appropriately dealt with as individual cases based on the following supplemental data. Point A represents an early precipitation episode when new snow was accumulating on bare ground or shallow old snow. In case B, 23 February, 1975, although little direct precipitation was recorded, additional loading did occur as the result of a wind transport episode with a duration of 18 hours and a mean wind speed of 13 m/sec. Case C, 13 April, 1975, occurred when numerous, predominately size two, soft slab events occurred within the new snow. During the twelve days preceding this cycle, 95 mm of precipitation had been recorded at the Red Mountain Pass study site without significant avalanche activity. The structural regime represented by Figure 18d is that of new snow collecting on an exceedingly stable, near-isothermal snowcover. Failure within the older snow structure was therefore precluded and a shear failure plane developed in conjunction with a freeze-thaw crust that was established during a brief clear weather episode within the longer period of heavy precipitation. This cycle is an isolated example of slab releases within new snow, an avalanche pattern which frequently occurs in climates where stable old-snow structure prevails, but is the exception within the San Juan snow climate.

The frequency and magnitude of wet slab avalanche release can also be a function of snowcover structure. The wet snow avalanche cycles of 1972-1973 and 1973-1974 differed greatly and this difference is explained in detail in Chapter 4. This discussion of wet snow avalanches includes criteria for forecasting their occurrence. These criteria were in fact met during the third week of April, 1975 but slab avalanches did not occur. The reason for this is directly related to snow structure. Free water, which began to percolate down through the snow structure during late April

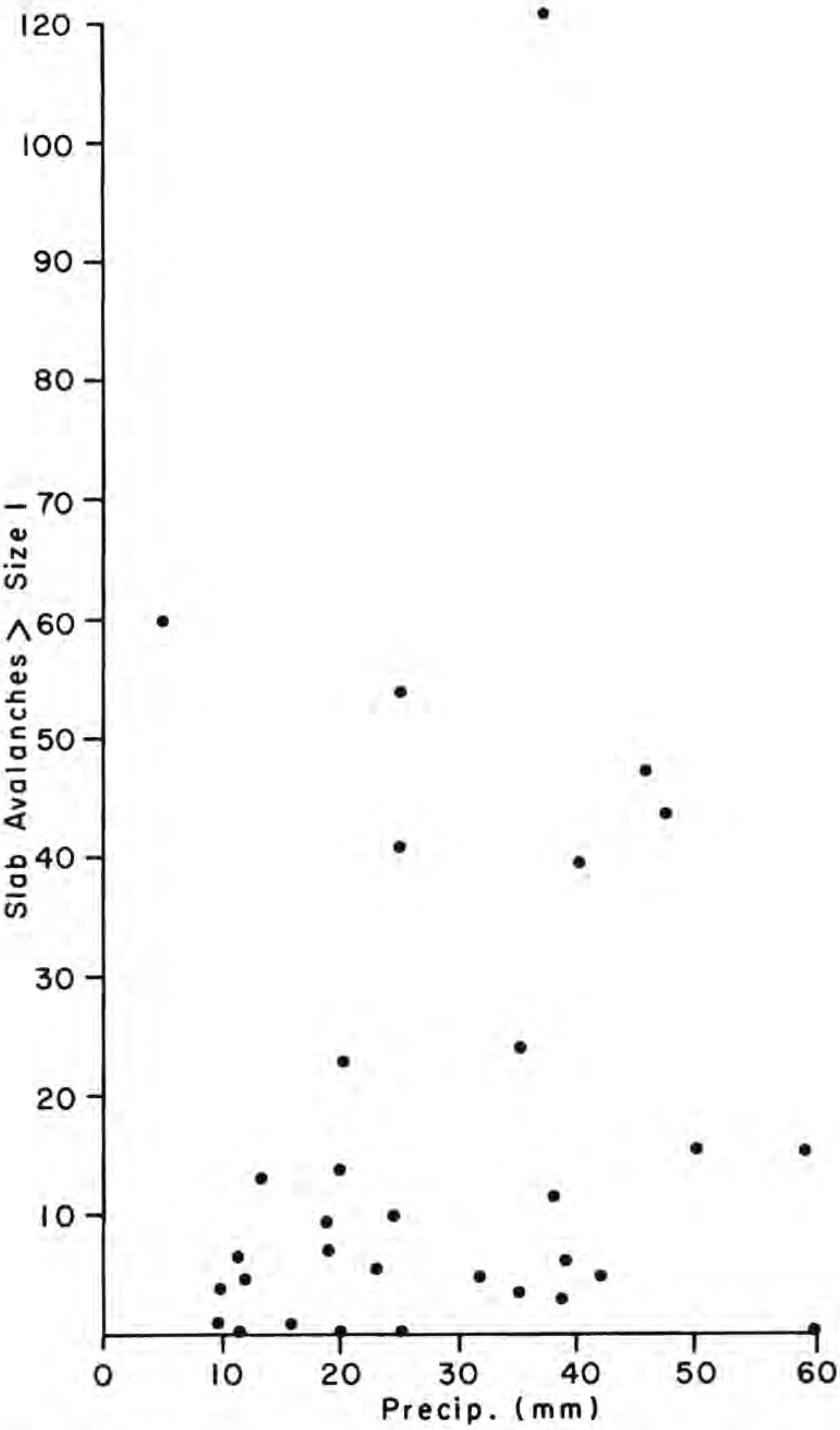

Figure 17. Relationship between individual storm precipitation totals (mm water equivalent) and number of observed slab avalanches larger than size one during the 1974-1975 winter.

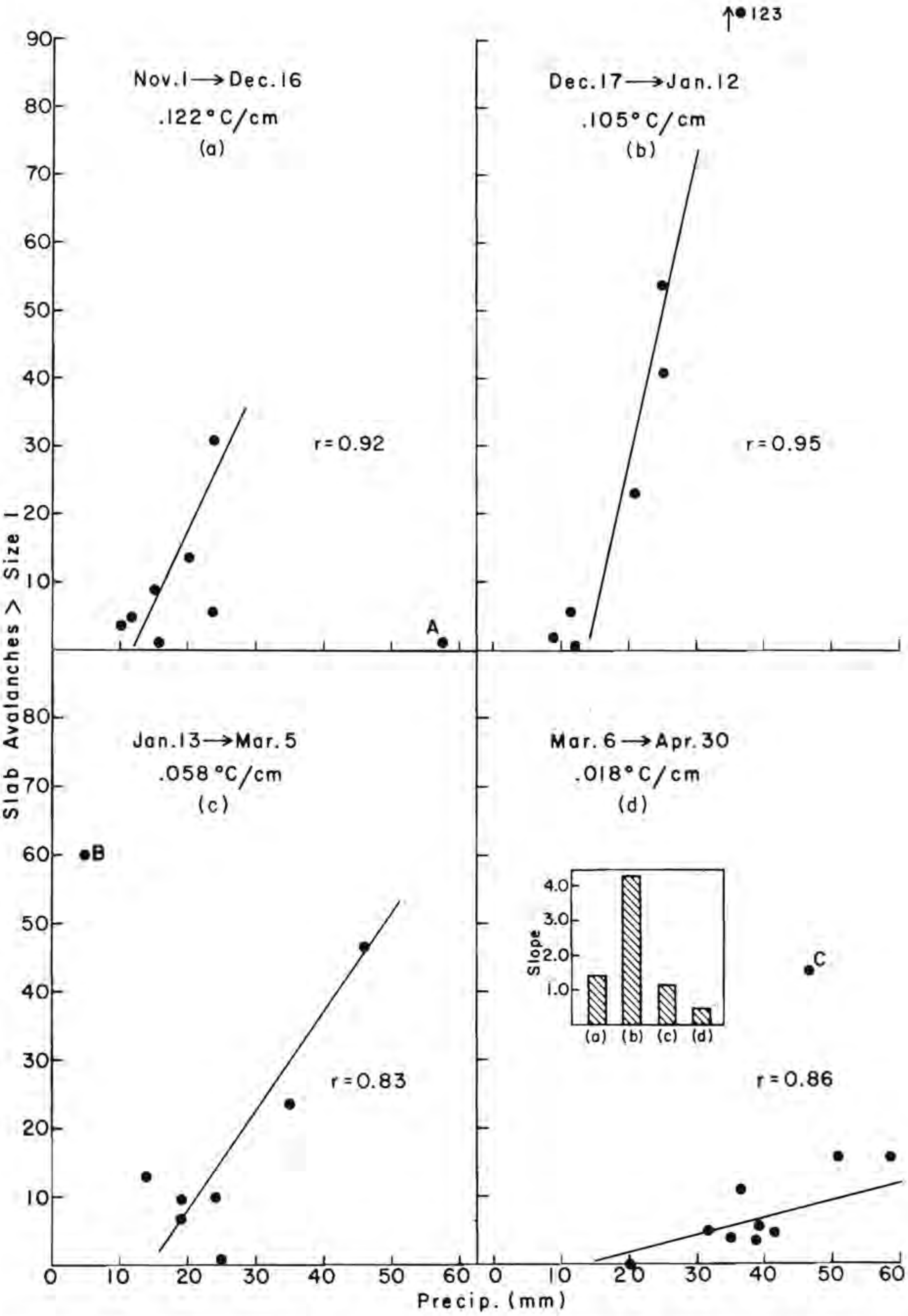

Figure 18. Relationship between individual storm precipitation totals and number of observed slab avalanches larger than size one subdivided into four periods according to progressive changes in snow structure for the 1974-1975 winter.

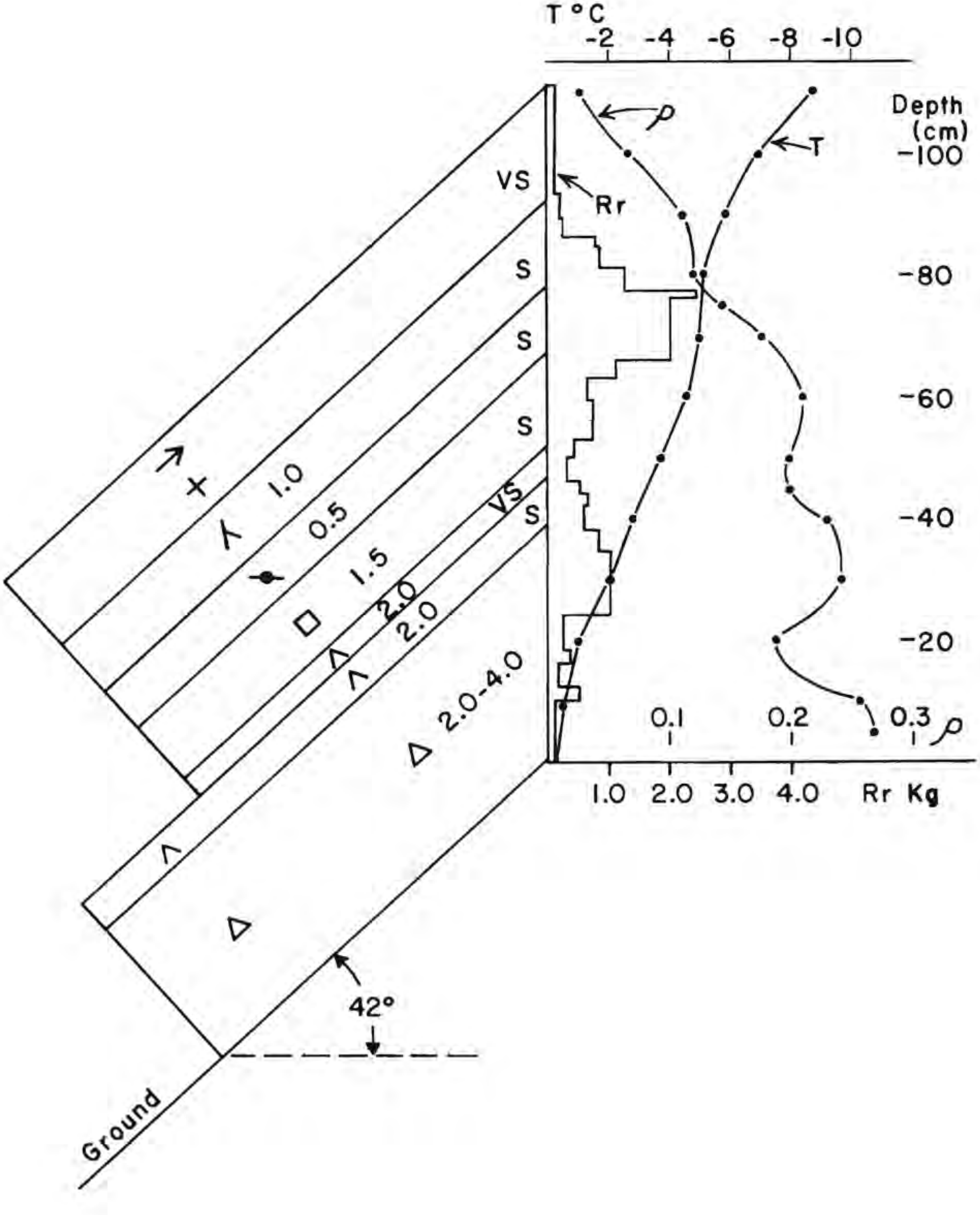

Figure 19. Fracture line profile data obtained from a soft-slab, artificial (artillery), size two event which ran to the ground on 22 Dec., 1974. The path is the Silver Ledge Mine (152100) with a slope aspect of 40° true.

of 1973 encountered a thick layer of well-developed temperature-gradient snow near the ground in most release zones. Avalanche activity had been minimal during the preceeding winter within many paths, causing the percolating free water to come into contact with a complex stratigraphy which, in some cases, had been developing during the previous four to six months. The typical snow structure of the Red Mountain Pass area consisting of alternating layers of weak temperature-gradient snow and stronger freeze-thaw crusts and wind slabs, in combination with the melt water, created the conditions at the shear boundaries required to initiate slab-type avalanches. In contrast, during the 1974-1975 winter, very extensive avalanching occurred as a result of the extremely weak old-snow structure during December, January and February within nearly all observed paths. As a result, when optimum conditions for wet slab releases occurred, little or no snow structure conducive to this type of snow failure existed within the release zones. Instead, the structural regime was one which allowed releases primarily within the new snow. A comparable situation has been recognized in the Swiss Alps during seasons when late fall and early winter meteorological and snowcover conditions do not promote the formation of a layer of temperature-gradient snow near the ground. Without this structural weakness, which persists into spring, the opportunity for significant wet slab releases is eliminated.*

Avalanche Hazard Evaluation and Cloud Seeding Criteria

The inconsistent relationships which exist between precipitation patterns and avalanche events, caused by the complexities of snow structure, have been discussed in the preceeding chapters. The answer to the question, which is of primary concern when establishing cloud seeding criteria with respect to avalanche hazard, "does more precipitation mean more avalanches?" is "not always." Avalanches in the San Juan Mountains are largely precipitation-triggered but the climax character of 80 to 90 percent of the total events is directly related to snow accumulation and metamorphism patterns evolving over weeks or even months. A light snowfall, or its lack, in November may set the stage for an avalanche in February by providing, through complex processes, a weak failure plane deep within the snowpack. Since most precipitation events above a certain size will trigger at least a few avalanches, there may be a valid reason to avoid seeding a light storm which would thereby be pushed above the critical size. Heavy storms will usually trigger many avalanches naturally, so an additional increment in precipitation will probably not make any significant difference to avalanche activity. But the lighter storms can also leave a snow layer that may provide a later snowpack weakness to cause climax avalanching, and the enhancement of such a snowfall by seeding can diminish this possibility.

Due to the complex relationships that exist between a given period of avalanche activity and the intricate and often prolonged series of meteorological conditions, there appears no practical way to determine the effect of any single cloud-seeding event on subsequent avalanche patterns. The results of seeding, or not seeding, a storm in November could not be predicted in terms of how the particular stratigraphic layer within the snowcover composed of that precipitation event would react to an avalanche cycle two or three months later.

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*Frutiger, H., 1975: personal communication.

Even though the effect of seeding a given storm on subsequent avalanche activity, or even the failure to seed it, is extremely difficult to identify, certain criteria for the suspension, or initiation, of cloud seeding might be applicable. Artificial augmentation of snowfall theoretically could be used as an avalanche control or "management" technique. In light of previous discussions regarding the San Juan snow climate, periods might exist when seeding efforts could be used to augment precipitation and encourage avalanche activity at a time when smaller avalanches are anticipated, thus limiting the size of later avalanches. For example, the heavy seeding of the first big storm in December following a long period of cold clear weather and the associated development of unstable temperature-gradient snow within the existing shallow snowcover would cause extensive avalanching and remove the weak substructure, perhaps for the remainder of the winter. Such a procedure would be compatible with the basic concept of active avalanche control, the replacement of infrequent, but large avalanches with smaller frequent events. While small frequent avalanching would often cause a significant amount of snow to reach the respective highways due to numerous areas of bank slides, the size and impact force of such events would be less, thus representing a reduced hazard level. Finally, if storms approaching from various directions were to be seeded, avalanche paths would be grouped in order to consider each group with respect to appropriate precipitation patterns. For example, many short paths affecting the highway in the Uncompahgre Gorge respond in an entirely different manner compared to the high release zones to the south of Red Mountain Pass, such as the Muleshoe group, when a storm approaches from the north.

In summary, let us assume that the basic aim of augmenting winter precipitation would be to optimize seeding results and minimize avalanche hazard. It has been shown that increased snowfall and increased avalanche hazard are not always directly related. In addition, precipitation augmentation by seeding is dispersed over a wide area, while avalanche problems exist only in a few concentrated locations, with high hazard areas being even less numerous. To generally reduce or suspend seeding in order to reduce the effects of avalanches, especially within the San Juan snow climate, would be extremely inefficient both with respect to seeding results as well as reducing avalanche hazard. The natural variations in hazard are much greater than any likely to be produced by snowfall augmentation. Due to the extreme complexities presented by this situation, it is suggested that operational cloud seeding in this area might best proceed for optimum yield, with the avalanche question being dealt with by an effective hazard evaluation (natural and artificial) and forecasting effort that would work with the augmented snowcover as it actually develops each winter. These data would provide the basis for an information service which would issue warnings as well as implement road closures and control measures. If such a comprehensive program were conducted with maximum efficiency, public safety would, without question, be increased over conditions where a natural precipitation regime, but no such hazard identification effort, existed.

To emphasize the point further, it can be stated categorically that the existing avalanche-control procedure along Highways 550 and 110 could be rendered much more efficient with relatively little expenditure. The following procedure should be undertaken whether or not an operational cloud-seeding project is applied to this area: artificial release of avalanches at a time when initial snowcover instability exists but before the resulting artificial event would present a significant hazard, i.e. produce a series of small, less harmful avalanches rather than one large event. Such a procedure must be implemented during storm periods and therefore necessitates a methodology which is not dependent on the release zone being visible. INSTAAR, in cooperation with the University of Washington, Seattle, Washington, is currently involved in the development of techniques to artificially release avalanches by remote methods (LaChapelle, et al., 1975).

Review of Operational, In-house Forecasting Procedures

(The following is reproduced from Chapter 4 of
INSTAAR Occasional Paper No. 13, 1974, and is written by E. R. LaChapelle.)

During the first winter of the Project, practical experience with the area was being developed by the Project staff. Forecasting and evaluation of avalanche hazard were limited to an informal basis. During the second and third winters, a formal forecasting program was established. Daily evaluations and forecasts were prepared and then were evaluated 24 hours later for accuracy. The method of compiling forecasts and the summary of their evaluations for the second winter have been discussed briefly in the Second Interim Report (September, 1973), Chapter 4, pp. 32-35. The same method of compiling forecasts was continued the third winter. Results from the third winter will now be given and the significance analyzed in more detail.

Briefly recapitulating, the avalanche forecast each day for the coming 24 hours was assigned an index number from I to V according to the anticipated degree of snow instability. The degree of instability characterized by each index number is given in Table 10. At the end of each 24-hour period (nominally from 0900 to 0900 each day) the actual degree of instability which was observed during the period was described by the same index numbers. This constituted the evaluation. Because the forecasting duty was rotated each day among the Project staff (three forecasters the second winter, four the third), the evaluation of the previous day's forecast was done by a different person than the forecaster and a degree of objectivity was preserved. This indexing method described here is a simple formalization for the results of conventional avalanche forecasting procedures which combine empirical experience with an analysis of contributory snow and weather factors. Other observers in other areas might well choose a different scale of index numbers or define them differently, but the basic methodology would be essentially the same. To this extent, the San Juan Avalanche Project has simply applied standard, developed practice in avalanche forecasting to a specific mountain area, then sought to maximize its accuracy on the basis of informed experience.

TABLE 10 NUMERICAL STABILITY INDEX

I.	Highly unstable:	More than 50% of slides that frequently run full track may be expected to run naturally. The remainder of all slides would react to control or run partially.
II.	Unstable:	Ten percent of slides that frequently run full track would run naturally. Most of the remainder would react to control or run partially.
III.	Transitional A:	Rare natural occurrence. Some slides would react to control depending on history or location. Index useful after a period of instability or during storm genesis.
IV.	Transitional B:	Some pockets of instability remaining or building in the absence of, or during insignificant precipitation.
V.	Stable:	Natural occurrence absent. Release only under extreme artificial conditions.

TABLE 11 AVALANCHE PATHS CONSTITUTING MAJOR

HAZARD TO U.S. HIGHWAY 550 BY GROUP

Ledge:	3 indistinct small paths
Muleshoe:	5 large paths
Brooklyns:	19 medium size paths
Champions:	4 medium size paths
Cement Fill:	1 path; complex starting zones
East Riverside:	1 path; complex starting zones

Additionally, beginning in mid-winter of 1972/73 and for the full winter of 1973/74, an attempt has been made to prepare highly specific forecasts for certain groups of avalanche paths which constitute the major hazard to U.S. Highway 550 in the research area. Each of these groups is geographically limited in extent and consists of paths with similar characteristics and behavior. These paths are listed in Table 11. Each day a short-term (3-hour forecast--essentially a current evaluation) plus a 24-hour forecast was prepared for each of these groups. These forecasts specified whether a natural release was likely and whether release by artificial triggering was possible. Furthermore, probable avalanches, both natural and artificial, were specified according to whether they would run in the upper track, to mid-track or for full length of the path for each group.

This degree of specificity introduces a new advance in avalanche forecasting in the United States. To our knowledge, no such forecasting precision has heretofore been formally and systematically attempted for an entire winter on so many diverse avalanche paths. The results discussed below demonstrate that forecasting of this type is operationally feasible in the hands of trained and experienced observers. Following the format in the Second Interim Report (Table 4, p. 35), the summary of forecast evaluations for the general forecasts (index numbers) is presented in Table 12. The final (end-of-season) evaluation is ommited, for improved rigor of the 24-hour evaluation was obtained during the third winter. Days for which either a forecast or an evaluation are missing are omitted from this summary.

Discussion and analysis are essential to understanding the bare information presented in Table 12. First, the index numbers form an ordinal scale divided on an arbitrary and not necessarily uniform basis. A substantial amount of subjective judgment is involved in assigning the index to any given forecast, no matter what degree of objectivity may have gone into the forecast itself. This is less true of the evaluation, which can be based in most cases on actual observation of avalanche occurrences, but even here the distinction between Index Conditions IV and V is not easy to determine. Consequently, the evaluation of forecast accuracy in Table 12 can be regarded only as a general indicator rather than a highly specific assessment. In the winter of 1973/74 there were 26 forecasting errors (evaluation index differed from forecast index) out of 128 days examined, giving an overall accuracy rating of 80%. Out of these 26 errors, 12 involved an error between Index IV and V, a distinction determined by subjective assessment of rather stable conditions largely irrelevant to serious avalanche hazards. Eleven more of the errors involved Index III, a transitional state predicting rare natural avalanche releases. Thus there remained only three errors for the entire winter involving Index II; the other two were overestimates of hazard. While the overall accuracy declined slightly from the second to the third winter (80% vs. 82%), this, in part, was a consequence of many more Index IV days occurring the third winter, a condition difficult to evaluate accurately. The maintenance of nearly the same accuracy in spite of this fact speaks for an increase in forecasting skill which is further born out by the success

TABLE 12

EVALUATION OF AVALANCHE FORECAST METHOD

1973-1974

Month	Days	% Accuracy	Number of Index Days (evaluated)				
	Examined	24 hr. eval.	I	II	III	IV	V
Nov.	12	58				3	9
Dec.	29	76		2	5	12	10
Jan.	30	90		4	10	13	4
Feb.	27	78			5	8	14
Mar.	30	84		3	6	9	12
Totals	128	Average 80		9	26	45	49
		1974-1975					
Nov.	24	79		1	9	14	
Dec.	28	89		3	18	7	
Jan.	29	90	4	4	17	4	
Feb.	26	81		5	15	6	
Mar.	29	83		5	12	12	
Apr.	29	86		1	14	12	2
Totals	151	Average 85	4	19	85	55	2

(If avalanche forecast errors caused by inaccurate weather forecast data are excluded the average accuracy for the 1974-1975 winter increases to 91%.)

in forecasting for specific path groups (see below). With only one failure to foresee a serious instability (Index II) out of nine such days during the winter, the practically important forecasting accuracy is in fact 89%.

Of much greater importance to practical avalanche hazards in the San Juan Mountains is the specific and detailed forecasts for avalanche path groups which affect U.S. 550. In Table 13 these forecasts for the winter of 1973/74 are compared with the record of actual avalanche occurrences which deposited snow on the highway. This, like the Index II situation above, is the only real test of forecasting accuracy: were the forecast procedures actually able to predict the avalanches which did occur? Including all the forecasts of stable conditions in a forecasting accuracy assessment gives a distorted picture, for stable conditions prevail most of the time. (In fact, someone completely ignorant of avalanche forecasting and the target area could achieve a creditable paper score by simply forecasting no avalanches every day of the winter--but practically this would be useless.)

For the 26 days on which avalanches reached the highway, forecasting errors were made on 7 days, giving a formal accuracy rating of 73%. Of these 7 errors, 3 involved the failure to predict large natural avalanches and, hence, were the most serious failures. More significant than the errors, though, is the fact that avalanches, both natural and artificial, were predicted on numerous occasions with high precision. Considering the technical difficulties of making such specific forecasts and the fact that new ground was being broken in the application of conventional forecasting procedures, the overall accuracy depicted in Table 13 is remarkable. Trained and experienced observers, building on experience with a given area, can apply conventional avalanche forecasting techniques in a highly specific fashion with good success.

Closer examination of some of the errors in forecasting avalanches which reached the highway is instructive. One error, that of 2 March, occurred when high wind transport of snow, developing after the forecast had been prepared, led to natural releases. The area meteorological forecast failed to predict this high wind. Four of the 7 errors occurred during the first half of March, during a period of transition from winter cold snow to spring wet snow conditions. Two of the errors, 12 and 15 March, were made by an inexperienced observer who was not alert to the problems of this transition period, but this period may, in fact, be a difficult one to forecast even by an experienced hand.

The daily forecasts during 1973/74 were prepared on a rotating basis by four different observers except for November, when one man did most of both forecasting and evaluating. These four observers can be ranked in order of decreasing experience as follows:

Observer A - Many years of experience with avalanche forecasting and control at a major ski area. With San Juan Project all three years.

Observer B - Diverse but interrupted experience with avalanche forecasting and control in ski areas. With San Juan Project all three years.

Observer C - Experienced meteorological observer but no avalanche experience prior to San Juan Project. With Project all three years.

Observer D - Experienced meteorological observer but no avalanche experience prior to 1973/74.

Observer D was intentionally added to the staff the third winter in order to ascertain how much of the developed experience with forecasting in the San Juan Mountains could be communicated to a newcomer. The individual forecasting scores (as determined from the Index analysis) for these four observers are listed in Table 14. Obviously, the forecasters were conservative: overestimates of hazard predominated over underestimates, 18 to 8. The newcomer accumulated a substantial error score, as might be expected, but even maximum experience does not guarantee success, for Observer A made the only underestimate of an Index II condition for the entire winter. Observer B's high error score is perhaps unfair, for 5 of the 12 errors were recorded in November when he was the only observer preparing his own evaluations, which he did all too consciencious1y when dealing with the tricky problems of separating Index IV from Index V.

The record of operational avalanche forecasting by the San Juan Project has demonstrated to date that application of conventional methodology, informed by the accumulated data on conditions peculiar to the San Juan Mountains, can lead to a successful general forecasting scheme and can, furthermore, allow the state of the art to be carried to the point where highly specific and accurate forecasts can be generated for individual avalanche paths or path groups. Forecasting accuracy is by no means 100% overall, but critical errors involving the prediction of serious snow instability have been reduced to a remarkably low minimum. In spite of the complex character of the natural phenomena involved, plus the uncertainties of mountain weather forecasts, it can be safely stated that an operational avalanche forecasting scheme is possible for the San Juan Mountains based on conventional procedures alone. The remaining problem now is to place the developed methodology on a formal basis which can be communicated to subsequent users. As a first step to this end, the four forecasters working during winter of 1973/74 were asked to put down on paper their individual operating procedures, including a list of the contributory factors which they reviewed in preparing their daily forecasts. The results are illuminating, but difinitely leave some unsolved problems.

Table 15 summarizes the factors of terrain, weather, snow and avalanche occurrence that each observer/forecaster deemed to be significant in his own forecasting. The outstanding feature of Table 15 is the lack of agreement on what was significant. Each forecaster obviously had his own ideas about how to forecast avalanches, or at least said he did.

The latter seems to be the actual case, as will be developed in this discussion. There is only one unanimous factor--wind speed and direction. Several other factors, such as snow stratigraphy, precipitation intensity, old snow stability, and new snow density and crystal type, are uniformly recognized as important by the experienced men. Obviously, the newcomer had developed a much shorter list of factors during the short history of his experience. This is only to be expected. But some of the anomalies among the experienced observers are less expected and deserve comment. Two observers, A and C, gave strong emphasis in their written reports to test-skiing on test slopes near the Red Mountain Pass station during storms. This is the classic and effective method of identifying soft slab, direct-action avalanche conditions. It is addressed to instabilities in new-fallen snow but is notoriously unreliable for climax avalanche conditions. The three-year record of fracture line profiles accumulated by this Project have demonstrated that no less than 89% of all avalanche releases examined are climax in nature. Does this reliance on test skiing come from habit? Does it represent self-deception on the part of the observers, or is there a real link between new snow instability and climax avalanche release in the San Juan Mountains whose physical nature has yet to be established? Further examination of Table 15 reveals other peculiarities. For instance, only two observers reported that they considered topographic features and current winter avalanche history of individual paths in preparing a forecast. Consideration of these factors is essential to the success in specific path forecasting described above. In fact, such forecasting is impossible without regard to these factors. It seems obvious that the other forecasters indeed did take them into account, but failed to so report.

The general conclusion here must be that the forecasters' written reports about what they did diverge widely from what they actually did. These men have definite skills in recognizing unstable snow, sharpened these skills for a particular area, and were able to communicate some of them to a newcomer on a daily tutelage basis. But the systematic codification of these skills and their written transmission is yet an unsolved problem. This problem is not peculiar to this Project, for it has been reported many times over by other workers in the field. In fact it is not peculiar to avalanche forecasting. A speed skater can tell that one rink has a different "feel" from another but he cannot explain what the difference is. A master baker can judge unerringly the quality of bread dough, but he cannot explain in words how he does it. An Australian aborigine can predict the occurrence of rain many miles away while leaving a Western observer completely puzzled about how he does it. Such examples can be multiplied many times over whenever complex natural phenomena are involved in human perception. Solution to this problem of how to communicate ill-defined but real skills is a pressing goal in psychology which lies outside the scope of this present study. We must conclude that an accurate forecasting methodology for the San Juan Mountains can be developed and applied by using conventional forecasting methods, but that this in large measure must be done by on-the-job training and experience rather than by formal pedagogy.

Nevertheless, a reasonable synthesis can be made of the forecasters' experience in this research area by examining the composite forecasting methodology in the light of information developed by investigating the physical causes of avalanching in the San Juan Mountains (summarized in Chapter 3). The conclusions reached in this fashion constitute the essential finding of this Project for the application of conventional forecasting methodology to this area. The following specific factors will need to be considered by anyone producing operational avalanche forecasts for the San Juan Mountains:

1. Dry snow avalanches are very predominantly the climax soft slab type. This information tells the experienced forecaster that he is dealing with an unstable snowcover of low structural strength and with frequent weak interface bonding between snow layers. Most, but not necessarily all, significant precipitation events will load at least some slopes to the point of failure.

2. Major avalanches generated by fair-weather transport of snow by the wind are rare. Only one path, Cement Fill, consistently produces a threat to the highway from this source.

3. Wet snow avalanches are confined to a clearly-defined spring cycle associated with initial thaw of the snow cover. Onset of wet avalanching appears to be closely related to rise of the mean daily air temperature above $0^{\circ}C$ in the release zones.

4. There are large meso-scale variations in snowfall and avalanche activity within the study area. Snowfall distribution is strongly affected by meteorological character of individual storms and especially by prevailing direction of moisture-laden winds.

TABLE 13

FORECASTING RECORD FOR AVALANCHES REACHING U.S. 550
WINTER OF 1973/74

The specified forecast in each case is for the period of 24 hours or less during which the avalanche event took place. Numbers following avalanches give depth and width on highway in feet. "A" means artillery release, all other events are natural.

Occurrence Date	Forecast	Avalanche Event(s)	Remarks
Dec 14	Natural slides in upper parts of paths	Blue Point 2 20	FCST OK
Dec 18	Natural slides in upper parts of paths	ERS Left 4 20 Blue Point 3 50 Mother Cline 6 25 ERS South 3 30	FCST OK
Dec 28	Artificial release possible, no natural slides	Willow Swamp 2 75	Natural instability underestimated
Dec 29	Brooklyns will run naturally to full track	Blue Point 2 70 Brooklyns B 2 50	FCST right on
Dec 30	Eagle and Telescope to mid-track evening of 29th, full track AM on 30th. (Natural release)	Eagle 3 50 Eagle I 100 Telescope 6 350	FCST right on
Dec 31	Full-track artificial releases possible in Muleshoe Group	Eagle A 3 150 Telescope A 2 100	FCST right on
Jan 5	Natural releases to run full-track.	Brooklyns G 15 250 Eagle 3 50 Porcupine 3 50 Rockwall 8 100	FCST right on
Jan 6	Artificial releases possible, running full-track	Brooklyns C A 2 75 East Riverside A 5 70 15 80	FCST right on
Jan 7	Artificial releases possible, running full-track	Brooklyns C A 1 25 Silver Ledge A 4 75	FCST right on
Jan 8	No natural slides	Willow Swamp 11 200	FCST ERROR

TABLE 13 (continued)

Occurrence Date	Forecast	Avalanche Event(s)	Remarks
Jan 9	General Class II hazard	Lime Creek 8 700 3 50	FCST OK
Jan 10	Artificial releases possible, running to mid- or upper track.	Mother Cline A 1 20 Willow Swamp A 15 250	FCST right on
Jan 11	Artificial releases possible, running to mid- or upper track.	Champion A 14 250	FCST right on
Jan 21	Natural releases running mid- or full-track	Blue Point 4 100 Rockwall 2 100 1 150	FCST OK
Feb 20	General Class III hazard on 19th, artificial releases possible on 20th but not natural slides	East Riverside 4 50 East Riverside A 14 Mother Cline 10 300 Silver Point 6 20 Blue Willow 2 20 Blue Point A 4 25	FCST ERROR for natural slides FCST OK for artificial releases
Mar 1	Stable conditions, no avalanches	Dunsmore 1 30	FCST ERROR
Mar 2	Stable conditions, no avalanches (fcst made March 1)	East Riverside 12 70	FCST ERROR (Mar 1 & 2 slides caused by high winds missed by weather fcst)
Mar 7	General Class III hazard, no activity for specific slide groups	Blue Point 5 100	FCST Marginal
Mar 10	General Class II hazard	Willow Swamp 4 80	FCST OK
Mar 11	No natural or artificial releases	East Riverside A 13 100 A 13 100 Blue Point A 7 30	FCST ERROR
Mar 12	No natural slides on Champion, no forecast given for artificial releases	Champion A 3 30	FCST not verifiable

TABLE 13 (continued)

Occurrence Date	Forecast	Avalanche Event(s)	Remarks
Mar 15	Stable conditions, no avalanches	Champion 8 40	FCST ERROR
Mar 16	Wet loose snow instability, natural releases to mid- or full-track	Blue Willow 3 60 Champion 4 25 Blue Willow 4 25 Champion 5 50 Brooklyns I 5 55	FCST right on
Mar 18	Class III condition for wet loose slides, otherwise stable	Mother Cline 3 20	FCST OK
Mar 17	Class II condition for wet loose slides	Blue Point 2 6	FCST OK but overstated
Mar 19	General instability for wet loose slides	Jackpot 2 70 Mother Cline 3 60	FCST OK

TABLE 14

FORECASTING ERRORS BY OBSERVERS

+ = hazard overestimated   - = hazard underestimated

Error by Index Number	Number of Events
A	
+1	2
-1	2 (one involved failure to predict II)
	4
B	
+1	6
+0.5	2 (one overestimated a II)
-1	3
-2	1
	12
C	
+1	1
-1	1
D	
+2	1
+1	6 (one overestimated a II)
-1	2
	9

Total of 26 errors in 128 evaluation days.

-11 involved III

- 3 involved II

TABLE 15

Factor	A	B	C	D
General Stratigraphy		X		X
Study Plot Stratigraphy	X	X	X	
Carbon Mtn. Stratigraphy	X		X	
Explosive Tests			X	
Ski Testing - Carbon Mtn.	X		X	
Weather Forecast			X	
Storm Precip. (Amount)	X		X	X
P.I. / S.I.	X	X	X	
Slope Loading (Precip. & Wind)			X	
Old Snow Stability	X	X	X	
Old Snow Sfc		X		X
Old Snow Depth			X	X
New Snow Properties (General)		X	X	
Specifically: Density	X	X	X	
Crystal Type	X	X	X	
Structure				
Depth	X			X
Old Snow - New Snow Bond			X	
Unstable Stratigraphy Patterns			X	
Wind Speed & Direction	X	X	X	X
New Snow Temperature		X	X	
Lt. Wt. Ram			X	
Tilt-board	X			
Current Avalanche Releases	X			
Air Temperature & Trend	X	X		X
Wind Drift in Clear Weather	X			
Snow Depth in Starting Zones		X		

TABLE 15 (continued)

Factor	A	B	C	D
Starting Zone Terrain		X	X	
Winter Meteorological History		X		
Avalanche Occur. History		X	X	
Meso-Scale Snowfall Distribution		X		

DAILY FORECAST AND EVALUATION RED MOUNTAIN PASS

X = natural
0 = artificial

date time observer

GROUPS	PRESENT FORECAST (3 hour) YES	NO	24 HR FORECAST (based on E.G. & G.) YES	NO	SLIDES WILL RUN TO: upper track	mid track	full track	HIGHWAY (yes/no)
Riverside								
Ledge								
Mule Shoe								
Brooklyns								
Cement Fill								
Champion								
REVISED FORECAST	time			observer				
Riverside								
Ledge								
Mule Shoe								
Brooklyns								
Cement Fill								
Champion								

COMMENTS:

EVALUATION: date____________ evaluator____________

CHAPTER 4: WET SNOW AVALANCHES

Richard L. Armstrong

By definition, the potential for wet avalanches is absent as long as the entire snowcover is below 0.0°C. Water in the liquid phase and thus a snow temperature equal to 0.0°C is the required ingredient for the formation of wet avalanches. Because of this rather simple relationship, it is sometimes felt that the time and location of wet avalanche releases can be predicted with greater precision than dry snow avalanches. Whether or not this is true, the need to accurately forecast wet snow avalanche occurrence is acute. This is because unlike dry snow, a wet snowcover does not respond in the desired manner to control by explosives. The physical properties of the wet snow suppress the propagation of the shock wave essential to the release of a snow slab. This condition may be due to an accelerated rate of stress relaxation through creep, preventing the existence of a mechanical condition comparable to the unstable dry slab. Therefore, while an efficient mid-winter avalanche control program may be capable of eliminating major portions of a given hazard, a comparable opportunity is not available in the case of wet snow avalanches. Wet avalanches must be forecast as natural occurrences and appropriate precautions taken at the predicted time and location of the event.

The need to acquire specific information regarding wet snow avalanches in the Red Mountain Pass area is emphasized by the fact that more than 30% of the avalanches recorded during the 1972/73 and 1973/74 winters were within this category. Of the avalanches reaching the highway, again more than 30% were of the wet snow type. Perhaps the most readily available data which can be used in the forecasting of wet snow avalanches is air temperature. Figures 20 and 21 show the relationship between mean daily air temperature as measured in a standard weather shelter at the snow study site at Red Mountain Pass and the occurrence of wet snow avalanches for the two periods, April 25-29 and May 7-12, 1973. Figure 22 shows this same relationship for March 15-19, 1974. The fact that temperature values exceed the freezing point at the time when the avalanching begins is simply a coincidental index value. Air temperatures within the areas of some starting zones may well be lower than those recorded at the Red Mountain Pass study site and snow temperatures of certain south-facing release zones could be expected to be higher than snow temperatures within the study site. However, these index values, as observed for two spring avalanche cycles do provide substantial information regarding event forecasting.

The following is a discussion of some of the meteorological and snowcover data which influence the formation of wet snow avalanches. The value of each parameter is analyzed in terms of wet snow avalanche forecasting in the Red Mountain Pass area of the San Juan Mountains. While the San Juan Avalanche Project has been in operation for three winters, data regarding wet snow avalanches is available for only two of these. This is because the 1971/72 winter experienced a low total snowfall, 60% of the fifteen-year average according to the Soil Conservation Service. In addition, several storms during the late winter produced sustained periods of high winds resulting in the catchment

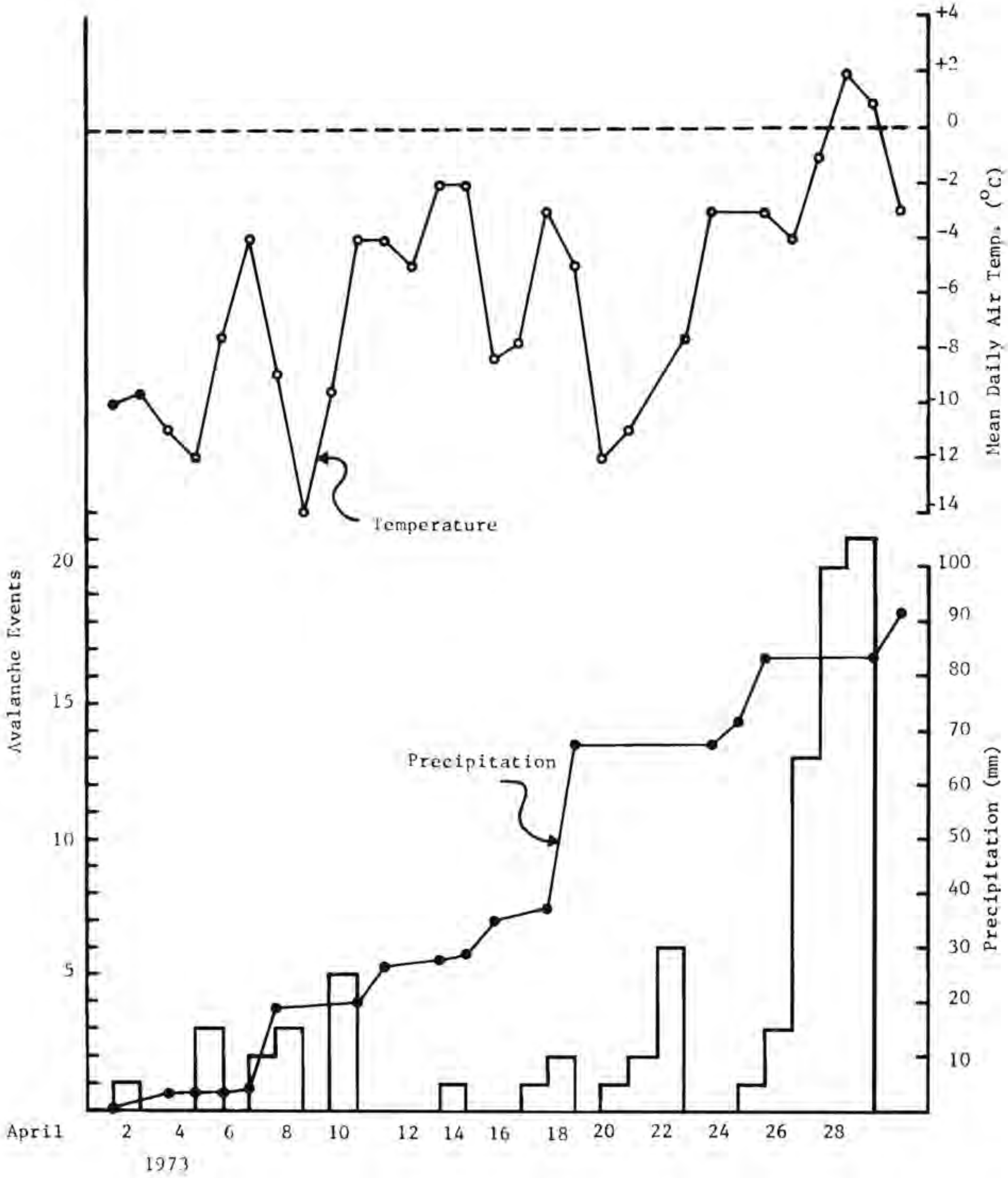

Figure 20. Wet snow avalanche events observed during April, 1973 compared to precipitation (mm) and mean daily air temperature (°C) recorded at Red Mountain Pass.

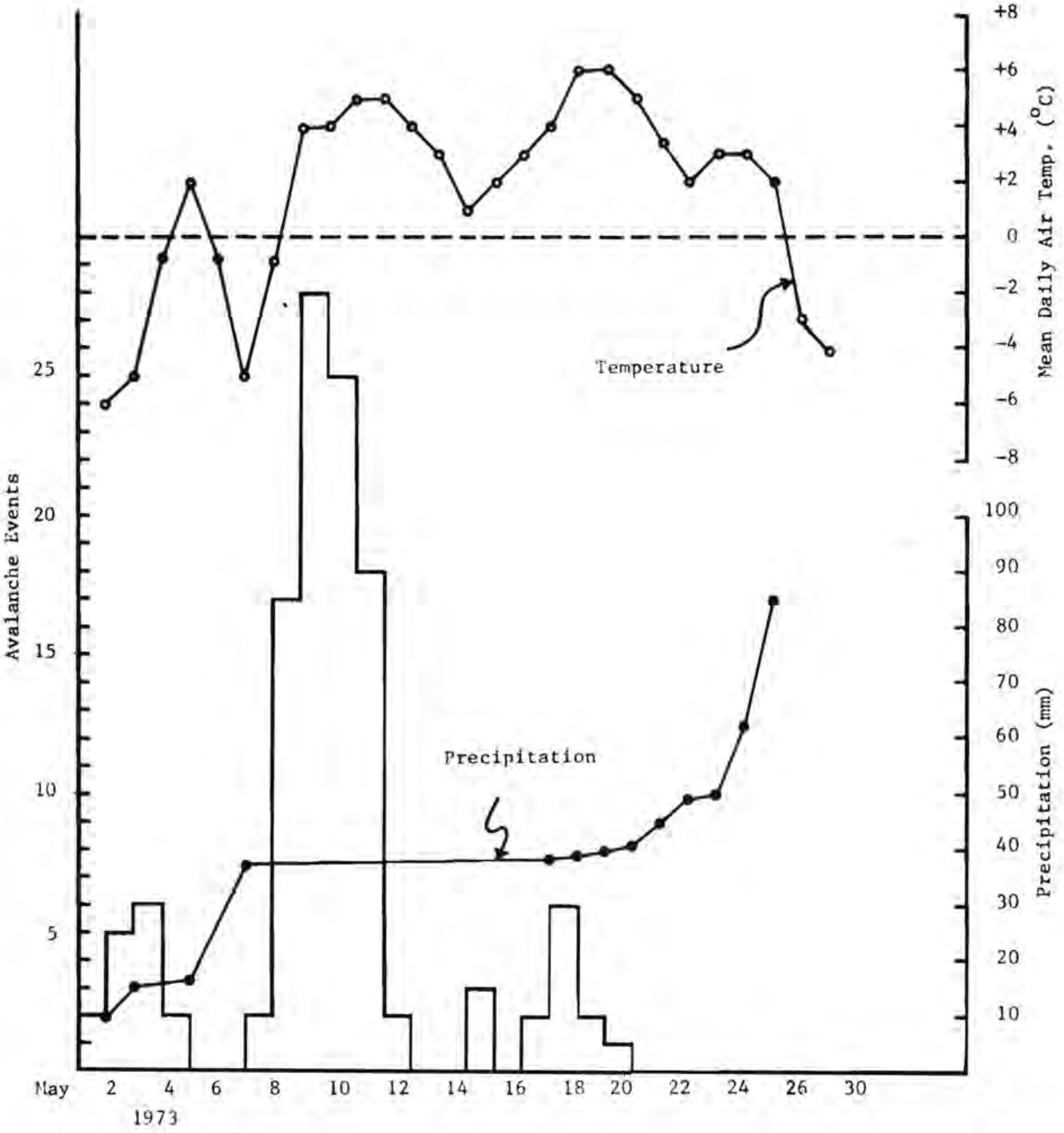

Figure 21. Wet snow avalanche events observed during May, 1973 compared to precipitation (mm) and mean daily air temperature (°C) recorded at Red Mountain Pass.

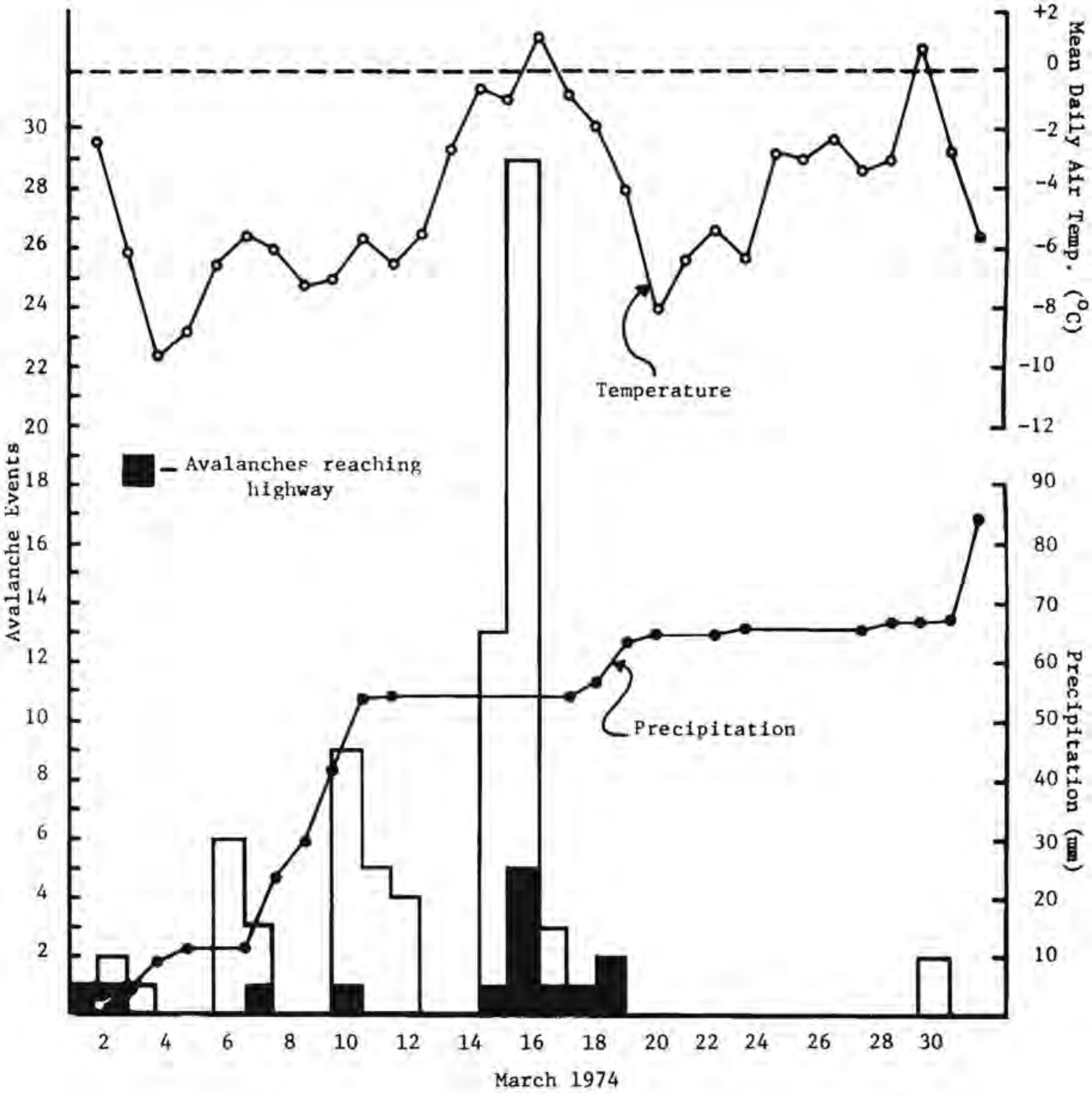

Figure 22. Wet snow avalanche events observed during March, 1974 compared to precipitation (mm) and mean daily air temperature (°C) recorded at Red Mountain Pass.

basins, which would have been the release zones for wet avalanches, being scoured free of snow. During late April and early May of 1973, a series of significant wet avalanches occurred. During March of 1974, numerous wet avalanches also occurred, and while they were smaller in magnitude and frequency than those of 1973, they did offer an additional opportunity to study this phenomenon.

A basic objective in the study of avalanches in cold (below 0.0°C) snow is to understand the relationship between changing strength and stress patterns. This changing stress pattern is the product of additional loading to the slope in the form of newly deposited snow with strength being a function of varying stratigraphic conditions. In the case of spring or temperature-induced avalanches, the primary emphasis is placed on changes in strength. Generally, this type of avalanche occurs without the additional loading of precipitation but with a condition of decreasing snow strength combined with a fixed stress pattern. It is possible that snowfall may occur at a time when such an additional load will contribute to wet avalanche release. However, the dominant pattern of decreasing snow strength had already provided the primary condition for release.

This decrease in the bulk strength of the snowcover is the result of a decrease in intergranular cohesion. Heat is available to melt these intergranular bonds from the increasing air temperatures (conductive or molecular component) and the greater amounts of solar energy (radiation component) available at the snow surface at the onset of spring conditions. The process of warming the snowcover is gradual and can take on the order of 15 to 30 days in the San Juan Mountains to change the snowcover from a mid-winter temperature regime to isothermal. When a given portion of the snowcover becomes isothermal, the bonds between the grains melt. Such bonds are the product of an earlier sintering process associated with equi-temperature metamorphism.

The effect of a warm rain falling on a sub-freezing snowpack must be considered within certain climatic zones, but such a condition is not known to occur in the San Juan Mountains. Rain falling on isothermal (0.0°C) snow provides negligible temperature gradients for conductive heat transfer and thus little energy for melting is introduced.

While increased solar energy is the cause of higher air temperatures, the effect of direct radiation is low on a snowcover with an albedo of 90 percent or greater. This value, however, drops to approximately 60 percent when the snow becomes wet. Also, some short-wave radiation penetrates 10-20 cm into the snowcover, causing near-surface melting. During midwinter, this has little effect on the temperature regime of the snowcover as a whole. As long as the major portion of the snowcover remains below 0.0°C, this warming of the surface layers to the freezing point may have no more effect than to release occasional small wet loose surface avalanches. The stronger midwinter temperature gradient slowly diminishes primarily as a long range function of heat conduction and insolation. This condition can be observed indirectly via mean daily temperature values.

Once the potentially unstable snow layer has been warmed to 0.0°C throughout, the entire amount of solar energy is available for the melting process. As initial melt occurs, small amounts of free water cling to the grains due to surface tension. As melting accelerates, free water begins to flow down into the snowcover. The rate of flow depends on the temperature and structure of the snow as well as the actual amounts of free water. The water flows until it either freezes due to contact with a colder layer or is blocked by an impermeable layer. The water will spread out over such layers until additional percolation channels can be created. As increasing amounts of free water become available, percolation continues, ice layers deteriorate and heat is transferred further down into the snowcover.

The metamorphism, strength, and densification of wet snow are controlled by the small temperature gradients between the grains. In order to describe these processes, Colbeck (1974) has catagorized the saturation regimes in wet snow as either pendular or funicular, i.e., low or high saturation respectively. At low values of saturation, the water volume is greater than the capillary requirement, but less than that necessary to cause adjacent water volumes, separated by air bubbles, to coalesce (Figure 23). In this regime, the water pressure is much less than atmospheric pressure and the air phase exists in more or less continuous paths throughout the snow matrix.

In the funicular regime saturations are greater than 14% of the pore volume and the air occurs in bubbles trapped between the ice particles (Figure 24). The equilibrium temperature of the snow matrix is controlled by the size of the air bubbles and the size of the ice particles and, for any given air content, the particle sizes dictate the distribution of temperature locally within the mixture of ice particles. The smaller particles exist at a lower equilibrium temperature, causing heat flow from the larger particles and rapid melting of the smaller particles. The result is the disappearance of the smaller particles and the subsequent growth of the intermediate and larger particles. The average particle size increases without a significant change of density in the snow matrix.

The thermodynamics of the pendular regime is significantly different because of the lesser cross-sectional areas of water available for heat flow and the existence of another interface, the gas-solid surface. The equilibrium temperature of the matrix is a decreasing function of both capillary pressure and particle size. At small water contents, the temperature differences between particles and the area of heat flow are both reduced and much lower rates of grain growth are observed. The large "tensional" forces developed in the water phase give strong intergranular attractions and the bonds assume a finite size which is determined by the relative effects of capillary pressure and particle size. The strength of snow at low water saturations should be high. Much of the grain-to-grain strength in the pendular regime is caused by the water "tension" drawing particles together. In spite of the large stresses induced by the attractive forces, no melting occurs at the grain contacts because the large values of capillary pressure reduce the temperature of the entire snow matrix.

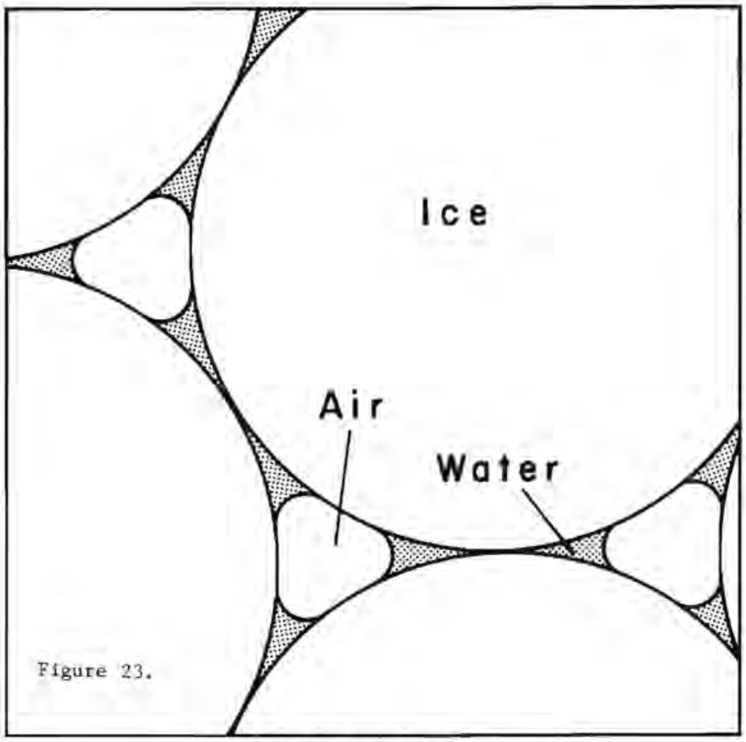

Figure 23.

Pendular Regime

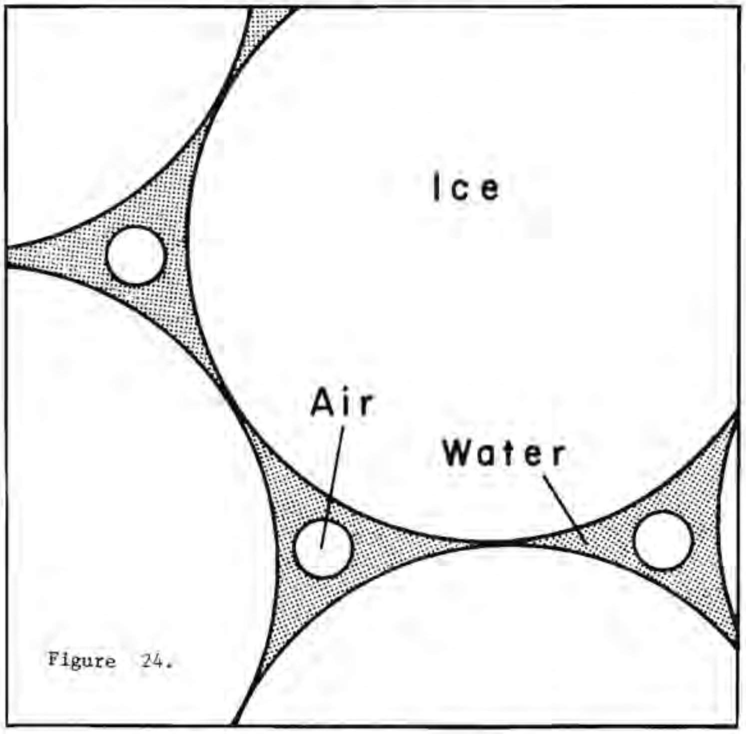

Figure 24.

Funicular Regime

In the funicular regime rings of water coalesce forming isolated bubbles of air trapped between the ice grains and the water phase exists in continuous paths completely surrounding the snow grains. The permeability to liquid water is greatly increased at larger saturations and the capillary pressure, or "tension", of the liquid water is reduced. In the funicular regime, the equilibrium temperature at a contact between grains is decreased by the compressive stress between the grains. The temperature depression is further increased by overburden pressure causing melting of the intergrain contacts and removing bond-to-bond strength.

Optimum conditions for the existence of the funicular regime would occur over impermeable boundaries, at stratigraphic interfaces, and within highly permeable zones capable of large flow rates. The type of snow structure common to the Red Mountain Pass area, consisting of alternating layers of coarse-grained, cohesionless temperature-gradient snow and stronger freeze-thaw crusts and wind slabs, would be highly conducive to the funicular regime. Melt associated with the equilibrium temperature depression occurring in the funicular regime would create extensive zones of minimal shear strength and provide those conditions contributing to the release of wet-slab avalanches.

Once the bulk of the snowcover has become isothermal, the immediate potential for wet avalanche release is greatly increased. The next period providing significantly warm air temperatures will be of much greater importance than an earlier period with comparable air temperatures but subfreezing snow temperatures. As noted above, wet snow has a lower albedo than dry snow. Therefore, as the surface layers begin to melt, the wet snow is capable of absorbing more solar radiation, which in turn causes more melt to occur. Once the deteriorating strength of the snowcover reaches the point where it can no longer resist gravitational stresses, it will release as either a loose or wet slab avalanche, depending on shear boundary conditions. These boundaries may be caused by stratigraphic irregularities within the snowcover or the snow-ground interface itself. While the slab type is often of greater magnitude, due to its release over a broader area, wet loose avalanches can also incorporate large amount of snow depending on how deep into the snowcover the percolation of meltwater has advanced prior to release, and how much additional snow may be released by the moving avalanche.

As mentioned above, the effect of rising air temperatures on avalanche occurrence is not independent of snow temperature. One would not expect significant wet snow avalanching if above freezing air temperatures occurred when the snowcover existed within a midwinter temperature regime. The first indicator of significant snow temperature increases occurs when the snowcover of the south-facing study area on Carbon Mountain becomes isothermal throughout. This has occurred approximately 10-15 days prior to significant spring avalanche cycles. In using the level study site as an index, the following observations were made. When the entire thickness of the snowcover has warmed to within 2.0°C or less of freezing, the possibility of thaw-induced avalanche events greatly increases. Once this criteria is met, the next requirement is for the mean daily air temperature to exceed the freezing level and at that point avalanches occur.

During both the late winter and early spring of 1973 and 1974, measurements of net all-wave radiation were made at the Red Mountain Pass study site. Daily net positive values did occur during these periods, but as with air temperature, such values were associated with significant wet snow avalanches only after the snowcover had warmed to the appropriate extent. Once this had been accomplished, daily net radiation values approaching zero (-5.0 to -15.0 cal/cm^2) occurred on those days just prior to the wet avalanche cycles. Because air temperature is partially a function of this radiation regime and since temperature data are both easier to record and reduce, greater emphasis is placed on the temperature parameter in the effort to forecast wet avalanche release.

As meteorological conditions begin to reflect a springtime regime, the responses within the snowcover are apparent at the study site. With the initial melting of intergranular bonds, rammsonde strength decreases. During both years when wet avalanches have been observed, this trend has been apparent prior to the beginning of the cycles. Snow settlement also appears to respond to the presence of free water within the snowcover. Accelerated settlement rates appear in late spring (see Figure 14, Chapter 2) but apparently occur only at that point when the snowcover is totally saturated with percolating free water, a condition which has occurred in the study site from two to six weeks following the wet avalanche cycle. Snow temperature is the critical parameter within the snowcover as values progress towards the freezing point. If the study site is to be used as an index, it would appear that when the entire snowcover has been warmed to a temperature between -2.0 and 0.0°C, conditions are adequate for wet snow avalanches given appropriate daytime air temperatures. These three parameters, air temperature, rammsonde resistance, and snow temperature, which do act as indicators before the fact, are shown for 1973 and 1974 in Figures 25 and 26 together with the avalanche event record. During both periods, snow temperature and rammsonde data have indicated that the stage was set, but in each case the avalanche cycle began only after the mean daily air temperature exceeded 0.0°C.

During both 1973 and 1974, an additional predictor has appeared in the form of wet snow avalanche events occurring on south and east facing slopes at elevations considerably lower than those of the release zones of the Red Mountain Pass area. On April 22, 1973, wet loose avalanches occurred on Engineer Mountain A (159); B (160); and C (161), five days prior to the major spring wet avalanche cycle. On April 25, 1973, a wet slab size three avalanche released to the ground on Engineer C, indicating the extent to which free water had penetrated the snowcover at that location. Again in 1974, a WS-N-3-G was recorded at Engineer B on March 12, three days prior to the major spring wet avalanche cycle. The elevation of the release area of the Engineer group is approximately 500 m lower than those with similar slope aspect in the Red Mountain Pass area. The value of wet snow

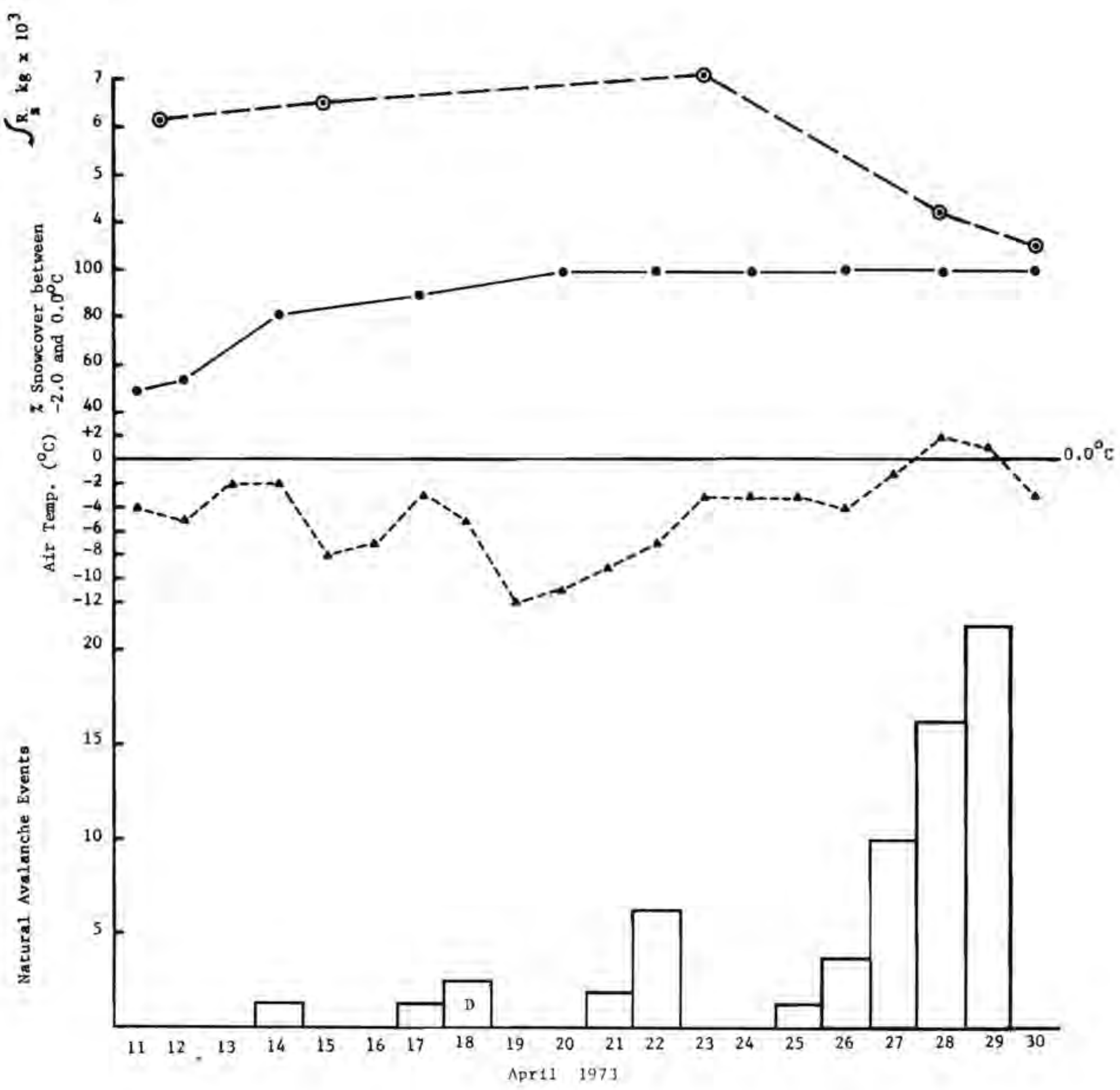

Figure 25. A comparison of integrated ram resistance, percent of snowcover between -2.0 and 0.0°C, and mean daily air temperature ($^{\circ}$C) at Red Mountain Pass and observed natural wet snow avalanche events during April, 1973. (D = dry snow event)

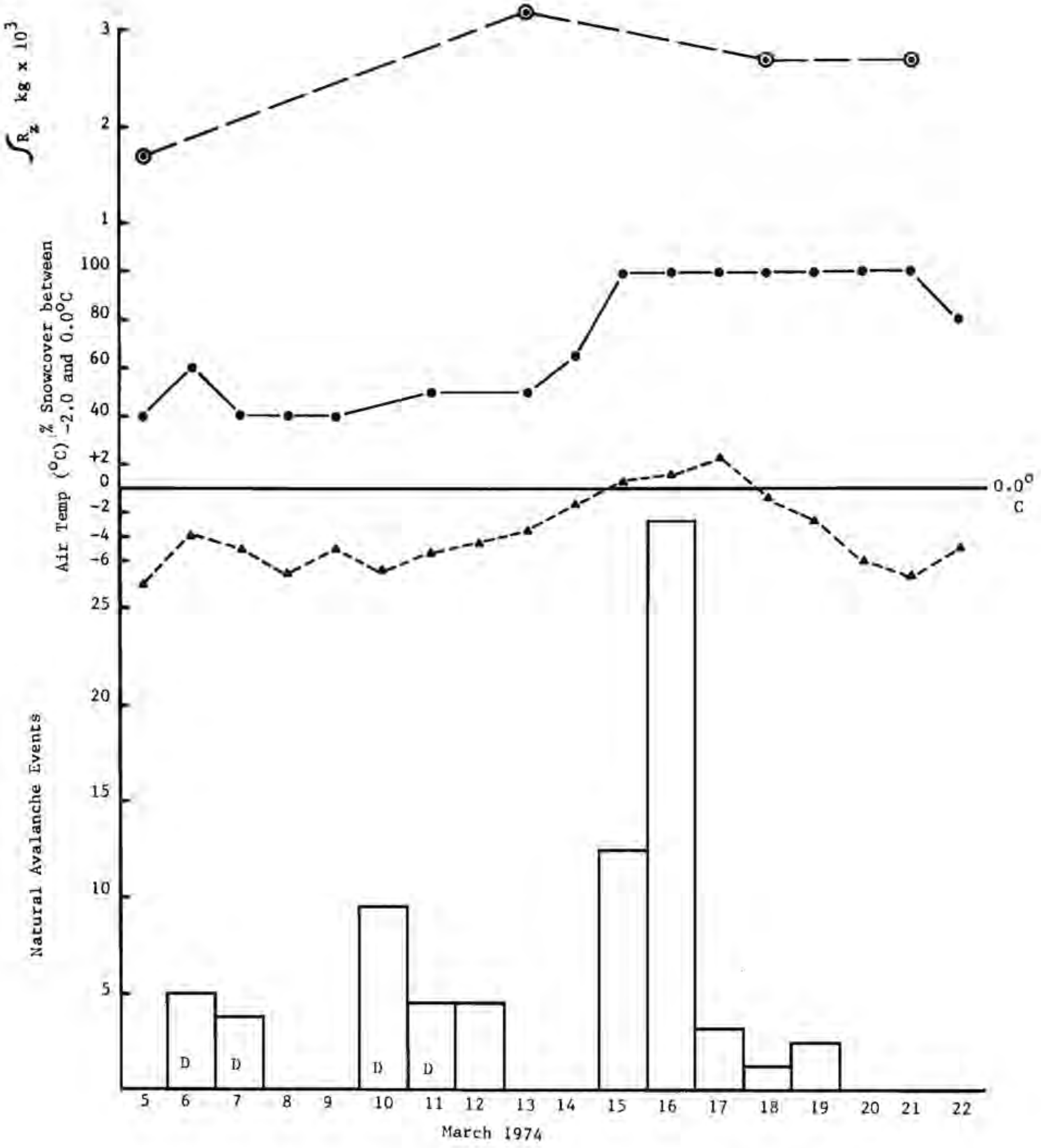

Figure 26. A comparison of integrated ram resistance, percent of snowcover between -2.0 and 0.0°C, and mean daily air temperature (°C) at Red Mountain Pass and observed natural wet snow avalanche events during March, 1974. (D = dry snow event)

avalanche activity on Engineer Mountain as a precurser to a major cycle in the Red Mountain Pass area is enhanced by the fact that these paths present little or no hazard to the highway.

During those days when wet avalanches occur, the time of an event is, to a considerable extent, a function of slope aspect. The possibility of a consistent relationship is complicated by several factors. If a release area is adjacent to exposed soil or rock surfaces, the snowcover will be receiving increased amounts of heat due to long-wave radiation from the bare ground. Consequently, the snow may be warmed at a rate greater than another area with more favorable slope angle and aspect regarding direct solar radiation. If the release zone possesses the topography of a steep-sided gully, the sides of the gully may be receiving maximum solar radiation at some time prior to that which would be expected when considering the aspect of the overall release zone. An avalanche releasing on such a sidewall could set the main track in motion. As described earlier, optimum conditions for release exist not necessarily at the time of maximum air temperature or solar radiation but somewhat later in the day when the wet snow surface is capable of absorbing increased amounts of solar radiation. Therefore, even though optimum sun angle for a south-facing slope might occur at noon, avalanching may not begin to occur until sometime later, perhaps coincidental with slopes possessing a more westerly orientation.

Figure 27 shows the extent to which the time of release is a function of the slope orientation within selected groups of avalanche tracks which frequently affect the highway during spring cycle conditions. A relationship between time of day and slope aspect is apparent, but an even more striking pattern appears within the clusters representing individual avalanche path groups. The large crosses indicate the time at which the appropriate slope angle and aspect of the given release zone would theoretically receive maximum direct, clear-sky solar radiation. The slope with the more easterly aspect shows a definite time lag between maximum energy received and the beginning of avalanche activity. This condition agrees with the concept of increased productivity of free water, and subsequent avalanche release at some point following that time when the surface snow first becomes wet. As the day progresses the lag diminishes because as time elapses, the snowcover is being gradually warmed by the increasing air temperatures so that when optimum solar angle occurs, a significant amount of melt has already taken place at the surface.

All of the preceeding information has related to the determination of the onset of the wet avalanche cycle. Once initiated, high hazard will continue until certain criteria are met. Avalanches will continue to release over a period of time depending upon slope angle, aspect and elevation of starting zones. Once north-facing slopes with relatively high elevations have released, such as East Riverside (064) and the Mill Creek Cirque Group (108-114) in the Red Mountain Pass area, general hazard could be considered diminished.

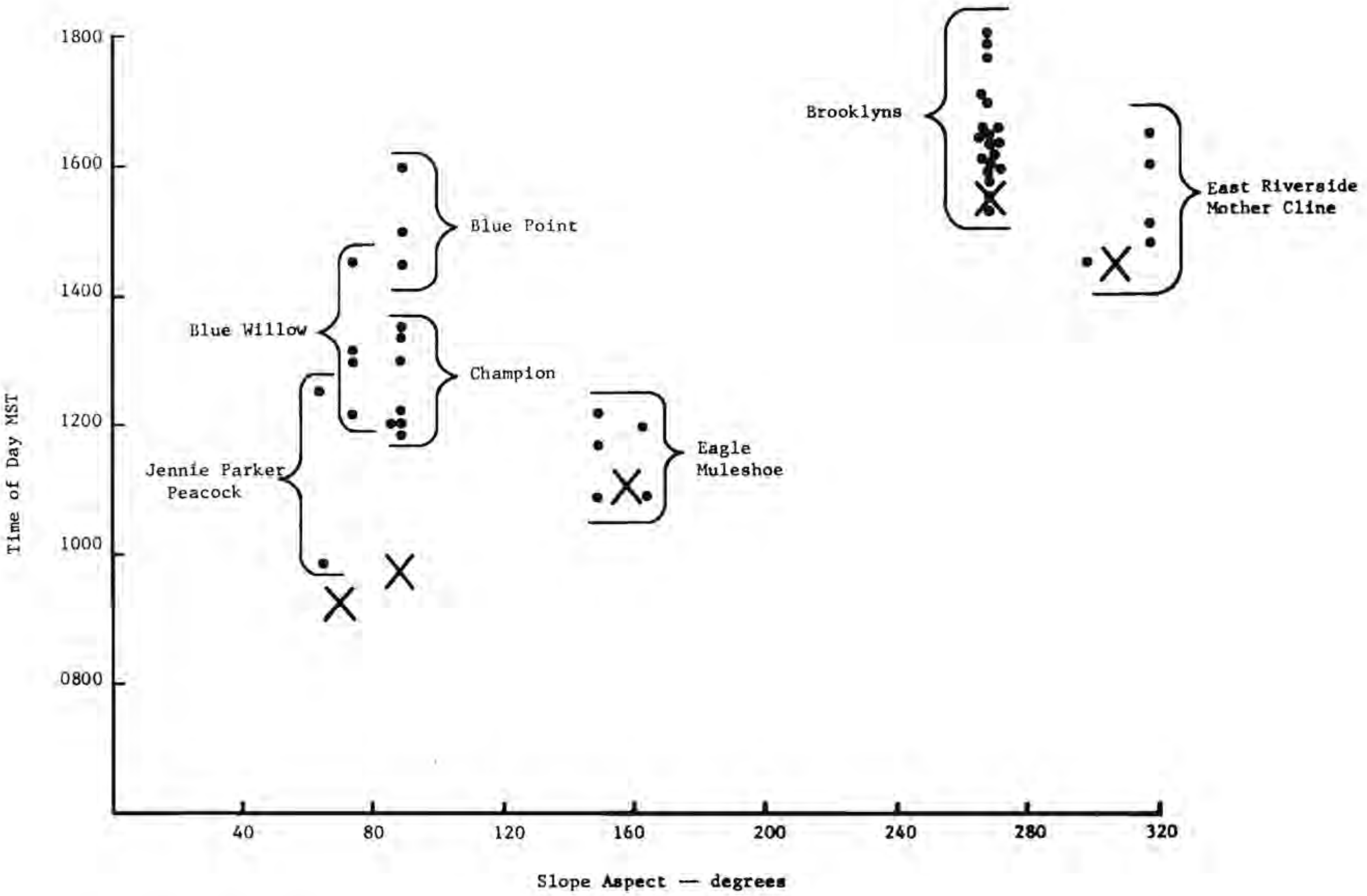

Figure 27 Wet snow avalanche events grouped by slide path as a function of slope aspect and time of day.

Finally, some discussion is necessary to explain those characteristics which caused the 1973 wet avalanche cycle to differ from that occurring in 1974. During late April and early May of 1973, the wet avalanche cycle produced 187 events, of which 60 crossed the highway. Thirty percent of the avalanches were slab type. During mid-March of 1974, a total of 68 wet snow avalanches were recorded, of which 13 crossed the highway. Only 4% of the avalanches were slab type. Not only did the frequency and type of wet avalanche differ from 1973 to 1974, but also the magnitude. In 1973, 24% of the events were size three or larger, while during 1974, avalanches of this magnitude accounted for only 13% of the total. Factors contributing to these differences are as follows. The total snowcover depth and water content at the time of the 1973 cycle exceeded that of 1974 by 60%. The spring cycle of 1973 occurred six weeks later in time, beginning on April 27 as opposed to March 15 of 1974. On the later date, 22% more solar energy is ideally available on a south-facing slope with an angle representative of actual release zones. The snowcover of 1973 was in, or very near to, an isothermal condition for at least eight days prior to the beginning of the April 27-29 cycle as can be seen in Figure 25. Each night during this period, air temperatures were 6.0 to 17.5° below freezing causing the surface snow layers to refreeze. This condition, however, would retard the melt process for only a short period. During the next cycle of May 8-12, air temperatures at an elevation of 3400 m remained above freezing throughout each night.

Nevertheless, it is likely that the snow surface within the avalanche release zones did reach sub-freezing temperatures due to radiation-cooling. However, the thickness of the crust and extent of sub-freezing temperatures within the surface layers must have produced minimal effect in terms of the energy required for melting the following day. This was the situation which preceeded the early morning release on the east-facing Peacock (142) at 0952 MST on May 11. This was a wet loose, size five avalanche which ran to the ground and crossed the highway for a distance of 50 m with a maximum depth of 2 m. In contrast, at the onset of the cycle of March 15, 1974, the snowcover had only begun to approach an isothermal condition (Figure 26). On the morning of the 15th, the temperature of the top 30 cm of the snowcover at Red Mountain Pass was between -10.0 and -2.0°C with the 90 cm layer beneath being -1.0 and -2.0°C, and only the lowermost 40 cm being at or near 0.0°C. The additional amount of solar energy available in late April and early May of 1973, combined with a snowcover temperature regime which caused only minimal amounts of heat to be consumed in raising the temperature of the snow to the freezing point created a condition where very rapid melt and subsequent percolation of free water prevailed. This rapid and deep percolation of melt water followed by an almost immediate loss of intergranular strength may have precluded any possible adjustment of stress conditions by slower creep deformation and caused instead the large volume releases associated with this particular period. The greater number of slab avalanches which occurred during the 1973 cycle may be explained by looking at the snow structure and avalanche occurrence record of the preceding winter period. Not only did precipitation during the 1972-1973 winter greatly exceed that of the following winter, but considerably more snow existed within the various release zones and avalanche paths for an additional reason. Numerous storms which produced moderate to heavy amounts of precipitation were associated with only small and infrequent avalanche events, causing significant amounts of snow to remain within the avalanche tracks. In such a snowcover, percolating free water came in contact with a complex stratigraphy which had been developing over the past four to six months. A snow structure, common to the Red Mountain Pass area, consisting of alternating layers of weak temperature-gradient snow and stronger freeze-thaw crusts and wind slabs, in combination with the melt water, created the inadequate strength conditions at the shear boundaries required to initiate slab-type avalanches.

The occurrence of wet snow avalanches depends largely upon air temperatures, heat flux and water content in the snow. The usual period for widespread release of wet snow avalanches is spring when snow temperatures rise and melting begins as a function of the seasonal trend of air temperature. Since the initial requirement for a wet snow avalanche is melting temperatures through the bulk of the snowpack, systematic snow temperature measurements are essential in order to forecast the onset of wet snow conditions. Once the snow is "warm," within 2.0°C of the melting temperature in the case of the Red Mountain data, the probability of release varies with the amount of free water held in the pore space of the snow and the effect of this free water on snow structure. Although it is possible to directly measure free water content as well as its subsequent effect on intergranular strength within the snowcover, emphasis here is given to indirect estimates of the generation of melt water. Air temperature is considered in conjunction with snow temperature data. In addition, consideration is given to slope exposure and radiation balance. Regarding the latter, it must be emphasized that the short-wave (solar) component of the radiation balance may not be a dominant factor for such a highly reflective material as snow. Long-wave radiation from warm clouds as well as warm winds are highly effective in melting snow.

CHAPTER 5: STATISTICAL ANALYSIS

Michael J. Bovis

Introduction

The purpose of this chapter is to outline the development of a real-time, statistical forecast model to predict avalanche occurrences along Highway 550 (Station 152), based on an analysis of data from the four seasons 1971-75. A preliminary test of the model is included, using independent data from the 1975-76 season. Climatic and snowpack variables incorporated into the model are from the Red Mountain Pass snow study site, or telemetered from the remote wind station at 3757 m. This ensures that future real-time testing of the model can be based on relatively accessible climatic stations. The calibration of the model to occurrences along Station 152 does not preclude its application to a somewhat wider area within the San Juan Mountains, since this stretch of Highway 550 involves over 150 slidepaths of different size and activity. However, it is likely that spatial variation in weather conditions will result in a loss of predictive accuracy as a function of distance from Red Mountain Pass. A controlled test of the regional applicability of the method has yet to be carried out.

Data Reduction

The continuous record of precipitation, air temperature, windspeed and wind direction is reduced to consecutive two-hour values (or one-hour values for wind variables), with calendar months demarcated by logical records; file markers are written on each data block at the end of the avalanche season (Appendix A to this chapter, Figure A.1). Avalanche occurrences on Station 152 are written in chronological sequence; on a given avalanche day, occurrences are ordered by slidepath number. No logical records are written, but each season is written as a separate file. Daily observations of snow density, surface condition, ram hardness are listed as a single file, with months defined by logical records. A sequential listing of all data files from 1971 through 1975 is given in Appendix B to this chapter. The magnetic tape described in Appendix B is a multi-file catalog of data, from which working copies are obtained in the manner outlined in Figure 28 and Appendix A.

The data reduction program in Figure 28 consists of several subroutines to reduce raw data to a set of input variables (Table 16). The operation of this program and other routines used in the development of the model is described in Appendix C to this chapter. Certain variables can be integrated over varying time periods to provide a recursive element in a forecast situation (Table 16).

A sequential list of avalanche days is obtained from the occurrence file using program AVAL; from this list, a non-avalanche day file is written using the data generator described in program NONAVAL (Appendix C). The

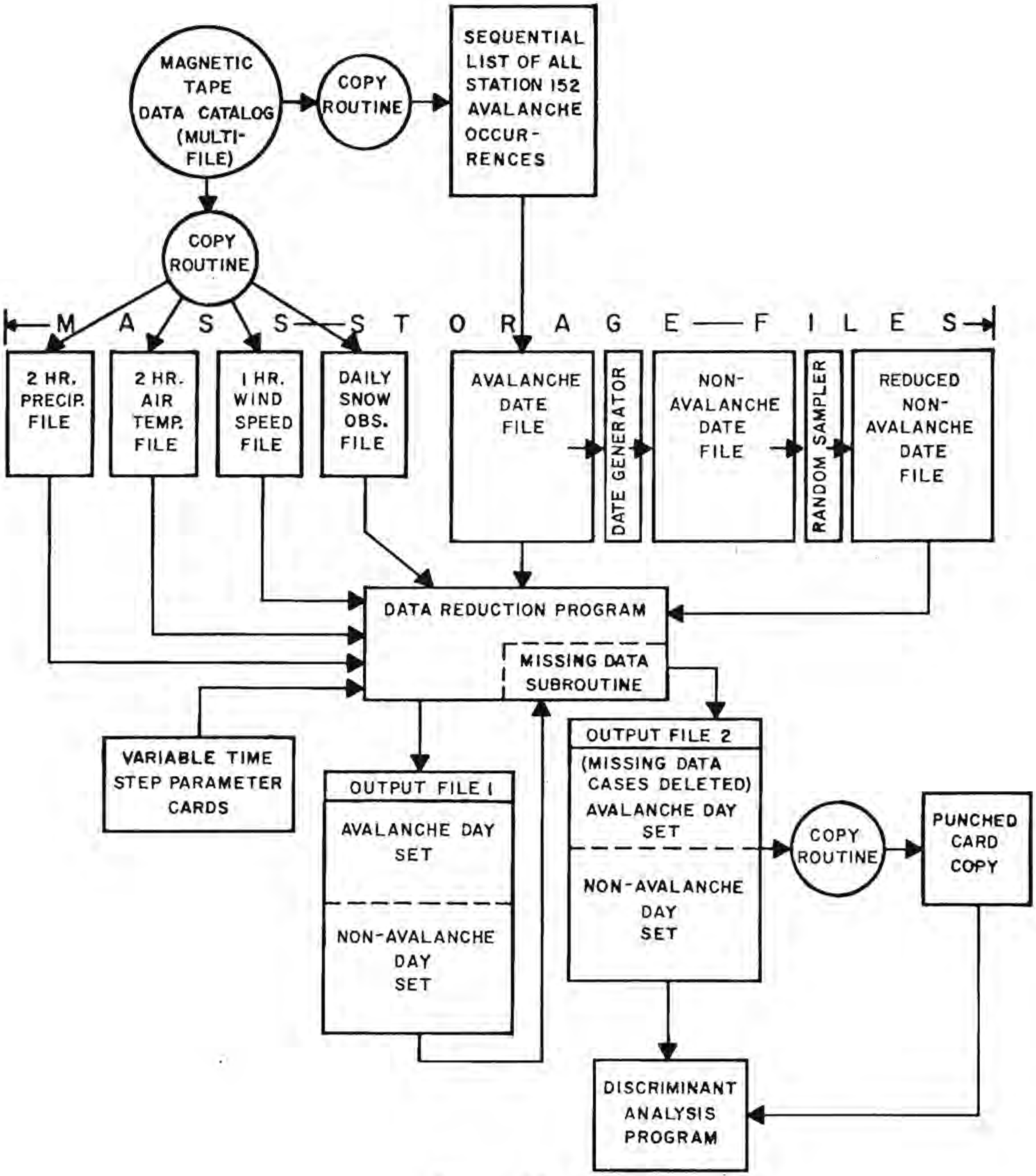
MAGNETIC TAPE DATA CATALOG (MULTI-FILE)
COPY ROUTINE
SEQUENTIAL LIST OF ALL STATION 152 AVALANCHE OCCURRENCES
COPY ROUTINE
MASS STORAGE FILES
2 HR. PRECIP. FILE
2 HR. AIR TEMP. FILE
1 HR. WIND SPEED FILE
DAILY SNOW OBS. FILE
AVALANCHE DATE FILE
DATE GENERATOR
NON-AVALANCHE DATE FILE
RANDOM SAMPLER
REDUCED NON-AVALANCHE DATE FILE
DATA REDUCTION PROGRAM
MISSING DATA SUBROUTINE
VARIABLE TIME STEP PARAMETER CARDS
OUTPUT FILE 1
AVALANCHE DAY SET
NON-AVALANCHE DAY SET
OUTPUT FILE 2
(MISSING DATA CASES DELETED)
AVALANCHE DAY SET
NON-AVALANCHE DAY SET
COPY ROUTINE
PUNCHED CARD COPY
DISCRIMINANT ANALYSIS PROGRAM

Figure 28.

TABLE 16

INPUT VARIABLES

Variable Number	Description
1	Total precipitation over an N* day period prior to event or non-event date (mm water equivalent).
2	Total precipitation in period 1200 hrs. on day prior to event to 1200 hrs. on event date (mm water equivalent).
3	Maximum 6hr. precipitation intensity in period 1200 hrs. on day prior to event to 1200 hrs. on event date (mm water equivalent).
4	Mean 2hr. air temperature over an N* day period prior to event or non-event date (°C).
5	Mean 2hr. air temperature during same period as (2) above,(°C).
6	Maximum 2hr. air temperature in same period as (2) above,(°C).
7	Mean 6hr. wind speed over an N* day period prior to event or non-event date (m/sec).
8	Mean 6hr. windspeed during same period as (2) above (m/sec).
9	Maximum 6hr. windspeed during same period as (2) above (m/sec).
10	Einsinktiefe reading (standard ram) at 0800 hr. on avalanche or non-avalanche day (cm).

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* N = 2, 3 or 5 days

non-avalanche day file is bounded by the first and last recorded occurrences along Station 152 and usually is reduced to approximately the same length as the avalanche day file by random sampling. As noted by Bois et al. (1974), this approach reduces serial correlation between days, such as might occur from persistence of a weather pattern; also it equalizes the sampling errors for parameters in each population of events.

The value of N, the number of days prior to an avalanche or non-avalanche day, (Table 16)is specified by the user (Figure 28) to produce an output file of reduced variables for all days in a season. Cases with missing data are eliminated prior to the statistical analysis and card copy of the remaining data is made for future reference (Figure 28).

Discriminant Analysis

The method described here is similar to those discussed previously by Judson and Erikson (1973) and Bois et al. (1974) in that it is based on linear discriminant functions computed from meteorological and snowpack variables measured on sets of avalanche and non-avalanche days, the purpose of the analysis being to select variables which maximize the separation of the two groups in multi-dimensional space. A two-variable case is illustrated in Figure 29, which indicates that the densities of the points in discriminant space are generated by a one-to-one mapping from the original score space. This is achieved by forming the dot product between a vector of coefficients, $\{\lambda\}$ and a vector of scores on selected variables in Table 16, for each avalanche and non-avalanche day. A scalar measure (discriminant score, D) is assigned to each day from:

$$D = \{X\} \cdot \{\lambda\} \qquad (1)$$

where $\{X\}=\{x_1, x_2, \ldots x_r\}$, with subscripts corresponding to variable numbers in Table 1. The vector $\{\lambda\}$ is derived empirically from the matrix operation:

$$\{\lambda\} = \{V\}^{-1}\{d\} \qquad (2)$$

in which the first term on the right hand side is the inverse of the pooled dispersion (variance-covariance) matrix for the two groups and $\{d\}$ is the vector of differences among the means of the r variables over both groups (Hope, 1968).

An assumption of the analysis is that the dispersion (variance-covariance) matrices in each group are approximately equal. When this is not satisfied, the likelihood function for the two groups is not a straight line, so that a linear discriminant function may produce a significant amount of misclassification of avalanche and non-avalanche days. Both the linear and nonlinear cases are illustrated in Figure 30. In both cases, the likelihood function is drawn through the points of intersection of corresponding percentile contours in each group; therefore, it is the locus of points which have equal probability of belonging to either group.

Given that the linear assumption holds true, a cutting point, or discriminant index is chosen, midway between the two means in discriminant space (Figure 29),

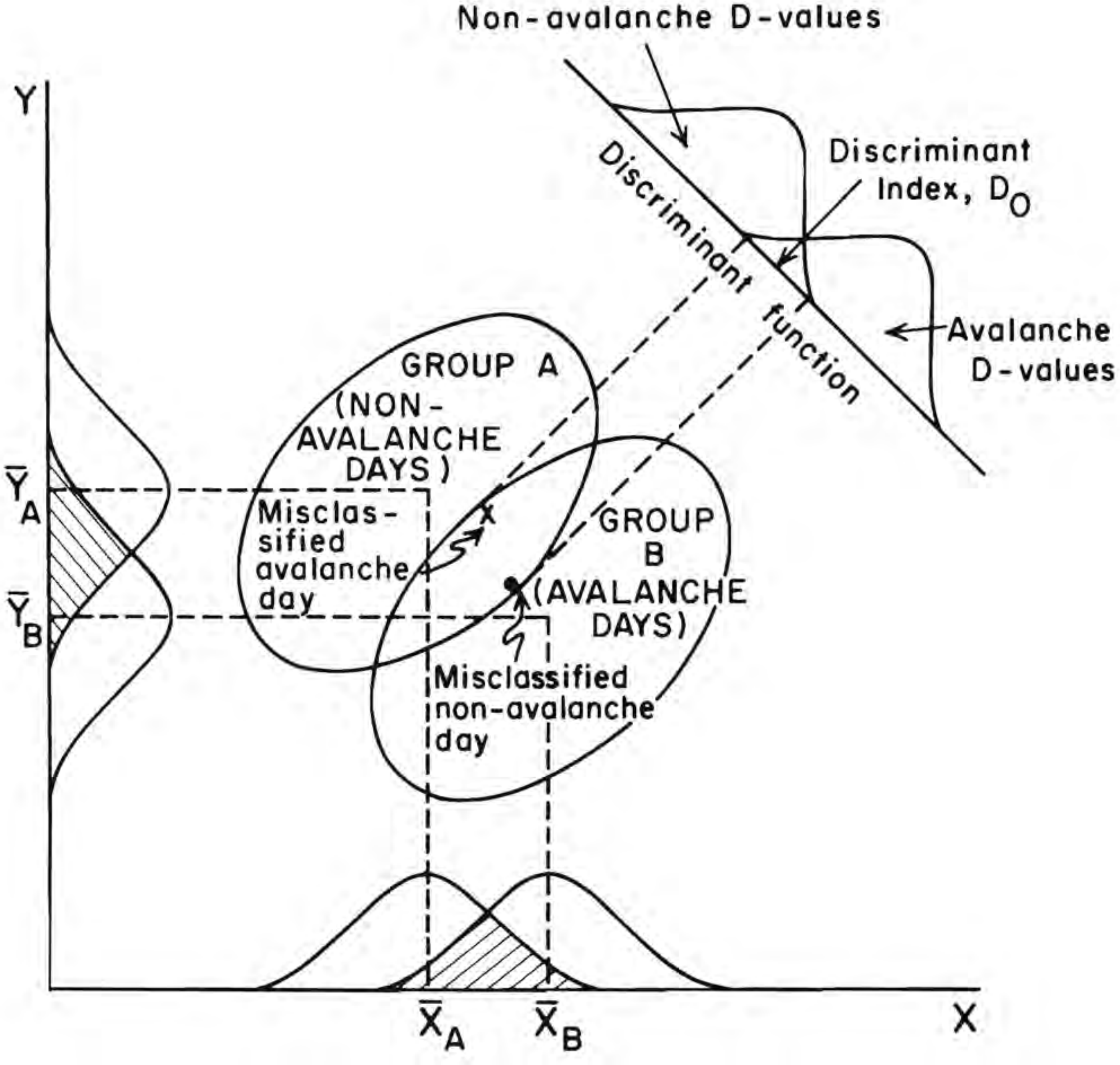
Non-avalanche D-values
Y
Discriminant function
Discriminant Index, D_O
Avalanche D-values
GROUP A (NON-AVALANCHE DAYS)
GROUP B (AVALANCHE DAYS)
Misclassified avalanche day
Misclassified non-avalanche day
$\bar{Y}_A$
$\bar{Y}_B$
$\bar{X}_A$
$\bar{X}_B$
X

Figure 29.

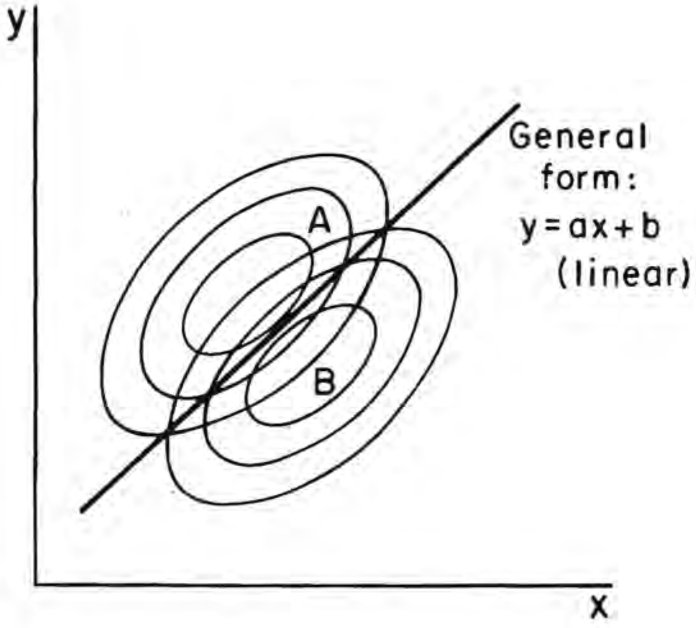

Figure 30(a)

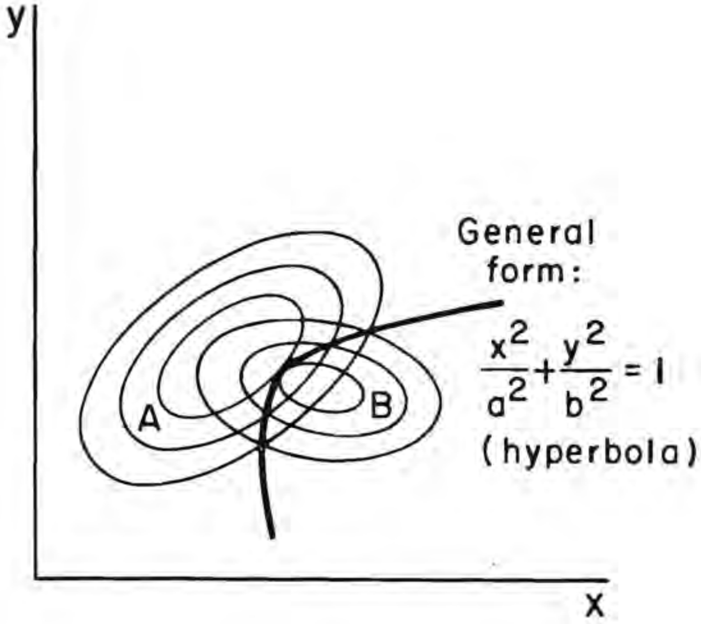

Figure 30(b)

which can be used to decide the status of a future event according to the decision rule:

$$\begin{aligned} D > D_0&: \text{ avalanche day} \\ D < D_0&: \text{ non-avalanche day} \end{aligned} \qquad (3)$$

As Figure 29 suggests, an approximate test of the validity of the linear model is that roughly equal numbers, or percentages, of objects (days) should be misclassified in each group (Hope, 1968). If this is not the case, the assumption of equal dispersion matrices has probably been violated. It should be noted that D_0 need not be chosen midway between the two discriminant score means (Figure 29). However, this is the conventional choice, so that the discriminant index is defined by:

$$D_0 = \frac{1}{2}\sum_{i=1}^{r} \lambda_i (\overline{A}_i + \overline{B}_i) \qquad (4)$$

where λ_i is the ith coefficient of the discriminant function and $\overline{A}_i$ and $\overline{B}_i$ are, respectively, the mean values of variable i over groups A and B in the original score space.

It is desirable to reduce the dimensions of the X matrix by choosing a set of input variables which maximize the separation of the avalanche and non-avalanche day means in multivariate space. Therefore, the order of $\{V\}$, $\{\lambda\}$ and $\{d\}$ will generally be less than r, thereby removing redundant variables from the model. This has the added advantage of minimizing the amount of data reduction in a real-time field test of the model. In this study, variables have been selected according to a stepwise-discriminant procedure (program BMD 07M)*, in which the first variable entered is always that which maximizes the initial difference between the means of the two groups relative to the pooled within groups variance. Using the notation of Hoel (1971), this amounts to maximizing the function:

$$G = \frac{(\overline{z}_1 - \overline{z}_2)^2}{\sum_{i=1}^{2}\sum_{j=1}^{n_i} (z_{ij} - \overline{z}_i)^2} \qquad (5)$$

In this two-dimensional example, the $\overline{z}$ terms are group means, i refers to groups, and j to items within groups. In a discriminant analysis of avalanche versus non-avalanche days, it is likely that the first term in the discriminant function will be a precipitation variable, at least within the dry slide season. Subsequent variables are entered which produce the greatest increase in the value of the function G.

At each stage of the stepwise discriminant analysis, a classification of all days is made, using the list of variables included prior to that step. The Mahalanobis' distance between the groups is computed and an F statistic applied to test the significance of the difference between the two multivariate means:

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*Biomedical Series, University of California, Berkeley, available at University of Colorado.

$$F = \frac{(N - 2 - r + 1)n_1n_2 \cdot \delta^2}{r(N - 2)(n_1 + n_2)} \tag{6}$$

where N is the total number of cases, n_1 from group 1, n_2 from group 2, r is the number of variables, and δ^2 the square of the Mahalanobis' distance between the two groups. Since the F statistic may not be robust under conditions of unequal dispersion matrices, the list of variables can be terminated when the addition of variables does not improve group separation, rather than relying on a test of significance. In fact, either method produces roughly the same results.

With the reduced set of variables, a discriminant score can be assigned to each day using formula (1). Expansion of (1) shows how real-time data are used to decide the status of future days as avalanche or non-avalanche, in linear combination with the λ coefficients:

$$D = \lambda_1X_1 + \lambda_2X_2 + \ldots + \lambda_kX_k \tag{7}$$

The λ terms are treated as fixed constants and the X terms are measured on a real-time basis by the observer. The D value is then compared with the discriminant index, D_0 using formula (3) and a forecast is issued. The variable time element in the data reduction program means that an updated forecast can be obtained at any time. This allows the forecaster to vary his perspective on previous weather events; however, a different prediction function is required at each time step. The reason for this can be illustrated as follows: variable 1 (Table 16) will probably increase as the time step is changed from 5 to 2 days; therefore the λ coefficient for this term must also be changed, although the rank position of the variable in the prediction equation is the same at each time step.

Stratification

A fundamental problem in statistical analysis is to reduce the amount of variation to increase the sensitivity of an experiment. When different levels, or strata are recognized within a population, the homogeneity of a sample can be controlled to some degree. From the avalanche occurrence files for Station 152, it is evident that the rank of avalanche days changes from a hazard standpoint, according to the number and the magnitude of releases; this is the basis for stratifying the avalanche season (Table 17). A basic division into dry slides and wet slides is recognized following prior work on avalanche forecasting (see Bois et al., 1974, and Chapters 2 and 3 of this report). Within each 'season', strata I-V are defined (Table 17) which allows the forecaster to specify the degree of hazard. As noted above in the discussion of the variable time step, each stratum requires a different discriminant function. Therefore, if all steps and strata are used, a total of 15 discriminant functions will result in the dry or wet seasons, although not all of these are needed in a practical forecast situation (see next section).

TABLE 17

STRATIFICATION OF DRY AND WET AVALANCHE SEASONS, 1971-75 ANALYSIS

Stratum	Sample size, 1971-75 combined analysis		Description of stratum
	Dry	Wet	
I	191	73	All avalanche days.
II	118	35	Days with at least three events of magnitude 2^* or above.
III	**	**	Days with events of magnitude 3^* or greater.
IV	80	**	Days with at least three events of magnitude 2^* or above, excluding days with predominantly loose snow avalanches.
V	30	11	Days with at least nine events of magnitude 2^* or above, excluding days with predominantly loose snow avalanches in the dry slide season.

* Number refers to U.S. Forest Service ordinal scale.

** Stratum not included in the combined analysis of four seasons 1971-75.

The hazard strata in Table 17 are based on the five-fold ordinal scale of the U.S. Forest Service which is weighted for the size of the catchment basin in which the release takes place. A release of rank 5 on a small path (for example, the Blue Point, 152097) would probably be listed as rank 1 or at most rank 2 on a much larger slide-path (for example, Battleship, 152128). Provided that the sample of paths is large relative to the number of releases occurring on a given day, weighting should not affect hazard forecasting since, with a few notable exceptions, there does not seem to be a close correlation between frequency of activity and size of an avalanche path. Therefore, paths which run frequently constitute a mixed sample from the standpoint of starting zone size, at least along Station 152. At the hazard level specified by Stratum II (Table 17), for example, a subset of paths can be defined which have an equal probability of running at magnitude 2 or above. The weighted ordinal scale only biases the hazard forecast in Stratum II when a combination occurs of three or more paths of the same starting zone size from the subset of active paths. However, this outcome is less likely than a combination of paths of different sizes, since the lack of correlation between frequency of occurrence and size of path implies a rectangular distribution of path size over the subset.

Prediction Model Based on Combined Data from 1972-73 and 1973-74 Seasons

Due to the anomalous pattern of occurrences during the 1971-72 season, the discriminant analysis was restricted initially to combined data from the 1972-73 and 1973-74 seasons, from which a vector of $\{\lambda\}$ coefficients was computed by formula (2) for Strata I, II and III. Within each stratum, three separate computations were made for the five-, three-, and two-day time steps mentioned earlier (Table 16). A total of nine discriminant functions were derived empirically to predict occurrences during the 1974-75 season from formula (7) and decision rule (3) (Tables 18 and 19 respectively). The figures in the right-hand column of each table refer to the variable numbers in Table 16, listed in their order of entry into the stepwise discriminant analysis. With the exception of line 9 in Table 18, total precipitation over the 12-hour to 24-hour period prior to the avalanche or non-avalanche day (variable 2, Table 16) and precipitation rate over the same period (variable 3) are first entered. In four out of the nine stratifications of events in Table 18, total precipitation over the five-, three- or two-day period prior to the avalanche or non-avalanche day is of 'secondary' importance in the discriminant function. However, the ordinal position of a variable in the discriminant function does not necessarily indicate physical significance. In line 1, (Table 18), the meaning of the order is as follows: variable 3 is entered first, since it is associated with the largest element of the vector $\{d\}$ in formula (2). Given that variable 3 is included in the model, the addition of variable 4 maximizes the function G in formula (4). The same reasoning applies to the inclusion of variable 5 in third position, at which point the list is terminated, since inclusion of additional variables does not increase the value of the function G.

The importance of variables 2 and 3 in dry slide predictions not only suggests that many releases are 'direct action', but that the best prediction should be achieved at the two-day time step. With the exception of Stratum I, a

TABLE 18

PREDICTION OF 1974-75 DRY AVALANCHE OCCURRENCES USING DISCRIMINANT FUNCTIONS FROM COMBINED 1972-73 AND 1973-74 SEASONS

Line number	Stratum (Table 2)	Time step*	Sample sizes		Percentage misclassified		Variables included
			Aval.	Non-aval	Avalanche	Non-avalanche	
1	I	5	92	57	48	21	3,4,5
2	I	3	90	56	43	30	2,1,5,4,3
3	I	2	93	57	46	23	3,8
4	II	5	59	53	32	21	2,1,3,5,4
5	II	3	60	56	40	21	2,1,5
6	II	2	61	57	31	21	2,1,8
7	III	5	42	53	45	15	2,6,5,3
8	III	3	42	56	36	16	2,6,8,5
9	III	2	42	57	29	12	8,2,5

*Number of days prior to avalanche or non-avalanche day.

TABLE 19

PREDICTION OF 1974-75 WET AVALANCHE OCCURRENCES USING DISCRIMINANT FUNCTIONS FROM COMBINED 1972-73 AND 1973-74 SEASONS

Line number	Stratum (Table 2)	Time step*	Sample sizes Aval.	Sample sizes Non-aval.	Percentage misclassified Avalanche	Percentage misclassified Non-avalanche	Variables included
1	I	5	23	25	43	68	5,1,2,3
2	I	3	Not performed - no data for variable 7				5,1,7,2,4
3	I	2	22	25	41	80	5,1,4,2
4	II	5	23	25	52	68	6,1
5	II	3	22	25	50	76	6,1,5
6	II	2	22	25	36	84	5,1,4
7	III	5	6	25	17	52	5,6,4
8	III	3	6	25	17	80	5,1,4
9	III	2	6	25	17	76	5,1,4

* Number of days prior to avalanche or non-avalanche day.

marked improvement in the predictive accuracy occurs at this time step. A second feature of Table 18 is the marked inequality between avalanche and non-avalanche misclassifications across all strata, which suggests that the assumption of homogeneity of the variances in the two groups may have been violated.

Wet slide occurrences in Table 19 are predicted most accurately from a linear combination of mean air temperature (variable 5) and total precipitation (variable 1), which concurs with prior experience using conventional forecasting techniques (Chapter 3). With the exception of Stratum III, (Table 17) in which all three time steps yield the same accuracy, there is a notable improvement at the two-day time step, suggesting that a model based on this step alone would suffice, and would be simpler to operate in a field situation due to the lesser amount of data reduction required. The number of discriminant functions is reduced from nine to three.

The accuracy of the two-day forecast, averaged across the three strata in Table 18 is 65 percent correct, with a standard deviation of 9 percent. Prediction of major avalanche cycles (line 9) is 71 percent correct (i.e., 29 percent misclassified), only about 10 percent lower than the accuracy claimed by experienced forecasters using traditional methods of forecasting in the San Juan study area (Chapter 3). For the wet slide season, the average is 69 percent correct, with a standard deviation of 13 percent. In view of the very small sample of avalanche days in Stratum III (Table 19), the overall accuracy for wet slide predictions is probably inflated. Also, a considerable number of non-avalanche days are misclassified at all levels in the wet season. As noted in the discussion of dry slide predictions, this points to a possible violation of the linear discriminant assumption, and suggests that a situation similar to that portrayed in Figure 30(b) may prevail.

Characteristics of Discriminant Score Distributions

Computation of the discriminant index (D_0) according to formula (4) places it midway between the two group means in discriminant space only when both densities of scores are both approximately normal (i.e., Gaussian). If this is not the case (Figure 31a), formula (4) is not a good estimator for a critical value, for much the same reason as the arithmetic mean is not an efficient estimator when a distribution is markedly skewed. The predominance of precipitation variables in the dry slide prediction equations (Table 18) and the large number of zero values of these variables over the non-avalanche day population suggests that their distributions should be positively skewed. This also applies to the avalanche group, since generally any short-term summation of precipitation (e.g., daily values) will be positively skewed, irrespective of whether numerous zero values occur. It is likely, therefore, that both densities of discriminant scores will deviate from normal, probably in the manner illustrated in Figure 31(a). The arithmetic means of both

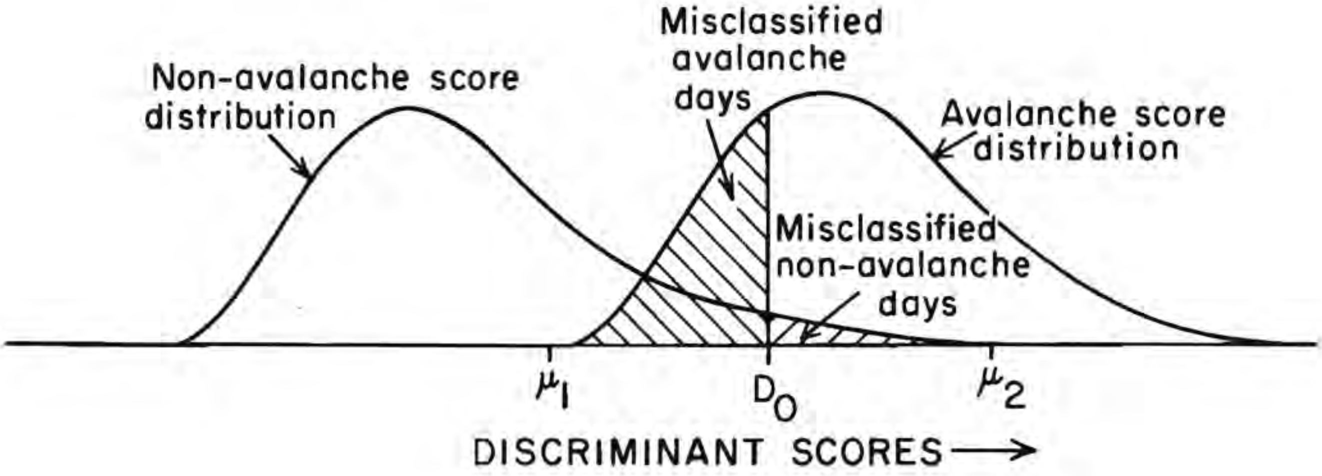

Figure 31(a)

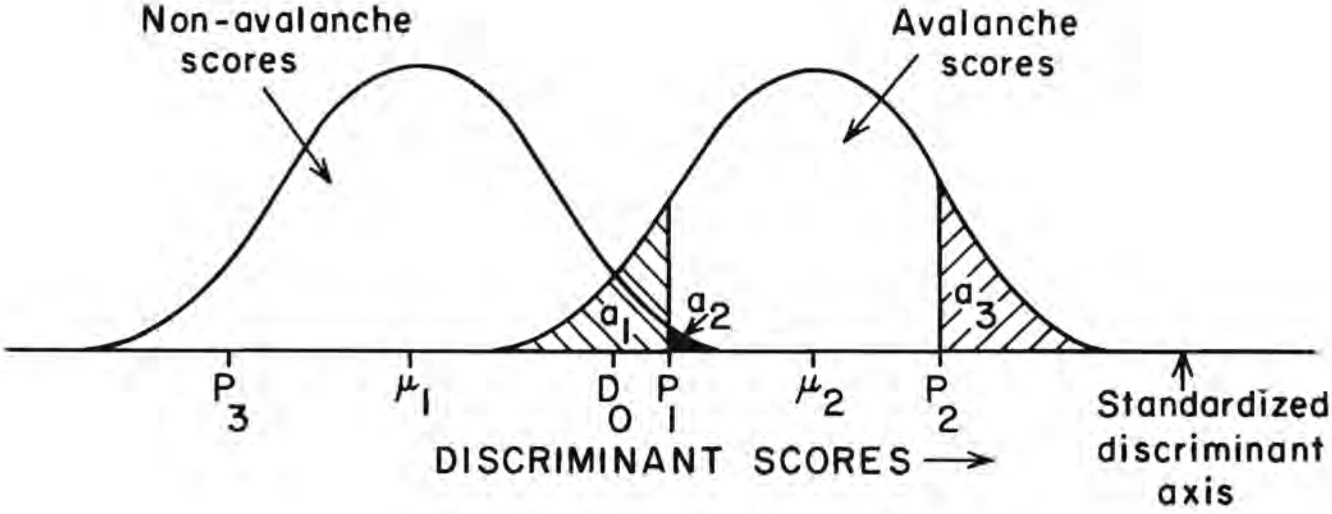

Figure 31(b)

distributions (μ_1,μ_2) are deflected to the right of their respective centers of mass since they are not good estimators of central tendency. By placing D_0 midway between these two values, a higher level of misclassification results for the avalanche day group (Table 18). This is not dependent on the degree of overlap between the two distributions, but is related to their relative position on the discriminant axis. This never changes on account of the high precipitation scores on most avalanche days and is preserved in the wet slide season also since avalanche days score higher on air temperature variables than do non-avalanche days. The greater number of misclassifications of non-avalanche days during the wet slide season may be attributable to negative, rather than positive, skewness in both distributions of scores.

The amount of skewness present in the discriminant scores is examined in Table 20 over the four dry slide seasons 1971-75. Results of the discriminant analysis are given in Table 20(a) and a Chi-square goodness-of-fit test for normality in Table 20(b). The null hypothesis that the two distributions of scores are normal is soundly rejected, due primarily to positive skewness. This can be removed or mitigated by applying a logarithmic transformation to the precipitation variables:

$$X_i^* = \ln(X_i + 1) \tag{8}$$

The arbitrary constant of one is added since ln(0) is minus infinity. The X_i^* are transformed scores, with i = 1,2,3 in Table 20(a).

The analysis is then repeated using formula (8) and results in a ten percent improvement in the accuracy of the avalanche day forecast. Also, the disparity in the numbers of misclassified days between the avalanche and non-avalanche groups is reduced to 12 percent in Table 21(a) versus 29 percent in Table 20(a). The Chi-square values in Table 21(b) are much lower than in Table 20(b), the computed value for avalanche days just exceeding the 95 percentage point (14.1 for seven degrees of freedom). Therefore, if a five percent chance is taken of rejecting a true null hypothesis (i.e., normal distribution in the scores), then the avalanche day sample can be considered as normal. Although not very stringent, the test indicates that the distribution of transformed scores may approach normality in the long-term, an important consideration in future applications of the forecast method.

The hypothesis is rejected in Table 21(b) for non-avalanche days, the 99.5 percentage point being 20.3 for seven degrees of freedom. Rejection is due to persistent positive skewness in the discriminant scores on account of the zero level of variables 1 and 2 on many non-avalanche days. (Under the transformation in formula (8), days with zero precipitation remain zero).

For wet slide days in the same period, the Chi-square values are as follows, using transformed precipitation scores:

Avalanche days: Chi-square = 6.6 for 7 degrees of freedom
Non-analanche days: Chi-square = 2.2 for 5 degrees of freedom

TABLE 20(a)

COMPARISON OF ALL AVALANCHE AND NON-AVALANCHE DAYS, DRY SEASON, 1971-75 BASED ON A TWO-DAY DATA INTEGRATION PERIOD

Sample Sizes		Percentage of Days Misclassified		Variables Selected
Avalanche	Non-avalanche	Avalanche	Non-avalanche	
191	190	47	18	1, 2, 5*

*Refers to variable numbers in Table 1.

TABLE 20(b)

GOODNESS-OF-FIT TEST FOR NORMALITY OF STANDARDIZED DISCRIMINANT SCORES FOR ALL DRY AVALANCHE AND NON-AVALANCHE DAYS, PERIOD 1971-75

Group	Chi-square value	Degrees of freedom	Significance level, α, percent**
Avalanche days	69.4	6	<<.5*
Non-avalanche days	87.7	6	<<.5*

** Indicates the probability of a Type I error

* Indicates that the probability of a Type I error is much less than .5%

TABLE 21(a)

COMPARISON OF ALL AVALANCHE AND NON-AVALANCHE DAYS, DRY SEASON, 1971-75 USING NATURAL LOGARITHM TRANSFORMATION (EQ. 8) OF PRECIPITATION DATA. TWO-DAY TIME STEP.

Sample Sizes		Percentage of Days Misclassified		Variables selected
Avalanche	Non-avalanche	Avalanche	Non-avalanche	
191	190	37	25	1, 2, 5*

*Refers to variable numbers in Table 1

TABLE 21(b)

GOODNESS-OF-FIT TEST FOR NORMALITY OF STANDARDIZED DISCRIMINANT SCORES FOR ALL AVALANCHE AND NON-AVALANCHE DAYS, DRY SEASON, PERIOD 1971-75. TRANSFORMED. precipitation data

Group	Chi-square value	Degrees of freedom	Significance level, α percent **
Avalanche days	14.8	7	2.5
Non-avalanche days	26.7	7	<.5

Both values are significant at the 90 percent level, so that the approximation to normality is acceptable in both distributions. This is due to the influence of normally distributed air temperature variables in both sets of discriminant scores.

Probability Forecasting From Standardized Scores

Operational testing of the model during the 1974-75 season indicated that a measure of the relative distance of a discriminant score from the discriminant index would have permitted a more meaningful forecast than a simple 'yes' or 'no' concerning the status of an avalanche day. The purpose of this section is to propose a method for computing this distance that permits forecasts to be made in probability terms. This important refinement requires that estimates be made of the mean and variance of the discriminant scores in both the avalanche and non-avalanche day groups; for this reason, data from all four seasons (1971-75) are compounded into a composite sample.

An idealized picture of discriminant space is given in Figure 31(b), in which the scores in both groups are normally distributed. It is desirable that any distance measured on the discriminant axis be a normal deviate, so that deviations from each mean correspond to areas under each curve, and are therefore measures of probability density. Following Hope (1968, pp. 104-5), the vector of discriminant coefficients is standardized:

$$\{\lambda\}^* = \frac{\{\lambda\}}{\delta} \tag{9}$$

where δ is the Mahalanobis' distance between the two groups. Standardized discriminant scores, D^*, then result from:

$$D^* = \lambda_1^* X_1 + \lambda_2^* X_2 + \ldots + \lambda_r^* X_r \tag{10}$$

in which the X terms are real-time variables, as in formula (7). (In anticipation of this, the Chi-square analyses in Tables 20(b) and 21(b) were based on standardized discriminant scores).

From the preceding section, the distributions of avalanche day scores in both the dry and wet slide seasons can be treated as approximately normal; therefore, deviations from the avalanche mean are normal deviates. In Figure 31(b), μ_1 and μ_2 are the mean scores on the non-avalanche and avalanche groups respectively. Therefore, the avalanche normal deviate for point p_2 is:

$$\Delta = (p_2 - \mu_2) = (1 - a_3) \tag{11}$$

which is the probability of avalanche group membership for p_2. The difference $(p_1 - \mu_2)$ yields a negative number, since the avalanche probability for p_1 is less than 50 percent.

The method of computing non-avalanche day probabilities differs slightly from formula (11) since non-avalanche probabilities increase to the left of D_0, not to the right as was the case for the avalanche group. Therefore, non-avalanche normal deviates are found from:

$$\Delta' = -(p_1 - \mu_1) = a_2 \tag{12}$$

This ensures that points falling to the left of μ_1 are positive deviates. From formula (12), point p_2 would have a large negative Δ' score, indicating a very small probability of belonging to the non-avalanche group, whereas point p_3 has a high probability for this group. In practice, the user need not be concerned with areas under each curve since probabilities can be read from a table of the standard normal distribution once the appropriate normal deviates have been computed.

Predictive Model Based on the Four Seasons 1971-75

In this section, data from all four seasons are compounded to produce a set of predictive equations for Strata I, II, IV and V in Table 17. Stratum III is not included since its membership is similar to that of II over the four seasons. Variables are integrated over the two-day time step only, since the results in Tables 18 and 19 pointed to a higher forecast accuracy at this step. Also, the discriminant analysis is based on a logarithmic transformation of all precipitation variables, using formula (8), and standardized coefficients and scores using formulas (9) and (10).

Results of the dry slide analysis over the four seasons are given in Table 22 and indicate the predictive importance of precipitation variables. This reflects the large number of so-called 'direct action' soft slab releases which occur during storms or shortly after. The best discriminator in all four strata is variable 2, indicating that precipitation totals in the few hours prior to avalanche release are more critical than accumulated precipitation over a longer time span. The means of the air temperature variables 4, 5 and 6 are generally lower over the avalanche group, so that the rate of snow settlement would be lower in this group, producing a snow deposit of low mechanical strength. This reasoning is supported by the observation that many avalanches in the San Juan study area are initiated by a failure within the new snow cover.

It is worth noting that none of the wind variables (numbers 7, 8 and 9 in Table 16) are included in the dry slide equations as good discriminators of avalanche and non-avalanche days. This is because variation in wind speed between the two groups is less marked than variation in precipitation and air temperature. In lines 1-3 (Table 22), the means of variables 7, 8 and 9 vary by only about one or two meters per second between the two groups, with standard deviations varying by about the same amount. In line 4, means and standard deviations vary by three to four meters per second. This finding is not at variance with the observation that wind is an important factor in loading avalanche starting zones. Their exclusion here means that they do

TABLE 22

DISCRIMINANT ANALYSIS OF OCCURRENCES IN DRY SLIDE SEASONS 1971-75*

Line number	Stratum	Sample sizes		Percentage of days misclassified			Variables included
		Aval.	Non-aval.	Avalanche	Non-avalanche	Overall	
1.	I	191	190	37	25	31	2,1,5
2.	II	118	118	31	23	27	2,1,6,5
3.	IV	80	80	19	23	21	2,1,6
4.	V	30	30	13	10	12	2,4

* Based on a logarithmic transformation of variables 1,2 and standardized discriminant scores.

TABLE 23

DISCRIMINANT ANALYSIS OF OCCURRENCES IN WET SLIDE SEASONS 1971-75*

Line number	Stratum	Sample sizes		Percentage of days misclassified			Variables included
		Aval.	Non-aval.	Avalanche	Non-avalanche	Overall	
1.	I	73	63	37	43	40	6,4
2.	II	35	35	31	29	30	6,1,4
3.	V	11	11	18	18	18	5,1,2

* Based on a logarithmic transformation of variables 1,2 and standardized discriminant scores.

not produce a significant increase in the value of G in formula (5); therefore, wind velocity is not an important discriminator. This characteristic of discriminant analysis should be clearly understood by persons implementing the model.

In lines 3 and 4 (Table 22), days with predominantly dry, loose snow avalanches are eliminated from the sample since it was found that the model would not predict properly under these conditions. In line 2, over half of the days misclassified were of this type; the improvement in the forecast accuracy between lines 2 and 3 is striking.

The order of entry of variables into the wet slide discriminant functions (Table 23) emphasizes the importance of air temperature variables and is, therefore, consistent with the findings of the traditional methods of forecasting used in this study (Chapter 3). The importance of variable 6 (Table 23) in lines 1 and 2 may indicate that a rapid rate of warming is responsible for small cycles of loose snow avalanches. The entry of variable 5 first in line 3 suggests that larger wet avalanche cycles require a more prolonged warming over a 24 hour period prior to avalanche release. The means of the air temperature variables differ by one or two degrees Celsius over avalanche and non-avalanche groups in lines 1 and 2, but differ by more than five degrees in line 3. Stratum III was not used in the wet slide analysis since its membership does not vary much from that of II over the four seasons. Also, Stratum IV was not used since many wet avalanche days would have been eliminated. In Stratum V, wet loose events are retained, since the accuracy of the model is not affected by their inclusion.

An important feature of Tables 22 and 23 is the approximately equal numbers of misclassified avalanche and non-avalanche days, particularly Stratum V in both seasons. This indicates that a linear function is effective in discriminating between avalanche and non-avalanche days. The overall accuracy figure in both tables is the average of the two preceding columns and refers to the average expected accuracy of the model. For major avalanche cycles in the dry and wet seasons, the accuracy figures are 88 percent and 82 percent, respectively.

Field Operation of the Forecast Model

Discriminant function coefficients for each stratum in Tables 22 and 23 are listed in Appendix D to this chapter, along with the mean discriminant score for each group. In both dry and wet seasons, variables 1, 2, 4, 5 and 6 are required. Given real-time data summaries for these variables, the steps involved in computing avalanche and non-avalanche probabilities for a given day are as follows:

(1) Perform the transformation in formula (8) to all precipitation variables included in a particular stratum. This is done by first adding 1 to the raw precipitation value and then taking the natural logarithm (ln) of this sum.

(2) Compute D* from formula (10), by forming the sum of products between the coefficients in Appendix D and the real-time variables obtained in (1) above.

(3) Subtract D^* from the appropriate group mean score in Appendix D. Use formula (11) for the avalanche group deviate and formula (12) for the non-avalanche group deviate, paying particular attention to the sign of the result.

(4) Read off the probabilities corresponding to the deviates obtained in step (3), using a table of the standard normal distribution. (This is reproduced in most statistics texts and in mathematical handbooks).

(5) Issue the forecast, or proceed to the next hazard stratum in Table 17, repeating steps (1) through (4) above, using the appropriate sets of coefficients and means from Appendix D.

To reduce the amount of computation, it is recommended that the forecaster begin with the highest level in each season (i.e., Stratum V) and then work downwards to Stratum I if necessary. This will allow a high hazard situation to be detected as early as possible.

The coefficients for variables 2, 5 and 6 in Appendix D, are calibrated to the period 1200 hr. on the day prior to the current day (day j-1), to 1200 hr. on the forecast day (day j). However, most observations are taken at about 0800 hr. on day j and a forecast issued shortly thereafter. For this reason, the observer should integrate these three variables over the period 1200 hr. on day (j-1) to 0800 hr. on day j. It is then possible to up-date the forecast during day j by reducing subsequent two-hour values for variables 2, 5 and 6. Therefore, at the end of day j, these variables will have been summed up to 2400 hr. The portion from 1200 hr. to 2400 hr. on day j now becomes the input for the succeeding day, (j+1). Also, the input for variables 1 and 4 on day (j+1) is derived from days (j-1) and j, since both require a two-day integration.

Test of the 1971-75 Forecast Model Using Data From the 1975-76 Dry Season

Two days are selected from the 1975-76 dry avalanche season to test the accuracy of forecasting using the coefficients listed in Appendix D. Real-time data summaries are given for both days in Table 24(a), with figures in parentheses referring to logarithmic transformation of the precipitation variables 1 and 2 according to formula (8). Results of a simulated real-time forecast are given in Table 24(b) for the four hazard strata V, IV, II and I. In each case, avalanche and non-avalanche deviates and probabilities are computed according to steps (1) through (4) above.

The avalanche probability for day A is high in line 1 and continues to increase as the hazard level is relaxed in lines 3, 5 and 7. The non-avalanche figure remains at less than one percent throughout all strata. The hazard forecaster would have to conclude that day A would probably give rise to a level V pattern of occurrences.

TABLE 24(a)

INDEPENDENT DATA FROM 1975-76 SEASON AS A TEST OF 1971-75 FORECAST MODEL

Day	Date	Real-time data summaries X_1	X_2	X_4	X_5	X_6
A	75 12 14	44.5(3.8)	32.5(3.5)	-8.2	-11.0	-8.5
B	75 12 30	.5(0.4)	0.0(0.0)	-14.0	-8.2	0.5

TABLE 24(b)

SIMULATED REAL-TIME FORECAST BASED ON DATA IN TABLE 24(a)

Line No.	Stratum	Day	D-value	Avalanche deviate	Non-avalanche deviate	Avalanche probability (percent)	Non-avalanche probability (percent)
1.	V	A	5.154	1.22	-3.81	89	<1
2.	V	B	1.225(0)	-2.61(-3.93)	.02(1.34)	<1	51(91)
3.	IV	A	4.626	1.80	-3.54	96	<1
4.	IV	B	.146	-2.68	.93	<1	82
5.	II	A	3.062	1.97	-3.16	98	<1
6.	II	B	-.846	-1.94	.75	<3	77
7.	I	A	3.412	2.13	-3.05	98	<1
8.	I	B	-.312	-1.60	.67	5	75

Day B represents a different situation from day A, reflected in the very low scores on variables 1 and 2 and the much lower mean two-hour temperature figure for variable 4 (Table 24a). A D value of 1.225 is obtained using the coefficients in line 1 of Appendix D, indicating an avalanche probability of less than one percent and a non-avalanche probability of 51 percent. In line 4, however, the non-avalanche probability increases to 82 percent, which is inconsistent with a reduced level of hazard in Stratum IV. This is explained by the effect of the very low mean temperature for variable 4 combined with low or zero scores on precipitation variables. When variable 4 is removed from the prediction equation, the figures in parentheses in line 2, Table 24(b) result. The avalanche figure remains unchanged but the non-avalanche figure increases to 91 percent. This indicates that the Stratum V equation may give false alarms when very low precipitation scores co-incide with very low air temperatures. Under these conditions, variable 4 should be dropped from the model and the prediction should be based on variable 2 only. Since the weight on variable 4 is small (-0.09422), this will introduce very little bias into the forecast.

The status of day B in strata II and I suggests that avalanching, even at magnitude 1, is unlikely to occur since the non-avalanche probability is 75 percent at level I. The actual occurrences on the two days used in this test are as follows:

14 December 1975:	45 loose releases, magnitude 1
	1 soft slab release, magnitude 1
	7 loose releases, magnitude 2
TOTAL:	53 releases
30 December 1975:	1 loose release, magnitude 1

Although Stratum V is not calibrated for loose avalanche forecasting, the model was correct in predicting widespread instability on December 14. Also the non-avalanche day forecast for 30 December was largely correct, since only one release was recorded.

Discussion

The model presented here does not include any weighting for avalanche releases prior to a given forecast day, nor does it attempt to 'decay' precipitation over the duration of a storm, and in these respects, it differs from the methods proposed by Judson and Erikson(1973) and Bois et al.(1974). The study of Judson and Erikson involved only 23 slide paths near Berthoud Pass, Colorado, and led to the development of a model in which running three-hour precipitation intensities were decayed over the duration of a storm. This was included to simulate progressive stabilization of the snowpack as avalanche releases occurred.

The study of Bois et al.(1974) included factors for the number of avalanche days since the beginning of the winter and the number of avalanche days per number of precipitation sequences, both of which were designed to serve as surrogates for the amount of snow removed from starting zones during past cycles of avalanche activity.

A statistical reason for including variables describing past avalanche activity is that dependence may develop between avalanche days when a large number of releases occur relative to the total sample of paths. It is therefore appropriate to address the question of the independence of avalanche days on Station 152. There are 161 named slidepaths along Highway 550, many of which have multiple starting zones. Therefore, the total number of potential release points is probably closer to 200. It is unusual that more than a small fraction of this total population is active on any given day, and in fact days with more than 20 releases per day represent less than five percent of all avalanche days in the period 1971-75, which leaves well over 150 zones in which avalanches can occur. During very unstable conditions certain paths have more than one natural release per day, due either to consecutive slides from more than one starting zone, particularly on the larger paths, or to a rapid regeneration of the snowpack on small paths from wind loading. It is therefore erroneous to assume that avalanching, on a slidepath basis, necessarily constitutes'sampling without replacement', since it is likely that the cessation of avalanching during a particular cycle is to be attributed to an increased state of stability in the snowpack rather than to the emptying of all starting zones during the cycle. Provided that forecasts are not attempted for specific slidepaths, it is likely that parameters describing prior avalanche occurrences will not need to be included in the model, at least during the dry slide season.

During the wet slide season, however, many starting zones are removed from the sample of avalanche release points due to large wet slab releases, following which the snowpack does not regenerate. Under these conditions, the probability of avalanches occurring must decrease as a function of time since the number of sample points is progressively reduced. Under extreme conditions, cessation of the wet slide cycle may occur when the supply of snow is depleted from widespread slab avalanching, so that the discriminant functions will over-estimate avalanche hazard. As in the dry slide season, however, it is much more likely that activity in the wet season will diminish in response to a progressive increase in snow stability. This view is supported by the relatively abrupt cessation of wet slab avalanching throughout the study area, and the fact that many starting zones retain a thick snow cover at the end of the wet season.

Given the large sample of release zones along Station 152, inclusion of variables describing previous avalanche cycles is regarded as a refinement of the existing method, rather than as a vital component at this stage. Also, the relative weighting of variables in Appendix D to this chapter suggests that decaying of precipitation over the period of a storm should not be necessary, during either the dry or wet seasons. The weighting of variable 2 is always greater than variable 1 in all four dry season equations (Appendix D). The 12-hour to 24-hour summation of variable 2 means that it can respond quickly to changing precipitation patterns, provided it is up-dated with successive two-hour observations after the 0800 hr. forecast. A slight lag may develop between discriminant scores and avalanche occurrences that amounts to an over-estimation of prevailing hazard for several hours, although this can be viewed as a built-in safety factor in the method, rather than a shortcoming.

Conclusion

The forecast method outlined in this chapter enables probability estimates to be made for several levels of avalanche hazard. A basic stratification into dry and wet slide seasons corresponds to two distinct sets of predictive equations that are calibrated to real-time data summaries.

None of the forecast equations require data integration for more than two days prior to an avalanche or non-avalanche day and provision is made for up-dating certain variables during the day on which forecasts are issued. This ensures that the model will respond relatively quickly to both improving and deteriorating hazard situations, so that avalanche occurrences and avalanche forecasts are only slightly out of phase with each other.

Provided that real-time data summaries can be obtained, on at least a two-hour basis, probability forecasting can be carried out with the aid of a pocket, programmable calculator, such as the Hewlett-Packard HP-65. The magnetic card storage capability of this machine allows the discriminant function terms (Appendix D) to be copied to storage registers without error at the time of the forecast. Also, retrievable programs can be written to speed up data reduction and calculations required to compute normal deviates. Although this machine can be programmed to compute areas under a normal curve, this will very likely necessitate using most of the storage registers, so that preceding results are destroyed if not first written down. Since this increases the chances of error from incorrectly entered data, it is recommended that a table of the normal curve be consulted, leaving the machine free to compute standardized discriminant scores and deviations from each group mean. Other, more sophisticated hardware configurations could be used that might involve automatic telemetering from all sensors, a digital clock for accurate timing of observations and a small desktop computer capable of blocking reduced data to storage locations in readiness for input into the prediction equations. (A system similar to the Tektronix 31 is envisioned here). Exclusive of data telemetry costs, then, a real-time data reduction system could be established for $800 to $4,500.

APPENDIX A

CHARACTERISTICS OF THE AVALANCHE DATA TAPE AND INSTRUCTIONS TO USERS

Introduction

The format of a typical segment of the 7-track avalanche data tape is shown in Figure A.1. Data are written in odd parity as card images at a density of 556 binary digits (bits) per inch (BPI). On the CDC 6400 KRONOS 2.1 system at the University of Colorado, Boulder, the tape is in so-called 'binary' format. This distinguishes it from blocked BCD tapes which are written in even parity.

Irrespective of the length of a particular data file or record, the system writes data in physical record units (PRU's) of 512 central memory words in length. At the end of each month, logical record marks are written, each record consisting of an integer multiple of a PRU plus a fraction of a PRU, assuming tape record marks and logical record marks do not co-incide.

The highest level data unit on the tape is the file, specified by an end-of-file mark (EOF). As Figure A.1 indicates, logical records are nested within files. The entire tape is, therefore, a multi-file catalog; however, the system does not write 'catalog' marks on tapes, so that this term is meaningful to the user and not to the system, in this context.

Reading the Tape

The tape is filed at INSTAAR under the internal tape library number AA 224. The user should transport the tape to the Computing Center and request a Volume Serial Number (VSN) and then request the tape to be mounted as follows:

```
LABEL(TAPE1,VSN=NNNNNN,F=X,LB=KU,PO=R)            (1)
```

in which the tape is equivalenced to local file TAPE1, the VSN is acquired at the Center, F=X indicates compatibility with the defunct KRONOS 2.0 system, LB=KU means the tape is of the KRONOS, unlabeled type and PO=R says that the processing option is read.

After the tape has been mounted, it is rewound to the beginning-of-information point (BOI) by:

```
REWIND(TAPE1)                                     (2)
```

The list of files in Appendix B is then consulted so as to position the tape at the beginning of the first file to be read. If a working copy is required of file number 2 on disk, the following system cards are needed:

```
SKIPF(TAPE1,1)                                    (3)

COPYBF(BF,TAPE1,PRECIP)                           (4)
```

where PRECIP is an arbitrary local file name (LFN) for this precipitation file. Working copies of other files are obtained by skipping the required number of file marks using (3) and the fast copy routine in (4). When reckoning the number of files to be skipped, do not include the EOF of the file just copied. Also, the LFN in (4) may be changed, otherwise a multi-file file will result under the name PRECIP.

When all files are copied from the tape, the tape drive is returned to the system. Users should consult persons knowledgable with the system before writing on the tape.

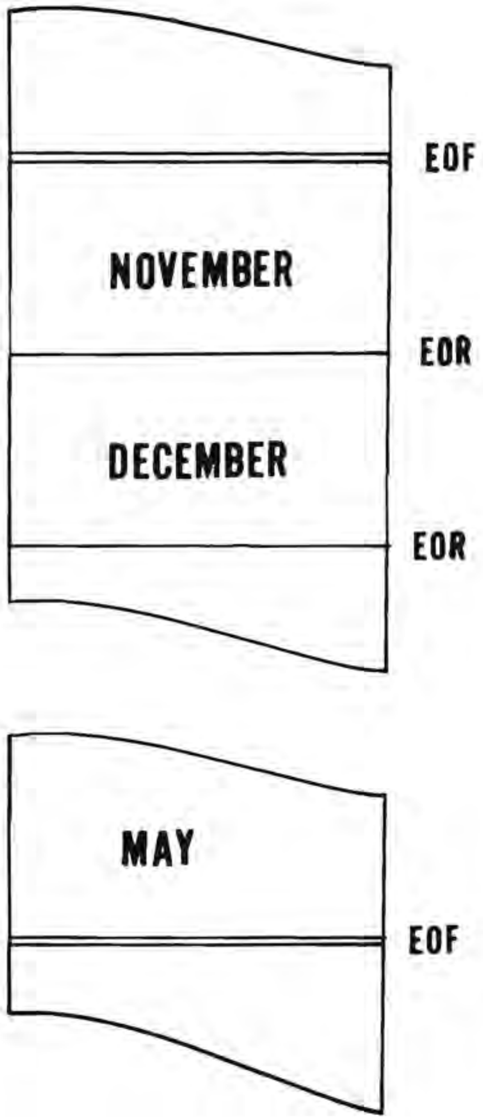

Figure A.1

APPENDIX B

LISTING OF DATA FILES ON THE MAGNETIC TAPE

A sequential listing of all data files for the period 1971-75 inclusive, is given in Table B.1 of this appendix. The format used in the avalanche occurrence data (file numbers 20, 21, 43-45, 69-71 and 90-92) is explained in Appendix 2 prior to the listing of all occurrences. To assist the user, the format of all other data files is given below.

In most cases, there is only one card for each day in each data file. For example, the logical record for December, 1971 in File 2 (2-hr precipitation, Red Mountain Pass Study Site) consists of 31 card images. Exceptions to this rule are:

(1) All wind speed and direction files for Pt. 12,325; due to the 1-hour data reduction, there are two cards per day on these files in all seasons.

(2) Western Scientific precipitation data for Ironton and Molas; again, the 1-hour data reduction means two cards per day.

(3) Daily observations, Red Mountain Pass, for 1974-75 only. Here, there is one card for each observation within a given day. Therefore, there may be from one to as many as five cards per day on this file.

Irrespective of the number of cards per day, the date and site identification format listed below applies to all cards on all data files:

Year: cols. 1,2. Month: cols. 4,5. Day: cols. 7,8.

Site (abbreviated): cols. 10-14. The abbreviations are self-explanatory when compared to the listing of files in Table B.1.

Type of data: cols. 16-19. A two-digit alphabetical abbreviation is used, followed by a two-digit number, specifying the period over which data was reduced. For example, 2-hour precipitation becomes PP02; 2-hour air temperature, TM02. One-hour windspeed becomes WS01. Snow temperatures(daily readings) from all fixed thermocouple arrays are listed as TS24. For Red Mountain Pass, 1974-75, an additional array was run adjacent to the isotopic profiler (File Number 75) and this is identified by TP24. The term 'snow surface temperatures' is possibly misleading and is explained more fully here. These files are all identified by TF24, and the data were gathered by inserting a battery of sensors fixed to rods of length 2.5 cm., 5 cm etc. into the snow from the surface. This is in contrast to readings from fixed thermocouple arrays (TS24, TP24) which involve measurement at levels that are fixed with respect to the ground surface.

Digit to describe numbers of cards per day or numbers of observations per day, where this is not constant (e.g., snow temperature): col. 20. On all files listed in (1) and (2) above, column 20 on the first card of each pair is punched '1', and the same column on the second card is punched '2'. In (3) above, column 20 is used to specify the number of observations (i.e., cards) for that day. On the TP24 and TS24 files, column 20 is used to specify the number of observations (i.e., temperature levels read) on a given day. Above 9, an alphabetical coding is used: i.e., A=10, etc.

From the foregoing, it is seen that the actual observations for a given day always begin in column 21. The floating-point decimal formats for each type of data are as follows:

(1) Precipitation - 12F4.1, in millimeters, with decimal point punched.
(2) Air temperature - 12F5.1, in degrees centigrade, with decimal point punched.
(3) Wind speed - 12(F3.0,1X), in meters per second.
(4) Wind direction - 12(F3.0,1X), azimuth.
(5) Snow temperatures - 12F5.1, in degrees centigrade, decimal point punched.
(6) Snow depth - F5.1, stake reading in centimeters, decimal point punched.

The format for daily observations is as follows for the seasons 1971-74:

Cols. 21-23: Master stake reading, centimeters, F3.0.
" 24-27: 24-hour board reading, centimeters, in F4.1, decimal point punched.
" 29-31: Einsinktiefe reading, centimeters, F3.0.
" 32-35: Crystal type (International classification), A4 format.
" 36-39: 24-hour water equivalent, millimeters, F4.1, decimal punched.

The format for daily observations for the season 1974-75 is as follows:

Cols. 21: Number of observations on given day.
" 23-26: Time of observation, 24-hour clock.
" 28-30: Master stake reading, centimeters, F3.0.
" 32-34: Interval board reading, centimeters, F3.0.
" 35: Punch 'D' if board was dumped after observation; otherwise, blank.
" 36-38: Density of interval board sample, F3.3, no decimal punched.
" 40-42: 24-hour board reading, centimeters, F3.0.
" 44-46: Density of 24-hour board sample, F3.3, no decimal punched.
" 48-50: Storm board reading, centimeters, F3.0.
" 51: Punch 'D' if board was dumped after observation; otherwise, blank.
" 52-54: Density of storm board sample, F3.3, no decimal punched.
" 55-57: Einsinktiefe reading, centimeters, F3.0.
" 59-62: Crystal type (International classification), A4 format.

If the data set is to be up-dated, the user should remember to include a 7-8-9 (End-of-record) card at the end of each calendar month, and a 6-7-9(End-of-file) card at the end of each data file. This will enable all data to be manipulated with the existing data reduction programs, described in Appendix C.

TABLE B.1

Sequential Listing of Files on Avalanche Data Tape

File Number	Station	Contents of File	Season	Length of Record
1	Ironton	1-hr precipitation[#]	1971-72	Oct 1-May 31
2	RMPSS[*]	2-hr precipitation	"	Nov 1-Apr 30
3	RMPSS	2-hr air temperature	"	Nov 1-Apr 30
4	RMPSS	Daily snow temperature	"	Dec 1-Mar 31
5	RMPSS	Daily observations	"	Dec 1-Mar 31
6	Silverton	2-hr precipitation	"	Oct 1-Apr 30
7	Silverton	2-hr air temperature	"	Oct 1-Apr 30
8	Silverton	Daily observations	"	Dec 1-Mar 31
9	Rainbow	2-hr wind speed	"	Oct 1-Mar 31
10	Rainbow	2-hr wind direction	"	Oct 1-Mar 31
11	Carbon	2-hr wind speed	"	Oct 1-Mar 31
12	Carbon	2-hr wind direction	"	Oct 1-Mar 31
13	Pt. 12,325	1-hr wind speed	"	Nov 1-Apr 30
14	Pt. 12,325	1-hr wind direction	"	Nov 1-Apr 30
15	Pt. 12,325	Daily max/min air temperature	"	Sep 1-May 31
16	Pt. 12,325	Daily max/min air temperature	"	Jun 1-Sep 30
17	Molas	1-hr precipitation[#]	"	Oct 1-May 31
18	Molas	Daily observations	"	Dec 1-Feb 29
19	Molas	2-hr air temperature	"	Nov 1-Apr 30
20	152	Avalanche occurrences	"	Nov 16-Mar 13
21	157	Avalanche occurrences	"	Dec 4-Mar 5
22	Ironton	1-hr precipitation[#]	1972-73	Oct 1-May 31
23	RMPSS	2-hr precipitation	"	Oct 1-May 31
24	RMPSS	2-hr air temperature	"	Nov 1-May 31
25	RMPSS	Daily snow temperature	"	Feb 1-May 31
26	RMPSS	Daily observations	"	Nov 1-May 31
27	Silverton	2-hr precipitation	"	Nov 1-May 31
28	Silverton	2-hr air temperature	"	Nov 1-May 31
29	Silverton	Daily observations	"	Nov 1-May 31
30	Rainbow	2-hr wind speed	"	Oct 1-Mar 31
31	Rainbow	2-hr wind direction	"	Oct 1-Mar 31
32	Rainbow	Daily max/min air temperature	"	Nov 1-May 31
33	Rainbow	2-hr precipitation	"	Nov 1-May 31
34	Carbon	2-hr wind speed	"	Oct 1-Apr 30
35	Carbon	2-hr wind direction	"	Oct 1-Apr 30
36	Pt. 12,325	1-hr wind speed	"	Nov 1-May 31
37	Pt. 12,325	1-hr wind direction	"	Nov 1-May 31
38	Pt. 12,325	Daily max/min air temperature	"	Oct 1-May 31
39	Pt. 12,325	Daily max/min air temperature	"	Jun 1-Sep 30
40	Molas	1-hr precipitation[#]	"	Oct 1-May 31

[*] Red Mountain Pass Study Site.

[#] Western Scientific Belfort Gauge.

TABLE B.1 (cont'd)

File Number	Station	Contents of File	Season	Length of Record
41	Molas	Daily observations	1972-73	Nov 1-Apr 30
42	Molas	2-hr air temperature	"	Nov 1-May 31
43	152	Avalanche occurrences	"	Oct 30-May 10
44	153	Avalanche occurrences	"	Nov 21-May 10
45	157	Avalanche occurrences	"	
46	Ironton	1-hr precipitation[#]	1973-74	Oct 1-May 31
47	RMPSS[*]	2-hr precipitation	"	Nov 1-Apr 30
48	RMPSS	2-hr air temperature	"	Nov 1-Apr 30
49	RMPSS	Daily snow temperature	"	Nov 1-Mar 31
50	RMPSS	Daily observations	"	Nov 1-Mar 31
51	RMPSS	Snow surf temperature	"	Nov 1-Mar 31
52	Silverton	2-hr precipitation	"	Nov 1-Apr 30
53	Silverton	2-hr air temperature	"	Nov 1-Apr 30
54	Silverton	Daily observations	"	Nov 1-Apr 30
55	Silverton	Daily snow temperature	"	Nov 1-Mar 31
56	Rainbow	2-hr wind speed	"	Nov 1-Mar 31
57	Rainbow	2-hr wind direction	"	Nov 1-Mar 31
58	Rainbow	Daily max/min air temperature	"	Nov 1-Apr 30
59	Rainbow	2-hr precipitation	"	Nov 1-Apr 30
60	Carbon	2-hr wind speed	"	Nov 1-Feb 28
61	Carbon	2-hr wind direction	"	Nov 1-Dec 31
62	Pt. 12,325	1-hr wind speed	"	Nov 1-Apr 30
63	Pt. 12,325	1-hr wind direction	"	Nov 1-Apr 30
64	Pt. 12,325	Daily max/min air temperature	"	Oct 1-Feb 28
65	Chattanooga	2-hr air temperature	"	Dec 1-Apr 30
66	Chattanooga	Daily observations	"	Dec 1-Apr 30
67	Chattanooga	Daily snow temperature	"	Nov 1-Mar 31
68	Molas	1-hr precipitation[#]	"	Nov 1-Mar 31
69	152	Avalanche occurrences	"	Nov 23-Apr 21
70	153	Avalanche occurrences	"	Mar 16-Apr 27
71	157	Avalanche occurrences	"	Jan 5-Apr 27
72	RMPSS	2-hr precipitation	1974-75	Oct 1-May 31
73	RMPSS	2-hr air temperature	"	Oct 1-May 31
74	RMPSS	Snow surf. temperature	"	Oct 1-May 31
75	RMPSS	Daily snow temperature, at profiler thermo. array	"	Oct 1-May 31
76	RMPSS	Daily snow temperature, at master stake thermo. array	"	Oct 1-May 31
77	RMPSS	Daily observations	"	Oct 1-May 31
78	Silverton	2-hr precipitation	"	Oct 1-May 31
79	Silverton	2-hr air temperature	"	Oct 1-May 31

---

[*] Red Mountain Pass Study Site

[#] Western Scientific Belfort Gauge

TABLE B.1 (cont'd)

File Number	Station	Contents of File	Season	Length of Record
80	Silverton	Daily snow temperature	1974-75	Nov 1-Apr 30
81	Silverton	Daily snowdepth	"	Nov 1-Apr 30
82	Rainbow	2-hr wind speed	"	Nov 1-Mar 31
83	Rainbow	2-hr wind direction	"	Nov 1-Mar 31
84	Chattanooga	2-hr air temperature	"	Oct 1-May 31
85	Chattanooga	Daily snow temperature	"	Nov 1-Apr 30
86	Chattanooga	Daily snow depth	"	Nov 1-Apr 30
87	Pt. 12,325	1-hr wind speed	"	Oct 1-May 31
88	Pt. 12,325	1-hr wind direction	"	Nov 1-Mar 31
89	Pt. 12,325	Daily max/min air temperature	1974	Jun 1-Oct 31
90	152	Avalanche occurrences	1974-75	Oct 29-May 30
91	153	Avalanche occurrences	"	Nov 11-May 17
92	157	Avalanche occurrences	"	Nov 24-May 17

APPENDIX C

DESCRIPTION OF DATA REDUCTION PROGRAMS

Program AVAL

This program generates a list of dates on which avalanches occurred from a sequential listing of all avalanche occurrences (Appendix 2), which should be copied to local file TAPE1 prior to program execution. If the copy is made from the magnetic tape catalog, the latter should be equivalenced to a local file other than TAPE1 to avoid confusion (See Appendix A). Avalanche dates are written onto local file TAPE2 in the format required by the data reduction program PRELIM (described below). To avoid confusion in later work involving several permanent files (See KRONOS 2.1 system Reference Manual) local file TAPE2 should be saved under an alphabetical name (e.g., AVAL) as follows:

```
SAVE(TAPE2=AVAL)                    (1)
```

There is no confusion between the program name and the permanent file name. A listing of the program is given at the end of this appendix.

Program NONAVAL

Since the discriminant analysis involves avalanche and non-avalanche days, it would be tedious for the user to have to supply the latter set of days. Instead, these are generated by NONAVAL from the output file of AVAL (i.e., local file TAPE2). Therefore, NONAVAL reads from TAPE2 and writes its output on local file TAPE3, so that both sets of dates can be generated in a single run. However, TAPE2 must be rewound before executing NONAVAL since the pointer is at EOF on this file after program AVAL. The output from NONAVAL can be saved as a permanent file under the same name as the program using (1) above when the LFN is changed. A listing of the program is given at the end of this appendix.

Program PRELIM

This is the main data reduction routine of this set of programs and comprises several subroutines which have clearly-defined functions. The main program (PRELIM) handles card input and printing of results and calls all other subroutines requested by the user in the array OPTION. Subroutines PRECIP, AIRTEMP and WSPEED reduce precipitation, air temperature and wind speed data respectively. The number of data points per day is specified by array NPOINT in program PRELIM. Subroutine FINDAY makes sure that each data file is positioned at the appropriate date before data reduction begins. This allows certain variables to be integrated over variable time periods (Table 16), the length of this period being specified by array NDAY in program PRELIM and by integer variable KOUNT in other subroutines. Subroutine T1200 creates an array of observations from 1200 hr on day (j-1) to 1200 hr on day j from card images which are punched in 0000 hr to 2400 hr format (Table 16). Subroutine CASELIM eliminates cases (days) which have any missing data. These variables are printed as -0.0 in the sample of output from PRELIM given at the end of this appendix. The card input to PRELIM from which the sample output was generated is listed at the end of subroutine CASELIM. Ordinarily, these cards would not be listed in this way.

Special note: It is especially important that the variable INIT be included on card number 4 of the input sequence to PRELIM. This is the month (e.g. 10 = October) in which data reduction is to commence, and is used by FINDAY to ensure that previous logical records (months) on the weather data files are skipped. For example, if all data files begin with October in a particular year, but the avalanche season did not start until November, then the number 11 would be punched for variable INIT at READ 580 in PRELIM. The file is always rewound by FINDAY, following which (INIT - 10) logical records are skipped. Also, FINDAY will only make allowance for leap years up to and including 1976.

Irrespective of the length of the data reduction period specified under NDAY for all three weather data files, variables 2, 3, 5, 6, 8 and 9 (Table 16) will always be generated by PRELIM. Therefore, only the levels of variables 1, 4 and 7 are changed by using a different time step. The variables are generated in the same order as the list in Table 16. However, if, say, the air temperature file is omitted under array OPTION, the three windspeed variables will be listed as 4, 5 and 6 on the output file. The output file with missing data cases deleted resides on TAPE5 and can be saved as a permanent file using (1) above with different local file and permanent file names.

```
RUN VERSION FEB 76  C1  15:20 76/04/27.

                  PROGRAM AVAL(TAPE1,TAPE2,OUTPUT)
         C
         C   PROGRAM GENERATES LIST OF AVALANCHE DAYS FROM A LIST OF AVALANCHE
         C   OCCURRENCES. THESE ARE LOCATED ON LOCAL FILE TAPE1 AND MUST BE
         C   LISTED SEQUENTIALLY ON THIS FILE.
         C   A SAVE CARD IS REQUIRED TO STORE OUTPUT ON PERMANENT FILE FOR
         C   FUTURE USE.
         C  NOTE - OUTPUT IS WRITTEN ON LOCAL FILE TAPE2
000003            INTEGER YEAR,YEAR1,DAY,DAY1
000003            M=0
000004            READ(1,100) YEAR,MONTH,DAY
000016        100 FORMAT(I2,I3,I4)
000016            WRITE(2,101) YEAR,MONTH,DAY
000030        101 FORMAT(3I3)
000030            MONTH1=MONTH
000032            DAY1=DAY
000033         99 READ(1,100) YEAR,MONTH,DAY
000045            IF(EOF,1) 50,98
000050         98 IF(MONTH1.EQ.MONTH.AND.DAY1.EQ.DAY) GO TO 99
000060            WRITE(2,101) YEAR,MONTH,DAY
000071            MONTH1=MONTH $ M=M+1
000074            DAY1=DAY
000076            GO TO 99
000076         50 ENDFILE 2
000100            PRINT 60, M
000106         60 FORMAT(/////,2X,*NUMBER OF AVALANCHE DAYS =*,I4)
000106            CALL EXIT
000107            END
```

```
RUN VERSION FEB 76  C1  13:26 76/04/28.

                PROGRAM NONAVAL(TAPE2,OUTPUT,TAPE3)
          C   PROGRAM GENERATES LIST ON NON-AVALANCHE DATES FOR SEASON, GIVEN THAT
          C   EVENT DATES EXIST ON TAPE 2.  TAPE 2 CAN BE GENERATED FROM A LIST
          C   OF AVALANCHE OCCURRENCES USING PROGRAM AVAL.
          C   FORMAT FOR INPUT AND OUTPUT IS FIXED AT 3I3 FOR YEAR, MONTH, DAY TO
          C   ALLOW BOTH EVENT FILE AND NON-EVENT FILE TO BE READ BY PRELIM(DATA
          C   REDUCTION PROGRAM FOR WEATHER VARIABLES)
          C   A SEQUENCE NUMBER SUPPLIED ALONGSIDE EACH NON-AVALANCHE DAY IN
          C   OUTPUT FILE FOR PURPOSES OF RANDOM SAMPLING (SEE MAIN TEXT)
000003          DIMENSION LMONTH(7),NMONTH(7)
000003          INTEGER DAY,DAY1,YEAR,FIRST,YEAR1
000003          DATA LMONTH/30,31,31,29,31,30,31/
000003          DATA NMONTH/11,12,1,2,3,4,5/
000003          K=0
000004          NSEQ=0
000005       99 READ(2,100) YEAR,MONTH,DAY
000017      100 FORMAT(3I3)
000017          IF(EOF,1) 50,98
000022       98 K=K+1
000024          IF(K.EQ.1) GO TO 11
000025          DO 1 I=1,7
000026          IF(MONTH.EQ.NMONTH(I)) GO TO 2
000030        1 CONTINUE
000032        2 LAST=LMONTH(I-1)
000034          IF(MONTH.NE.MONTH1) GO TO 10
000036          LENGTH=(DAY-DAY1)-1
000041          IF(LENGTH.EQ.0) GO TO 11
000042          DO 9 I=1,LENGTH $ DAY1=DAY1+1 $ NSEQ=NSEQ+1
000046        9 WRITE(3,200) YEAR,MONTH,DAY1,NSEQ
000064      200 FORMAT(3I3,I4)
000064       11 DAY1=DAY $ MONTH1=MONTH $ YEAR1=YEAR $ K=K+1 $ GO TO 99
000073       10 FIRST=LAST-DAY1
000075          IF(FIRST.EQ.0) GO TO 20
000076          DO 12 I=1,FIRST
000077          DAY1=DAY1+1 $ NSEQ=NSEQ+1
000102       12 WRITE(3,200) YEAR1,MONTH1,DAY1,NSEQ
000120       20 IF(DAY.EQ.1) GO TO 15 $ FIRST=DAY-1
000123          DO 16 I=1,FIRST
000124          DAY1=I $ NSEQ=NSEQ+1
000126       16 WRITE(3,200) YEAR,MONTH,DAY1,NSEQ
000144       15 DAY1=DAY
000146          MONTH1=MONTH $ YEAR1=YEAR $ GO TO 99
000151       50 PRINT 60, NSEQ
000157       60 FORMAT(/////,2X,*NUMBER OF NON-AVALANCHE DAYS =*,I4)
000157          ENDFILE 2
000161          CALL EXIT
000162          END
```

```
RUN VERSION FEB 76  C1  17:06 76/04/28.

                    PROGRAM PRELIM(INPUT,OUTPUT,TAPE1,TAPE2,TAPE3,TAPE4,TAPE5,TAPE6,
                   1TAPE7)
000003              COMMON/IFORMAT/NDAY(3),NTAPE(3),ITN,BUFF(24),JJ
000003              COMMON/DATES/ YEAR,MONTH,DAY,INIT
000003              COMMON/XVAR/X(20),M,NPOINT(3)
000003              COMMON SAMSIZ(3),NVAR,NGROUP,NC(3)
000003              DIMENSION OFMT(8),ITAPE(2),LABEL(8),VLABEL(90),TITLE(16),OPTION(3)
000003              INTEGER YEAR,DAY,SAMSIZ,OPTION
000003              DATA NTAPE/1,2,3/
000003              DATA ITAPE/6,7/
              C   THIS PROGRAM INTEGRATES WEATHER DATA OVER PERIODS SPECIFIED BY THE
              C   USER. EACH DATA FILE IS ANALYSED IN SEPARATE SUBROUTINE.
              C   FOLLOWING SEQUENCE OF FILES SHOULD BE NOTED
              C         1.  PRECIPITATION DATA (TAPE1)
              C         2.  AIR TEMPERATURE DATA (TAPE2)
              C         3.  WINDSPEED DATA (TAPE3)
              C         4.  AVALANCHE DATES (TAPE6)
              C         5.  NON-AVALANCHE DATES (TAPE7)
              C   OUTPUT DATA WILL BE WRITTEN ON LOCAL FILE TAPE5.  IT IS THE USERS
              C   TASK TO SAVE THIS AS A PERMANENT FILE FOR LATER USE.
              C   ORDER OF CARDS ON INPUT FILE
              C         1.  OPTION CARD FOR SUBROUTINE CALL(SEE WRITE-UP IN APPENDIX)
              C   2 AND 3.  TITLE CARDS FOR RUN(TWO CARDS MUST BE INCLUDED)
              C         4.  NUMBER OF GROUPS(GENERALLY TWO), SIZE OF EACH(DAYS),
              C              AND THE EARLIEST MONTH WRITTEN ON THE WEATHER FILES(E.G.,
              C              10 = OCTOBER)
              C         5.  OUTPUT FORMAT FOR REDUCED DATA
              C         6.  NO.OF INPUT TAPES(GENERALLY 3) AND NO.OF DATA POINTS PER
              C              DAY ON EACH(=12 FOR 2HR DATA, 24 FOR 1HR DATA)
              C         7.  LABELS FOR INPUT VARIABLES(10 COLUMNS PER LABEL)
              C         8.  LENGTH OF DATA INTEGRATION PERIODS ON WEATHER DATA FILES
              C               (NEED NOT BE THE SAME)
              C         9.  LABELS FOR VARIABLES(30 COLUMNS PER VARIABLE)
              C
000003              PRINT 2000
000007         2000 FORMAT(1H1)
              C  READ OPTION CARD FOR DESIRED SUBROUTINES
000007              READ 504,OPTION $ READ 501,TITLE $ PRINT 511,TITLE
000031          504 FORMAT(5I1)
000031          501 FORMAT(8A10)
000031          511 FORMAT(2X,8A10)
              C   READ NUMBER OF GROUPS,SIZE OF EACH AND START MONTH FOR DATA FILES.
              C  READ OUTPUT FORMAT FOR REDUCED DATA
000031              READ 580, NGROUP,(SAMSIZ(I),I=1,NGROUP),INIT $ READ 1001,OFMT
000055          580 FORMAT(10I3)
000055         1001 FORMAT(8A10)
000055              LOOP=0
              C  READ NUMBER OF DATA POINTS PER DAY ON EACH DATA FILE
              C   COMPUTE NUMBER OF OUTPUT VARIABLES
000056              READ 500, NT,(NPOINT(I),I=1,NT) $ NVAR=NT*3
000075          500 FORMAT(6I2)
              C  LABELS FOR INPUT FILES
              C  READ LENGTH OF DATA INTEGRATION PERIOD DESIRED FOR EACH FILE
000075              READ 502,(LABEL(I),I=1,NT) $ K=NVAR*3 $ READ 525,(NDAY(I),I=1,NT)
000123          502 FORMAT(8A10)
```

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RUN VERSION FEB 76  C1  17:06 76/04/28.

000123      525 FORMAT(5I2)
          C  LABELS FOR OUTPUT(REDUCED) VARIABLES
000123          READ 503,(VLABEL(I),I=1,K) $ PRINT 520,NGROUP,NVAR
000146      503 FORMAT(6A10)
000146      520 FORMAT(///2X,*NUMBER OF GROUPS=*,I3,* NUMBER OF VARIABLES=*,I3///)
000146          DO 521 I=1,NGROUP
000150      521 PRINT 522,I,SAMSIZ(I)
000162      522 FORMAT(2X,*SIZE OF GROUP*,I2,* IS*,I3)
000162          PRINT 560 $ K=K-2 $ IJ=0
000170      560 FORMAT(///)
000170          DO 505 I=1,K,3 $ J=I+2 $ IJ=IJ+1
000174      505 PRINT 508,IJ,(VLABEL(L),L=I,J) $ PRINT 560
000217      508 FORMAT(2X,*VARIABLE*,I3,* = *,3A10)
000217          DO 530 I=1,NT
000221      530 PRINT 531, NDAY(I),LABEL(I) $ MAX=NDAY(1)
000234      531 FORMAT(2X,*COMPUTATION SPECIFIED*,I3,* DAYS AHEAD ON *,A10,*FILE*)
000234          DO 600 I=2,NT $ IF(NDAY(I).GT.MAX) GO TO 601 $ GO TO 600
000242      601 MAX=NDAY(I)
000244      600 CONTINUE
000247          DO 1 NG=1,NGROUP $ LOOP=LOOP+1 $ NN=ITAPE(LOOP) $ L=0
          C   SKIP AVALANCHE DATES WHICH ARE LESS THAN NDAY(MAX) DAYS FROM START
          C   OF  WEATHER FILES.
000255        7 READ(NN,100) YEAR,MONTH,DAY $ L=L+1 $ IF(DAY.LT.MAX+1) GO TO 7
000274          IF(L.EQ.1) GO TO 8$GO TO 9
000275        8 NCASES=SAMSIZ(LOOP) $ GO TO 10
000300        9 NCASES=SAMSIZ(LOOP)-L+1
000303          PRINT 11, LOOP,MAX,NCASES
000315       11 FORMAT(//2X,*REMAINING SAMPLE SIZE IN GROUP*,I2,* AFTER DELETION O
               1F EVENTS LESS THAN OR EQUAL TO*,I3,* DAYS FROM START OF FILE IS*,
                2I3//)
000315       10 NC(LOOP)=NCASES $ PRINT 450,LOOP
000325      450 FORMAT(//2X,*INPUT DATA FOR GROUP*,I2/)
000325          DO 2 LL=1,NCASES
000327          DO 851 I=1,20
000330      851 X(I)=0. $ JJ=1 $ M=1 $ ITN=NTAPE(JJ) $ IF(LL.EQ.1) GO TO 108
000341          READ(NN,100) YEAR,MONTH,DAY
000353      100 FORMAT(3I3)
000353      108 DO 200 I=1,3 $ IF(OPTION(I).EQ.1) GO TO 201 $ GO TO 200
000360      201 GO TO (101,102,103)I
000367      101 CALL PRECIP $ GO TO 200
000371      102 CALL AIRTEMP $ GO TO 200
000373      103 CALL WSPEED
000374      200 CONTINUE $ NVAR=M
000400          WRITE(4,OFMT) YEAR,MONTH,DAY,(X(I),I=1,M)
000421          PRINT 550, YEAR,MONTH,DAY,(X(I),I=1,M)
000442      550 FORMAT(2X,3I4,5X,20F5.1)
000442        2 CONTINUE
000445        1 CONTINUE
000447          CALL CASFLIM
000450          END
```

```
RUN VERSION FEB 76  C1  09:42 76/04/27.


                  SUBROUTINE PRECIP
000002            COMMON/IFORMAT/NDAY(3),NTAPE(3),ITN,BUFF(24),JJ
000002            COMMON/XVAR/X(20),M,NPOINT(3)
000002            DIMENSION PTEMP(12),PI(4),P(12),INF(2)
000002            DATA INF/12H(20X,12F4.1)/
000002            KOUNT=NDAY(JJ) $ NPT=NPOINT(JJ) $ CALL FINDAY(KOUNT,NPT)
000010            CALL SETEOR(ITN,0) $ MD=0 $ PSUM=0. $ DO 1 J=1,KOUNT
000015            READ(ITN,INF) P $ IF(J.LT.KOUNT) GO TO 2 $ DO 3 K=1,NPT
000027          3 PTEMP(K)=P(K)
000033          2 DO 4 I=1,NPT $ IF(.NOT.P(I)) 4,11
000037         11 MD=MD+1
000041          4 PSUM=PSUM+P(I)
000046          1 CONTINUE
          C     COMPUTE TOTAL WATER EQUIVALENT
000050            IF(MD.GT.((NPT/6)*KOUNT))GO TO 13 $ X(M)=PSUM $ GO TO 14
000060         13 X(M)=-0.
000062         14 M=M+1
          C     COMPUTE WATER EQUIVALENT FOR PERIOD 1200H ON DAY-1 TO 1200H ON DAY
          C     AND MAXIMUM 6HR INTENSITY DURING THIS PERIOD.
000064            DO 120 I=1,24
000065        120 BUFF(I)=0. $ CALL T1200(PTEMP,INF,NPT) $ PSUM=0. $ MD=0
000075            DO 65 I=1,NPT $ IF(.NOT.BUFF(I)) 65,66
000100         66 MD=MD+1
000102         65 PSUM=PSUM+BUFF(I)
000107            IF(MD.GT.(NPT/6)) GO TO 67 $ X(M)=PSUM $ GO TO 68
000116         67 X(M)=-0.
000120         68 M=M+1 $ MD=0 $ DO 451 I=1,4
000124        451 PI(I)=0. $ INCR=NPT/4 $ INCR2=INCR-1 $ J=-2
000134            DO 5 I=1,4 $ J=J+INCR $ K=J+INCR2
000141            DO 6 L=J,K $ IF(.NOT.BUFF(L)) 6,9
000144          9 MD=MD+1
000146          6 PI(I)=PI(I)+BUFF(L)
000154            IF(MD.GT.0) GO TO 17 $ GO TO 18
000156         17 PI(I)=-0.
000160         18 MD=0
000161          5 CONTINUE
          C     SEARCH 6HR INTENSITY VECTOR FOR NULL ENTRIES
000163            DO 7 I=1,4 $ IF(.NOT.P(I)) 7,8
000167          8 MD=MD+1
000171          7 CONTINUE
          C     FIND LARGEST PI(I) ELEMENT
000173            IF(MD.GT.1) GO TO 19 $ BIG=PI(1)
000200            DO 20 I=2,4
000201            IF(PI(I).GT.BIG) GO TO 41 $ GO TO 20
000205         41 BIG=PI(I)
000207         20 CONTINUE
000211            X(M)=BIG $ GO TO 23
          C     REJECT DAY
000214         19 X(M)=-0.
000216         23 M=M+1 $ JJ=JJ+1
000221            RETURN
000221            END
```

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RUN VERSION FEB 76  C1  09:42 76/04/27.

                          SUBROUTINE AIRTEMP
000002                    COMMON/IFORMAT/NDAY(3),NTAPE(3),ITN,BUFF(24),JJ
000002                    COMMON/XVAR/X(20),M,NPOINT(3)
000002                    DIMENSION TTEMP(12),T(12),INF(2)
000002                    DATA INF/12H(20X,12F5.1)/
000002                    KOUNT=NDAY(JJ) $ NPT=NPOINT(JJ) $ ITN=NTAPF(JJ) $ ANPT=NPT
000011                    AKOUNT=KOUNT
000012                    CALL FINDAY(KOUNT,NPT)
000014                    MD=0 $ TSUM=0.
000016                    CALL SETEOR(ITN,0)
000020                    DO 1 L=1,KOUNT
000022                    READ(ITN,INF) T
000030                    IF(L.LT.KOUNT) GO TO 2
000033                    DO 40 J=1,NPT
000034                 40 TTEMP(J)=T(J)
000040                  2 DO 3 I=1,NPT
000042                    IF(.NOT.T(I)) 3,11
000044                 11 MD=MD+1
000046                  3 TSUM=TSUM+T(I)
000053                  1 CONTINUE
000055                    IF(MD.GT.((NPT/6)*KOUNT))GO TO 113 $ AMD=MD
                C   MEAN TEMPERATURE OF PRECEDING NDAY PERIOD
000064                    X(M)=TSUM/((ANPT*AKOUNT)-AMD) $ GO TO 114
000071                113 X(M)=-0.
000073                114 M=M+1
000075                    DO 120 I=1,24
000076                120 BUFF(I)=0.
000101                    CALL T1200(TTEMP,INF,NPT)
000104                    MD=0 $ TSUM=0.
000106                    DO 8 I=1,NPT
000107                    IF(.NOT.BUFF(I)) 8,9
000111                  9 MD=MD+1
000113                  8 TSUM=TSUM+BUFF(I)
                C   MEAN AIR TEMP. 1200H-1200H
000120                    IF(MD.GT.NPT/6) GO TO 10 $ AMD=MD $ X(M)=TSUM/(ANPT-AMD)$GO TO 31
000132                 10 X(M)=-0. $ X(M+1)=-0. $ GO TO 500
000136                 31 M=M+1 $ BIG=BUFF(1)
000141                    DO 20 I=2,NPT
000143                    IF(BUFF(I).GT.BIG) GO TO 21 $ GO TO 20
000147                 21 BIG=BUFF(I)
                C   MAX AIR TEMP. 1200H-1200H
000151                 20 CONTINUE $ X(M)=BIG
000156                500 M=M+1 $ JJ=JJ+1
000161                    RETURN
000161                    END
```

```
RUN VERSION FEB 76  C1   09:42 76/04/27.

                      SUBROUTINE WSPEED
000002                COMMON/IFORMAT/NDAY(3),NTAPE(3),ITN,BUFF(24),JJ
000002                COMMON/XVAR/X(20),M,NPOINT(3)
000002                DIMENSION WTEMP(24),WS(40),W(24),INF(4)
000002                DATA INF/34H(20X,12(F3.0,1X)/,20X,12(F3.0,1X))/
000002                ITN=NTAPE(JJ) $ KOUNT=NDAY(JJ) $ NPT=NPOINT(JJ)
000007                CALL FINDAY(KOUNT,NPT) $ DO 150 I=1,40
000013            150 WS(I)=0. $ KK=0 $ MM=NPT/4 $ NSTEP=NPT-(MM-1) $ LL=MM-1$AMM=MM
               C    COMPUTE MEAN WINDSPEED OVER NDAY PERIOD PRECEDING EVENT DATE.
000025                CALL SETEOR(ITN,0) $ DO 100 K=1,KOUNT $ READ(ITN,INF) W
000037                IF(K.LT.KOUNT) GO TO 2 $ DO 3 I=1,NPT
000043              3 WTEMP(I)=W(I)
000047              2 DO 6 I=1,NSTEP,MM $ MD=0 $ J=I+LL $ KK=KK+1 $ DO 7 L=I,J
000057                WS(KK)=WS(KK)+W(L) $ IF(.NOT.W(L)) 7,11
000064             11 MD=MD+1
000066              7 CONTINUE
000071                IF(MD.GT.NPT/6)GO TO 12 $ GO TO 14
000077             12 WS(KK)=-0. $ GO TO 6
000102             14 AMD=MD $  WS(KK)=WS(KK)/(AMM-AMD)
000107              6 CONTINUE
000112            100 CONTINUE $ K=KOUNT*4 $ MD=0 $ WSUM=0. $ DO 8 I=1,K
000120                IF(.NOT.WS(I)) 8,9
000122              9 MD=MD+1
000124              8 WSUM=WSUM+WS(I) $ IF(MD.GT.KOUNT) GO TO 20 $ AK=K
000135                AMD=MD $ X(M)=WSUM/(AK-AMD) $ GO TO 21
000142             20 X(M)=-0.
000144             21 M=M+1
               C    COMPUTE MEAN AND MAXIMUM 6HR WINDSPEED OVER 1200H-1200H PERIOD.
000146                DO 120 I=1,24
000147            120 BUFF(I)=0. $ CALL T1200(WTEMP,INF,NPT) $ DO 29 I=1,40
000157             29 WS(I)=0. $ KK=0 $ DO 30 I=1,NSTEP,MM $ J=I+LL $ MD=0 $ KK=KK+1
000171                DO 31 L=I,J
000173                WS(KK)=WS(KK)+BUFF(L) $ IF(.NOT.BUFF(L)) 31,32
000200             32 MD=MD+1
000202             31 CONTINUE $ IF(MD.GT.(NPT/6)) GO TO 33  $  GO TO 34
000212             33 WS(KK)=-0. $ GO TO 30
000215             34 AMD=MD $ WS(KK)=WS(KK)/(AMM-AMD)
               C    COMPUTE MEAN 6HR SPEED.
000222             30 CONTINUE $ MD=0  $  WSUM=0. $  DO 400 I=1,4 $IF(.NOT.WS(I))400,401
000232            401 MD=MD+1
000234            400 CONTINUE $ IF(MD.GT.1) GO TO 40  $  DO 402 I=1,4
000243            402 WSUM=WSUM+WS(I)
000247                AMD=MD $ X(M)=WSUM/(4.-AMD) $ M=M+1 $ GO TO 61
000256             40 X(M)=-0. $ M=M+1 $ X(M)=-0. $ GO TO 60
               C    COMPUTE MAX. 6HR SPEED
000263             61 BIG=WS(1)  $ DO 50 I=1,4
000266                IF(WS(I).GT.BIG) GO TO 51 $ GO TO 50
000272             51 BIG=WS(I)
000274             50 CONTINUE $ X(M)=BIG
000300             60 JJ=JJ+1
000302                RETURN
000302                END
```

```
RUN VERSION FEB 76  C1   09:42 76/04/27.

                 SUBROUTINE FINDAY(KOUNT,NPT)
           C
           C    THIS SUBROUTINE POSITIONS POINTER ON DATA FILES SO THAT READING CAN
           C    BEGIN AT CORRECT DATE WHEN RETURN TO CALLING SUBROUTINE OCCURS.
           C    KOUNT IS LENGTH OF DATA INTEGRATION PERIOD.  FILE MUST BE POSITIONED
           C    ON DAY PRECEDING THIS DATE BEFORE RETURN TO CALLING SUBROUTINE.
           C
000005           COMMON/IFORMAT/NDAY(3),NTAPE(3),ITN,BUFF(24),JJ
000005           COMMON/DATES/ YEAR,MONTH,DAY,INIT
000005           DIMENSION LMONTH(8),NMONTH(8)
000005           INTEGER DAY1,DAY
000005           DATA LMONTH/31,30,31,31,28,31,30,31/
000005           DATA NMONTH/10,11,12,1,2,3,4,5/
000005           K=ITN
000006           CALL SETEOR(K,1)
000010           REWIND K
           C  CHECK FOR LEAP YEAR
000012           IF(YEAR.EQ.72.OR.YEAR.EQ.76) LMONTH(5)=29 $ N=INIT-10 $ J=1
000030           IF(NPT.EQ.24) J=2 $ IF(MONTH.EQ.NMONTH(1)) GO TO 199 $ GO TO 200
000036       199 IF(DAY.EQ.(KOUNT+1)) GO TO 50
000041           DO 201 I=1,J
000042       201 READ(ITN,100) MONTH1,DAY1
000055       100 FORMAT(2X,2I3)
000055           GO TO 40
           C    FIND MONTH IN WHICH EVENT DATE LIES
000056       200 DO 8 I=1,8
000060           IF(MONTH.EQ.NMONTH(I)) GO TO 9
000062         8 CONTINUE
000064         9 LAST=LMONTH(I-1)
000066           IF(DAY.GE.(KOUNT+1)) GO TO 45 $ GO TO 46
           C    POSITION FILE AT BEGINNING OF CURRENT MONTH
           C    N IS SUBTRACTED FROM THE RECORD COUNT TO KEEP THE BOOKS STRAIGHT----
000072        45 NR=I-1-N
000075           CALL SKIP(K,0,NR)
000077           IF(DAY.GT.(KOUNT+1)) GO TO 47 $ GO TO 50
           C    POSITION FILE AT BEGINNING OF PRECEDING MONTH
000104        46 NR=I-2-N $ IF(NR.LT.0) NR=0
000111           CALL SKIP(K,0,NR)
000114        47 DO 205 I=1,J
000117       205 READ(ITN,100) MONTH1,DAY1
000132           IF(DAY.LE.(KOUNT+1)) GO TO 10
000135        40 LENGTH=DAY-DAY1 $ IF(LENGTH.EQ.(KOUNT+1)) GO TO 50
000142       211 DO 210 I=1,J
000144       210 READ(ITN,100) MONTH1,DAY1 $ GO TO 40
000160        10 LENGTH=LAST-DAY1+DAY-1 $ IF(LENGTH.EQ.KOUNT) GO TO 50
000165           DO 61 I=1,J
000167        61 READ(ITN,100) MONTH1,DAY1 $ GO TO 10
000203        50 RETURN
000204           END
```

```
RUN VERSION FEB 76  C1  09:42 76/04/27.


                  SUBROUTINE T1200(Q,JNF,NPT)
000006            COMMON/IFORMAT/NDAY(3),NTAPE(3),ITN,BUFF(24),JJ
000006            DIMENSION Q(24),JNF(4)
000006            MX=(NPT/2)+1 $ J=0
000011            DO 1 K=MX,NPT
000013            J=J+1
000015          1 BUFF(J)=Q(K)
000022            CALL SETEOR(ITN,0)
000024            READ(ITN,JNF) (Q(I),I=1,NPT) $ MX=NPT/2
000051            DO 2 K=1,MX $ J=J+1
000055          2 BUFF(J)=Q(K)
000062            RETURN
000062            END
```

```
RUN VERSION FEB 76  C1  09:42 76/04/27.


                  SUBROUTINE CASELIM
000002            COMMON SAMSIZ(3),NVAR,NGROUP,NC(3)
000002            DIMENSION A(3),B(20)
000002            REWIND 4 $ REWIND 5 $ PRINT 20
000012         20 FORMAT(1H1)
000012            L=0
000013            DO 1 K=1,NGROUP $ KK=0 $ PRINT 30,K,NVAR
000026         30 FORMAT(//2X,*INPUT DATA FOR GROUP*,I2,* CASES WITH MISSING DATA EL
                 1IMINATED*/,2X,*NUMBER OF VARIABLES IS*,I3/)
000026            L=L+1 $ NCASES=NC(L)
000032            DO 2 J=1,NCASES $ READ(4,100) A,(B(I),I=1,NVAR) $ MD=0
000050        100 FORMAT(3I3,15F5.1)
000050            DO 3 N=1,NVAR $ IF(.NOT.B(N)) 4,5
000055          4 GO TO 3
000056          5 MD=MD+1
000060          3 CONTINUE $ IF(MD.GT.0) GO TO 2 $ WRITE(5,100) A,(B(I),I=1,NVAR)
000101            PRINT 10, A,(B(I),I=1,NVAR) $ KK=KK+1
000120         10 FORMAT(2X,3I4,5X,15F5.1)
000120          2 CONTINUE $ PRINT 40,K,KK
000132         40 FORMAT(/2X,*REMAINING SAMPLE SIZE IN GROUP*,I2,*=*,I3)
000132          1 CONTINUE
000135            RETURN
000135            END
```

CARD INPUT FOR TEST EXAMPLE WHICH FOLLOWS --- USUALLY NOT LISTED AT THIS POINT

```
111
DISCRIMINANT ANALYSIS - TEST SEGMENT OF 1974-75 DRY AVALANCHE SEASON
PRECIP., AIRTEMP. FROM RED MTN. PASS.  WIND SPEED FROM POINT 12.325.
  2 26 26 10
(3I3,9F5.1)
 3121224
PRECIP    AIRTEMP   WIND SPEED
 2 2 2
WAT.EQUIV. 2 DAYS PRIOR EVENT WAT.EQUIV.1200H-1200H
MAX.6HR.INTEN.1200H-1200H     MEAN 2HR.AIRTEMP.2 DAYS PRIOR
MEAN 2HR.AIRTEMP.1200H-122H   MAX.2HR.AIRTEMP.1200H-1200H
MEAN 6HR.W.SPEED 2 DAYS PRIOR MEAN 6HR.W.SPEED 1200H-1200H
MAX.6HR.W.SPEED 1200H-1200H
```

```
DISCRIMINANT ANALYSIS - TEST SEGMENT OF 1974-75 DRY AVALANCHE SEASON
PRECIP.. AIRTEMP. FROM RED MTN. PASS.  WIND SPEED FROM POINT 12,325.


NUMBER OF GROUPS=  2 NUMBER OF VARIABLES=  9


SIZE OF GROUP 1 IS 26
SIZE OF GROUP 2 IS 26



VARIABLE  1 = WAT.EQUIV. 2 DAYS PRIOR EVENT
VARIABLE  2 = WAT.EQUIV.1200H-1200H
VARIABLE  3 = MAX.6HR.INTEN.1200H-1200H
VARIABLE  4 = MEAN 2HR.AIRTEMP.2 DAYS PRIOR
VARIABLE  5 = MEAN 2HR.AIRTEMP.1200H-122H
VARIABLE  6 = MAX.2HR.AIRTEMP.1200H-1200H
VARIABLE  7 = MEAN 6HR.W.SPEED 2 DAYS PRIOR
VARIABLE  8 = MEAN 6HR.W.SPEED 1200H-1200H
VARIABLE  9 = MAX.6HR.W.SPEED 1200H-1200H



COMPUTATION SPECIFIED  2 DAYS AHEAD ON PRECIP     FILE
COMPUTATION SPECIFIED  2 DAYS AHEAD ON AIRTEMP    FILE
COMPUTATION SPECIFIED  2 DAYS AHEAD ON WIND SPEEDFILE


INPUT DATA FOR GROUP 1

  74  10  29        -0.0 28.0 17.0 -1.7 -2.9  1.0 -0.0 -0.0 -0.0
  74  11   1        11.5  6.0  2.0 -8.3 -6.4 -3.0 -0.0 -0.0 -0.0
  74  11   2        18.0 16.5  9.5 -7.0 -6.0 -2.0 -0.0 -0.0 -0.0
  74  11   7         0.0  0.0  0.0 -8.5 -7.8  1.5 -0.0  1.8  3.4
  74  11   8         0.0  0.0  0.0 -7.3 -5.6  5.0  2.8  5.3  6.0
  74  11  11         6.5  0.0  0.0 -6.2 -7.3 -2.0  3.0  4.1  6.2
  74  11  13         0.0  0.0  0.0 -4.6  -.2  4.5  4.4  7.9 11.2
  74  11  14         0.0  0.0  0.0 -1.9 -3.9  1.0  7.3  9.0 11.3
  74  11  15         0.0  0.0  0.0 -2.5 -2.5  3.5  8.3  6.2  8.2
  74  11  19         1.5  5.5  4.0 -5.1 -4.9 -2.0  5.2 12.0 15.8
  74  11  22         0.0  0.0  0.0 -4.0 -1.9  8.5  3.6  5.1  8.5
  74  11  23         7.0 21.5  9.0 -3.0 -4.3  3.5  5.0  6.2  9.2
  74  11  28         0.0  2.5  2.5 -7.3 -5.4  4.0  5.1  5.1  7.3
  74  11  29         8.0  6.1  4.5 -7.9-13.1 -9.0  4.6  3.3  4.2
  74  12   2         0.0  0.0  0.0 -6.9 -4.3  4.5  3.5  2.1  3.3
  74  12   5         0.0  4.5  2.5 -5.6 -3.9  3.0  3.5  4.7  5.3
  74  12   6        10.0  9.5  4.0 -5.5 -7.5 -5.0  4.2  3.0  3.5
  74  12   9         2.5  0.0  0.0-12.7-12.3 -7.0  2.8  2.9  3.2
  74  12  11         0.0  0.0  0.0 -8.3 -9.3 -1.5  2.9  3.1  3.8
  74  12  12         0.0  1.0  1.0 -8.4 -9.2 -2.5  3.3  4.1  6.2
  74  12  13         1.0  3.0  3.0 -9.8-10.5 -4.0  3.5  5.0  9.8
  74  12  14         8.5  7.0  2.5-11.7-15.4-10.0  6.3  9.4 13.2
  74  12  15        11.0 12.5  7.0-14.5-14.2-12.5  7.7  9.3 14.5
  74  12  16        16.5  5.5  3.0-14.4-12.4-10.5  8.1  9.7 13.8
  74  12  18         8.0  4.5  2.0-10.2-10.9  -.5  9.8  9.6 13.5
  74  12  20         6.0  4.5  1.5-11.3-13.0-10.0  9.2  6.7 11.3
```

```
INPUT DATA FOR GROUP 1 CASES WITH MISSING DATA ELIMINATED
NUMBER OF VARIABLES IS   9

   74   11    8       0.0  0.0   0.0 -7.3 -5.6  5.0   2.8  5.3  6.0
   74   11   11       6.5  0.0   0.0 -6.2 -7.3 -2.0   3.0  4.1  6.2
   74   11   13       0.0  0.0   0.0 -4.6  -.2  4.5   4.4  7.9 11.2
   74   11   14       0.0  0.0   0.0 -1.9 -3.9  1.0   7.3  9.0 11.3
   74   11   15       0.0  0.0   0.0 -2.5 -2.5  3.5   8.3  6.2  8.2
   74   11   19       1.5  5.5   4.0 -5.1 -4.9 -2.0   5.2 12.0 15.8
   74   11   22       0.0  0.0   0.0 -4.0 -1.9  8.5   3.8  5.1  8.5
   74   11   23       7.0 21.5   9.0 -3.0 -4.3  3.5   5.0  6.2  9.2
   74   11   28       0.0  2.5   2.5 -7.3 -5.4  4.0   5.1  5.1  7.3
   74   11   29       8.0  6.1   4.5 -7.9-13.1 -9.0   4.6  3.3  4.2
   74   12    2       0.0  0.0   0.0 -6.9 -4.3  4.5   3.5  2.1  3.3
   74   12    5       0.0  4.5   2.5 -5.6 -3.9  3.0   3.5  4.7  5.3
   74   12    6      10.0  9.5   4.0 -5.5 -7.5 -5.0   4.2  3.0  3.5
   74   12    9       2.5  0.0   0.0-12.7-12.3 -7.0   2.8  2.9  3.2
   74   12   11       0.0  0.0   0.0 -8.3 -9.3 -1.5   2.9  3.1  3.8
   74   12   12       0.0  1.0   1.0 -8.4 -9.2 -2.5   3.3  4.1  6.2
   74   12   13       1.0  3.0   3.0 -9.8-10.5 -4.0   3.5  5.0  9.8
   74   12   14       8.5  7.0   2.5-11.7-15.4-10.0   6.3  4.4 13.2
   74   12   15      11.0 12.5   7.0-14.5-14.2-12.5   7.7  9.3 14.5
   74   12   16      16.5  5.5   3.0-14.4-12.4-10.5   8.1  9.7 13.8
   74   12   18       6.0  4.5   2.0-10.2-10.9  -.5   9.8  9.6 13.5
   74   12   20       6.0  4.5   1.5-11.3-13.0-10.0   9.2  6.7 11.3

REMAINING SAMPLE SIZE IN GROUP 1= 22


INPUT DATA FOR GROUP 2 CASES WITH MISSING DATA ELIMINATED
NUMBER OF VARIABLES IS   9

   74   11    9       4.5  8.0   4.5 -5.9 -3.9  2.0   4.3  4.4  6.0
   74   11   10      11.0  3.0   2.0 -5.4 -6.7 -2.5   4.3  1.8  3.0
   74   11   12       0.0  0.0   0.0 -6.9 -5.0  2.0   3.6  4.4  5.5
   74   11   16       0.0  0.0   0.0 -3.5 -5.7  2.5   5.7  4.0  6.0
   74   11   17       0.0  0.0   0.0 -4.5 -5.8  3.5   3.9  2.3  2.8
   74   11   18       0.0  0.0   0.0 -5.4 -4.2  5.0   3.0  6.4  7.0
   74   11   20       6.5  1.0   1.0 -6.4 -9.6 -1.0   8.7  4.5  7.7
   74   11   21       5.0  0.0   0.0 -6.5 -3.7  7.0   7.0  6.0  4.8
   74   11   24      21.5  0.0   0.0 -5.6 -9.5 -4.0   6.1  5.5  6.3
   74   11   25      14.5  0.0   0.0 -7.4 -6.2  2.5   4.3  3.5  7.8
   74   11   26       0.0  0.0   0.0 -6.3 -6.5  2.5   4.7  7.0  8.8
   74   11   27       0.0  0.0   0.0 -7.1 -8.3  -.5   5.7  4.0  6.3
   74   11   30       9.0   .4    .4-11.6-11.8 -5.0   3.2  3.8  6.0
   74   12    1       1.0  0.0   0.0-11.2 -6.8 -2.0   3.4  3.3  4.5
   74   12    3       0.0  0.0   0.0 -4.7 -5.2  3.5   2.6  2.3  2.8
   74   12    4       0.0  0.0   0.0 -5.4 -6.1  2.0   2.3  3.6  6.0
   74   12    7      14.0  1.0   1.0 -7.6-11.1 -5.0   3.5  2.9  3.7
   74   12    8       6.0  1.5    .8-10.4-13.3 -7.5   3.1  2.9  3.7
   74   12   10        .5  0.0   0.0-11.4 -6.6  1.0   2.7  2.7  3.2
   74   12   17      17.0  0.0   0.0-11.7-10.6 -6.5  10.1  6.4  8.2
   74   12   19       4.5  4.0   3.5-10.3 -9.3 -4.5   8.4 11.0 13.8

REMAINING SAMPLE SIZE IN GROUP 2= 21
```

```
INPUT DATA FOR GROUP 2

  74  10  30      45.5 18.5 14.0 -3.5 -8.4 -2.0 -0.0 -0.0 -0.0
  74  11   3      24.5  5.0  3.0 -5.8 -6.8  0.0 -0.0 -0.0 -0.0
  74  11   4      17.5  2.0  1.0 -6.4 -7.6 -4.0 -0.0 -0.0 -0.0
  74  11   5       3.0  0.0  0.0 -7.8-10.0 -3.0 -0.0 -0.0 -0.0
  74  11   6        .5  0.0  0.0 -8.5 -8.0  1.5 -0.0 -0.0 -0.0
  74  11   9       4.5  8.0  4.5 -5.9 -3.9  2.0  4.3  4.4  6.0
  74  11  10      11.0  3.0  2.0 -5.4 -6.7 -2.5  4.3  1.8  3.0
  74  11  12       0.0  0.0  0.0 -6.9 -5.0  2.0  3.6  4.4  5.5
  74  11  16       0.0  0.0  0.0 -3.5 -5.7  2.5  5.7  4.0  6.0
  74  11  17       0.0  0.0  0.0 -4.5 -5.8  3.5  3.9  2.3  2.8
  74  11  18       0.0  0.0  0.0 -5.4 -4.2  5.0  3.0  4.4  7.0
  74  11  20       6.5  1.0  1.0 -6.4 -9.6 -1.0  8.7  4.5  7.7
  74  11  21       5.0  0.0  0.0 -6.6 -3.7  7.0  7.0  4.0  4.8
  74  11  24      21.5  0.0  0.0 -5.6 -9.5 -4.0  6.1  4.5  6.3
  74  11  25      14.5  0.0  0.0 -7.4 -6.2  2.5  4.3  3.5  7.8
  74  11  26       0.0  0.0  0.0 -6.3 -6.5  2.5  4.7  7.0  8.8
  74  11  27       0.0  0.0  0.0 -7.1 -8.3  -.5  5.7  4.0  6.3
  74  11  30       9.0   .4   .4-11.6-11.8 -5.0  3.2  3.8  6.0
  74  12   1       1.0  0.0  0.0-11.2 -6.8 -2.0  3.4  3.3  4.5
  74  12   3       0.0  0.0  0.0 -4.7 -5.2  3.5  2.6  2.3  2.8
  74  12   4       0.0  0.0  0.0 -5.4 -6.1  2.0  2.3  3.6  6.0
  74  12   7      14.0  1.0  1.0 -7.6-11.1 -5.0  3.5  2.9  3.7
  74  12   8       6.0  1.5   .8-10.4-13.3 -7.5  3.1  2.9  3.7
  74  12  10        .5  0.0  0.0-11.4 -6.6  1.0  2.7  2.7  3.2
  74  12  17      17.0  0.0  0.0-11.7-10.6 -6.5 10.1  5.4  8.2
  74  12  19       4.5  4.0  3.5-10.3 -9.3 -4.5  8.4 11.0 13.8
```

APPENDIX D

DISCRIMINANT FUNCTION COEFFICIENTS FROM COMBINED SEASONS 1971-75

1: Dry Season

Line Number	Stratum[**]	Discriminant Function Coefficients[*]	Avalanche mean score	Non-avalanche mean score
1.	V	$1.24786X_2 - .09422X_4$	3.93184	1.34157
2.	IV	$.42262X_1 + .75094X_2 - .04522X_6$	2.82551	1.07849
3.	II	$.33416X_1 + .61521X_2 + .11309X_5 - .10389X_6$	1.09350	-.09497
4.	I	$.44269X_1 + .68174X_2 + .05962X_5$	1.28534	.35911

2: Wet Season

Line Number	Stratum[**]	Discriminant Function Coefficients[*]	Avalanche mean score	Non-avalanche mean score
5.	V	$.09463X_1 - .11578X_2 + .31081X_5$	.55034	-1.22100
6.	II	$.12596X_1 - .16528X_4 + .37840X_6$	3.24747	2.19566
7.	I	$-.29613X_4 + .31529X_6$	2.29313	1.98300

[*] Variable sub-scripts refer to the numbers in Table 16.

[**] Roman numerals refer to hazard levels in Table 17.

CHAPTER 6: THE APPLICATION OF ISOTOPIC PROFILING SNOW GAUGE DATA TO AVALANCHE RESEARCH

Richard L. Armstrong

Introduction

A profiling isotopic snow gauge has been a part of the instrumentation network utilized by this project during five consecutive winters. An Aerojet Nuclear gauge was operated during the first three winter periods, 1971-1974, while a modified gauge, constructed by Idaho Industrial Instuments, was operated during the latter two winter periods, 1974-1976.

The earlier gauge was installed by Aerojet Nuclear personnel in December of 1971 at the Red Mountain Pass site (3400 m). The prototype of this isotopic gauge was developed by Dr. James L. Smith, U.S. Department of Agriculture, Forest Service, Berkeley, California. The first radioactive gamma transmission snow gauge was used sucessfully during the winter of 1964-1965 (Smith, 1965, 1967). As this first gauge required an operator, the next step in the development was the fabrication of a remotely operated, telemetered gauge. This work was undertaken by the Aerojet Nuclear Company with funding from the Division of Isotopes Development of the Atomic Energy Commission.

The field unit of the Aerojet Nuclear gauge consists of a radioactive source, 10 mc ^{137}Cs, and a scintillation detector, each horizontally suspended in one of the two parallel access tubes which extend vertically from below ground to a height greater than the maximum anticipated snow accumulation. The scintillation detector is a sodium iodide crystal. This crystal is attached to a photomultiplier tube and both are sealed in a cylindrical aluminum case. The photomultiplier signal is transmitted by a coiled cable to a preamplifier housed in the lift unit. The lift unit consists of two reels connected to a drive shaft. One reel is positioned at the top of each of the parallel access tubes.

A remote gauge of this type requires the following additional components: 1)a telemetry system via commercial data-telephone, which communicates data and commands between the field unit and the base station; 2) a field unit which has the function of decoding and executing commands (i.e. taking snow density data, running the lift motor, etc.) and formating the acquired data for transmission; and 3) a base station which receives the data, formats the commands for transmission to the field unit, and reduces and prints out the data in digital and analog form. The base station for this gauge was located in Idaho Falls, Idaho, at the Aerojet Nuclear facility, National Reactor Testing Station. The personnel at

Aerojet would transmit the resultant data to INSTAAR Project Headquarters, Silverton, Colorado, by mail. The original intent was that the Aerojet gauge could be interrogated daily, or more frequently, at prescribed intervals. However, the low quality of telephone transmission between Red Mountain Pass and Idaho Falls precluded the operation of the computer link in an automatic mode. Therefore, data runs were essentially limited to one per day during the conventional work week when personnel were available at the base station.

The INSTAAR study was concerned with monitoring physical changes within the snowcover on a daily or even hourly basis. The full value of the gauge could only be realized if data acquisition could continue uninterrupted from one day to the next. It was therefore necessary to develop some type of locally operated on-site readout capability. Such a facility would not only provide continuous data access, but the location of the gauge would no longer be dependent on the availability of telephone service. The loss of both telephone service and 110 VAC power at a high alpine site is not unusual during storm periods, the very time when data regarding avalanche studies must be available.

The existing gauge was modified to meet various new specifications by Idaho Industrial Instruments, Inc. While the modified version is similar in structure to the Aerojet gauge, basic differences exist in the measurement technique and data acquisition systems. A collimated Co^{60} source and a ganged GM tube detector system replaces the Cs^{137} source and photomultiplier detector. $Cobalt^{60}$ has approximately four times the water penetration ability of Cs^{137} enabling greater spacing between source and detector, thus increasing the horizontal zone of measurement. Access tube spacing was increased to 1.0 m. Geiger-Müller tubes provide excellent temperature stability over a range of +50°C to -50°C. They are durable, long lasting and inexpensive. The GM tube is a straight digital event transducer and is not count rate sensitive. No precision pulse shaping or high precision power supply is required. The lower efficiency compared to the photomultiplier systems is overcome by paralleling several GM tubes within the detection unit. By collimating the source the scatter is greatly reduced. Coupled with sufficient counting time, the GM tube acts as a discriminator and approaches the overall efficiency of a photomultiplier system.

The onsite controller and readout located in the instrument cabin 30 m from the gauge allow both manual and automatic operation. The detector unit may be operated in a manual mode within any segment of the snowcover where specific measurements are required or the system may be placed in automatic mode and a profile of the entire snowcover made with the detector system automatically returning to the bottom after reaching a preset upper limit. A console LED display indicates the vertical position of the detector system and nuclear counts for each position. A printer also provides a hard copy of the count data. The system is powered by direct-current with the batteries receiving occasional trickle-charging from 110 VAC. The Red Mountain gauge can be operated for approximately two weeks without the need for charging the batteries.

Any isotopic source is gradually decaying and requires a constant correction for this decay. The calibration of the present gauge is achieved by having the measurement event dependent rather than time dependent. This is accomplished by a reference detector which is driven by a small microcurie source of the isotope used. The reference scaler is programmed to accept a specific number of counts from the source and then terminate the counting period. This establishes the same statistical accuracy for the system throughout the lifetime of the source; however a longer time period is required to obtain a specific measurement. As an example, if the time to receive 10,000 counts at the detector is 10 seconds initially, in 5.2 years the time constant would gradually have increased to 20 seconds.

Installation of the Profiling Snow Gauge

When a profiling snow gauge is to be utilized in avalanche research, careful consideration must be given to the location of the gauge. For the INSTAAR study, the location was initially determined by the availability of 110 VAC power and telephone service. Fortunately, both were available at the Red Mountain Pass snow study site. Numerous parameters relating to meteorology and snow structure are measured at this location and it was considered highly desirable to be able to have access to such data adjacent to the snow gauge.

A standard snow study site is by definition a level area, below tree line, protected from the wind and easily accessible by the observer. An actual avalanche starting zone is certain to be in sharp contrast with the above definition. A common dilemma in avalanche research results. While it is highly desirable, theoretically, to locate instrumentation within an avalanche starting zone, the practical limitations are obvious. In addition to the need to avoid the destructive force of the avalanche itself, sloping surfaces offer additional difficulties. Local snow structure is influenced by solar radiation and wind patterns, according to slope angle and orientation. Mechanical processes involved in creep and glide of the snowpack relate to the type and shape of the ground surface beneath the snow as well as to the slope angle and orientation. The difficulties involved in determining a representative slope become apparent and one returns to the concept of a standard snow study site for instrument location.

It then becomes necessary to extrapolate data obtained at a level, sheltered site to what may actually be happening on adjacent slopes, both above and below timberline. Such empirical relationships can be established between study plot and release zone, although many years of observation may well be an essential requirement. Therefore, if a profiling snow gauge is to be installed for avalanche research in an area where such a relationship has been or is in the process of being established, it should certainly be located at the site where these studies are underway.

Support structures required for the access tubes should be located in the lee of the instrument opposite the direction of the prevailing wind to prevent drifting of snow near the tubes. The access tubes should be maintained with a highly reflective surface in regard to both short and long wave radiation to prevent melting of the snow in contact with the tubes.

Field Calibration

On-site calibration and accuracy tests have been carried out adjacent to the Red Mountain Pass gauge by relating the density values of the profiler to those conventional measurements obtained by acquiring samples of known volume from the wall of a snowpit (see Table 25). This method is considered to possess a potential accuracy of 0.001 Mg/m^3 (Bader, 1939).

TABLE 25. ISOTOPIC PROFILER-SNOW PIT CORRELATION AT RED MOUNTAIN PASS, WINTER 1971-1972

Mean Density (Mg/m^3)			Water Equivalent (mm)		Standard Deviation of Density Values at 5.0 intervals
Date	Profiler	Pit	Profiler	Pit	
Dec. 22	.266	.273	144.0	156.4	0.012
Jan. 11	.244	.283	242.8	259.0	0.014
Jan. 19	.280	.268	272.0	274.0	0.009
Jan. 26	.279	.295	266.9	284.9	0.011
Feb. 1	.287	.294	277.8	284.2	0.013
Feb. 9	.282	.299	287.5	319.5	0.017
Mar. 3	.282	.278	357.1	353.5	0.015
	Mean Deviation		Mean Deviation		
	0.017		12.8		

The same type of field calibration was undertaken following the installation of the modified gauge. At that time data reduction (conversion of nuclear counts to snow density) was based on a log-linear relationship derived from calibration in water. These calibration values did not agree with subsequent field calibration in natural snow. It was determined that increased scatter occurred when the radiation passed through snow, thus increasing the ratio of counts to density compared to the relationship based on water samples of various thicknesses. Figure 32 shows a comparison between snow pit data and profiler data based on the initial calibration values. The snow pit was located approximately 10 m from the profiler. Note that the stratigraphic agreement is excellent and only the calibration relationship required adjustment resulting in the data provided in Figure 33.

A second aspect of field calibration requires that the source and detector be located in a precise horizontal plane such that maximum counts are achieved. This may be undertaken in a calibration tank or in air. Periodic checks should then be made to identify any misalignment of source and detector which may develop. If maximum count level is established in air above a snow surface, the source-detector system should be located at least 40 cm above the snow to avoid scatter from the surface.

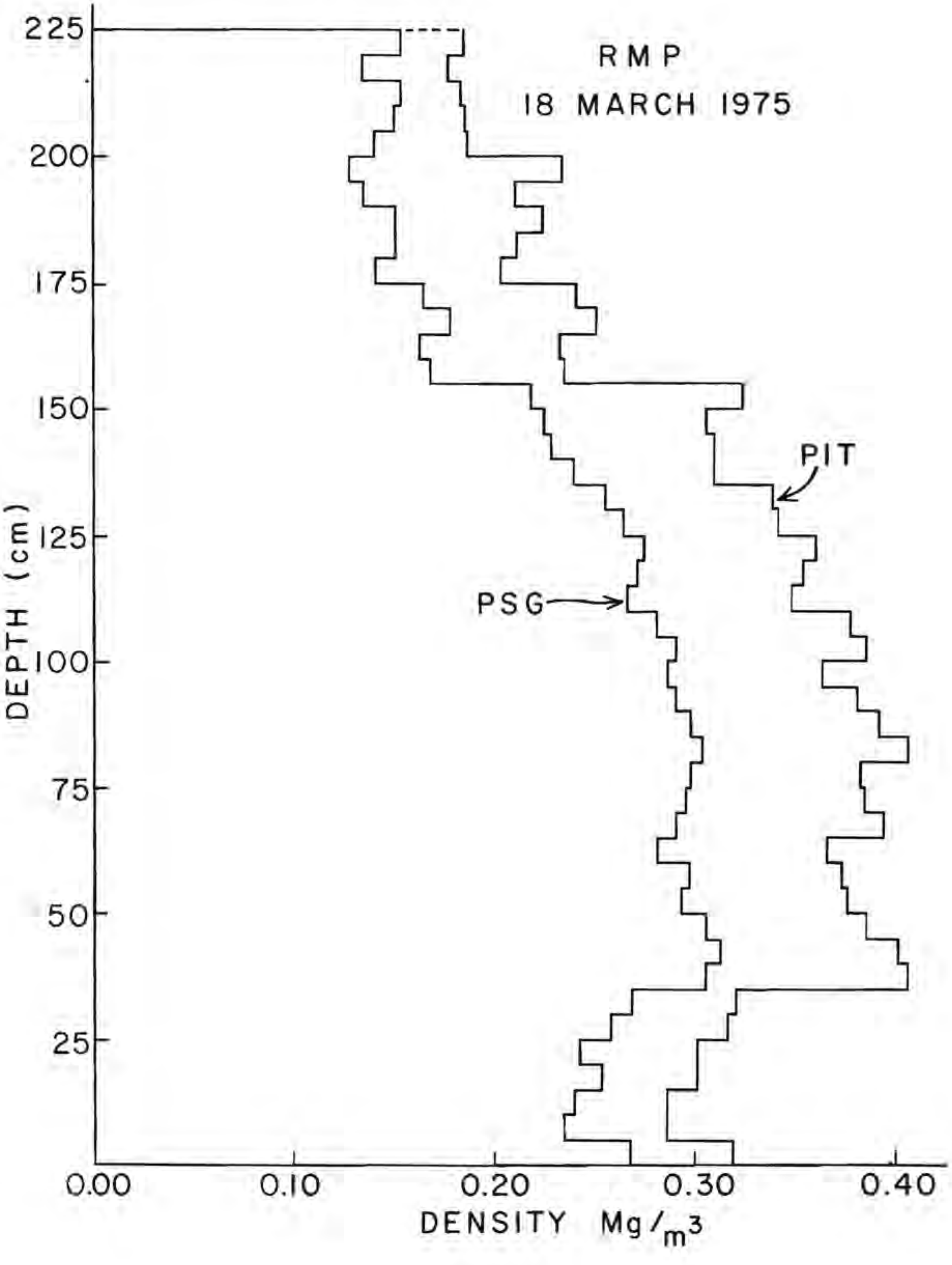


Figure 32. A comparison of snowpit and profiler density data for field calibration purposes.

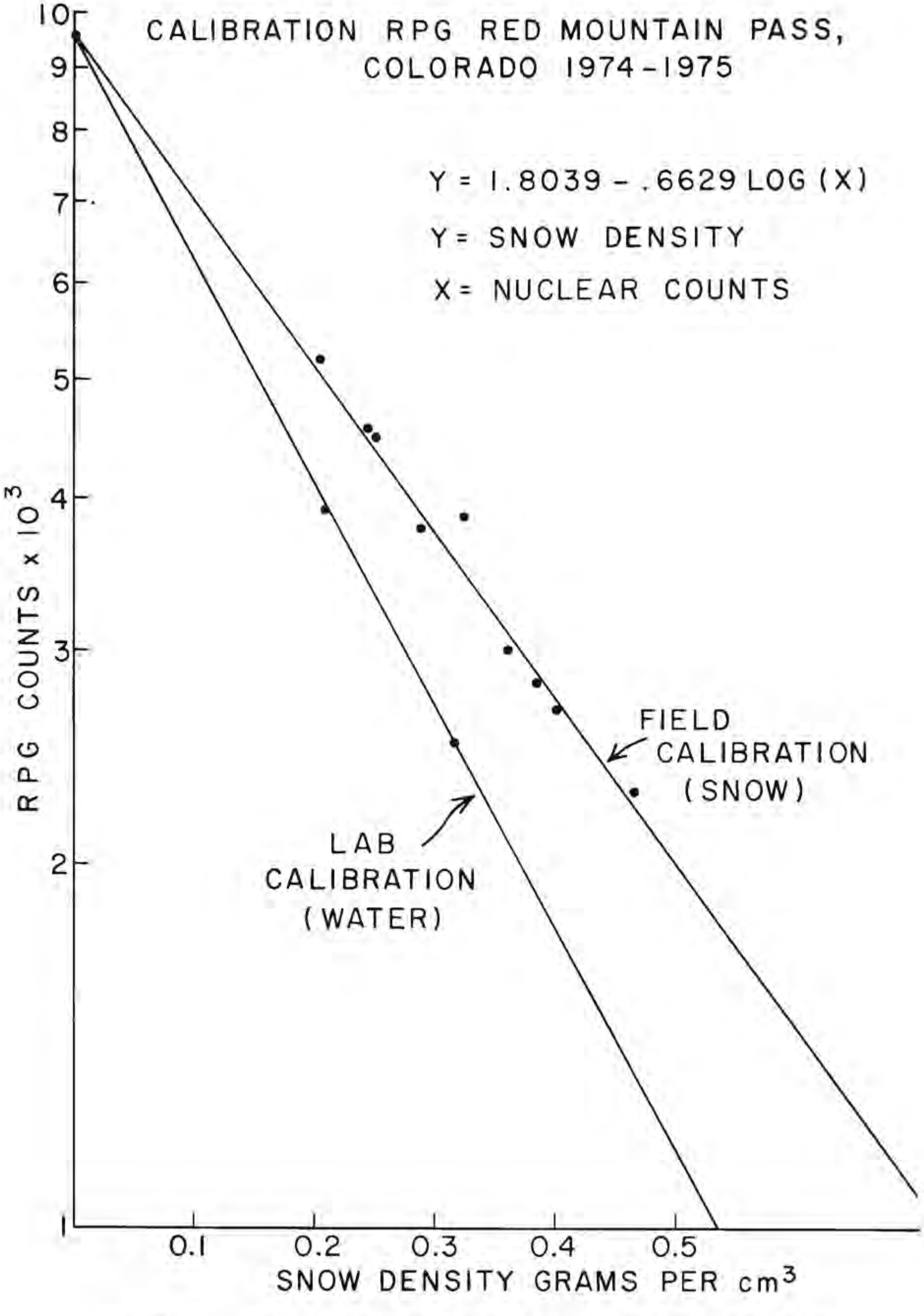


Figure 33. The corrected profiler calibration data based on field calibration in snow compared to laboratory calibration in water.

Application of Data to Avalanche Research

There are numerous criteria in use today for categorizing types of snow avalanches. One basic genetic discriminator divides all avalanches into two groups: direct action and delayed action. A direct action avalanche occurs during or immediately after a storm and is the result of the increased stress applied to the snowpack in the form of new snow. This type of avalanche is the immediate consequence of a prevailing meteorological situation. A delayed action avalanche is the result of gradual changes taking place within the snowcover over a longer period of time. Such avalanches may occur as the culmination of a slow load build-up, with a weak layer within the snowpack being the eventual zone of failure, or may occur without the increased stress of additional loading when gradual adverse metamorphism continues until existing stress exceeds the deteriorating strength at some point within the snowpack. This may occur both during mid-winter when temperature-gradient metamorphism results in depth hoar formation, and in the spring when the snowpack becomes isothermal and the bonds between the individual grains break down. Therefore, instrumentation and field methods have been developed to measure new-snow accumulation as well as changes in old-snow structure.

The standard methods for monitoring physical and structural changes on and within the snowpack involve the following. To measure accumulation, some type of recording precipitation gauge is used. Special problems are encountered, however, as most gauges available are primarily designed to measure precipitation in the liquid phase. When the intent is to monitor the precipitation rate of snow, provision must be made to prevent capping or clogging of the gauge orifice due to high snowfall rates. Periods of high precipitation intensity are of great interest to avalanche research and therefore an unfortunate moment not to be receiving data. An additional drawback associated with this method of snowfall recording is that the accuracy of the gauge may be greatly influenced by the wind field in the vicinity of the orifice. At wind speeds often associated with winter storms such a gauge tends to underestimate the actual amount of mass being delivered to the snowpack. An alternate method is to measure new snow increments falling on a snow board placed on the surface of the snow prior to the storm and to melt samples taken from the boards in order to determine water equivalent. Inaccurate measurements by this method result when the initial portion of the sample is removed by wind, as well as when melt occurs through solar heating of the board. The ideal surface on which to measure new snow increments is not an artificial device which obstructs the natural terrain, but rather the snow surface itself. Such a method is employed by the profiling gauge.

Among the derived properties of snow, density is perhaps the most used as an index of snow type. The standard method in avalanche studies for measuring density involves digging a pit through the pack to the ground and then extracting samples of a known volume from the wall of the pit and weighing each sample to determine density. The stratigraphic frequency at which these values can be obtained is determined by the thickness of the sample container, generally from 3.0 to 5.0 cm. Since zones of weakness are often only 0.5 cm or less in thickness, critical information concerning the strength properties of the snowpack may well be overlooked with this method. In addition, this type of measurement is destructive and therefore useless in terms of accurate in situ studies of changes in density with time. The anisotropic nature of snow precludes the possibility of taking density samples in adjacent locations during successive days or perhaps even hours in time and still being able to assume an accurate time-stratigraphic profile. Changes in snow structure as a function of spatial variation may equal or exceed those changes which one wishes to monitor.

The rate and amount of settlement which takes place within the snowpack is another index which can be related to snow strength. A layer of newly fallen snow in the absence of wind exists as a delicate cellular matrix. Although the individual crystals may interlock mechanically, they adhere weakly at points of mutual contact. Gradually as the snow settles, the stellar or similarly complex crystalline shapes are reduced to a more spherical grain. Such a shape permits greater amounts of common surface area to exist among the grains. In the absence of significant temperature gradients (approximately 0.1°C/cm), intergranular bonding is enhanced and strength increases. The density profiles produced by the isotopic gauge may serve as an indicator of snow settlement. One simply locates a particular layer within the snowpack which is easily identifiable due to a particularly high or low density value in relation to surrounding layers. The vertical movement of this layer reflects the degree of settlement within this immediate area. The settlement rate of snow involved in an individual storm can be observed by noting the compression of that layer which represents the appropriate storm increment.

Data Analysis

In terms of general snow structure, two types of avalanche release exist. The first is referred to as a loose-snow avalanche and occurs when snow crystals which adhere poorly to each other collect on a slope steeper than their angle of repose. Failure begins near the surface when a small amount of cohesionless snow slips out of place and starts moving down the slope. The second type is known as a slab avalanche and occurs when snow lies on a slope in a cohesive layer which is poorly bonded to the snow or ground below. The slab event presents a greater hazard because it incorporates larger amounts of snow, and also because the wide variety of snow conditions which lead to its formation cause problems in predicting such events.

The layered structure of a natural snowcover is directly related to slab releases. Stratigraphic data regarding the alternating weak and strong layers within the snowcover are extremely valuable to avalanche prediction. Weak layers comprising potential shear failure zones exist within new snow, at old snow-new snow interfaces, and within the old snow structure. Stratigraphy within new snow is primarily a function of meteorological conditions at the time of deposition while structure within older snow layers may be a consequence of metamorphic changes occurring over a period of weeks or even months. An example of a weak layer within new snow as detected by the profiling gauge and a light-weight (0.1 kg) ram penetrometer appears in Figure 34. This condition alone did not produce

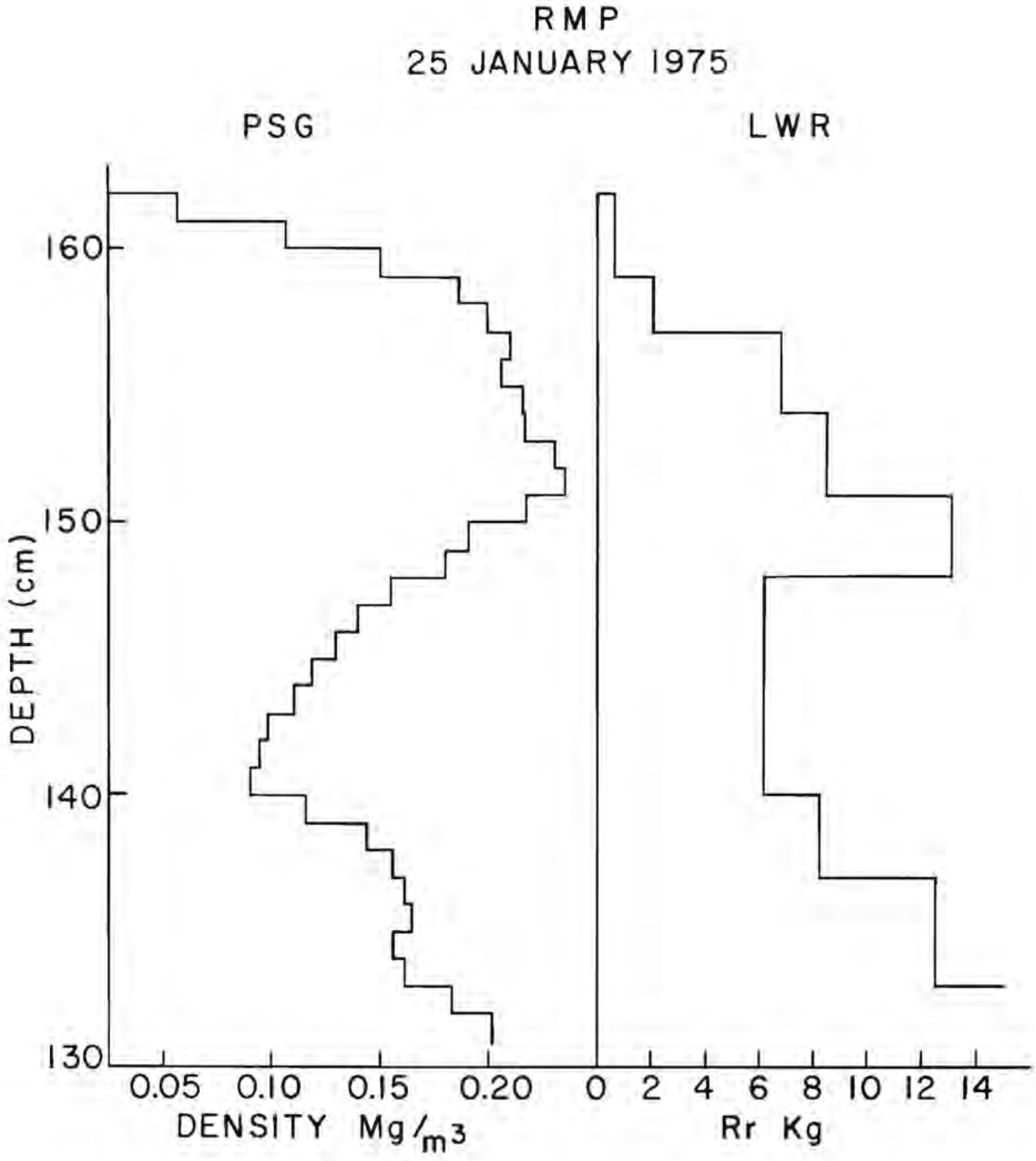


Figure 34. Comparison of stratigraphy provided by profiler density values and light-weight rammsonde (0.1 kg.) strength data. The weak, low density layer is a new snow accumulation in the absence of wind. Above this layer is a stronger, higher density slab deposited during a period of relatively high winds.

avalanche releases but three days later on January 28, 1975, 53.0 cm of new snow containing 46.6 mm of water was recorded at Red Mountain Pass. This new snow combined with the weak layer below produced a widespread cycle of slab avalanches.

The development of a layer of temperature-gradient snow or "depth hoar" at the base of a snowcover is a common phenomenon in the Rocky Mountains. The thickness and degree of metamorphism of this layer often exerts a significant influence on avalanche activity during the entire winter season. The ability to continuously monitor density values within the basal layer is made possible with the profiling gauge. Figure 35 provides an example of the progressive development of this snow layer from early winter to December 23, 1974. At that time the accumulation of additional snow provided a load sufficient to initiate slab avalanches which released within this weak basal layer. Avalanche activity associated with the depth hoar layer continued throughout January and well into February until virtually all of this type of snow structure had been removed from the various avalanche paths.

Figure 36 shows the basal temperature-gradient layer as it existed on April 15, 1973. Such data describe the snow structure at the study site only and it must be noted that when considering the avalanche paths themselves, significant portions of this stratigraphy may have been removed by avalanche activity. This was in fact the case by the latter portion of the 1974-1975 winter. However, Figure 36 is representative of the snow structure as it existed in the majority of avalanche starting zones on April 15, 1973. Only a limited amount of midwinter avalanche activity had occurred during the 1972-1973 season. During the third week in April, the snow temperatures in most avalanche release zones had reached 0.0°C and as free water began to percolate down through the snowcover, it came in contact with a complex stratigraphy which had been developing over the past four to six months. On April 27, a widespread cycle of large wet slab avalanches began. Subsequent investigations of the avalanche fracture lines indicated that these slabs failed within the old layer of temperature-gradient snow near the ground. It is significant to note that once mature depth hoar has developed, even though the temperature gradient which caused it to form diminishes as the winter progresses, no significant inter-granular bonding occurs and a condition of relatively low mechanical strength continues into the spring. This condition is even more apparent from the rammsonde data in Figure36 than from the density data. This is because the direct relationship between strength and density for dry snow is not easily applied to wet snow. As free water begins to melt the bonds between grains and reduce mechanical strength, associated density values may remain unchanged. However, it is apparent from the density profile that temperature-gradient processes dominated the lower 75 cm of the profile through much of the winter; fine-grained, equitemperature snow generally exhibits a consistent increase in density with depth (Figure 36 75 to 220 cm) while temperature-gradient snow does not, tending rather to inhibit settlement and thus densification rate (Figure 36 ground to 75 cm). Therefore, given the density profile alone, an experienced observer would recognize a snowcover with a significantly weak basal layer.

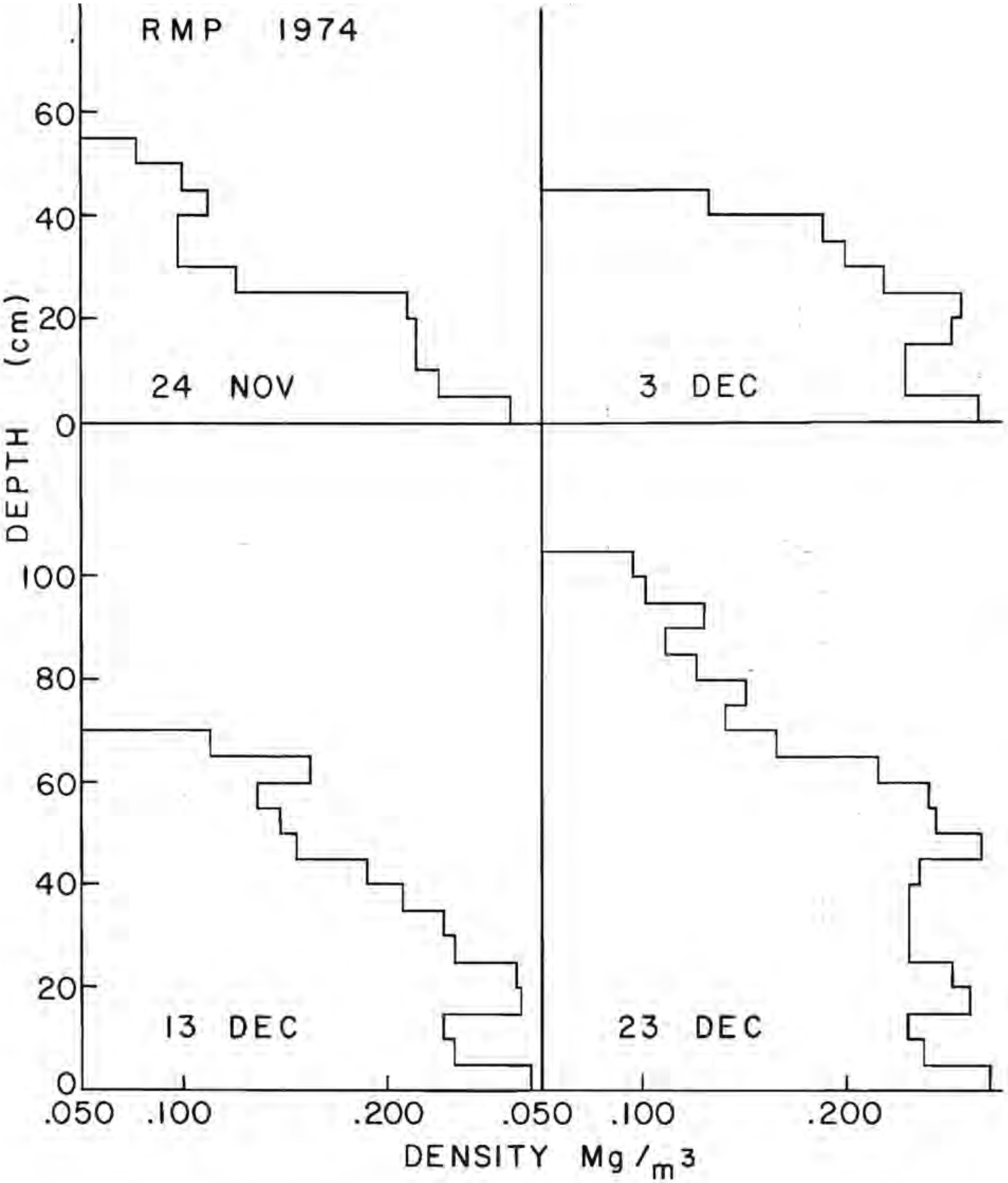


Figure 35. Sequential development of a structurally weak temperature-gradient layer at the base of the snowcover as monitored by profiling snow gauge density values.

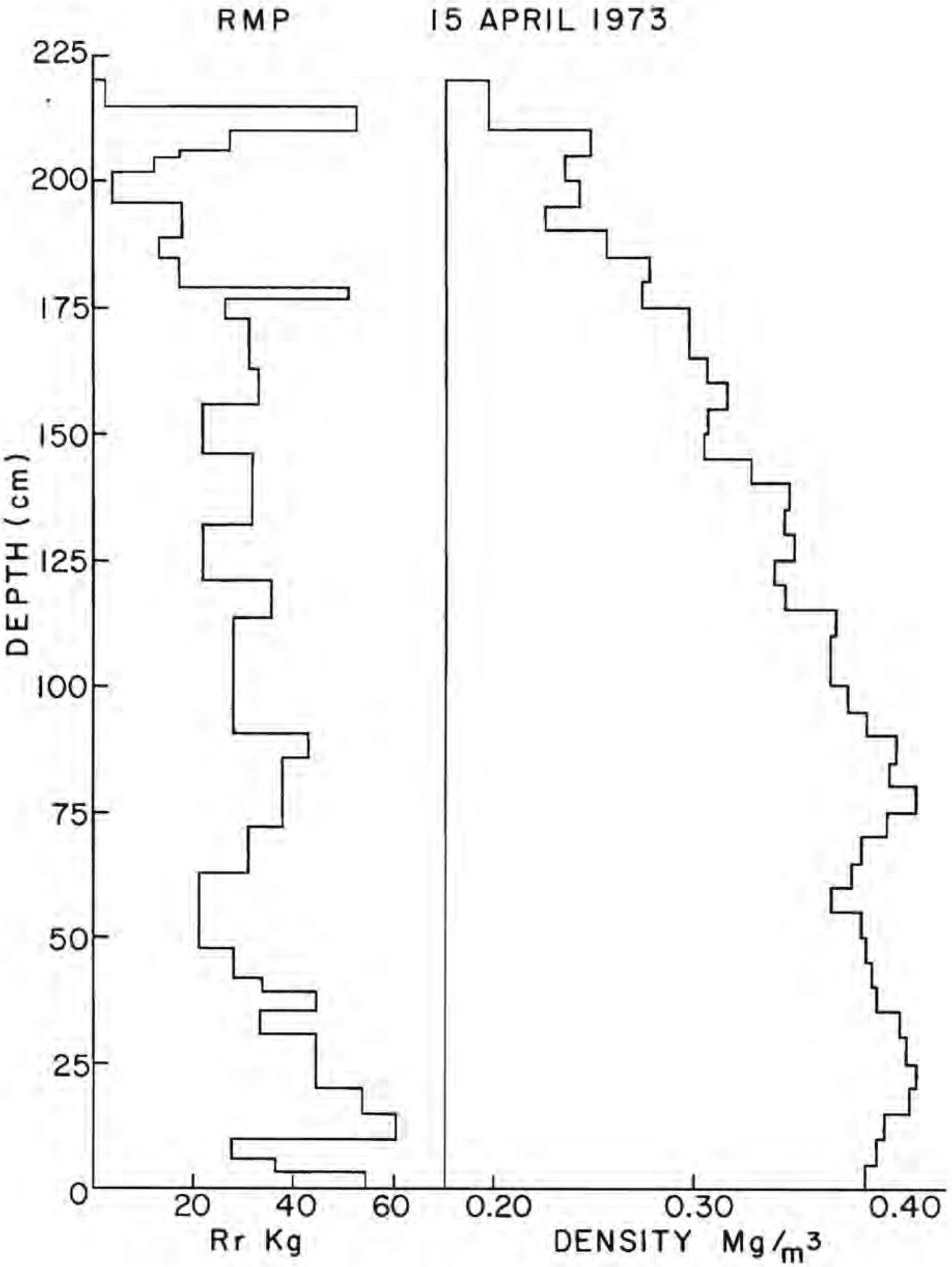


Figure 36. Comparison of rammsonde strength data and profiler snow density values within a mature snowcover.

Performance History

During the winter of 1971-1972, the Aerojet isotopic profiling snow gauge successfully provided this study with data on a total of 31 occasions. This number would have been substantially higher had not an instrument failure within the field logic unit required nearly three weeks to correct. Aerojet intentionally designed the remote gauge in such a way as to provide all field electronics mounted on plug-in cards to facilitate rapid and easy repair by field personnel unfamiliar with the inherent electronics. Such an effort is to be praised considering the great distance of the Red Mountain Pass gauge from Idaho Falls. One such repair was carried out within three days as a result of Aerojet personnel mailing the necessary replacement component. Unfortunately, the above mentioned lengthy interruption was caused by lack of availability of the necessary component.

During the 1972-1973 season, successful data runs were made on a total of 108 days, from November 2 to May 1. Within this period, standard daily data acquisition was prevented on 13 occasions, 9 due to telephone transmission difficulties, and only 4 due to malfunction within the snow gauge itself.

During the 1973-1974 winter the profiling gauge was operated from November 19 to May 28. Of a total of 133 days during which the gauge could have operated, data was not available on 43 days. Problems causing these interruptions included poor quality or interrupted telephone transmission, malfunctions within the electronic components at the Red Mountain Pass site, as well as two periods when moisture, resulting from either condensation or a leak in the seal at the base of the access tubes, froze in the tubes and prevented the vertical travel of the detector unit.

The current RPG Idaho Industrial Instruments snow gauge has been operated from November 1, 1974 through June 23, 1975 and from October 23, 1975 through March of 1976. An uninterrupted series of daily data runs was achieved for this period, with more frequent runs often made according to the needs of the study.

CHAPTER 7: SEISMIC SIGNALS FROM AVALANCHES

J. C. Harrison

Introduction

In schemes of avalanche prediction which either use a data bank of past occurrence together with meteorological and other conditions at the time, or which use test slopes observed to run under the same conditions as, and prior to, slopes posing a hazard to highway traffic, it is important to have good records of time of avalanche release on slopes which probably will not be visible from the highway under storm conditions. Thus, a network of a few sensors which remotely could detect and locate avalanches during storm conditions over an area of a few square miles would have important application. The investigations described here were made to evaluate possible application of seismic and infrasonic techniques to avalanche detection.

Seismometers and infrasonic microphones were operated at Red Mountain Pass, and, in cooperation with the U.S. Forest Service, at Berthoud Pass during the early months of 1972. The spring of 1972 had few avalanches and results were inconclusive (see Ives, et al., 1972). Two things, however, became evident: 1) the mountain passes are noisy sites for both the infrasonic and seismic installations owing to the high winds during the storms; and 2) avalanches generate high frequency seismic signals which cannot be adequately resolved on a drum recorder operating at normal seismic speeds.

It was therefore decided to install the seismic and infrasonic detectors at the Chattanooga Ranch on the south side of Red Mountain Pass for the 1972-1973 winter season. Seismic equipment from Byrd Station, Antarctica, became available for the winter on a loan basis. This included a 14-track tape recorder with amplifiers allowing four data channels to be recorded, each at three different gains, in addition to time reference marks. Two data channels were used for a vertical and a horizontal component Benioff seismometer installed in a stable on the ranch on a site chosen to be as far as possible from the road. The horizontal seismometer gave trouble, evidently because of the low temperature of operation, and was replaced with a Hall-Sears HS-10 1-second horizontal geophone. The other two channels were used to record signals from two infrasonic microphones. The noise levels on these microphones were reduced by using two perpendicular 200 foot hoses and spatial filters in place of the single 100 foot length used during the previous winter. In addition the seismic signals were monitored on a 2-pen helicorder drum running at 30 mm per minute which could record either the seismic amplifier outputs or a slightly delayed playback from the tape. Normally vertical component signal and playback were monitored in order to check operation of the tape recorder. The infrasonic signals were likewise monitored directly and on playback using Esterline Angus chart recorders. The pass band of the seismic amplifier and tape recorder was 5-.05hz; the helicorder pens would respond up to 30 hz although this signal could not be resolved. The high frequency end of the infrasonic signal was limited by the response of the microphones themselves to 0.3 hz, leading to a pass band of 0.3-0.05 hz on the tape recorded signal. The vertical seismometer was calibrated by means of a weightlift test and was normally run at a gain of 108,000 at one hz, which was determined by the noise level. The limiting factor here is the strong signals from heavy vehicles.

The seismic equipment was installed early in November 1972 and functioned without major difficulty through to the middle of May 1973 when observations were discontinued. Some data was lost on the horizontal channel owing to the difficulties with the horizontal component seismometer. The infrasonic strip chart recorders were operated from middle November through mid-May but, because of an incompatibility with the tape recorder input which was resolved in mid-January 1973, these data were only recorded on magnetic tape after this latter date.

In addition to the fixed station at Chattanooga Ranch a portable seismic system consisting of an HS-10 geophone with a battery operated amplifier and a strip chart recorder (Sanborn 299) was used. This equipment was carried in one of the project vehicles which could follow the Highway Department's artillery crew and record as slopes were being controlled. This technique was not as successful as might have been hoped because of the high level of man-made noise near the geophone during the shooting. However, a few successful records were made.

Results

The first definite results were obtained on December 5, 1972 during artillery control of slopes near the Chattanooga Ranch. Shot number 2 produced an observed snow release (SS-AA-2-0) and an associated seismic signal on the drum recorder (Figure 37). Tape playbacks were made at paper speeds corresponding to 18 (Figure 38) and 90 inches of paper to 1 minute of recording time, the latter record being digitized at .03 second intervals. Its power spectrum is shown in Figure 39. The low frequency peak is due to background of 6-second microseisms always present during the winter months. The avalanche signal itself shows two peaks, one centered on 4 hz, the other on 6.5 hz. The very sharp fall off at frequencies higher than 6.5 hz is due to the limited bandwidth of the seismic amplifier and tape recorder. It is likely that part of the signal was lost due to this cut off. The tape playback system was not calibrated, so that Figure 39 shows relative amplitude squared only. However, peak amplitudes as shown on the

Figure 37. Drum record of December 5 avalanche.

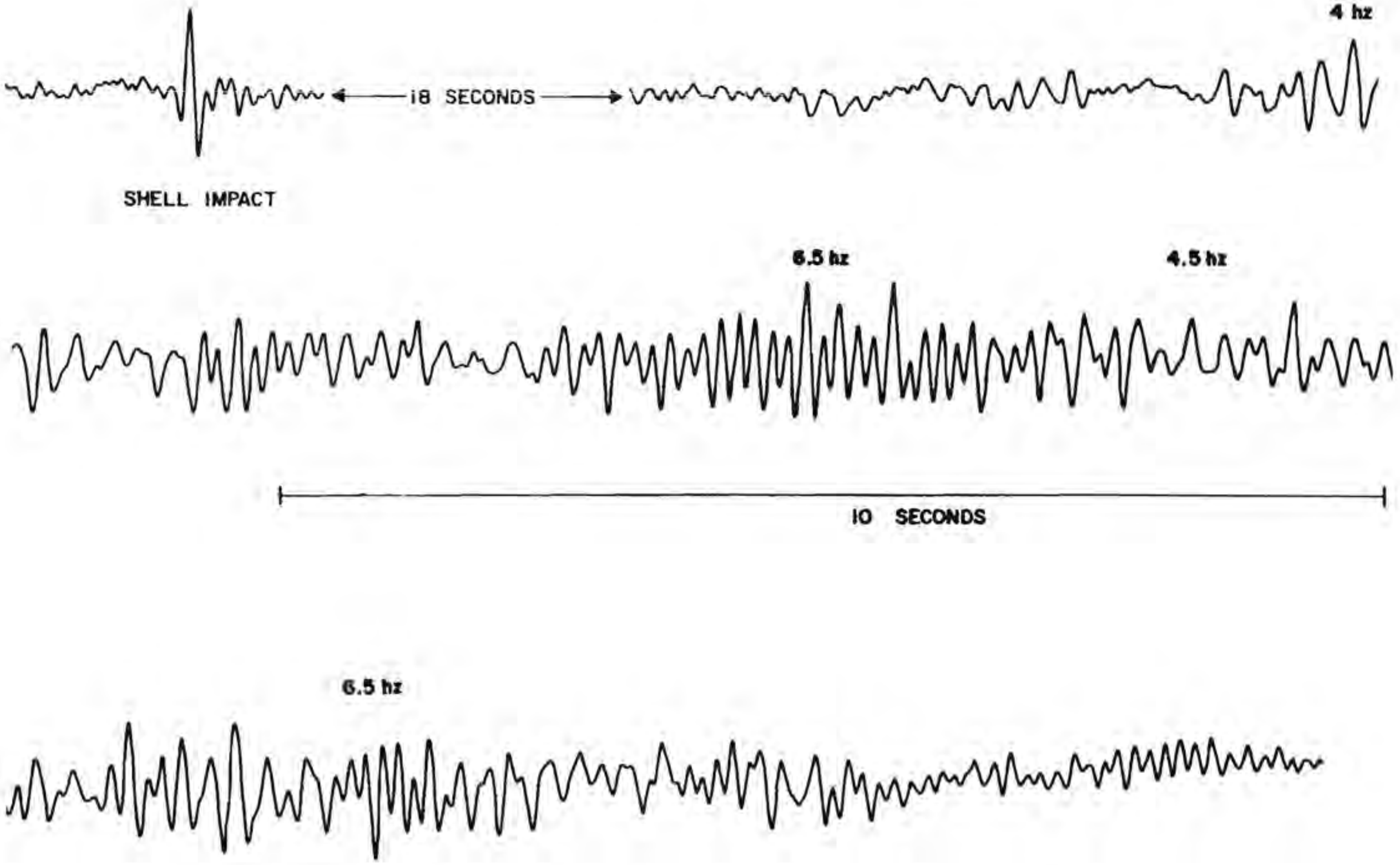


Figure 38. Tape playback of December 5, 1972 avalanche.

drum recorder correspond to ground movements of 50 millimicrons peak to trough.

The two peaks in Figure 39 correspond to definite phases of the seismic signal. As may be seen in Figure 38 there is no recognizable signal for about 20 seconds after the shell explosion. The first signals to arrive are of relatively low frequency (4 hz), followed by a second, higher amplitude, phase of about 6.5 hz frequency. There are then intervals from 1 to several seconds in length when either the high or low frequency arrivals predominate.

The next opportunity to observe seismic signals from avalanches came on February 13. The shooting sequence at Chatanooga Ranch produced some small snow releases but no seismic signals which could be unambiguously correlated with these releases. The portable equipment was used during control of the Willow Swamp slide and three observed snow releases were correlated with seismic signals. The frequencies of the observed signals were high (7-12 hz) and amplitudes low compared with those generated by people and vehicles moving about in the vicinity. One shot was interesting in that a second release, occurring spontaneously after the primary release appeared to start with a large amplitude, very high frequency arrival which could be associated with an elastic fracture of the snowpack.

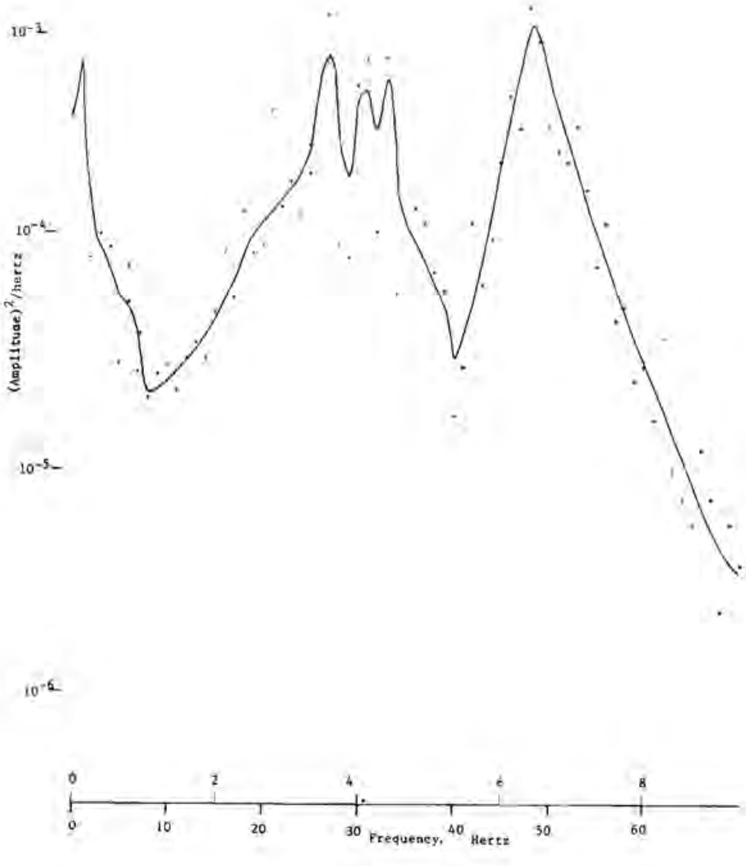


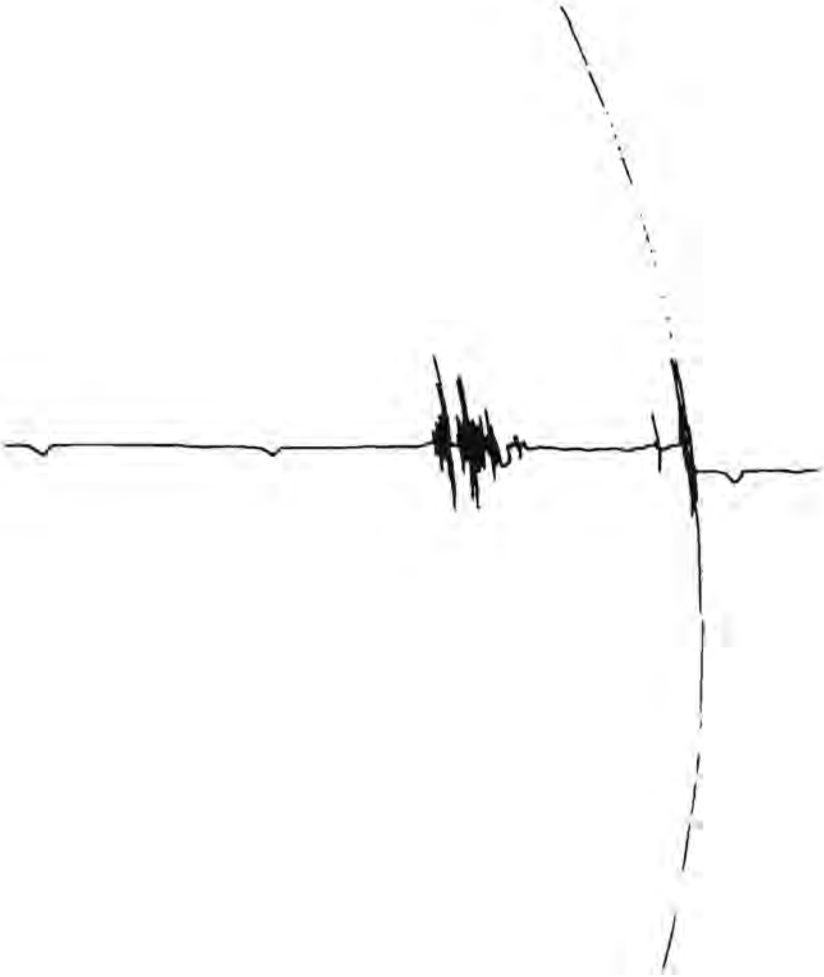
Figure 39. Power spectrum of December 5, 1972 avalanche.

Control work on April 27 produced some snow releases one of which, the Eagle, (WS-AA-3-G) produced a signal resembling the December 5 event in general character. However, the seismic signals generated by avalanches are small compared with those generated by heavy vehicles and, particularly, bulldozers clearing snow off the highway. Unless a slide and associated seismic signal can be observed simultaneously and the absense of traffic noise established it is very difficult to be sure that a particular signal is associated with a snow release. One such correlation was made on April 28 (Figure 40) when peak to trough ground motions of about 120 millimicrons were observed.

The Brooklyns were reported to run at 1700 on May 4. There is a small seismic signal at 1659 which, however, bears a rather unfortunate resemblance to a signal at 1730 which was almost certainly made by a small vehicle (see next section).

Control work on May 9 produced six observed snow releases but no seismic signals. Eagle and Muleshoe ran on May 11 at about 1050. Seismic signals persisting for about 40 seconds and of amplitude up to 120 millicrons ground movement were observed at 1043 and 1044 1/2. Unfortunately these were not recorded on tape and the drum records were largely obscured by the noise of subsequent snow removal operations.

Figure 40. Drum record of April 28, 1973 avalanche.



Conclusions

A number of weak, high frequency seismic signals have been correlated with small snow releases. No large avalanches occurred in the vicinity of the seismic station during the winter. No infrasonic signals were observed to correlate with the snow releases; if the seismic and sound signals be supposed to have a common cause, then it would be necessary to look for signals of much higher frequency (2-30 hz) than could be detected with the microphones used in this work (high frequency cut-off at about .3 hz).

Traffic generated seismic signals lie in the same frequency band as the avalanche signals and heavy vehicles produce larger signals. It was noted that a heavy vehicle produces a very characteristic signal; one approaching from the south can be detected for about 40 seconds passing beneath the foot of the Brooklyns slides. Amplitudes are generally fairly low but there are several bursts of higher than average amplitude giving the record a "lumpy" look. The signal disappears abruptly as the vehicle crosses North Mineral Creek, giving about 20 seconds of quiet, only to reappear and give about 10 seconds of a very high amplitude signal as the vehicle passes the trailer itself. The signal level falls rapidly after the ranch is passed but persists as a low level spiky signal as the vehicle rounds the Muleshoe bend and starts to ascend the steep grade to Red Mountain Pass. The vehicle's direction of travel can easily be determined by a quick inspection of the record and its speed of travel and size estimated. This characteristic vehicle-associated signal allows many traffic generated signals to be immediately identified as such; however, small vehicles near the threshold of detection do not always produce recognizable signals and the operational gain of the system is limited by the large traffic generated signals.

The weakness of the avalanche generated signals precludes the monitoring of slide activity in an area of many square miles with a few conventional seismic stations. However, the positive results obtained do suggest that such monitoring could be successful on a limited scale. Steps recommended include:

1. Use of a high frequency system -- it appears that the relevant bandwidth is 2-20hz;
2. Location of geophone halfway up the sides of the valleys, well above the highways and close to the slopes being maintained;
3. Use of pattern recognition techniques to aid in discrimination of the signals received for generally vehicles will move slowly through an array and generate a characteristic pattern at each site (at least our records at Chattanooga suggest this). Avalanche signals will be detected nearly simultaneously by geophones in the slide vicinity and signal amplitudes will decrease away from the slide. This discrimination could be done in real time by use of a mini-computer, probably using signal amplitude in various pass-bands as a function of time, rather than actual wave forms.

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APPENDIX 1

1974-1975 WINTER SUMMARY

Richard L. Armstrong

During the period November 1 through April 30 precipitation occurred in the form of snow on 109 days at the Red Mountain Pass study site. On April 30 the snowpack contained 937 mm of water. Total snowfall measured at daily intervals amounted to 1295 cm. Maximum snowdepth at this site was 310 cm on April 13. The average new snow density was .077 Mg/m^3. The mean daily temperature for the Red Mountain Pass site for the period November through April was -8.4°C with the mean minimum and maximum being -13.6°C and -2.3°C respectively. The lowest recorded temperature was -27.0°C and occurred on January 12. During this period the average wind speed at Pt. 12,325 was 6.0 m/sec, with the highest one-hour average being 28.0 m/sec recorded on March 25. Monthly summaries of temperature, precipitation, and wind speed data are contained in Table 29 og Appendix 2.

Within the boundaries of the study area and along the 58 km of U.S. Highway 550 between Coal Bank Hill and Bear Creek Falls in the Uncompaghre Gorge, 1008 avalanches were observed during the 1974-1975 winter season with 252 of these events coming in contact with the highway system. Of all avalanches observed, soft slab avalanches amounted to 58%; hard slab, 11%; wet slab, 1%; dry loose, 19%; and wet loose, 11%. Of the total avalanche events listed above, 69 were released by artificial means.

A graphical presentation of precipitation, air temperature, wind speed and avalanche occurrence for the winter period is found in Figures 41 and 42. The variation in the density of the snowcover with time at the Red Mountain Pass study site is presented in Figure 43. The isolines within the upper portion of the snowcover reflect a general increase in density with time and snow depth. The lower portion, to a depth of approximately 50.0 cm, deviates from this pattern due to the development of temperature-gradient snow, or "depth hoar" within this layer. Above this layer the snowcover is primarily made up of fine-grained, equi-temperature snow which continues to increase in density while the lower portion is comprised of coarse-grained, temperature-gradient snow which due to its inherent mechanical properties is resistant to settlement and thus densification. This retarded densification rate is also evident in Figure 44 where platter number one represents the settlement rate of the "depth hoar" layer. This layer of weaker temperature-gradient snow at the base of the snowcover is a common phenomenon in the Rocky Mountains and has been identified within the Red Mountain Pass study area, as well as on all slope aspects, throughout the four year research period. However, the thickness of this layer during the 1974-1975 winter was approximately twice that which had been observed during the three preceeding winters and this additional amount of unstable snow at the base of the snowcover provided the lubricating layer for the higher than normal frequency and magnitude of avalanche events during the months of December, January and February.

A time-stratigraphic diagram of temperature variations ($^{\circ}$C) within the snowcover at the Red Mountain Pass study site appears in Figure 45. The

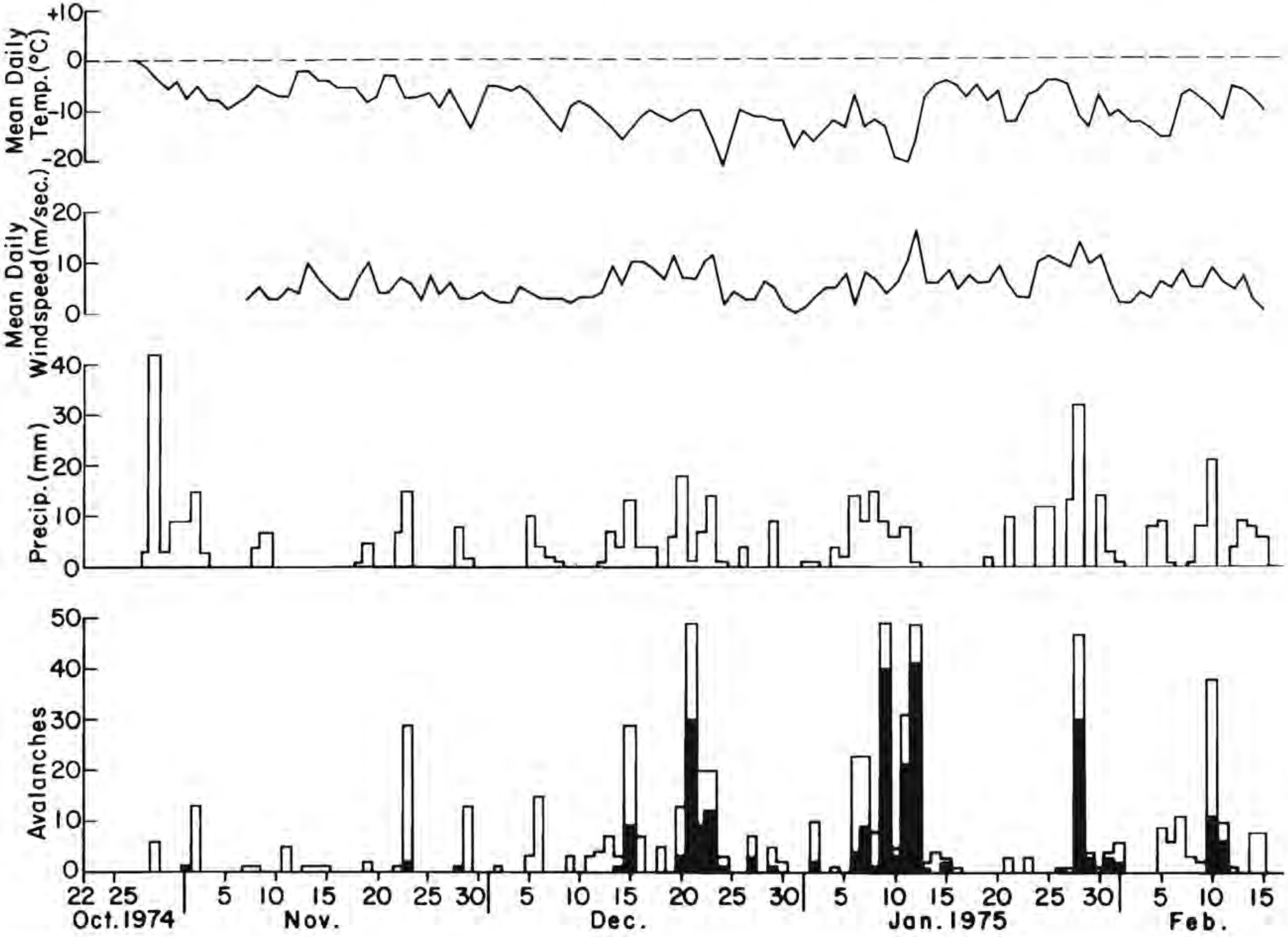

Figure 41. A diagram showing the variation in mean daily air temperature (^{o}C) and precipitation (mm of water equivalent) measured at the Red Mountain Pass study site, wind speed (meters per second) measured at Pt. 12325 and daily totals of observed avalanches for the period 22 October, 1974 to 15 February, 1975. The solid portion of the avalanche event bar graph indicates the number of events larger than size two.

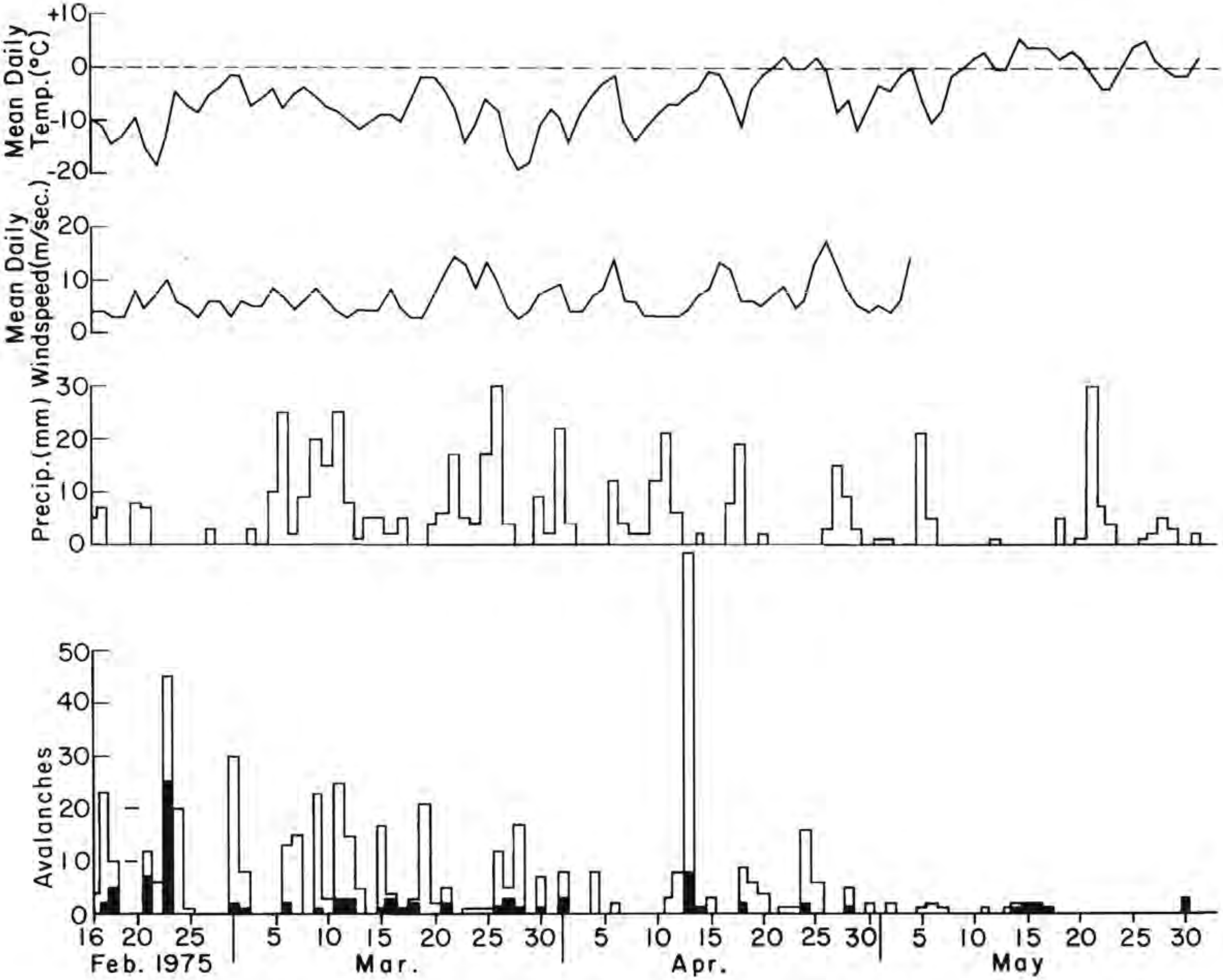

Figure 42. A diagram showing the variation in mean daily air temperature (^{o}C) and precipitation (mm of water equivalent) measured at the Red Mountain Pass study site, wind speed (meters per second) measured at Pt. 12325 and daily totals of observed avalanches for the period 16 February, 1975 to 30 May, 1975. The solid portion of the avalanche event bar graph indicates the number of events larger than size two.

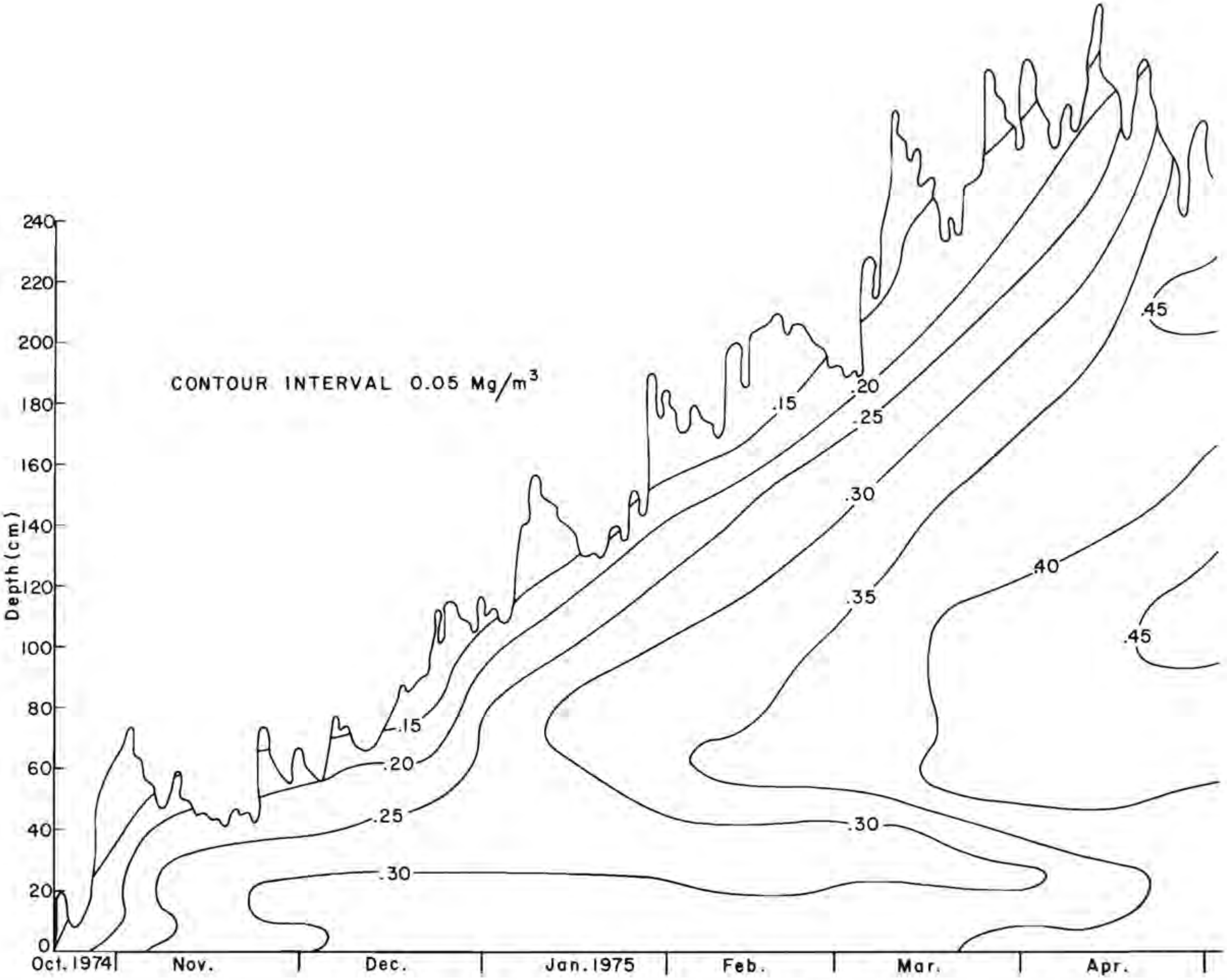

Figure 43. A time-stratigraphic diagram of density variations (Mg/m^3) at the Red Mountain Pass study site for the period 15 October, 1974 through 30 April, 1975.

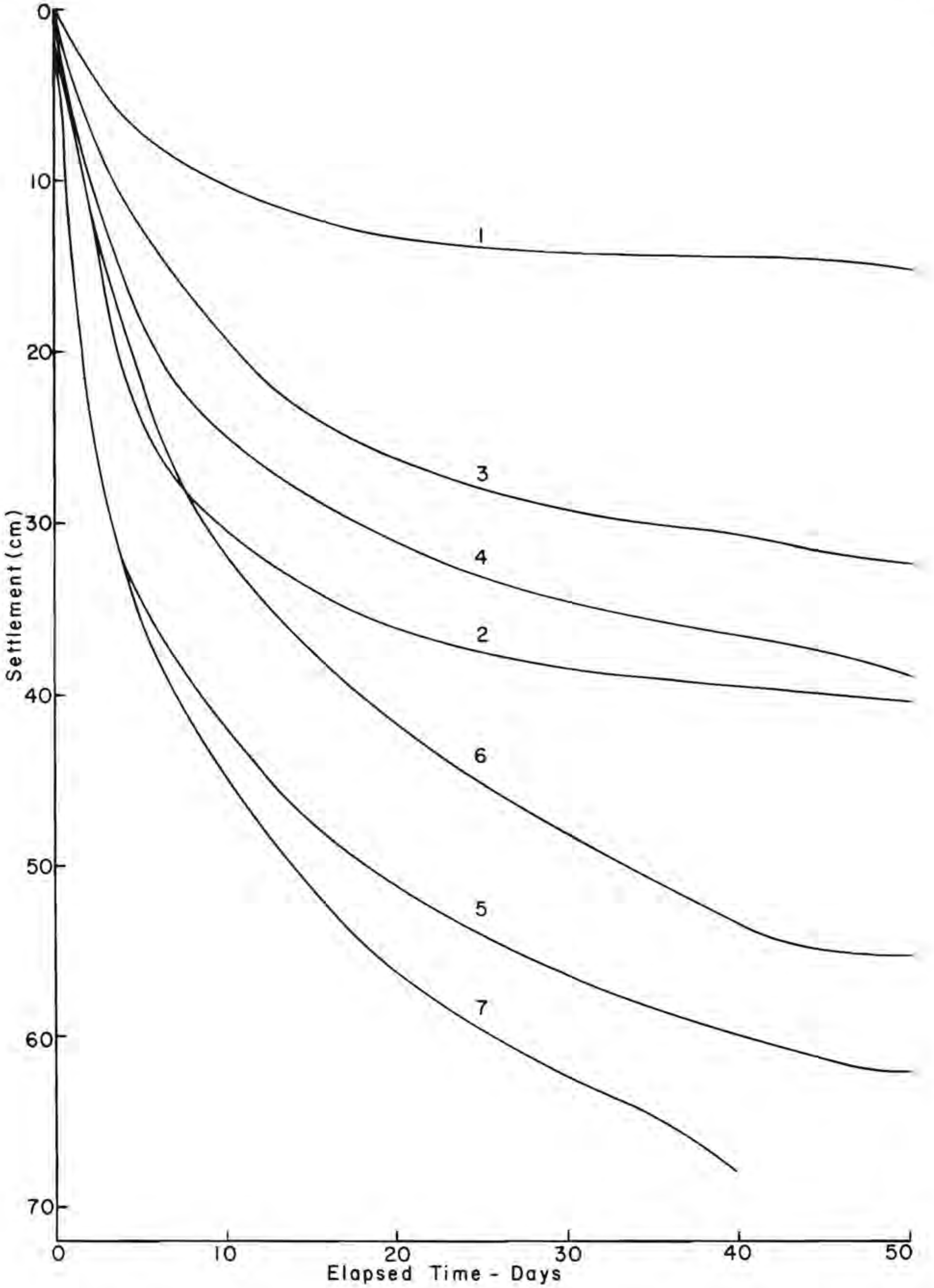

Figure 44. Initial settlement rates at seven points within the snowcover at the Red Mountain Pass study site, 1974-1975. Number 1 is representative of the early winter snowcover, numbers 2 through 4 are mid-winter and 5 through 7 are early spring conditions.

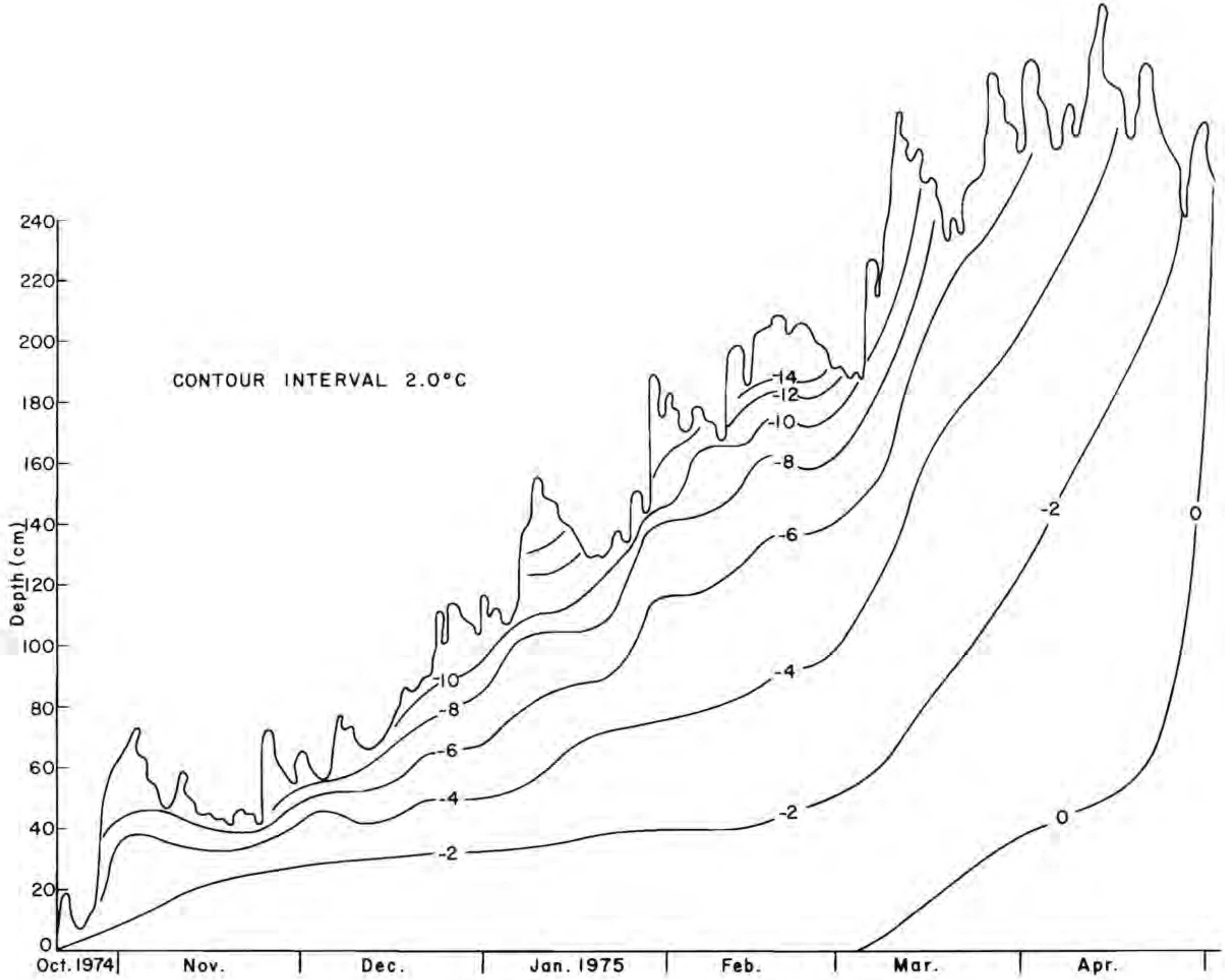

Figure 45. A time-stratigraphic diagram of temperature variations (^{o}C) within the snowcover at the Red Mountain Pass study site for the period 15 October, 1974 through 30 April, 1975.

isotherms represent that temperature regime which exists far enough below the snow-air interface (25-35 cm) so as to be appreciably insulated from the short-term or diurnal temperature influence. Temperatures within this lower portion of the snowcover respond in accordance with longer term variations in mean daily temperature, with the response-time lag being a function of depth. This relationship is apparent in Figure 45. As the snowcover continues to increase in depth, the general tendency is for the isotherms to slowly migrate upwards seeking to maintain the same distance from the snow surface. A significant warming trend began during early March and the zero degree centigrade isotherm began to move uninterrupted towards the surface with the entire snowcover becoming isothermal by the end of April.

Temperature measurements which comprise the data contained in Figure 45. are made daily just prior to sunrise at the study site. Near-surface snow temperatures at this time of the day often reflect the relatively low values (-15.0 - -25.0°C) caused by intense radiation cooling associated with the local climate. By mid-afternoon, these same layers may well be at or within a few degrees of freezing.

Snow strength or hardness data as obtained by the rammsonde penetrometer at the Red Mountain site are presented in Figure 46. These data are composed of integrated rammsonde values to given depths (z) below the snow surface with the ground as the base reference. Such a total integrated rammsonde profile is equal to the area (in kg/cm) under the resistance curve to that depth, i.e.

$$R_i = \sum_{z=0}^{z} R \Delta z$$

where R is the rammsonde resistance in kg, Δz is the depth increment in cm and R_i is the integrated rammsonde resistance in kg/cm. The dates corresponding to each data sample were chosen to indicate the progressive increase in strength with time. The relatively weak layer of temperature-gradient snow comprising the lowermost 60 cm of the snowcover is quite evident in Figure 46 as well as the fact that such a layer remains low in strength throughout the winter season.

The preceeding summaries of snow density, temperature, and rammsonde values representing the 1974-1975 winter pertain solely to the study site located on Red Mountain Pass. While this site is employed as the basic snowcover and climatic reference for the study area, other locations of snowcover investigations may or may not reflect the general pattern of snow structure development at the Red Mountain site. This lack of correlation is frequently the case at slope study sites where, generally, the snow structure is weaker with more frequent examples of poor layer bonding and more evidence of stratigraphic conditions produced by temperature-gradient processes. While average density values within the snowcover at the Red Mountain site are greater than the majority of the slope sites, the range of density values at the slope sites exceeds that which occurs at the primary study site. A more detailed description of snow structure with respect to slope angle and orientation is contained in Chapter 2.

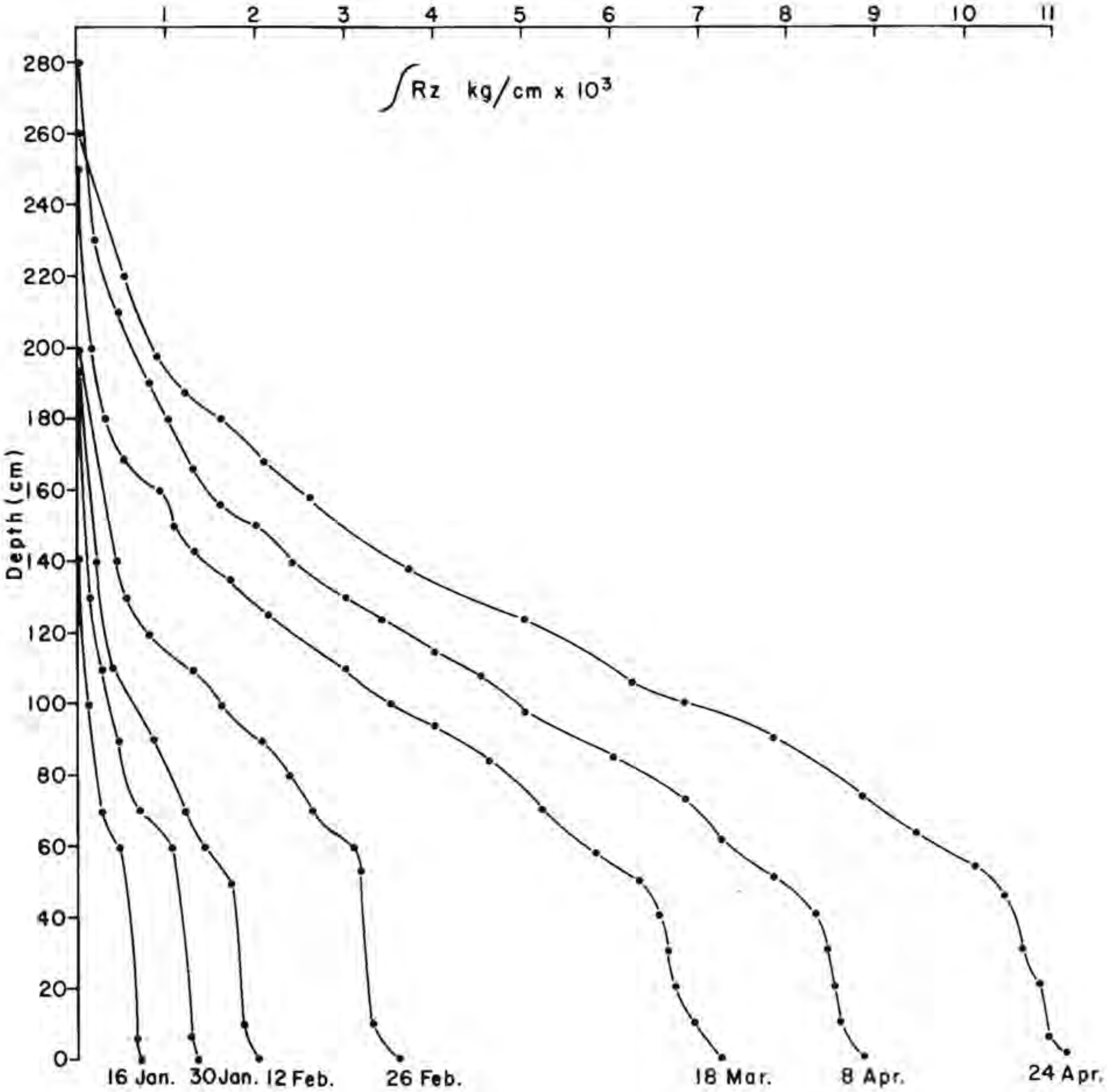

Figure 46. Integrated rammsonde resistance curves for seven selected dates at the Red Mountain Pass study site during the 1974-1975 winter.

Unless otherwise stated, all air temperature and snowcover data contained in the following winter summary were recorded at the Red Mountain Pass snow study site. Wind speed and direction data were recorded at Point 12,325.

Monthly Summary

October-November: A continuous snowcover began to develop at the Red Mountain study site on October 21 with an accumulation of 19 cm of snow. Snowdepth at the end of the month was 65 cm. Avalanche activity was restricted to seven small loose snow releases observed in the vicinity of Red Mountain Pass.

During the month of November 73 avalanches were observed. All but seven of these incorporated only surface snow, with 39 being soft slab type and the remainder dry loose events. Five soft slab events observed on the 11th of November were associated with wind loading and released in the absence of precipitation. Eight small avalanches reached the highway. The relatively shallow snow cover prevented most avalanches from reaching further than mid-track.

December: Snowdepth increased from 65 cm to 112 cm during the month. During November the snowcover had been slowly gaining strength but this trend was reversed when the lower air temperatures of December began to contribute to the formation of temperature-gradient snow. On December 6 investigation at the North Carbon site indicated that 68% of the snowcover on this north facing slope was made up of temperature-gradient snow while in the Red Mountain study site 57% of the snowcover was identified as the same type. Through December 12 only loose snow avalanche events were observed. For the period of the 13th through the 15th 38 slab avalanches occurred as a consequence of 30 cm of new snow and significant wind speeds. Three of these events ran to the ground and five, which had originated above timberline, were hard slab types. Twenty-two smaller events were recorded from the 16th through the 19th as the result of continued, but moderate precipitation.

A cycle of 102 events occurred from the evening of the 20th through the afternoon of the 23rd. Thirty-seven of these released to the ground and 53 were size three or larger. Twenty-four events reached the highway with 2 of these being artificial releases. The total length of highway covered was 632 m with the mean depth being 1.6 m. Analysis of fracture line profiles obtained following this cycle indicated that releases were occurring within the basal temperature-gradient layers, causing the high percentage of events which released to the ground. Precipitation during this period amounted to 44 mm and provided a new snow load too great to be supported by the old snow structure which was dominated by temperature-gradient metamorphism. A total of 234 events were observed with 30 of these reaching the highway.

January: Precipitation and avalanche magnitude greatly increased during January. Snowdepth increased from 112 cm to 184 cm and avalanches were recorded on 21 days during the month. A total of 269 events were recorded with 71 of these reaching the highway. The weak old-snow structure which had developed during December persisted through January causing 32% of the observed avalanches to release to the ground surface. An example of the snow structure prevalent at this time is presented in Figure 47.

Of the total events 75% occurred during a period of continuous storm conditions between the 6th and 12th. On the night of the 6th the East Riverside avalanche reached the highway and deposited debris 10 m deep over a distance of 30 m. Increased precipitation rates and windspeeds developed on January 8 and contributed to the release of 71 events on the 9th, 14 of which reached U.S. Highway 550 with an additional 4 crossing Colorado Highway 110, the Standard Metals Mine access road between Silverton and Gladstone. The debris deposited by the avalanches on Colorado 110 was significant enough to cause the road to be closed for several days.

During this portion of the cycle 50% of the events reached full track and 25% released to full depth removing the snow in the starting zone to the ground. Such conditions reflect exceptionally low snow strengths both within the starting zones as well as within the tracks of the individual avalanche paths. Although precipitation continued, only 4 events were observed on the 10th. On the 11th 43 additional events were recorded, 9 of which crossed the highway with the West Riverside depositing debris to a depth of 5 m over a distance of 35 m. Sixty-six percent of the events on the 11th reached full track, 50% released to the ground and 67% were size 3 or larger. On the 12th, 61 events were recorded with 16 crossing the highway. Within these events 75% reached full track, 50% released to the ground and 78% were size three or larger. Of the avalanches reaching U.S. Highway 550 during the entire cycle, which in total closed this highway for 20 hours, the release in the Muleshoe avalanche path on January 12 was the largest, averaging 6 m in depth for a distance of 100 m along the highway. The avalanche occurrences during this seven day period were significant not only because of their frequency but also due to the high percentages of events reaching full track and releasing to the ground. The fact that the snowcover at the Red Mountain study site attained an average depth of 143 cm during this period offers some indication of the volumes of snow involved in these releases.

No significant precipitation occurred again until the 24th when a total of 35 mm of water was recorded. During and after this storm period wind transport of snow was significant and it is exceptional that no new slab releases were reported. New snow was accumulating on bare ground in many of the starting zones due to the extensive cycle of January 6 through 12 and a warming trend which developed during the last portion of the storm and continued for two days following the storm contributed to a more stable snowcover than had previously existed. On January 26 the maximum air temperature was +3.0°C and the mean daily air temperature was -2.3°C.

During the 24 hour period beginning at noon on the 27th 53 cm of snow containing 46 mm of water were recorded. This new snow added to that of the

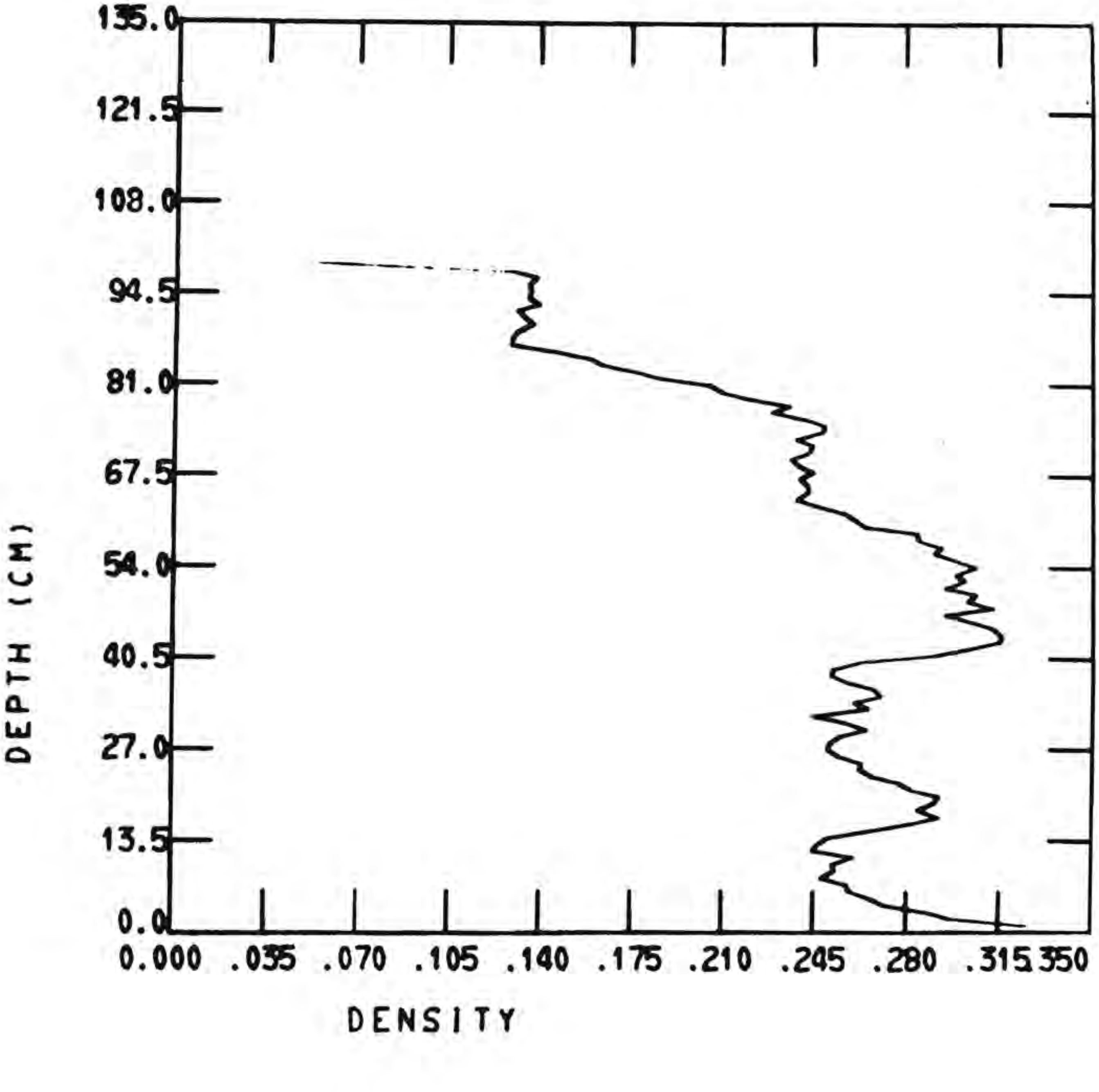

Figure 47. An example of stratigraphic density values (Mg/m^3) at 1.0 cm intervals at the Red Mountain Pass study site on 2 January, 1975. Data are obtained from an isotopic profiling snow gauge.

24th and 25th in combination with significant wind speeds was sufficient to produce 48 slab avalanches on the morning of the 28th. Of the total events 68% were size three or larger, 62% reached full track, but only 23% released to the ground. At this point the weaker snow layers at the base of the snowcover had been removed in most paths by previous avalanche activity and failures were taking place in the relatively stronger layers of the newer snow. The general condition of the snowcover was still described as unstable however, and on the 29th artificial control caused the Willow Swamp to reach the highway with a depth of 4.5 m for a distance of 100 m.

February: Precipitation as well as avalanche activity decreased compared to January but both remained above average for monthly values during the 4 year study. Snowdepth increased from 180 cm to only 193 cm during the month but 238 avalanche events were recorded with 40 reaching the highway. While total avalanche frequency remained high, the number reaching the highway decreased by 62% indicating a more stable snow structure within the avalanche tracks which restricted full track events.

An avalanche cycle consisting of 41 soft slab events occurred on the 10th and 11th as the result of 35 mm of water contained in 49.5 cm of new snow. The Eagle and the Telescope avalanches released during the evening of the 10th closing the road for several hours. On the following day artificial control produced releases in 10 of 16 paths. A significant warming trend followed this storm.

Light but nearly continuous precipitation from the 13th through the 18th produced 34.4 mm of water in 52.0 cm of snow. Twenty-three slab events were recorded on the 17th. Control efforts on the 18th produced avalanches in 10 of 16 paths. Precipitation totalling 20.0 cm of snow and 18 mm of water was recorded from midnight on the 19th through midnight on the 21st. During early morning on the 23rd a cycle of hard slab releases in the absence of precipitation began. Most releases occurred between 0400 and 1000 hours during which time winds from the north averaged 13.0 m/sec with frequent gusts to 20.0 m/sec. A total of 42 hard slab events were recorded with 8 reaching the highway. The majority of the releases occurred in catchment basins above timberline with loading aspects favorable to north winds such as the Muleshoe and Cement Fill to the north of Silverton and the Springs and Waterfall to the south. Mean fracture line depths were estimated to be 1.0 m.

March: Avalanche activity continued to be high with 305 events observed, 46 of which reached the highway. Precipitation during the month exceeded that of any winter month since data collection began in October of 1971; 296 cm of snow containing 244.4 mm of water were recorded. Snowfall occurred on 24 days and total depth increased from 192 cm to 262 cm.

Although precipitation amounts and avalanche frequency were very high, avalanche magnitude was minimal. In general snowpack structure gained strength due to higher snow temperatures and the formation of freeze-thaw crusts on all but north-facing slopes. Therefore, in spite of maximum precipitation amounts, optimum conditions for large load-induced avalanches did not exist. Only 8% of the observed avalanches were larger than size 2 and only one of these was size 4. Only 2% released to the ground surface. Storm precipitation amounts that would have been sufficient to cause extreme avalanche conditions during mid-winter accumulated on a stable old-snow structure (see Figure 42). Of the 46 events which did reach the highway, more than 50% were classified as bank slides which released no more than 20 to 30 m in vertical distance above the highway. This type of event occurred frequently in the Uncompahgre Gorge and in the Ledge and Rockwall area.

The two major precipitation periods of March 8 through 12 and 22 through 27 produced 83 mm and 92 mm respectively. However, of the resulting avalanche events only 12% were larger than size 2. This pattern of high frequency and minimal magnitude is apparent in Figure 42.

On the 16th the East Riverside reached the highway with debris being 3 m deep over a distance of 10 m. The estimated depth of the fracture line was 3 m. This event was one of five slab avalanches observed during the evening of the 16th and the morning of the 17th. These releases were preceeded by nine hours of wind speeds with an average of 14 m/sec.

April: During this month 155 avalanches were observed with 50 reaching the highway. Total snowdepth increased from 262 cm to a maximum of 310 cm on the 13th and then decreased to a depth of 265 cm by the 30th. The average depth for the month was 283 cm. The majority of the avalanches occurring before mid-month were dry loose surface events, while those occurring after mid-month were wet loose surface events. Both types were small in size releasing only to shallow depths and sliding on near-surface freeze-thaw crusts. Mean daily temperatures remained above freezing during the period April 22-25, the snowcover on south- and west-facing slopes became isothermal and the conditions appeared optimum for the release of significant wet snow slab avalanches. However, colder temperatures occurred on the 26th and by the 29th the mean daily temperature had dropped to $-11.0^{\circ}C$ eliminating the possibility of wet snow avalanche activity.

The most significant precipitation period occurred on the 11th and 12th when 49.5 cm of snow containing 36.3 mm of water was recorded. For the period of the 11th through the 13th, 86 avalanches were recorded. Only 11 events occurred on the 11th and 12th with the remainder releasing on the 13th. Of the total, 50% were soft slab type but only 10% were larger than size two. This period of activity was restricted to releases in the new snow due to the adequate bearing strength of the freeze-thaw crusts below.

The increasing air temperatures of the 22nd through the 25th, (average daily maximum temperature of $+7.5^{\circ}C$) resulted in 24 wet snow releases, 5 of which were slab events. Four of the 11 avalanches which reached the highway during this period released from the Mother Cline slide path between the hours of 1630 and 1830 on the 25th. The fourth event buried and caused considerable damage to a Colorado Department of Highways snowplow and the driver received minor injuries.

May: The mean monthly temperature was $0.0^{\circ}C$ but all precipitation was in the form of snow and amounted to 90 cm, containing 89 mm of water resulting in a mean new snow density of .098 Mg/m^3, a value representative of late spring snowfall. A total of 26 avalanches were observed with 2 reaching the highway. Eighteen of 26 events occurred between the 14th and 17th during a cycle of wet snow avalanches resulting from increasing air temperatures. The remaining events were small direct action surface releases in new snow which was deposited during storms on the 5th and 21st. On the 30th three wet slabs released on north-facing slopes but involved only the new snow deposited on the 21st. The fact that these releases were in catchment basins of relatively high altitude, (Mill Creek Cirque, 3700 m and Snowslide Gulch, 3500 m) indicated the extent to which the snowcover of even north-facing, high altitude slopes had warmed. Due to this fact no additional wet snow avalanching on the remaining slopes was anticipated or encountered.

APPENDIX 2

1971 - 1975 METEOROLOGICAL AND AVALANCHE SUMMARY TABLES

TABLE 26

1971-1972 MONTHLY METEOROLOGICAL SUMMARY

	Nov	Dec	Jan	Feb	Mar	Apr
Snowcover water equivalent (mm) 1st day of month, PG	0	72	213	243	281	342
Number of days with precipitation	11	20	8	14	10	11
Total snowfall (cm) 24 hour board	78	116	38	40	78	
Total water equivalent (mm), PG	72	140	31	37	61	78
Mean monthly temperature °C	-6.0	-10.0	-10.0	-8.0	-4.0	
Mean daily max temperature °C	0.0	-6.0	-4.0	-2.0	+2.0	
Mean daily min temperature °C	-11.0	-15.0	-15.0	-13.0	-10.0	
Max temperature °C	+11.0	+3.0	+5.0	+7.0	+9.0	
Min temperature °C	-21.0	-22.5	-27.0	-24.0	-20.0	
Number of days with temperatures > 0.0°C	15	2	5	8	21	
Mean monthly wind speed (m/sec)	6	7	9	7	6	
Max one hour average (m/sec)	20	21	36	20	21	
Max gust (m/sec)	28	37	57	32	31	

TABLE 27

1972-1973 MONTHLY METEOROLOGICAL SUMMARY

	Nov	Dec	Jan	Feb	Mar	Apr	May
Snowcover water equivalent (mm) 1st day of month, PG	155	329	491	553	602	742	834
Number of days with precipitation	20	16	15	13	21	18	12
Total snowfall (cm) 24 hour board	255	229	94	87	188	135	55 (to May 16)
Total water equivalent (mm), PG	174	162	62	49	140	92	38 (to May 16)
Mean monthly temperature °C	-8.0	-11.0	-10.0	-8.0	-8.0	-5.0	+1.5
Mean daily max temperature °C	-3.0	-4.0	-3.0	-1.0	-1.0	0.0	+8.1
Mean daily min temperature °C	-14.0	-15.0	-15.0	-14.0	-14.0	-12.0	-3.6
Max temperature °C	+4.0	+5.0	+6.0	+4.0	+4.0	+7.0	+15.0
Min temperature °C	-19.0	-24.5	-20.5	-19.5	-17.5	-19.0	-10.0
Number of days with temperature $> 0.0°C$	5	9	10	10	9	18	25
Mean monthly wind speed (m/sec)	5	6	5	3	5	6	
Max one hour average (m/sec)	27	20	20	12	23	15	
Max gust (m/sec)	40	25	35	21	42	26	

TABLE 28

1973-1974 MONTHLY METEOROLOGICAL SUMMARY

	Nov (18-30 only)	Dec	Jan	Feb	Mar	Apr (1-22 only)
Snowcover water equivalent (mm) 1st day of month 24 hour board	0	51	188	323	360	439
Number of days with precipitation	12	15	17	12	15	14
Total snowfall (cm) 24 hour board	76	166	178	63	87	199
Total water equivalent (mm) 24 hour board	51	137	135	37	79	162
New snow density range (Mg/m^3)	.05-.087	.053-.094	.050-.120	.030-.090	.063-.103	.053-.100
Mean monthly temperature °C	-7.7	-8.7	-10.0	-10.0	-4.3	-5.3
Mean daily max temperature °C	-6.3	-3.6	-5.0	-2.4	+2.1	+1.4
Mean daily min temperature °C	-12.4	-13.7	-15.0	-15.9	-9.4	-12.2
Max temperature °C	+7.5	+5.0	+8.5	+6.5	+9.0	+9.0
Min temperature °C	-17.5	-23.0	-24.5	-24.5	-15.0	-18.0
Number of days with temperature > 0.0°C	4	9	9	11	22	11
Mean monthly wind speed (m/sec)	7	8	6	5	8	6
Max one hour average (m/sec)	19	35	22	15	26	23
Max gust (m/sec)	29	53	41	28	46	43

TABLE 29

1974-1975 MONTHLY METEOROLOGICAL SUMMARY

	Nov	Dec	Jan	Feb	Mar	Apr	May
Snowcover water equivalent (mm) 1st day of month 24 hour board	87	172	294	501	622	869	1050
Number of days with precipitation	12	19	20	17	24	17	15
Total snowfall (cm) 24 hour board	125	161	235	152	296	224	90
Total water equivalent (mm) 24 hour board	85	122	207	121	247	181	85
New snow density range (Mg/m^3)	.056-.076	.042-.118	.029-.166	.027-.109	.050-.116	.053-.123	.043-.174
Mean monthly temperature °C	-6.3	-10.5	-10.0	-10.0	-8.0	-5.3	0.0
Mean daily max temperature	+1.4	-4.3	-4.6	-3.3	-3.9	+1.1	+6.7
Mean daily min temperature	-11.2	-15.3	-15.0	-15.8	-13.2	-11.0	-5.0
Max temperature °C	+9.0	+4.5	+3.0	+5.0	+7.0	+9.0	+13.0
Min temperature °C	-20.0	-25.5	-27.0	-23.5	-25.5	-19.5	-14.0
Number of days with temperature > 0.0°C	18	6	7	6	11	17	28
Mean monthly wind speed (m/sec)	5	5	7	5	6	7	
Max one hour average (m/sec)	21	22	23	17	28	25	
Max gust (m/sec)	29	38	32	30	40	35	

TABLE 30

AVALANCHE EVENTS ALONG HIGHWAY 550 GREATER THAN SIZE 1 IN ORDER OF FREQUENCY, 1971 - 1975

avalanche path number	avalanche path name	number of events
104	Eagle	94
097	Blue Point	80
095	Willow Swamp	57
105	Telescope	48
033	North Mineral Bridge	48
106	Muleshoe	42
064	East Riverside	32
022	Brooklyn G	32
061	Slippery Jim	30
128	Battleship	30
020	Brooklyn F	27
069	Mother Cline	27
101	Rock Wall	27
065	East Riverside Left	26
027	Brooklyn L	25
018	Brooklyn D	24
017	Brooklyn C	23
023	Brooklyn H	23
144	Champion	23
160	Engineer Mountain B	22
024	Brooklyn I	22
019	Brooklyn E	21
026	Brooklyn K	21
025	Brooklyn J	21
159	Engineer Mountain A	20
110	Mill Creek C	20
119	Imogene	20
161	Engineer Mountain C	20

TABLE 30 (continued)

avalanche path number	avalanche path name	number of events
151	Gobblers Knob	20
107	Bullion King	19
060	East Guadalupe	18
032	2nd Twin Crossings	18
010	Cement Fill	17
016	Brooklyn B	17
155	Henry Brown	17
031	1st Twin Crossing	17
044	Red Mountain 3	16
085	Daisy Hill	15
096	Blue Willow	15
073	Silver Gulch	14
039	Longfellow	14
109	Mill Creek B	13
074	West Riverside	13
150	West Lime Creek	13
035	U.S. Basin	13
112	Mill Creek E	13
127	Bismark	13
091	King	12
117	Sam	12
125	Ophir Road East	12
047	Red Mountain 2	12
084	Full Moon Gulch	12
113	Mill Creek F	11
132	Snowslide Gulch	11
076	Water Gauge North	11
100	Silver Ledge Mine	11
004	Pit	11
003	Old South Mineral Road	11
114	Mill Creek G	10

TABLE 30 (continued)

avalanche path number	avalanche path name	number of events
075	West Guadalupe	10
002	Water Gauge	10
001	Anvil Mountain	10
154	Swamp	10
030	Cemetery	9
108	Mill Creek A	9
072	White Fir	9
028	Brooklyn M	9
043	National Bell North	8
082	Ironton	8
090	Governor Gulch	8
115	Ernest	8
126	Ophir Road West	8
149	East Lime Creek	8
140	Jennie Parker North	7
045	Gennessee South	7
103	Porcupine	7
063	East Riverside Right	6
007	Hopi	6
015	Brooklyn A	5

TABLE 31

RECORD OF AVALANCHE OCCURRENCES IN THE STUDY AREA FOR THE 1971-75 WINTERS

Within each season, occurrences are listed by Station in the order 152, 153 157. For each day, avalanche paths are listed in numerical sequence according to path number on a given Station. Occurrences of uncertain origin, that do not bear a path number are listed at the end of each day.

The numbers listed in the second column below refer to the punched card format.

Data	Column(s)	Description of data
Year	1-2	
Month	4-5	
Day	8-9	
Time	10-13	2405 = event thought to have occurred in the A.M., exact time unknown. 2417 = event thought to have occurred in the P.M., exact time unknown.
Name	14-29	Name of individual avalanche path.
Station	30-32	152 = U.S. Highway 550 153 = Cement Creek 157 = Silverton
Path number	33-35	Number for individual avalanche path.
Control	36	4 = 75 mm howitzer
	37	Number of shots fired.
Type of release	39-40	HS = Hard slab SS = Soft slab WS = Wet slab L = Loose WL = Wet loose
Trigger	41-42	N = Natural AS = Artificial-Skier AE = " -Explosive AA = " -Artillery AL = " -Avalauncher AO = " -Other(snowmobile, sonic boom, etc).

TABLE 31 (cont'd)

Data	Column(s)	Description of data
Size of release	43	1 = Sluff, any snowslide, running less than 150 feet slope distance, regardless of other dimensions such as width, fracture line, etc. All other avalanches are classified by a number 2-5, that designates their sizes. This size classification is based on the concept that size should convey the volume of snow that is transported down an avalanche path, rather than a threat to life and property. In addition, sizes 2 to 5 are reported relative to the slide path, that is, a "small" avalanche is one that is small (moves a small volume of snow down the path) for a particular avalanche path. 2 = Small, relative to the avalanche path 3 = Medium 4 = Large 5 = Major or maximum
Running surface	44	O = Avalanche ran on old snow surface in the starting zone. G = Avalanche ran to ground in the starting zone.
Motion	46	S = Sliding, occurs when snow breaks loose and moves downslope without rolling or tumbling. F = Flowing or tumbling motion; snow whether granular or in blocks, moves along the snow or ground surface in a rolling, turbulent motion. M = Mixed airborne and ground motion.
Slab depth	48	Estimate of height of fracture line, measured at right angles to the slope, to the nearest foot.
Layers	49	A = Avalanche involves only new snow B = Avalanche penetrates deeper and includes old snow layer or layers.
Percent	51-52	Percent of total avalanche path affected.
Starting zone	53-54	Starting area when avalanche is viewed from below: T, M, B = top, middle, bottom L, C, R = left, center, right, of the midline of path.

TABLE 31 (cont'd)

Data	Column(s)	Description of data
Vertical fall	55-58	Estimate, in feet, of the vertical fall distance of the avalanche, not slope distance.
Debris location	59	Location of debris or where avalanche stopped. A = Fracture or starting zone B = Transition or bench partway down track C = Bottom of track or runout zone
Center line depth	60-61	Estimate, in feet, of the maximum depth of avalanche debris at the centerline of a road.
Length of centerline	62-65	Estimate, in feet, of the maximum length of centerline covered by avalanche debris.

AVALANCHE OCCURRENCES, STATION 152, 1971-72

year	month	day	time	avalanche path	station number	path number	control	type	trigger	size	running surface	motion	slab depth	layers	percent	starting zone	vertical fall	location of debris	center line depth	length of center line
71	11	16	1300	BLUE POINT	152	097		L	N	2	0				25	T	200	C		
71	11	16	1300	MILL CK E	152	112		SS	N	2	0		2	A	25	M	400	B		
71	11	16	1300	MILL CK F	152	113		SS	N	2	0		2	A	50	T	1200	B		
71	11	16	2417	BISMARK	152	127		SS	N	2	0		3	B	40	T	1000	B		
71	11	16	2417	BROOKLYNS	152			SS	N	2	0		2	A	5	T	300	B		
71	11	16	2417	BROOKLYNS	152			SS	N	2	0		2	A	5	T	300	B		
71	11	16	2417	BROOKLYNX	152			SS	N	2	0		2	A	5	T	600	B		
71	11	17	2405	1ST TWIN CROSSNG	152	031		L	N	1	0					M				
71	11	17	2405	NO MINERAL BRDGE	152	033		L	N	1	0					M				
71	11	17	2405	US BASIN W	152	035		SS	N	2	0					T				
71	11	17	2405	JENNIE PARKER SO	152	141		L	N	1	0					T		B		
71	11	17	2405	SPRINGS	152	148		SS	N	2	0		1			M		C		
71	11	17	2405	W LIME CK	152	150		L	N	1	0					B				
71	11	17	2405	GOBBLERS KNOB	152	151		SS	N	2	G					TL				
71	11	17	2405	HENERY BROWN	152	155		L	N	1	0					M				
71	11	18		MILL CK B	152	109		SS	N	2	0					M				
71	11	18	2417	BATTLESHIP	152	128		L	N	1	0					T				
71	11	18		COAL CK W	152	158		WL	N	1	G					T				
71	11	18		ENGINEER MTN B	152	160		L	N	1	0									
71	11	18		ENGINEER MTN C	152	161		L	N	1	0									
71	11	20	2417	1ST TWIN CROSSNG	152	031		WL	N	1	0					T				
71	11	20	2417	NO MINERAL BRDGE	152	033		WL	N	2	0					T				
71	11	20	2417	NO MINERAL BRDGE	152	033		WL	N	2	0					T				
71	11	20	2115	BLUE POINT	152	097		L	N	2	0			A	20	T	200	C		
71	11	20	2417	TELESCOPE	152	105		WL	N	2	G			B	5	T	500	B		
71	11	22	2405	BROOKLYNS	152			WL	N	2	G			B	5	T	600	B		
71	11	22	2405	BROOKLYNS	152			WL	N	2	G			B	5	T	600	B		
71	11	22	2405	BROOKLYNS	152			WL	N	2	G			B	5	T	600	B		
71	11	28	2405	E RIVERSIDE S.	152	062		L	N	2	0			A	10	T	300	C		
71	11	28		MILL CK F	152	113		SS	N	2	G		2	B	20	T	400	C		
71	11	28	2405	BATTLESHIP	152	128		SS	N	2	0		2	B	5	T	1000	B		
71	11	29	2405	US BASIN W	152	035		SS	N	3	G		3	A	50	T	400	C		
71	11	29	2405	MOTHER CLINE	152	069		SS	N	2	G		1	B	5	M	300	B		
71	11	29	2405	KING	152	091		SS	N	2	0		1	B	5	T	150	B		
71	11	29	2405	WILLOW SWAMP	152	095		L	N	1	0			B	10	T	75	B		
71	11	29	2405	BLUE POINT	152	097		SS	N	2	0			B	80	T	200	C		
71	11	29	2405	BULLION KING	152	107		SS	N	2	0		2	B	5	M	500	B		
71	11	29	2405	SAM	152	117		SS	N	2	0		2	B	5	M	300	B		
71	11	29	2405	SAM	152	117		SS	N	2	0		2	B	5	M	100	B		
71	11	29	2405	BISMARK	152	127		SS	N	2	0		2	B	30	T	900	B		
71	11	29		W LIME CK	152	150		L	N	1	0									
71	11	29	2405	GOBBLERS KNOB	152	151		L	N	2	0			B	5	T	100	B		
71	11	29		ENGINEER MTN A	152	159		L	N	2	0									
71	11	29		ENGINEER MTN B	152	160		L	N	2	0									
71	12	02		BROOKLYNS B	152	016		L	N	1	0									
71	12	02		SAM	152	117		SS	N	2	0		1			M	100	B		
71	12	02		BATTLESHIP	152	128		L	N	1	0									
71	12	02		ENGINEER MTN B	152	160		L	N	1	0									
71	12	04		BROOKLYNS G	152	022		L	N	1	0					T				
71	12	04		BROOKLYNS H	152	023		L	N	1	0					T				
71	12	04		2ND TWIN CROSSNG	152	032		SS	N	2	0			A		M	250	C		
71	12	04		NO MINERAL BRDGE	152	033		L	N	1	0					T				
71	12	04	2405	LONGFELLOW	152	039		SS	N	1	0			A						
71	12	04	2417	LONGFELLOW	152	039		L	N	1	0									
71	12	04		LONGFELLOW	152	039		L	N	1	0					T				
71	12	04		RMP	152	040		L	N	1	0					T				
71	12	04		CORA BELL	152	048		L	N	1	0					M				
71	12	04		E GUADALUPE	152	060		L	N	1	0					T				
71	12	04		SLIPPERY JIM	152	061		L	N	1	0					M				
71	12	04		W GUADALUPE	152	075		L	N	1	0					T				

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71 12  042405WILLOW SWAMP    152095     L N10    A
71 12  04     BLUE POINT     152097     L N10         M
71 12  042405TELESCOPE       152105     L N20    A   5
71 12  04     BULLION KING   152107     L N20         T  500
71 12  04     MILL CK A      152108     L N10         M
71 12  04     MILL CK E      152112     L N10         T
71 12  04     OPHIR RD E     152125     L N30         T
71 12  04     OPHIR RD W     152126     L N30         T
71 12  04     BATTLESHIP     152128     L N20         T  400B
71 12  04     PUMPHOUSE      152136     L N30         T 1500C
71 12  04     E LIME CK      152149     L N10
71 12  041130W LIME CK       152150     L N10         B
71 12  041230W LIME CK       152150     L N10         B
71 12  04     GUBBLERS KNOB  152151     L N20         T
71 12  04     ENGINEER MTN A 152159     L N20         T
71 12  04     ENGINEER MTN B 152160     L N30         T
71 12  04     ENGINEER MTN C 152161     L N20         T
71 12  07     BLUE POINT     152097     L N20
71 12  08     CEMENT FILL    152010    HS N20    5    T
71 12  081430BROOKLYNS B     15201641  LAA1                75
71 12  081430BROOKLYNS D     15201841 SSAA2           T  600
71 12  08     BROOKLYNS G    152022     L N2          M  200
71 12  081430BROOKLYNS I     15202441 SSAA2      2    T  600
71 12  08     NO MINERAL BRDGE152033    L N2             400
71 12  08     US BASIN E     152035    HS N20    4    T  500
71 12  08     US BASIN F     152035    HS N20    2    T  500
71 12  08     CORA BELL      152048       N 0
71 12  08     E GUADALUPE    152060    HS N30    5  35TR1600
71 12  08     SLIPPERY JIM   152061       N20            500
71 12  08     W GUADALUPE    152075    HS N30    4      1000
71 12  08     LAKE           152077       N20            300
71 12  08     GOVERNER GULCH 152090    HS N30    5     TL1000
71 12  08     KING           152091    SS N20    1A   M
71 12  08     WILLOW SWAMP   152095    SS N30    3B 50T  400
71 12  08     BLUE PT.       152097     L N20       20T  150
71 12  081400EAGLE           15210442 HSAA2      4    M  800
71 12  081400EAGLE           15210441 HSAA2      4    T 1100
71 12  08     EAGLE          152104    HS N20    3    M  800
71 12  08     TELESCOPE      152105    HS N20    3    M  800C 3   50
71 12  081400MULESHOE        15210641 HSAA2           T  800
71 12  08     MULESHOE       152106    HS N2     3    M  900C
71 12  08     MILL CK F      152113    HS N30    3    T 1000C
71 12  08     IMOGENE        152119    SS N20          L 200
71 12  08     PORTAL         152120    SS N10
71 12  08     OPHIR RD E     152125    HS N40
71 12  08     CHAMPION       152144    SS N10    2    M
71 12  08     W LIME CK      152150    SS N20    2    M  200
71 12  08     GUBBLERS KNOB  152151     L N1
71 12  08     HENRY BROWN    152155     L N10
71 12  08     ENGINEER MTN B 152160    SS N1     1    T
71 12  08     ENGINEER MTN C 152161    SS N1          M
71 12  09     BATTLESHIP     152128    SS N10    1    B
71 12  10     MILL CK C      152110     L N20         M
71 12  10     MILL CK E      152112     L N20         M
71 12  10     MILL CK F      152113     L N20         M
71 12  14     CEMENT FILL    152010    SS N30    3     TL2000
71 12  141100BROOKLUNS C     15201741 SSAA20 M 3A  5TC 800C      50
71 12  141055BROOKLYNS E     15201941 SSAA20 M 3A 40TR1000C     100
71 12  141055BROOKLYNS F     15202040 SSAA20 M 3A 40TR1000C      50
71 12  141050BROOKLYNS G     15202241 SSAA20 M 3A 50TR1000C     100
71 12  141050BROOKLYNS H     15202340 SSAA20 M 3A 30TC1000C     100
71 12  141315E RIVERSIDE     15206442 SSAA20 M 4B  5TR1500C10 150
71 12  141300E RIVERSIDE     15206445 SSAA30 M 5B 30TR2800C 8 200
71 12  141325E RIVERSIDE     15206445
71 12  141130WILLOW SWAMP    15209541 SSAA20 S 1A  5TR 100A
71 12  141130WILLOW SWAMP    15209541 SSAA3G M 4B 40TL 400C
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71 12  141140BLUE POINT      15209741 SSAA3G M 3B100TC 400C 5 250
71 12  141045EAGLE           15210442 SSAA20 M 2A 10TR 600B
71 12  141040EAGLE           15210441 SSAA20 M 3A 30TC1200C
71 12  141036MULESHOE        15210641 SSAA20 M 1A 10TL 900B
71 12  141035MULESHOE        15210641 SSAA20 M 3A 20TC1600C
71 12  142417OPHIR RD E      152125   SS N20      20TC 400
71 12  141005JENNIE PARKER NO15214041 SSAA20 M 2A 20TC 900B
71 12  141000JENNIE PARKER SO15214142 SSAA20 M 2A 20TL1000B
71 12  141010PEACOCK         15214241
71 12  142417W LIME CK       152149   SS N10   1   5T   30
71 12  142417E LIME CK       152150    L N10       5TC  25
71 12  142417GOBBLERS KNOB   152151    L N20      10T  100
71 12  142417SWAMP           152154    L N10       5TL  50
71 12  142417HENRY BROWN     152155    L N10       5TL  50
71 12  142417COAL CK E       152157    L N10       5T   30
71 12  142417ENGINEER MTN B  152160    L N20       5T  100
71 12  172405E GUADALUPE     152060   SS N20   2B 10ML1200B
71 12  172405GALENA LION GLCH152088   HS N30   6B 30TC1900B
71 12  17    EAGLE           152104   SS N20   2      1600
71 12  172405MULESHOE        152106   SS N20   2B 60TL1900C
71 12  172405BULLION KING    152107   SS N20   2B   T 1700C
71 12  172405IMOGENE         152119   SS N30   4B 60TL1500C
71 12  182417W LIME CK       152150   WL N20    A 10TC 200
71 12  18    SWAMP           152154    L N1
71 12  18    HENRY BROWN     152155    L N1
71 12  18    ENGINEER MTN A  152159    L N10
71 12  18    ENGINEER MTN B  152160   WL N10        T
71 12  182417ENGINEER MTN B  152160   WL N20    A 20TC 200
71 12  192417WATER GAUGE     152002   WL N20    A 10TC 300B
71 12  192417OLD SO MINERALRD152003   WL N20    A 10TC 450B
71 12  192405ENGINEER MTN A  152159   WL N20       5TC 200B
71 12  222405BROOKLYNS D     152018    L N10    A
71 12  222405SAM             152117   SS N20    A 10M  200B
71 12  222405BATTLESHIP      152128    L N20    A  5T  200A
71 12  222405ENGINEER MTN B  152160    L N10    A  5T   75B
71 12  252300BROOKLYNS D     152018   SS N3G   6B 40CM 600C 3 250
71 12  252405SILVER BULCH    152073   HS N40  10B 70TL2600C
71 12  261600CEMENT FILL     152010   HS N4G  15B 80TC2600C15 400
71 12  262200BARTON          152012   SS N4    4B 90TC1500C 4 100
71 12  261800BLACKBURN       152013   SS N30   3B 25TR 300C 6 100
71 12  262200BENNY LONG      152014   SS N20   2B 20TC 200C 6  75 3        I
71 12  261800BROOKLYNS D     152018   SS N30   4B 90TC1000C 5 300
71 12  261800BROOKLYNS I     152024   SS N30   4B 60TC1000C10 300
71 12  261600BROOKLYNS J     152025   SS N30   3B 60TR1000C 3 150
71 12  261600CEMETARY        152030   SS N30   3B 50TC 700B
71 12  2616001ST TWIN CROSING152031   SS N30   3B 70TC 700B
71 12  261600NO MINERAL BRDGE152033   SS N30   3B 60TC 900B
71 12  262000NATIONAL BELL SO152042   HS N5G   8B100TC1500C
71 12  262000NATIONAL BELL NO152043   HS N5G  15B100TC1900C
71 12  261842RED MTN 3       152044   HS N5G  20B100TC2200C
71 12  262300ROCKWALL        152101   SS N5G   5B100TC 900C101000
71 12  262300SILVE LEDGE MILL152102   SS N5G   5B100TC 800C10 500
71 12  262300PORCUPINE       152103   SS N4G   8B 80TC1300C 8 400
71 12  262300EAGLE           152104   SS N4G   8B 80TC1900C12 300
71 12  262300TELESCOPE       152105   HS N5G  20B100TC2200C20 600
71 12  262300MULESHOE        152106   SS N36   8B 80TC2100C 6 200
71 12  261600SAM             152117   SS N20   3B 20MC 400L
71 12  261600CHAMPION        152144   SS N46    B 70TC1600C15 350
71 12  272405OLD SO MINERALRD152003   SS N20              B
71 12  272405LOWER CEMENT FIL152009   SS N30   3B 30TC1000B
71 12  272405BROOKLYNS C     152017   SS N30   3B 70TL1000C 4 400
71 12  272405BROOKLYNS E     152019   SS N3G   4B 70TC1000C 5 200
71 12  272405BROOKLYNS I     152024   SS N4G   5B 80TC1000C10 300
71 12  272405ALBANY GULCH    152055   HS N5G  15B 90TC3100C
71 12  270930SLIPPERY JIM    152061   SS N3G   4B 50MC1100C 9 300
71 12  270930E RIVERSIDE     152064   HS N5GJ 30B100TC3200C15 600
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71 12  272405SILVER GULCH      152073   SS N30    5  20TC2000B
71 12  271245W RIVERSIDE       15207446 HSAA40 M 8B 70TL2900C 2  20
71 12  272405W GUADALUPE       152075   HS N30   8B 30TL2000B
71 12  272405IRONTON PARK      152082   SS N4G   5B100TC1600C
71 12  272405TIDY              152083   SS N30   3B100TC1000C
71 12  272405FULL MOON GULCH   152084   SS N30   3B 90TC1200C
71 12  271215KING              152091   SSAA20
71 12  271200WILLOW SWAMP      15209541 SSAA20 S 1A  5TL 200B
71 12  271205BLUE POINT        15209741 SSAA30 S 2A 20T3 200B10  50
71 12  271115PORCUPINE         15210341
71 12  271100EAGLE             15210441 SSAA20   3B 20TR1400  3  75
71 12  271100EAGLE             15210444
71 12  272405BULLION KING      152107   SS N40   6  90TC2000C
71 12  272405MILL CK A         152108   SS N20   2  30MC 900C
71 12  272405MILL CK B         152109   SS N20   2  30MC 900C
71 12  272405MILL CK C         152110   SS N20   2  30MC 900C
71 12  272405MILL CK E         152112   SS N20   2  30MC 900C
71 12  272405MILL CK F         152113   SS N20   2  30MC 200C
71 12  272405SAM               152117   SS N30   3  80TC 600C
71 12  272405OUTLAW            152121   SS N30   3 100TC1200C
71 12  272405SAN JUAN          152122   SS N40   4 100TC1400C
71 12  272405TAVERN            152123   SS N30   3 100TC1200C
71 12  272405OPHIR RD E        152125   SS N30   5  90TC1900C
71 12  272405OPHIR RD W        152126   SS N30   5  90TC1800C
71 12  272405BISMARK           152127   SS N40   3B100TC2000C
71 12  272405BATTLESHIP        152128   SS N40   4B100TC2400C
71 12  272405DESTROYER         152129   SS N40   3B100TC1400C
71 12  272405SNOWSLIDE GULCH   152132   HS N40   6B100TC2200C
71 12  272405BEAR CK W         152134   SS N30     100TC1800C
71 12  272405PUMPHOUSE         152136   SS N40   4 100TC2000C
71 12  272405NORTH STAR        152137   SS N30      20TR1000B
71 12  272405JENNIE PARKER     152141   SS N30   3B 20TR1000B 2  50
71 12  272405KENO MINE         152146   SS N30   3B    MC 700B
71 12  272405HENERY BROWN      152155   SS N20   2B 30TL 400B
71 12  281150PEACOCK           15214242 SSAA4G M 5B 90TC1500C18 200
71 12  281155HARLEY SHORT      15214342 SSAA20 S 2A 50TC 150B 2 100
71 12  291200BROOKLYNS E       15201941 SSAA3G   3B 30TR1000C12 200
71 12  290800BROOKLYNS F       152020   SS N3G   3B 70TC1000C12 300
72 01  031100LIME CK W         15215044
72 01  031045COAL CK W         15215843
72 01  031030ENGINEER MTN B    15216045 SSAA20    A 30    200
72 01  042417CORA BELL         152048   SS N20      20MR 200
72 01  042417WILLOW SWAMP      152095   SS N20      20MC 150
72 01  042417BLUE POINT        152097   SS N20      20TC 100
72 01  042405HENRY BROWN       152155    L N10        HL  50
72 01  062405BLUE POINT        152097    L N20    A 20TC 200
72 01  062405OPHIR ROAD E      152125   SS N30   3  30MC 900
72 01  11    BROOKLYNS B       152016   SS N30   2  80TC 900
72 01  11    ITALIAN           152051   SS N20   2  70TR 900
72 01  11    BULLION KING      152107   SS N20
72 01  11    MILL CK B         152109   HS N20   1  15BC 200
72 01  11    MILL CK C         152110   HS N20   1  15MC 300
72 01  11    MILL CK E         152112   HS N20   1  20MC 300
72 01  11    MILL CK F         152113   HS N20   1  20MC 300
72 01  130900EAGLE             152104   HS N30   3  50TL1500C 4 350
72 01  13    MILL CK G         152114   HS N2G   3  40MC 600
72 01  142405IMOGENE           152119   HS N20   2  10TL 400
72 01  14    SAN JUAN          152122   SS N10       5MC  50
72 01  14    TAVERN            152123   SS N20   1  40TC 400
72 01  14    BATTLESHIP        152128   HS N30   3    TC1900
72 01  181513E RIVERSIDE SO    152062   SS N20   1    BR 100  2  40
72 01  202417SLIPPERY JIM      152061   WL N20       5BC 150
72 01  222417MOTHER CLINE      152069   WL N20       5BR 200  2  20
72 02  18    BLUE POINT        152097   WL N20       5TL 100
72 02  182417TELESCOPE         152105   WL N20      10TC 200
72 02  19    SLIPPERY JIM      152061   WL N20       5BL 200
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72 02  212417BROOKLYNS J     152025    WL N20       30TC 350
72 02  22    NO MINERAL BRDGE152033    WL N10        5    50
72 02  222417LONGFELLOW      152039    WL N20        5   100
72 02  22    MOE             152057    WL N20       30   250
72 02  22    SLIPPERY JIM    152061    WL N20        5BR 150
72 02  22    E RIVERSIDE     152063    WL N20        5BR 300   3  15
72 02  222415DUNSMORE        152068    WL N10        5BC  75   1  25
72 02  22    DUNSMORE        152068    WL N20       10TL 150
72 02  22    DUNSMORE        152068    WL N20       10TR 200   1  10
72 02  22    SILVER GULCH    152073    WL N20        5MC 250
72 02  22    LAKE            152077    WL N20       40MR 300
72 03  011620BROOKLYNS B     152016    WLAS20 S     10T  400B
72 03  011620BROOKLYNS C     152017    WLAS10 S      5M   75B
72 03  012417E GUADALUPE     152060    WL N20        5M  250B
72 03  012417SLIPPERY JIM    152061    WL N20        5M  100B
72 03  012417E RIVERSIDE LEFT152065    WL N20        5BC 200B
72 03  021500NO MINERAL BRDGE152033    WL N20       10T  350B
72 03  021500RED MTN 3       152044    WS N20    2   5BC 150B
72 03  022417WATER GUAGE NO  152076    WL N20       15TC 250B
72 03  021000BATTLESHIP      152128    WL N20        5T  200B
72 03  032417E RIVERSIDE LEFT152065    WL N20        5MC 150B
72 03  032417SILVER GULCH    152073    WL N10        5MC  75B
72 03  03    SILVER GULCH    152073    SS N20    1  15MC 900B
72 03  031200MILLCK C        152110    SS N20    1  75   700C
72 03  051300GALENA LION GLCH152088B    WL N2       20TC 300A
72 03  05    WILLOW SWAMP    152095    SS N20    1  20TR 200B
72 03  052417EAGLE           152104    WL N20       15TC 300B
72 03  052417SAM             152117    SS N20    2  20TC 200B
72 03  052417SAN SUAN        152122    SS N20    1  50MC 200B
72 03  051300GI              152130    WL N2        20TC 200
72 03  051300 G.I.           152130    WL N2        20TC 175B
72 03  052417PICKLE BARREL   152131    WL N20       20TC 175B
72 03  102417BROOKLYNS G     152022    WS N2G    1  30TC 700B
72 03  102417BATTLESHIP      152128    HS N30    3  40TC1600C
72 03  132417BROOKLYNS H     152023    WS N2G       40TC 600B
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AVALANCHE OCCURRENCES, STATION 157, 1971-72

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71 12  04    RIO GRANDE       157002     L N20          T  500
71 12  04    WESTERN          157003     L N20          T  500
71 12  04    IDAHO            157004     L N20          T  500
71 12  04    TIGER GULCH      157041    SS N20          TR
71 12  04    BILLBOARD        157042    SS N20             800
71 12  04    BILLBOARD        157042    SS N20             900
71 12  04    BILLBOARD        157042    SS N20             800
71 12  04    BILLBOARD        157042    SS N20             800
71 12  04    GRASSY GULCH     157043    SS N20          TR
71 12  142405ARCADE           157008    SS N20        30MR1200
71 12  161030IRENE            15700541 HSAA30 M 5B 30TR1300C
71 12  161030IRENE            15700541 HSAA30 M10B 40TL1200C
71 12  161130W JUMP A         15702841 SSAA20 M 3B   TC 800B
71 12  161130W JUMP B         15702941
71 12  161045FAIRVIEW         15701641 HSAA20 M 5B 30TR1000B
71 12  161045FAIRVIEW         15701641 HSAA40 M10B 70TC 900C 2  50
71 12  161045FAIRVIEW         15701645
71 12  161100DRY GULCH W      15703941 SSAA40 M 3B 90TC1400C 2  75
71 12  242405DRY GULCH NO     157027    SS N30   3A 40TL 600C
71 12  272405DENVER           157001    SS N30   6B 40MC1500
71 12  272405HENRIETTA GULCH  157004    SS N40   8B100TC2000C
71 12  270530IDAHO            157004    HS N5GJ 20B100TC3500
71 12  270600ARCADE           157009    HS N4GJ 12B 80TC2900
71 12  272405ERIE             157014    SS N20   2A 90TC 700C
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71 12   272405MICHIGAN        157015   SS N4G   5B100TC 700C 3 100
71 12   272405FAIRVIEW        157016   HS N3G   5B 20TR1000C
71 12   272405BEATLES         157017   SS N30   3B 90TC 900C
71 12   272405GEORGIA GULCH   157021   HS N3G   6B 20TL2200C
71 12   272405W JUMP B        157029   SS N4G   5B 90TC 900C 4 150
71 12   272405MOGUL           157030   SS N30   3B 80TC 700C 4 300
71 12   272405STANDARD MINE   157031   SS N30   3B 60TC 900C
71 12   272405COLORADO SLIDE  157032   HS N40   6B100TC1000C
71 12   272405DRY BULCH SO    157040   SS N30           900
71 12   272405TIGER GULCH     157041   HS N4G   6B 60TL2000C
71 12   272405GRASSY GULCH    157043   HS N4G   8B 80TC2000C
72 02   21    BEATLES         157017   WL N20      30TC 300
72 03   051000MICHIGAN        157015   WL N20      10TL 200B
72 03   051000GEORGIN GULCH   157021   SS N20   1   5BL 250B
72 03   051000DRY GULCH NO    157027   SS N20   1   5BL 250B
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AVALANCHE OCCURRENCES, STATION 152, 1972-73

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72 10   302417RED MTN 3       152044   SS N30      30TC 900B
72 10   301300BLUE POINT      152097    L N20      50TC 150B
72 11   012405RED MTN 2       152047   SS N20   2   5TL 400M
72 11   012405BULLION KING    152107   SS N30   3  25TC 900M
72 11   012405ENG MTN B       152160   WL N10       5    75
72 11   062417BROOKLYN G      152022   WL N20      10TC 300M
72 11   062405MARMOT TOWN     152038    L N10       5TR  75M
72 11   062405NATL BELL       152042    L N20       5TL 300M
72 11   062405KING            152091    L N10       5TR  75T
72 11   062405WILLOW SWAMP    152095    L N10       5TR  75T
72 11   062405BLUE WILLOW     152096    L N10      20TC  75B
72 11   062405BLUE POINT      152097   SS N10       5ML  75M
72 11   062405BLUE POINT      152097    L N20      10TC 150M
72 11   062405ENG MTN B       152160   L  N10       5TC  65T
72 11   082417NATIONAL BELL NC152043   SS N20       5TL 250M
72 11   082417BLUE POINT      152097   SS N20      80TC 300B 3 150
72 11   082417FENCE           152098   SS N1G      80TC  75B 2  40
72 11   082417SNOW FLAKE      152099   SS N10      60TC  75B 2  30
72 11   082200ROCKWALL        152101   SS N20      70TC 200M 4 200
72 11   092405E RIVERSIDE     152064   SS N30   3  25TC3000B 4  50
72 11   091330EAST RIVERSIDE  15206443
72 11   091045EAGLE           15210444 SSAA20       5TC 400M
72 11   091045TELESCOPE       15210542
72 11   091050MULE SHOE       15210641
72 11   092405ENG MTN A       152159    L N20       5TC 100T
72 11   121000LONGFELLOW      152039   SS N20   1   5TR 100M
72 11   122405MILL CK B       152109   SS N20      25TR 500M
72 11   122405MILL CK C       152110   SS N20      25TR 500M
72 11   122405MILL CK D       152111   SS N20      15TR 500M
72 11   122405MILL CK F       152113   SS N20      30TR 500M
72 11   131345BROOKLYN E      152019   SS N20   1  10MC 250M
72 11   131345BROOKLYN F      152020    L N20      10MC 250M
72 11   131447BROOKLYN N      152029   WL N20 F  A 10ML 250M
72 11   131345NC MIN BDG      152033    L N20       5MC 250M
72 11   132405RED MTN 3       152044   SS N20   2   5TL 300T
72 11   132417E GUADALUPE     152060   WL N20       5MC 400M
72 11   132417E RIVERSIDE SOUT152062    L N20      10MC 150B
72 11   132417E RIVERSIDE LEFT152065   WL N20       5TR 200B
72 11   131245GOVERNER GULCH  152090    L N20       5TC 350T
72 11   132405WILLOW SWAMP    152095   SS N10   1    TR  75
72 11   131245BLUE WILLOW     152096    L N10      50TC  75B
72 11   132405MILL CK F       152113   SS N20   2  50TC 900B
72 11   132405MILL CK G       152114   SS N20   2  30TR 900B
72 11   132405ENG MTN B       152160   SS N20   1  30TC 200M
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72 11   132405NC SNOWDON      152      SS N3          T  800
72 11   142405RED MTN 3       152044   HS N20         5TR 450M
72 11   160945TWIN CROSSINGS  152032    L N20         5MR 300M
72 11   202405BROOKLYN K      152026   SS N20   1A 10TC 250M
72 11   201000MARMOT TOWN     152038   SS N10   1A  5TR  75M
72 11   202405BLUE WILLOW     152096   SS N10   1A 50TC  75B
72 11   202405BLUE POINT      152097   SS N20   1A 25TR 150B
72 11   202100BLUE POINT      152097   SS N20    A 25T  150B 2  30
72 11   202405MILL CREEK A    152108   SS N20   1A 25TC 200M
72 11   202405MILL CREEK B    152109   SS N20   1A 25TR 250M
72 11   202405SNOWSLIDE GULCH 152132   SS N20   1A 10TR 800M
72 11   202405BEAR CREEK EAST 152135   SS N20   1A 10TC 700M
72 11   212405CEMENT FILL     152010   SS N20   2A  5TR 200T
72 11   211000BROOKLYN H      15202341
72 11   211005BROOKLYN J      15202541
72 11   210915NC MINERAL BRIDG152033   SS N20   1A  5MC 250M
72 11   210200E RIVERSIDE SOUT152062   SS N20   1A 25TC 300B 2  25
72 11   211130E RIVERSIDE     15206444
72 11   210200E RIVERSIDE LEFT152065   SS N10   1A 10MC  70B
72 11   211010EAGLE           15210441 SSAA20   1A  5TC 400M
72 11   211015EAGLE           15210441 SSAA20 M 1A  5TR 200T
72 11   211020MULESHOE        15210641 SSAA20 M 1A  5TR 150T
72 11   272405CEMENT FILL     152010   HS N30   2  10TL1000M
72 11   270700BROOKLYN F      152020   SS N20   2  50TC 900B 1 100
72 11   270700BROOKLYN G      152022   SS N20   2  50TC 950B
72 11   2724051ST TWIN CROSSIN152031   SS N20   1  10TL1000B
72 11   270830NCRTH MINERAL BD152033   SS N20   2  25TR 800B
72 11   272405E GUADALUPE     152060   SS N20         5ML1000B
72 11   272405RICHMOND        152086   SS N30   3  50TC 700M
72 11   272405WILLOW SWAMP    152095   SS N20   1   5TR 150M
72 11   272405EAGLE           152104   SS N20   3  25TL 800M
72 11   272405TELESCOPE       152105   SS N30      75T 1800B 1  30
72 11   272405MULESHOE        152106   SS N20      50T 1600B
72 11   272405BULLION KING    152107   SS N30      75T 1800B
72 11   272405IMOGENE         152119   SS N30   2  75TR1900B
72 11   272405OPHIR ROAD EAST 152125   SS N30   2  50TL1500B
72 11   272405BATTLESHIP      152128   HS N30   3  50TR2100B
72 11   272405SNOWSLIDE GULCH 152132   SS N20   1  10TL1000B
72 11   292405RED MTN 3       152044   HS N20         5TL 350M
72 11   301000EAGLE           152104   SS N20   2   5TR 500M
72 12   012417WATER GAGE      152002    L N20 S       5TC 400M
72 12   012405SLIPPERY JIM    152061    L N20 S       5BL 150B
72 12   012405GALENA LION GULC152088    L N20 S       5TC1000B
72 12   042417BROOKLYN B      152016   SS N30      50TC 700B 3 100
72 12   042417BROOKLYN H      152023   SS N30      75T  800B 4 100
72 12   042417E GUADALUPE     152060   SS N20         5TL 400M
72 12   042030E RIVERSIDE LEFT152065   SS N20      50TC 200B 3  70
72 12   042417W RIVERSIDE     152074   SS N30      25TL1900B
72 12   042417BLUE POINT      152097   SS N20      25TC 150B 5  25
72 12   042417BLUE POINT      152097   SS N20      25TC 150B 5  25
72 12   042417BLUE POINT      152097   SS N20      25TC 150B 5  25
72 12   042417BLUE POINT      152097   SS N20      25TC 150B 5  25
72 12   042115ROCKWALL        152101   SS N20      25MC 150B 5 100
72 12   042415MULESHOE        152106   SS N30      50TC1900B
72 12   042417IMOGENE         152119   SS N20      50T 1800B
72 12   042015PEACOCK         152142   SS N20      50TC 800B 3  75
72 12   042015HARLEY SHORT    152143   SS N10      50 C  60B 2  75
72 12   042000CHAMPION        152144   SS N20      25TC 900B 5 120
72 12   042415W LIME CK       152150   SS N10      10MR  60B 1  50
72 12   041630SWAMP           152154   SS N20      50TC 200B 1  30
72 12   041630HENRY BROWN     152155   SS N20      75TC 350B 3  20
72 12   042100LOWERLEDGE      152       L N20 M   100TC1000  8 250
72 12   042200LOWER POND      152       L N20 M   100TC1000  5 100
72 12   052405N MINERAL BRIDGE152033   SS N20   2   5ML 150B
72 12   052405N MINERAL BRIDGE152033   SS N20   2  10ML 500B
72 12   051400E RIVERSIDE     15206441 SSAA30 F    25TR2500B 9  40
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72 12   051400E RIVERSIDE     15206444
72 12   051225WILLOW SWAMP    15209542 HSAA20 M 2A 25TL 300B
72 12   051150SILVER LEDGE MIN15210042
72 12   051115EAGLE           15210444 SSAA30 M 4  75TC2000B
72 12   051115TELESCOPE       15210542 SSAA20 M 3  50TC2000B
72 12   070900BROOKLYN H      152023   SS N20   3  10MR 300B
72 12   070900BROOKLYN J      152025   SS N20   2  25TR 400M
72 12   070900N MINERAL BRIDGE152033   SS N20   3  50TC1000B
72 12   092405ENG MTN B       152160   SS N20   2  25TC 300B
72 12   092405ENG MTN C       152161   SS N30   3  50TC 350B
72 12   111400E RIVERSIDE     15206444
72 12   111230TELESCOPE       152105    L N20      10TR 300M
72 12   112417BATTLESHIP      152128    L N20       5TR 700M
72 12   112417BATTLESHIP      152128    L N20       5TR 600M
72 12   111500JEANNIE PARKER N15214041
72 12   111500JEANNIE PARKER S15214141
72 12   122405BROOKLYN D      152018    L N20        TR 300M
72 12   122405BROOKLYN L      152027    L N20        TR 400M
72 12   121540ENG MTN C       152161   SSAE20   1A 25TC 350B
72 12   161500OLD S MINERAL RD152003   WL N20       5TC 300B
72 12   161500PIT             152004   WL N20      50TC 700B
72 12   171500E LIME CK       152149   WL N10       5MR  70B
72 12   211300WATER GUAGE     152002    L N20      10TL 600M
72 12   212417PIT             152004    L N20 S    25TR 300M
72 12   211045E RIVERSIDE     15206447
72 12   210900WATER GUAGE NO  152076   SS N20   3  10MC 300M
72 12   210900FULL MOON GULCH 152084   SS N20   3  25TC1000M
72 12   211000EAGLE           152104   SS N20   3  10TC2000B
72 12   212417TELESCOPE       152105    L N10
72 12   212417MULESHOE        152106    L N10
72 12   232405EAGLE           152104    L N20       5TC 300M
72 12   251345CEMENT FILL     152010   HS N30 M 3  50TC2400B 7 100
72 12   262405EAGLE           152104   SS N20   1A 10TR1200M
72 12   282417BROOKLYN L      152027   SS N20      10TC 400M
72 12   282417IDARADO         152094   SS N10   1A 75TC  40B 3  30
72 12   282405WILLOW SWAMP    152095   SS N20   1  10TL 200M
72 12   281130BLUE POINT      152097   SS N20              B 4 200
72 12   291600CEMENT FILL     15201042
72 12   291130BROOKLYN F      15201941 SSAA20 F 1A  5TR 250M
72 12   291115BROOKLYN H      15202341 SSAA20 F 1A  5TR 300M
72 12   291110BROOKLYN J      15202541 SSAA20 F 1A 10TC 300M
72 12   291100BROOKLYN M      15202841 SSAA20 F 1A  5TR 300M
72 12   291140WILLOW SWAMP    15209542 SSAA20 F 1A  5TC 250M
72 12   291150BLUE POINT      15209741 SSAA20 S 1A 25TC 200B 1  30
72 12   290300ROCKWALL        152101   SS N20              B 4 300
72 12   291035EAGLE           15210443  LAA20 S  A  5ML 600B
72 12   291050TELESCOPE       15210541
72 12   291045MULESHOE        15210642
73 01   042405E GUADALUPE     152060   HS N30   3  25TL2000B
73 01   041400WEST LIME CK    152150    L N10        TM 100
73 01   041300COAL CK EAST    152157    L N10       5T  100  1  20
73 01   041400ENGINEER MTN A  152159   SS N20   2  75TC 400
73 01   052405BLUE POINT      152097   SS N10   1   5TC  50B
73 01   051900BLUE POINT      152097   SS N20   1  10TL 100B 1  20
73 01   051000SWAMP           15215441
73 01   051000HENRY BROWN     15215541 SSAA20   1  25TC 250  2  40
73 01   052405ENGINEER MTN A  152159   SS N30   1 100TC 600B
73 01   050950ENGINEER MTN B  15216041 SSAA10   1   5TC  75A
73 01   050950ENGINEER MTN C  15216141 SSAA20   1  10TL 300B
73 01   061000MILL CK F       152113   SS N20   1  10TL 900B
73 01   091130WILLOW SWAMP    152095   SS N20      25TL 250B
73 01   091000BLUE PT         152097   SS N20      10TL 150B 2 100
73 01   102417EAGLE           152104   SS N 0       5TR 300B
73 01   102417TELESCOPE       152105   SS N20      10TC1100B
73 01   102405GOBBLERS KNOB   152151   SS N20   2  10TL 250B
73 01   112417BULLION KING    152107   SS N20       5TC 600B
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73 01  110800BATTLESHIP      152128   SS N20       5TR 400B
73 01  121400WATER GUAGE     152002    L N20      10TL1200B
73 01  121400PIT             152004    L N20        TM 800B
73 01  122405MILL CREEK C    152110   SS N20        TC 500B
73 01  122405MILL CK G       152114   SS N20      10TC 700B
73 01  131500OLD SO MINERAL R152003   WL N20      25TC 600B
73 01  131500HCPI            152007   WL N20        TC 400B
73 01  131500CAMP            152008   WL N20        TC1000B
73 01  131500BROOKLIN C      152017   WL N20        TC 300B
73 01  132417SLIPPERY JIM    152061   WL N20        BC 150
73 01  132417SLIPPERY JIM    152061   WL N20        BC 150
73 01  132417SLIPPERY JIM    152061   WL N20        BC 150
73 01  132417SLIPPERY JIM    152061   WL N20        BC 150
73 01  131400E RIVERSIDE LEFT152065   WL N20      25TL 200B 1  50
73 01  141400BROOKLYN L      152027   WL N20       5TL    B
73 01  141445TWIN CROSSING   152032   WL N20       5TR 350B
73 01  141400ENGINEER MTN A  152159   WL N20      10TC 350B
73 01  141400ENGINEER MTN C  152161   WL N20       5TR 250B
73 01  151400BROOKLIN B      152016   WL N20       5T  350B
73 01  151400BROOKLIN K      152026   WL N20       5TL 200B
73 01  151400MULESHOE        152106   WL N20       5TR 200A
73 01  251300W LIME CK       152150    L N10       5BC  80B
73 01  271300SPRINGS         152148    L N20      25TR 450B
73 02  062417RED MTN 3       152044    L N20      10TC 500B
73 02  062417E RIVERSIDE     152064    L N20      10TC1000B
73 02  062417GALENA LION GULC152088    L N10       5TC 300B
73 02  062417GOVERNOR GULCH  152090    L N10       5TC 200B
73 02  062417WILLOW SWAMP    152095    L N10      10TL 100B
73 02  062417BLUE POINT      152097    L N20      75TC 200B 1  50
73 02  062417EAGLE           152104    L N20      10TC 300B
73 02  062417EAGLE           152104    L N20      10TR1500C
73 02  072405LONGFELLOW      152039    LAS10       5TC 250B
73 02  072405SLIPPERY JIM    152061    L N10       5BC 100B
73 02  072405SILVER GULCH    152073    L N10       5ML 200B
73 02  072405KING            152091    L N20       5TC 200B
73 02  072405BLUE POINT      152097    L N20      75TC 200B 1  50
73 02  080800EAST LIME CK    152149    LA010       5MC  80B
73 02  082200GOBBLERS KNOB   152151   SS N20   1   5TL 350B
73 02  082200ENGINEER MTN B  152160    L N20      10TC 250B
73 02  082000ENGINEER MTN C  152161    L N10      50TC 350B
73 02  101930BLUE POINT      152097   SS N20   1  25TL 150B 1  15
73 02  121300CARA BELL       152048   SS N30      25TC 900B
73 02  121230E RIVERSIDE LEFT152065    L N10       5BL  75B
73 02  122405WILLOW SWAMP    152095   SS N20      10TC 200B
73 02  122405BLUE WILLOW     152096    L N10      10TC  75B
73 02  122405BLUE PT         152097    L N10
73 02  121720TELESCOPE       152105   SS N30   2B 65TC2000B 2  40
73 02  121400JENNIE PARKER SC152141    L N10
73 02  121400CHAMPION        152144    L N10
73 02  121400KING MINE       152146    L N10
73 02  122405EAST LIME CK    152149   SS N20      25TC 150B 1 300
73 02  122405WEST LIME CK    152150   SS N20   1  25TC 150B 1 400
73 02  121720WEST LIME CK    152150   SS N20   1   5M  100B 3  25
73 02  122405GOBBLERS KNOB   152151   SS N20   1  10TC 400B
73 02  121400SWAMP           152154   SS N20   1B 75T  350B
73 02  122300HENRY BROWN     152155   SS N30   1B100T  350B 4  45
73 02  121400ENGINEER MTN A  152159    L N1
73 02  121400ENGINEER MTN B  152160    L N1
73 02  131200BROOKLYN H      15202341  LAA20    A 10TC 500B
73 02  131200N MINERAL BRIDGE15203341
73 02  131400E RIVERSIDE     15206447
73 02  131255WILLOW SWAMP    15209542 SSAA30   2B 75TC 600B 1  80
73 02  131300BLUE PT         15209742 SSAA30   1A 75TC 200B 1  70
73 02  131200EAGLE           15210441 SSAA20   1B   TR1600B 1  20
73 02  131200EAGLE           15210444
73 02  131200MULESHOE        15210641  LAA20    A   TL 300B
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73 02   131200MULESHOE        15210641
73 02   150800JENNIE PARKER NC152140   SS N20   1A  5MC 200B
73 02   231430BROOKLYN D      152018    L N20       5TC 350B
73 02   251400BROOKLYN I      152024    L N20      10TC 500B
73 02   250800BROOKLYN J      152025    L N20       5TC 600B
73 02   250800NC MIN BDG      152033    L N20       5MC 400B
73 02   252417SLIPPERY JIM    152061    L N20       5BL 150B
73 02   252417E RIVERSIDE RIGH152063   DL N20       5TR 150B
73 02   252417E RIVERSIDE LEFT152065    L N20       5TR 250B 1   15
73 02   252417SILVER PT       152070    L N20      10TC 600B 1   10
73 02   261300BROOKLYN G      152022    L N20       5TC 450B
73 02   261400GOBBLERS KNOB   152151    L N20      10TC 200B
73 03   012417CARA BELL       152048    L N20       5TC 500B
73 03   051155BROOKLYN E      15201941 SSAA20   1   5TR 400B
73 03   051150BROOKLYN G      15202241 SSAA20   2  10TC 800C
73 03   051145BROOKLYN H      15202341 SSAA20   2   5TC 300B
73 03   051145BROOKLYN K      15202641
73 03   051245WILLOW SWAMP    15209541 SSAA20   2   5TL 200B
73 03   051250WILLOW SWAMP    15209542
73 03   050800BLUE POINT      152097   SS N20   2  10TL 200C 1   20
73 03   051130EAGLE           15210441 SSAA20   2   5TL 600B
73 03   051130EAGLE           15210441 SSAA20   2   5TL 300B
73 03   051135EAGLE           15210441
73 03   051115TELESCOPE       15210541 SSAA20   2  10TC 500B
73 03   051120TELESCOPE       15210541 SSAA20   2  10TL 500B
73 03   051125TELESCOPE       15210541 SSAA20   1   5TR 300B
73 03   051140TELESCOPE       15210541
73 03   051135MULESHOE        15210641 SSAA20        TL
73 03   051135MULESHOE        15210641
73 03   050930ENG MTN B       152160   SS N20   1    MR 200C
73 03   061415CEMENT FILL     15201042
73 03   061000GENNESSE NO     152046   SS N20   2  10BR 150C
73 03   061330E RIVERSIDE     15206446
73 03   091000N MINERAL BDG   152033   SS N20       5MC 450B
73 03   090800STUDY PLOT      152037   SS N10   1A  5MC  50B
73 03   090800MARMOT TOWN     152038   SS N10   1A  5TR  75B
73 03   092417CARA BELL       152048    L N20       5TC 400B
73 03   090800IDARADO         152094   SS N10   1A  5MC  30C
73 03   090800BLUE POINT      152097   SS N10   1A  5ML  75C
73 03   090800BLUE POINT      152097   SS N20   1A 10TC 200C 1   10
73 03   090800FENCE           152098   SS N10   1A  5TC  75C
73 03   090800SNOWFLAKE       152099   SS N10   1A  5TC  75C
73 03   090800SILVER LEDGE MIN152100   SS N10   1A  5BC  30C
73 03   090800ROCKWALL        152101   SS N10   1A  5BL  50C
73 03   090800SILVER LEDGE MIL152102   SS N10   1A  5BL  50C
73 03   091200MILL CK B       152109   SS N20   2  10MC 500C
73 03   100900RED MTN 3       152044   SS N20   1   5TC 500B
73 03   101330E RIVERSIDE LEFT152065    LN 20       5TR 150C
73 03   101000W RIVERSIDE     152074   SS N20   2  10TL1400B
73 03   112417HENRY BROWN     152155    L N10       5BL  75C 1    8
73 03   112417ENG MTN A       152159    L N20      10TL 225C
73 03   132405BROOKLYN F      152020   SS N20   2  10TC 750C
73 03   131500BROOKLYN J      1520254  SSAA30   3B 50TL 800C12 120
73 03   131500BROOKLYN K      15202641 SSAA30   3B 50TR 600C
73 03   131500BROOKLYN M      15202841 SSAA20   2  25TR 600C
73 03   130830ITALIAN         152051   SS N30   3  75TC1200C
73 03   131200E RIVERSIDE     15206441 SSAA20   1A  5TR 400A
73 03   131200E RIVERSIDE     15206449
73 03   130930E RIVERSIDE LEFT152065    L N20       5MR 100C
73 03   132405G RIDGE         152089   SS N20   1  25TC 450C
73 03   130900KING            152091   SS N20   1  25TR 250B
73 03   131100BLUE POINT      152097   SS N20   1  50TR 200C 2   80
73 03   131430EAGLE           15210441 SSAA20   2   5TR 450B
73 03   131410EAGLE           15210441 SSAA20   2  25TL1600C
73 03   131410MULESHOE        152106   SS N20
73 03   131500MULESHOE        15210641
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73 03  130900MILL CK A       152108   HS N30   2  75TC1000C
73 03  141800CEMETARY        152030   SS N30   3B 75TC 960C
73 03  142405WHITE FIR       152072   SS N30   2  50TC1600B
73 03  151400NC MINERAL BDG  152033   WL N20       5MC 300B
73 03  151130BLUE POINT      152097   SSAE30   2B100TC 200C 8 120
73 03  151400ENG MTN A       152159   SS N20   1  25TC 300C
73 03  151400ENG MTN C       152161   SS N20   1  25TR 300C
73 03  171935E RIVERSIDE     152064   SS N20   1A  1TC 250A
73 03  171935E RIVERSIDE     152064   HS N30 J 5B 30TC2600C12  60
73 03  202400BROOKLYN I      152024   SS N30      75T 1000C 8 100
73 03  212417GOBBLERS KNOB   152151   SS N20   1  25TR 250C
73 03  221200MARMOT TOWN     152038   SSAS10   1  10TR  75B
73 03  241500CEMENT FILL     152010   SS N20   3  25TL 900B
73 03  301515TWIN CROSSING   152032    L N20   A   5MC 400B
73 03  301300SLIPPERY JIM    15206141 SSAA20   2   5TC 300A
73 03  301330E RIVERSIDE     15206441 HSAA30   4B 10TC2900A
73 03  301330E RIVERSIDE     15206447
73 03  301130EAGLE           15210441  LAA20 F A   5TL 800B
73 03  301130EAGLE           15210441  LAA20 F A   5TL 500B
73 03  301130EAGLE           15210441  LAA20 F A   5TC 500B
73 03  301130EAGLE           15210441               MC
73 03  301130TELESCOPE       15210541  LAA20 F A   5TC 700B
73 03  301130TELESCOPE       15210541  LAA20 F A   5TL 300A
73 03  301130MULESHOE        15210641
73 04  022417SNOWDON L SHOULD152      HS N40   6 100TC1000C
73 04  051615BROOKLYN B      1520161   LAS20      25TC 700B
73 04  051600BROOKLYN F      1520201   LAS20      25TR 800B
73 04  051430ENG MT A        152159    L N20       5TC 300B
73 04  072417E RIVERSIDE RIGH152063    L N20      10MC 150C
73 04  072417E RIVERSIDE LEFT152065   SS N20      25TC 150C 4  30
73 04  080915SLIPPERY JIM    15206141 SSAA10 F 1   2TC 100A
73 04  080845E RIVERSIDE     15206441 HSAA20   2   5TC1800B
73 04  080915E RIVERSIDE     15206442               M
73 04  080845E RIVERSIDE     15206449               T
73 04  100900FULL MOON GULCH 152084   SS N20   1  10TC 500B
73 04  101200WILLOW SWAMP    152095    L N20       5TC 150B
73 04  101200BLUE POINT      152097    L N20      25   150C
73 04  101130BISMARK         152127    L N20      10TL 400A
73 04  101130BISMARK         152127   SS N20   1   5TC 400A
73 04  141200CHAMPION        152144   WL N30      25MC1600C 4  50
73 04  172417E GUADALUPE     152060   WS N3G   4  50TR2000C
73 04  182417MILL CK G       152114   SS N40   4 100TC1500C
73 04  182417SNOWSLIDE GULCH 152132   SS N30   2  75MR1300C
73 04  201445EAGLE           15210441 SSAA30   2  75TC1600C
73 04  201430TELESCOPE       15210545 SSAA20 M 1  50  1100B
73 04  211600BROOKLYN G      152022   WL N20      50TC 600B
73 04  211600NC MINERAL BRIDG152033   WL N20      50TC 600B
73 04  221400COAL CK W       152158   WL N20      50TC 300C 1  40
73 04  222417ENG MT A        152159   WL N20       5TR 200C
73 04  222417ENG MT B        152160   WL N20       5TR 200C
73 04  222417ENG MT B        152160   WL N20       5TC 200C
73 04  222417ENG MT B        152160   WL N20       5TL 200C
73 04  222417ENG MT C        152161   WL N20      10TC 300C
73 04  252417ENG MT C        152161   WS N3G   5  75TR 250C
73 04  261600SLIPPERY JIM    152061   WL N20       5BR 300C
73 04  261600E RIVERSIDE LEFT152065   WS N2G       5BC 200C 4  50
73 04  261600MOTHER CLINE    152069   WS N2G      10BC 100C12  75
73 04  271750BROOKLYN B      152016   WS N4G F 4B 50TC 700C 8 100
73 04  271615BROOKLYN C      152017   WS N3G F 2B 50TC 600C 3  40
73 04  271745BROOKLYN F      152020   WS N3G F 4B 75TC 650C
73 04  271605BROOKLYN F      152020   WS N3G F 4B 50TC 600C
73 04  271550BROOKLYN G      152022   WS N4G F 4B 75TC 750C20 150
73 04  271515BROOKLYN K      152026   WS N3G F 4B 75TC 700C
73 04  271800BROOKLYN L      152027   WS N3G F 4B 50TC 600C
73 04  271710TWIN CROSSING   152032   WL N2G F  B 50TC 300C
73 04  271600ST GERMAIN      152059   WS N3G   4  25TR 300C
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73 04  271100E RIVERSIDE     15206441 WSAA20       5ML1200C10  50
73 04  271100E RIVERSIDE     15206441 WSAA20       5ML1200C12  60
73 04  271430BLUE WILLOW     152096   WL N3G      75TC 150C 3  50
73 04  271530EAGLE           15210445 WSAA3G F 6B 25TR1400C12 250
73 04  281600LOWER CEMENT FIL152009   WL N20      10TC 300B
73 04  281500BROOKLYN E      15201941 WSAA3G F 4B 25TC 700C 3  50
73 04  281553BROOKLYN E      152019   WS N4G F 4B 75TC 750C10 200
73 04  281548BROOKLYN F      152020   WS N3G   4  25TC 500C
73 04  281600SLIPPERY JIM    152061   WL N2G      10BR 200C
73 04  281630E RIVERSIDE RT  152063   WS N2G      25MC 200C 6  75
73 04  281630E RIVERSIDE LEFT152065   WS N2G      25MC 200C 6  80
73 04  281630NC EMERGENCY PHO152066   WL N2G      25MC 200C 4  60
73 04  281530CLIFF           152067   WL N2G      25BC 150C 3  50
73 04  281530DUNSMORE        152068   WL N2G      25BC 150C 3  50
73 04  281500MOTHER CLINE    152069   WS N2G      25MC 200C 5 100
73 04  281730SILVER POINT    152070   WL N5G     100TC 900C14  50
73 04  281330ROCKWALL        152101   WS N1G       5BC  60C 3  40
73 04  281230JEANIE PARKER NC152140   WS N20      50MR 500C 8  80
73 04  291625BROOKLYN B      152016   WS N30   4  75TC 550C 2  50
73 04  291625BROOKLYN D      152018   WS N3G   4  75TC 650C 8 125
73 04  291625BROOKLYN G      152022   WL N20      25TR 750
73 04  291625BROOKLYN I      152024   WL N3G F  B 75TC 700C 5  75
73 04  291625BROOKLYN J      152025   WL N3G F  B 50TC 600C
73 04  291656BROOKLYN L      152027   WL N20 F  B 25TL 600
73 04  291615BROOKLYN L      152027   WL N3G F  B 50TR 700C
73 04  291650BROOKLYN N      152029   WL N20 F  B 10TC 400C
73 04  291602TWIN CROSSING   152032   WL N3G F  B 75TC 600C
73 04  291550NC MINERAL BRIDG152033   WL N2G      10MC 500C
73 04  291605NC MINERAL BRIDG152033   WS N2G F 3B 25MC 500C
73 04  291621NC MINERAL BRIDG152033   WS N2G S 2B  5ML 250C
73 04  291600MANIE           152056   WL N2G      50TR 250C
73 04  291600MOE             152057   WL N2G      50TL 250C
73 04  291600JACK            152058   WL N2G      50TC 250C
73 04  291400WHITE FIR       152072   WS N40   6  50TC1200B
73 04  291300WATER GUAGE NO  152076   WL N20      25TC 600B
73 04  291300LAKE            152077   WL N2G      50TC 400C
73 04  291300EARTH           152078   WL N2G      50TC 400C
73 04  291300FIRE            152079   WL N2G      50TC 400C
73 04  292417HENRY BROWN     152155   WL N20      10TR 250C 3  15
73 05  012417MILL CK D       152111   SS N20   1  10TR 500C
73 05  012417MILL CK G       152114   SS N20      10TR1000C
73 05  021700BROOKLYN D      152018   WL N2G      25TC 400B
73 05  021700BROOKLYN E      152019   WL N2G      25TC 300B
73 05  021600BROOKLYN G      152022   WS N20   4  25MC 600C
73 05  021000RED MTN 3       152044    L N20       5TL 500A
73 05  021000BLUE PT         152097    L N20      50TC 200C 1 175
73 05  031700LOWER CEMENT FIL152009   WL N20      10MR 300B
73 05  031800CEMENT FILL     152010    L N20       5TL 200A
73 05  031400BULLION KING    152107   WL N30      10MC1000C
73 05  031400MILL CK C       152110    L N20      10MR 500C
73 05  031400MILL CK F       152113    L N20       5MR 400C
73 05  030800BATTLESHIP      152128    L N20       5TR 400A
73 05  041700BROOKLYNS C     152017   WL N3G      50TL 500C
73 05  041700BROOKLYNS L     152027   WL N3G      75TC 900C
73 05  062405MILL CK B       152109    L N20      10MR 400B
73 05  062405MILL CK C       152110   SS N20   1  10MR 600C
73 05  071000EAGLE           152104   WL N20      10TC1200C
73 05  071200CHAMPION        152144   WL N2G      10TR 500B 3  30
73 05  082417WILLOW SWAMP    152005   WL N20      10TL 250B
73 05  082417RED MTN 2       152047   WL N20       5TL 400A
73 05  082417SWISS           152052   WL N20      25TC1600C
73 05  082417W RIVERSIDE     152074   WL N20       5ML 900B
73 05  082417DAISY HILL      152085   WL N20      25TC 350B
73 05  082417DAISY HILL      152085   WL N20      25TC 350B
73 05  082417DAISY HILL      152085   WL N20      25TC 350B
73 05  082417DAISY HILL      152085   WL N20      25TC 350B
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73 05  082417DAISY HILL      152085   WL N20      25TC 350B
73 05  082417KING            152091   WS N20      10TR 350C
73 05  082417EAGLE           152104   WS N20   4  10MR 600B
73 05  081400HARLEY SHORT    152143   WL N2G      10TC 150C 3  50
73 05  081300CHAMPION        152144   WL N20              B 3  30
73 05  081330CHAMPION        152144   WL N2G      10TC 400B 6  40 1       1
73 05  081500CHAMPION        152144   WL N20              B 3  30
73 05  091600BROOKLYNS N     152029   WL N2G      50TC 300C
73 05  0916001ST TWIN XING   152031   WL N2G      25TR 400C
73 05  091430SLIPPERY JIM    152061   WL N2G      10TR 900C
73 05  091430E RIVERSIDE     152064   WS N2G       5BR 300C 2  20
73 05  091400E RIVERSIDE     15206449
73 05  091330MOTHER CLINE    15206942 WLAA2G S  B  5BR 100C 1  20
73 05  092417W RIVERSIDE     152074   WS N3G      10TL2000C
73 05  091430BLUE POINT      152097   WL N20      25TC 200C 3  75
73 05  091630LEDGE MINE      152100   WL N20      10TL 150C 4  40
73 05  091530ROCKWALL        152101   WL N20       5TC 200C 2  30
73 05  091630ROCKWALL        152101   WL N2G       5TR 100C 3  30
73 05  091530LEDGE MILL      152102   WL N20       5TL 200C 3  60 1       2
73 05  091645EAGLE           15210441 WSAA20 F 4B   MR 400B
73 05  091645EAGLE           15210441 WSAA20 F 4B  5TC 400A
73 05  091640EAGLE           15210441 WSAA20 F 4B  5MC 300B
73 05  091650EAGLE           15210441 WSAA30 F 4B 10TC2000C
73 05  091635EAGLE           152104   WSAA30 F 4B 10TL2200C 8 100
73 05  091600EAGLE           15210442
73 05  091640TELESCOPE       15210541 WSAA20 F 1A  5TL 300A
73 05  091635TELESCOPE       15210541 WSAA30 F 4B 10TR2200C 3  50
73 05  091600MULESHOE        15210643
73 05  092417MILL CK C       152110   WL N20      10MC 400C
73 05  092417MILL CK G       152114   WL N20      25TC 900C
73 05  092417EARNEST         152115   WL N20      10MC 350C
73 05  092417CHAMPION        152144   WL N2G                3  25
73 05  092417CHAMPION        152144   WL N2G                4  35
73 05  092417CHAMPION        152144   WL N2G                4  35
73 05  101445CEMENT FILL     15201041 HSAA3G F 6B 50TR2200C
73 05  101730BENNY LONG      152014   WL N2G       5TL 150C 4  60
73 05  101700B LYN F         152020   WL N3G      50TC 700C 6 100
73 05  101700B LYN G         152022   WL N2G      25TR 700C
73 05  102417LONGFELLOW      152039   WS N3G    B 50TL 250C
73 05  101700MULESHOE        152106   WS N20   2  10TR2000C
73 05  102417MILL CK B       152109   WL N20      10TC 500C
73 05  102417MILL CK C       152110   WL N3G      25MC 700C
73 05  102417IMOGENE         152119   WL N20       5TC 400B
73 05  102417SAN JUAN        152122   WL N20      10TC 300B
73 05  101245JENNIE PARKER NC15214045 WLAA20 F  A  5TC 200A
73 05  101245JENNIE PARKER SC15214141 WLAA20 F  B 25TC 900C
73 05  101300PEACOCK         15214243
73 05  101300CHAMPION        15214441 WSAA3G F 4B 10TR1100B 6  50
73 05  111715B LYN H         152023   WL N3G      50TC 800C 7  75
73 05  111600B LYN N         152029   WL N2G      25TR 600C
73 05  111700NO MINERAL BRDGE152033   WL N3G      50TR1000C
73 05  112417ITALIAN         152051   WS N3G   6  25TL1900C
73 05  112417E GUADALUPE     152060   WS N2G   6   5TC 800B
73 05  112417SILVER GULCH    152073   WS N2G       5TC 900B
73 05  112417W GUADALUPE     152075   WS N2G   6  10TC1000B
73 05  112417IRONTON         152082   WL N20       5TC 350B
73 05  111220EAGLE           152104   WS N3G F 4  10TC2000C
73 05  111050EAGLE           152104   WL N3G      25TL2100C22 150
73 05  111200MULESHOE        152106   WL N3G      10TC2100C
73 05  111050MULESHOE        152106   WS N3G   6  25MC1600C 3  60
73 05  111500IMOGENE         152119   WL N20      10TC1800C
73 05  111500OPHIR POND E    152125   WS N4G   8  75TC2000C
73 05  111430BATTLESHIP      152128   WS N2G   4  10TC2500C
73 05  110952PEACOCK         152142   WL N5G F   100TC1700C 6 150
73 05  121800BKLYN K         152026   WS N2G   4  25MC 500C
73 05  122417MILL CK C       152110   WS N2G   4  25MC 600C
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73 05 131300BLUE WILLOW     152096   WL N1G     25TR  75C 2  25
73 05 151610NC MINERAL BRIDG152033   WL N2G F  B 5TC 450B
73 05 152417TELESCOPE       152105   WL N2G      5TC 600B
73 05 152417MILL CK G       152114   WS N3G   5 50TR 800C
73 05 171600BLUE POINT      152097   WS N1G   4 25ML  60C 4  50
73 05 172417MILL CK F       152113   WS N3G   6 50MR 500C
73 05 182417NAT L BELL SO   152042   WL N2G     10TC 400B
73 05 182417RED MTN 2       152047   WS N20      5TL 500B
73 05 182417RED MTN 2       152047   WS N3G   5 10TC1200C
73 05 182417COLONY          152053   WL N4G     75TC1800C
73 05 182417GALENA LION GULC152088   WL N3G     25TC1200B
73 05 181100MILL CK F       152113   WS N2G   6 50TC1000C
73 05 202417MILL CK G       152114   WL N3G     50TL 900C
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AVALANCHE OCCURRENCES, STATION 153, 1972-73

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72 11 212405RIO GRANDE      153002   SS N20   2  5TR 400M
72 11 212405WESTERN         153003   SS N20   2  5TC 600M
72 11 212405IDAHO GULCH     153004   SS N20   2  5TC 450T
72 11 252417IDAHO GULCH     153004   SS N20   2  5TL 250T
73 03 061000WESTERN         153003   SS N20   1 10MC 400B
73 03 061000IDAHO GULCH     153004   SS N20   1 10MC1000B
73 03 151600WESTERN         153003   SS N20   2  5ML 400B
73 03 162405RIO GRANDE      153002   SS N20   2  5TR 700B
73 03 171055IDAHO GULCH     153004    L N20 S  A 5TC 400A
73 05 072417SHRINE          153      WL N2G     50TL 400B
73 05 101630ARCADE          153008   WL N2G     10ML 400C
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AVALANCHE OCCURRENCES, STATION 157, 1972-73

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72 11 272405FAIRVIEW        157016   HS N30     75TL1900B
72 11 272405BILLBOARD       157042   HS N20      5TR 500M
72 11 272405BILLBOARD       157042   HS N20      5TL 700M
73 03 132405BILLBOARD       157042   HS N30   2 50TC1100C
73 04 281600BAD NUMBER      157013   WL N2G     50TC 300C
73 04 281600EIRE            157014   WL N3G     75TC 450C
73 04 281600MICHIGAN        157015   WL N2G     50TC 300C
73 04 281600DUMP SO         157025   WL N2G     50TC 200B
73 04 281600DUMP NO         157026   WL N2G     75TC 200C
73 04 282417ARRASTRA GULCH  157      WS N4G   6   T   700C
73 05 081430MICHIGAN        157015   WL N20     75TR 350C
73 05 081430FAIRVIEW        157016   WL N20      5MR 200B
73 05 081430BEATLES         157017   WL N20     50MC 300C
73 05 081430STONES          157018   WL N3G     75TC 450C
73 05 081430DRY GULCH NO    157027   WL N2G     50TC 400C
73 05 082417COLORADO        157032   WL N20      5MR 200B
73 05 092417CREME           157020   WL N2G     50TC 300C
73 05 102417MINNEAPOLIS     157011   WL N20     25TC 400C
73 05 102417ST PAUL         157012   WL N3G     75TC 650C
73 05 102417FAIRVIEW        157016   WS N2G   1 25TL 800C
73 05 102417GEORGIA GULCH   157021   WS N3G   6 10TL1200B
73 05 102417DUMP SO         157025   WL N2G     25TC 450C 2  30
73 05 102417W JUMP A        157028   WL N20     10TC 400B
73 05 102417W JUMP B        157029   WL N20     10TC 250B
73 05 102417MOGUL           157030   WL N20      5TC 300B
73 05 102417BILLBOARD       157042   WS N2G     10MC 600C
73 05 102417HEMITITE        157      WS N3G   8 25TC3150C
73 05 102417CABIN           157      WL N2G
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73 05   111400FAIRVIEW        157016   WS N3G   7  25TR1800C
73 05   192417COLORADO        157032   WL N3G      10ML 900C
73 05   111400COLORADO        157032   WS N2G   4  10BR 400C
73 05   192417BILLBOARD       157042   WS N3G      10TC2400C
73 05   132405ARRASTRA GULCH  157      WS N3
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AVALANCHE OCCURRENCES, STATION 152, 1973-74

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73 11   232415US BASIN        152035   SS N20       5 T    B
73 11   232405BLUE POINT      152097    L N10       5 M  75C
73 11   292405IMOGENE         152119   SS N2G   2   5 M    B
73 12   032405CEMENT FILL     152010   HS N20   2   5TC 500B
73 12   140400BLUE POINT      152097    L N20   1  50TR 200C 2  20
73 12   181530ERS SOUTH       152062   SS N20      25TC 150C 3  30
73 12   180830ERS LEFT        152065   SS N2G   2  25TC 150C 4  20
73 12   181530MOTHER CLINE    152069   SS N20   1  10TR 200C 6  25 2       2
73 12   182405BLUE POINT      152097    L N20      10T  150C 3  50
73 12   281000BROOKLYNS E     152019   SS N20      10TR 700C
73 12   281300BROOKLYNS H     152023   SS N20      25TC1000C
73 12   281000BROOKLYNS I     152024   SS N20      25TC 900C
73 12   281445WILLOW SWAMP    152095   SS N20   2  10ML 200C 2  75
73 12   281430BLUE WILLOW     152096   SS N20   2  25TC 150C
73 12   281000BLUE POINT      152097      N20      10T  150C
73 12   292230BROOKLYNS B     152016   SS N20      50T  500C 2  50
73 12   292030BROOKLYNS E     152019   SS N20      25T  700C
73 12   292030BROOKLYNS F     152020   SS N20      25T  900C
73 12   292405SILVER GULCH    152073   SS N3       10T 2200C
73 12   291400BLUE POINT      152097   SS N2       10TC 200C 2  70
73 12   302415RED MTN 2       152047   SS N20   4  25TR 800C
73 12   301330ERS             15206441 SSAA30JP 6  25TC3000C 6 200
73 12   300200EAGLE           152104   SS N20   4  10ML1000C 3  50
73 12   301245EAGLE           152104   SS N30 J    10TC2200C 1 100
73 12   300230TELESCOPE       152105   SS N30 J    25MC1000C 6 350
73 12   301500BULLION KING    152107   SS N30      25T 2000C
73 12   302405SAN JUAN        152122   SS N20      10TC 250B
73 12   302405BATTLESHIP      152128   SS N20   4  10TC2500C
73 12   302405DESTROYER       152129   SS N30   4  75TC2200C
73 12   302405PICKLE BARREL   152131   SS N20   2  50TC 450C
73 12   302405SNOWSLIDE GULCH 152132   SS N20      25TC2000C
73 12   311110BROOKLYNS E     15201941 SSAA     2  50TR 900C 2 150
73 12   311105BROOKLYNS F     15202041
73 12   311107BROOKLYNS J     15202541
73 12   311110BROOKLYNS L     15202741 SSAA     2  50TR 900C
73 12   311120CEMETERY        15203042
73 12   311040PORCUPINE       152103411
73 12   311025EAGLE           15210441 SSAA20 P 2  25TC1800C
73 12   311020EAGLE           15210441 SSAA30JP 4  25TR1800C 3 150
73 12   311020TELESCOPE       15210541 SSAA30 M 4  50TC1800C 2 100
73 12   311030MULESHOE        15210641 SSAA30 M 2  25TC2100C
73 12   311035BULLION KING    15210741 SSAA30 M 6  50TC2100C
74 01   032405FULL MOON GULCH 152034   SS N40   4  75TC1900C
74 01   031135N CARBON        152   2 3SSRE30 F 4B 50TL 200C
74 01   051404CEMENT FILL     152010   SS N30   4  25TR2500C
74 01   051300BROOKLYNS G     152022   SS N40      75TC 800C15 250   1     1 1
74 01   051400BROOKLYNS I     152024   SS N30      50TC1000C
74 01   052415CEMETARY        152030   SS N20      10TC 300B
74 01   0515002ND TWIN CROSSNG152032   SS N20   2  50MC 800C
74 01   051500ROCKWALL        152101   SS N30      50TC 400C 8 100
74 01   051500PORCUPINE       152103   SS N2       25T 1300C 3  50
74 01   051500EAGLE           152104   SS N2       25T 1500C 3  50
74 01   051500JULIO           152116   SS N20   2  50MC 300C
74 01   051500SAM             152117   SS N20   2  25MC 500C
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74 01  051500OUTAH           152118   SS N30   4  50MC 300C
74 01  051330IMOGENE         152119   SS N30      75TC1900C
74 01  052415BISMARK         152127   SS N30   4  25TR1800C
74 01  052415BATTLESHIP      152128   SS N30   4  10TR2600C
74 01  060930BROOKLYN C      15201741 SSAA20 P  B 50TC 900C 2  75
74 01  060930BROOKLYN G      15202241 SSAA20 P  A 25TC 300B
74 01  060930BROOKLYN K      15202641 SSAA20 P  A 75TC 700C
74 01  060930BROOKLYN L      15202741 SSAA20 P  A 25TC 350B
74 01  061500SLIPPERY JIM    152061   SS N2G   2  10MR 300C
74 01  061100SLIPPERY JIM    15206142
74 01  061055E RIVERSIDE     15206441 SSAA2G P  B  5MC1000C 5  70
74 01  061210E RIVERSIDE     15206443 SSAA2G P  B  5MR1800C15  80
74 01  061210E RIVERSIDE     15206448
74 01  061000EAGLE           15210444
74 01  061000TELESCOPE       15210541
74 01  060930BROOKLYNS-OTHERS152   45
74 01  071330BROOKLYNS B     15201641 SSAA2G      10TL 400B
74 01  071330BROOKLYNS C     15201741 SSAA2G      25TC 650C 1  25
74 01  071330BROOKLYNS C     15201741 SSAA2G      10TR 200
74 01  071330BROOKLYNS G     15202242
74 01  071400SILVER LDGE MINE15210041 SSAA10   1A  5TL  50A
74 01  071400SILVER LDGE MINE15210041 SSAA2G M 4B 10TL 150B
74 01  071400SILVER LDGE MINE15210041 SSAA3G S 4B 10TR 200C 4  75
74 01  071100JENNIE PARKER   15214143
74 01  071100PEACOCK         15214241
74 01  071100CHAMPION        15214441
74 01  082415NATIONAL BELL N 152043   SS N30   6  10MR 500C
74 01  081045WILLOW SWAMP SN 152095   SS N3G   4C 75TL 200C11 200
74 01  092415SILVER GULCH    152073   SS N30   4  25TL2000C
74 01  092405W GUADALUPE     152075   SS N2G   4B 25MC 800C
74 01  092415FULL MOON GULCH 152084   SS N3G   6  25TL1500B
74 01  091530BLUE POINT      152097   SS N20   1  10ML 150C
74 01  092405ERNEST          152115   SS N20   2  50MC 450C
74 01  092405JULIO           152116   SS N20   4  25MR 300C
74 01  092000E LIME CREEK    152149   SS N2G   4   5TL 250C 3  50
74 01  092000W LIME CREEK    152150   SS N3G   4  75TC 250C 8 700          1
74 01  100930E RIVERSIDE     15206444
74 01  100900MOTHER CLINF    15206943 SSAA20 M 1   5TL 400C 1  20
74 01  101400W RIVERSIDE     15207545
74 01  101445WILLOW SWAMP    15209541 SSAA2G   3  10TR 200C
74 01  101445WILLOW SWAMP    15209541 SSAA3G   5  25TL 300C15 250
74 01  101445WILLOW SWAMP    15209542 SSAA3G   5  50TC 400C
74 01  101345BATTLESHIP      152128   SS N4G   6  50TR2500C
74 01  112405NATIONAL BELL N 152043   SS N30   4  25TC 700C
74 01  112405RED MTN 3       152044   SS N20   4  10ML 700B
74 01  112405TAVERN          152123   SS N30   4  75TC 350C
74 01  111005CHAMPION        15214441 SSAA2G   4   5TC 300B
74 01  111005CHAMPION        15214441 SSAA4GJM 6B 80TL1900C14 250
74 01  111200SWAMP           15215441
74 01  111200HENRY BROWN     15215543 SSAA20 F 1A  5TL 200C
74 01  111030ENGINEER MTN C  15216141 SSAA20 F 1A  5TL 150B
74 01  111030ENGINEER MTN C  15216141 SSAA20 F 1A  5TR 200B
74 01  152415BROOKLYNS G     152022   WL N20       5TL 250B
74 01  152415BROOKLYNS K     152026   WL N20        TC 250B
74 01  152415EAGLE           152104   WL N20       5TC 400B
74 01  182415BROOKLYNS G     152022   SS N20   1   5TC 300B
74 01  1824151ST TWIN XING   152031    L N20       5TL 450B
74 01  182415N MINERAL BRIDGE152033    L N20      10TC 450B
74 01  182415EAGLE           152104    L N20       5MR 700B
74 01  182415TELESCOPE       152105    L N20       5TL 750B
74 01  210200BLUE POINT      152097   SS N30      75TC 200C 4 100
74 01  210845ROCKWALL        152101   SS N20                2 100
74 01  210845ROCKWALL        152101   SS N20                1 150
74 02  010900BLUE WILLOW     152096    L N20           100C
74 02  010900BLUE POINT      152097    L N20           150C
74 02  021000NO MINERAL RDGE 152033    L N20       5MC 300H
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74 02  112417WILLOW SWAMP     152095    L N20       10TL 180B
74 02  190920NO CARBON        152      LA520         TC 200C
74 02  202415SWISS            152052   SS N30    4  75MC1500C
74 02  201300E RIVERSIDE      15206444 SSAA20    4  10MC2200C14  70
74 02  202405E RIVERSIDE      152064      N                   4  50
74 02  201300E RIVERSIDE      15206442
74 02  202405MOTHER CLINE     152069   SS N20    1  75TC 250C10 300
74 02  200230SILVER POINT     152070    L N20       50T  900C 6  20
74 02  201100WILLOW SWAMP     15209541  SAA20        5TL 150B
74 02  201100WILLOW SWAMP     152095    L N20        5TC 200C
74 02  201000BLUE WILLOW      152096   SS N20    1  25TC 200C 2  20
74 02  201100BLUE POINT       15209742 SSAA20    1  25TL 300C 4  25
74 02  201030EAGLE            15210442
74 02  201030TELESCOPE        15210543
74 02  211500LONGFELLOW       152039   SS N20    1  25TC 200C
74 02  212405MILL CK A        152108   SS N20    1   5MC 200B
74 02  212405MILL CK C        152110   SS N20    1  10MC 300B
74 02  212405MILL CK D        152111   SS N20    1  25MC 600C
74 02. 212405IMOGENE          152119   SS N20    1   5TR 200B
74 02  221245E RIVERSIDF      15206449
74 02  221300W RIVERSIDE      15207448
74 02  231500BULLION KING     152107   SS M20    1  10TL2000C
74 02  251030BROOKLYNS K      152026    L N20       10TC 600C
74 02  262417TELESCOPE        152105    L N20        5TR 350B
74 02  272405BROOKLYNS C      152017    L N20       10TC 400B
74 02  271100NO MINERAL RDGE  152033    L N20        5MC 350B
74 03  012417DUNSMORE         152068   WL N20       25TC 250C 1  30
74 03  022405SLIPPERY JIM     152061   HS N30   4B  25TL1900B
74 03  020800E RIVERSIDE      152064   HS N30   7B  25TR2600C12  70
74 03  031300SNOWSLIDE GL     152132   SS N20        5TL1000B
74 03  062405BROOKLYNS B      152016    L N20             350
74 03  062405BROOKLYNS H      152023    L N20             400
74 03  062405BROOKLYNS I      152024    L N20             400
74 03  062405BROOKLYNS N      152029    L N20          M  300
74 03  062405EAGLE            152104   SS N20    1  10ML 500B
74 03  072417BROOKLYNS I      152024   SS N30    2    MC 700C
74 03  072417BROOKLYNS M      152028   SS N20    1  25MC 450C
74 03  071330BLUE POINT       152097   SS N30    1  75TC 250C 5 100
74 03  102417BROOKLYNS D      152018   SS N20    2  50TC 450C
74 03  102417BROOKLYNS E      152019   SS N20    2  50TC 500C
74 03  102417BROOKLYNS F      152020   SS N20    1  50TC 900C
74 03  102417BROOKLYNS G      152022   SS N20    2  50TC 700C
74 03  102417BROOKLYNS K      152026   SS N20    1  50TC 600C
74 03  102417WILLOW SWAMP     152095   SS N2G    2  10ML 150C 4  80
74 03  102405EAGLE            152104   SS N20    2   5BL 400C
74 03  102405MULESHOE         152106   SS N20
74 03  102417ERNEST           152115   SS N3G    2  50TC 600C
74 03  112417BROOKLYNS G      152022    L N10
74 03  112417BROOKLYNS H      152023   SS N20       50
74 03  112417BROOKLYNS I      152024    L N20       50   900
74 03  110845BROOKLYNS J      15202541  LAA20       75TC 900
74 03  112417BROOKLYNS K      152026    L N20       25   300
74 03  110845BROOKLYNS L      15202741 SSAA20 M 2   75   900
74 03  110845BROOKLYNS M      15202941 SSAA20 M 1     TC 300B
74 03  110845BROOKLYNS N      15202941 SSAA2G 7 2   75   600C
74 03  112405NATIONAL BELL NO152043    HS N20    5  25MR 250B
74 03  111030E RIVERSIDE      15206441 SSAA2L    2    ML1100
74 03  111120E RIVERSIDE      15206441 SSAA30   2U    M 2700C13 100
74 03  111120E RIVERSIDE      15206441 SSAA30   20    M 2700C13 100
74 03  111120E RIVERSIDE      15206447
74 03  111120E RIVERSIDE      15206443
74 03  111050W RIVERSIDE      15207442
74 03  110915WILLOW SWAMP     15209542 HSAA20 M 2  75TC 350C
74 03  110925BLUE POINT       15209741 SSAA30 M 2A 75TC 200C 7  30
74 03  110815PORCUPINE        15210344  LAA10
74 03  110815EAGLE            15210441  LAA10          T   80A
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74 03  110835TELESCOPE       15210542 SSAA20              1100
74 03  110835MULESHOE        15210641 SSAA20   1           500B
74 03  122417BROOKLYN C      152017     L N20              450
74 03  122417BROOKLYN D      152018     L N20       50     500
74 03  121015JENNIE PARKER   15214045
74 03  121015PEACOCK         15214241
74 03  121030CHAMPION        15214443  LAA30        25  1200C 3   30
74 03  121500ENGINEER MTN A  152159    WL N20       50TC 500B
74 03  121200ENGINEER MTN B  152160    WS N3G   1   75TL 700C
74 03  151600BROOKLYNS C     152017    WL N2G       25TC 300B
74 03  151600BROOKLYNS C     152017    WL N2G       25TC 300B
74 03  151600BROOKLYNS D     152018    WL N3G       75TC 650C
74 03  151600BROOKLYNS G     152022    WL N2G       25TC 500B
74 03  151600BROOKLYNS H     152023    WL N3G       75TR 900C
74 03  151600BROOKLYNS K     152026    WL N2G       50TC 400B
74 03  151600BROOKLYNS L     152027    WL N2G       75TC 400B
74 03  151600N MINERAL BRIDGE152033    WL N2G       25MC 300B
74 03  152417SLIPPERY JIM    152061    WL N20        5HC 300
74 03  152417E RIVERSIDE     152064    WL N2G        5BL 500C
74 03  152417DAISY HILL      152085    WL N20        5TA 300B
74 03  152417DAISY HILL      152085    WL N20        5TC 300B
74 03  151200CHAMPION        152144    WL N3G       10MC 650B 8   40
74 03  161700BROOKLYNS F     152020    WL N2G       10TL 600B
74 03  161530BROOKLYNS G     152022    WL N2G       10TC 500B
74 03  161500BROOKLYNS H     152023    WL N2G       25TC 350B
74 03  161530BROOKLYNS I     152024    WL N3G       75TC 900D 5   55
74 03  161300BROOKLYNS L     152027    WL N20       10TR 400B
74 03  161700CEMETARY        152030    WS N20   1    5ML 300B
74 03  1616002ND TWIN CROSSNG152032    WS N3G       25ML 600C
74 03  161500N MINERAL BDGE  152033    WS N3G   3   25TL 400B
74 03  161200ST GERMAIN      152059    WL N20       25TL 150B
74 03  161100WHITE FIR       152072    WL N2G       10TL 600B
74 03  161100SILVER GULCH    152073    WL N20        5ML 600B
74 03  161100W GUADALUPE     152075    WL N20        5BL 300C
74 03  161100WATER GUAGE N   152076    WL N20       50TC 300B
74 03  161210BLUE WILLOW     152096    WL N10       75TC  75C 3   60
74 03  161300BLUE WILLOW     152096    WL N2G       25TR 100C 4   25
74 03  161210BLUE POINT      152097    WL N20       10TR 175C
74 03  161030ROCKWALL        152101    WL N1G        5BR  75C
74 03  161700EAGLE           152104    WL N20        5TR1500B
74 03  161200TAVERN          152123    WL M20       25TL 300C
74 03  161400JENNIE PARKER N 152140    WL N20        5TC 250B
74 03  161320CHAMPION        152144    WL N2G       25TR 900B 5   50 1
74 03  161215CHAMPION        152144    WL N2G       25TC 900B 4   25
74 03  172417WATER GUAGE N   152076    WL N3G       75TC 400C
74 03  172417EARTH           152078    WL N2G       75MC 250C
74 03  171500BLUE POINT      152097    WL N2G       25TR 150C 2    6
74 03  181450MUTHER CLINE    152069    WL N20        5TR 250C 3   20
74 03  191630MOTHER CLINE    152069    WL N20       10MR 200C 3   60
74 03  191600JACKPOT         152071    WL N30       50TC 350C 2   70
74 03  301500MILL CK A       152108     L N20        5BC 175C
74 03  301500MILL CK C       152110     L N20       10MC 300B
74 04  021000BROOKLYNS K     152026    SS N20   1   25TC 500M
74 04  021000BLUE POINT      152097    SS N20   1   50TC 200B
74 04  0324171ST TWIN CROSSNG152031    SS N20       10TR 500M
74 04  032145EAGLE           152104    SS N30       25TR1200B
74 04  042405BROOKLYN GULCH  152054    SS N20   1    5ML 300M
74 04  042485 GUADALUPE      152060    SS N20   1    5ML 400M
74 04  042405E RIVERSIDE R   152063    SS N20   1   25TL 350B
74 04  042405E RIVERSIDE L   152065     L M20          TC 250B
74 04  042405MUTHER CLINE    152069    SS N20   1   10ML 250M
74 04  040830MUTHER CLINE    152069     L N20
74 04  041000BLUE POINT      152097    SS N20   1   50TC 200B
74 04  0516001ST TWIN CROSSNG152031    WL N2G        5ML 300M
74 04  052417N MINERAL BDGE  152033    WL N2G        5M  200M
74 04  051600BROOKLYNS       152       WL N2G        5T  350M
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74 04  161600BROOKLYNS F      152020   WL N20        5TC 300M
74 04  161600BROOKLYNS G      152022   WL N20       10TC 400M
74 04  161600BROOKLYNS K      152026   WL N20        5TL 200M
74 04  161600N MINERAL RDGE   152033   WL N2G        5MC 300M
74 04  161600TELESCOPE        152105   WL N20        5MC 350M
74 04  161600MULESHOE         152106   WL N20        5TC 250M
74 04  171600EAGLE            152104   WL N20        5TC 900M
74 04  171600MULESHOE         152106   WL N20        5TC 400M
74 04  201300WILLOW SWAMP     152095   SS N20       25TL 200M
74 04  201300BLUE POINT       152097   SS N20       75TC 200B     75
74 04  202405EAGLE            152104      N20               B
74 04  211145EAGLE            152104   WL N30       50T 1900B 6  30


                AVALANCHE OCCURRENCES, STATION 153, 1973-74
74 03  161200DENVER           153001   WL N20       10TL1200
74 04  062405SWANSEA GULCH    153      SS N30    5  25TR2000M


                AVALANCHE OCCURRENCES, STATION 157, 1973-74
74 01  051600ERIE             157014   SS N30      100TC 450C 3 150
74 01  051600MICHIGAN         157015   SS N20    2  25MC 350B
74 01  051600FAIRVIEW         157016   SS N30    4  25TL1900C
74 01  051600BEATLES          157017   SS N20    4  50TC 400C
74 01  051600STONES           157018   SS N3G    4  75TC 550C
74 01  051600WHO              157019   SS N20    2  50TC 400C
74 01  051600CREME            157020   SS N30    4  75TC 300C
74 01  051600GEORGIA GULCH    157021   SS N40    6  50TC2400C 1 200
74 01  051600DRY GULCH N      157027   SS N30    4  75TC 900C
74 01  051600W JUMP A         157028   SS N30    4  75TC 900C 3  75
74 01  051600W JUMP B         157029   SS N40    5 100TC 900C10 200
74 01  051600MOGUL            157030   SS N30       50TC 900C
74 01  091400IRENE            15700542 SSAA3G    4  50TR1900C
74 01  091430FAIRVIEW         15701641
74 01  091550DRY GULCH S      15703942
74 01  091445SCOF RED POINT   157         N3G    4  75MC 200C                    1       1
74 01  101430FAIRVIEW         157016   SS N4GJ   6  75TC1700C12 200
74 01  212415IRENE            157005   SS N20    4   5MR1000B
74 01  212415CREME            157020   SS N20    3  25TR 250B
74 03  062417IRENE            157005   WL N20        5ML 500B
74 03  161200FIRE             157014   WL N3G       75TC 600C
74 03  161330MICHIGAN         157015   WL N3G       75MR 400C
74 03  161330STONES           157018   WS N3G       75TR 600C
74 03  161330WHO              157019   WL N2G       25TC 500C
74 03  162405GEORGIA GULCH     57021   WS N20    4   5MC 250B
74 03  161330DRY GULCH N      157027   WL N3G       25TL 400C
74 04  272417FAIRVIEW         157016   WL N30       25TL1900B


                AVALANCHE OCCURRENCES, STATION 152, 1974-75

74 10  291100WILLOW SWAMP     152095    L N2         5TL 250B
74 10  291100BLUE WILLOW      152096    L N2         5TC 150C                            1
74 10  291100BLUE POINT       152097    L N1         5TL  50C                            1
74 10  291100BLUE POINT       152097    L N2         5TL 150C                            1
74 10  291100BLUE POINT       152097    L N2         5TR 150C                            1
74 10  291100BLUE POINT       152097    L N2         5TC 150C                            1
74 11   12405US BASIN         152035   HS N3G    4  50T  500C
74 11   204001STTWIN CROSSING152031     L N2         5TC 200B
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74 11   204002NDTWIN CROSSING152032    L N2        5TC 200B
74 11   20400N MINERAL BRIDGE152033    L N2        5TC 200B
74 11   20400BLUE POINT      152097    L N2        5TR 200C 1    7
74 11   20400MILL CREEK B    152109   SS N2G    2 25TC 700C
74 11   20400MILL CREEK D    152111   SS N2G    2 25TC 700C
74 11   21200W LIME CREEK    152150   LS N1G    1 10MC 100C
74 11   21200W LIME CREEK    152150   SS N2G    1 10TR 100B
74 11   21200GOBBLERS KNOB   152151   SS N2     1  5TR 150B
74 11   21200DEER CREEK S    152153    L                30
74 11   21200SWAMP           152154   SS N2     1 25TC 100
74 11   21200HENRY BROWN     152155   SS N2     1      100
74 11   20400BROOKLYNS       152       L N1        5TC 100A
74 11   72417NATL BELL N     152043   SS N2     1  5MC 350B
74 11   81430BLUE POINT      152097    LA02   F 4 10TL 200C                    1
74 11  111230MILL CREEK A    152108   SS N2     2 10TC 600B
74 11  110800MILL CREEK B    152109   SS N2     2 10TC 400B
74 11  112405MILL CREEK C    152110   SS N2     2 10TR 600B
74 11  112417IMOGENE         152119   SS N2     2  5TR 200A
74 11  112405BATTLESHIP      152128   SSIN2     2  5TR 450B
74 11  131645CEMENT FILL     152010   HS N2     4  5TL 450B
74 11  141100BROOKLYNS B     152023    L N2        5MR 400B
74 11  152417OPHIR ROAD F    152125   SS N2G    1   ML 300C
74 11  191500BROOKLYN G      152022   SS N2     1  5T  100B
74 11  192405GENNESSE S      152045   SS N2     1  5R  100C
74 11  220955LONGFELLOW      152039   WL N2G      50TC 150C
74 11  231400BROOKLYN E      152019    L N2        5TR 400B
74 11  231400BROOKLYN F      152020    L N2        5TC 600B
74 11  230200BROOKLYN H      152023                    300B
74 11  230200BROOKLYN I      152024                    400B
74 11  2314002ND TWIN CROSSIN152032    L N1
74 11  2314002ND TWIN CROSSIN152032    L N1
74 11  2314002ND TWIN CROSSIN152032   SS N2     1  5MC 150B
74 11  230700NATIONAL BELL N 152043   SS N3     3 25MC 300C
74 11  230700RED MT 3        152044   SS N2     2  5MC 300B
74 11  230200GENNESSE N      152046   SS N2     2 25TC 200B
74 11  230700RED MT 2        152047   SS N2       25TL 400B
74 11  230200E GUADALUPE     152060   SS N2     2  5MR 200B
74 11  230200E RIVERSIDE     152064                 ML
74 11  230200W RIVERSIDE     152074                 TL
74 11  230200IRONTON         152082   SS N2        5TC 200B
74 11  230200FULL MOON GULCH 152084    L N2        5TC 600B
74 11  230200FULL MOON GULCH 152084    L N2        5TL 600B
74 11  230200GOVERNOR≠S GULCH152090   SS N2G       5TR 200A
74 11  230200KING            152091   SS N2     2 10TC 200C
74 11  230200WILLOW SWAMP    152095                 TL    B
74 11  230200BLUE POINT      152097   SS N2       25TC 250C 1 100
74 11  230500SNOWFLAKE       152098                                            1
74 11  230845ROCKWALL        152101   SS N1     1  5M   40C                    1
74 11  231200PORCUPINE       152103   SS N2     1  5TC 250A
74 11  230200EAGLE           152104   SS N2        5TC 200B
74 11  231500EAGLE           152104    L N2        5TR1000B
74 11  231200MILL CREEK D    152111                       B
74 11  231200MILL CREEK F    152113                       B
74 11  230500IMOGENE         152119   SS N2        5TR 250
74 11  231230KING RED MULE   152      SS N3     4   TC 300B
74 11  281500US BASIN        152035   HS N3     2 25TF 300C
74 11  291000BROOKLYN E      152019    L N1        5TC  50A
74 11  291000BROOKLYN F      152020    L N1        5TC  50A
74 11  291000BROOKLYN G      152022    L N1        5TC  50A
74 11  291000BROOKLYN K      152026    L N1        5TC  50A
74 11  2910002ND TWIN CROSS  152032    L N1        5TL 200A
74 11  2910002ND TWIN CROSS  152032    L N1        5TR 200A
74 11  2910002ND TWIN CROSS  152032    L N1        5TC 200A
74 11  2910002ND TWIN CROSS  152032    L N1        5TF  50A
74 11  291000WILLOW SWAMP    152095    L N1        5TL  50A
74 11  291000BLUE POINT      152097    L N1        5T   20A
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74 11  292417MILL CREEK B     152109   SS N2        T  250B
74 11  292417MILL CREEK C     152110   SS N2    1 10TC 300B
74 11  292417IMOGENE          152119   SS N2    1  5TC 250B
74 12   22417MINERAL BASIN LT152       SS N2    1 25TR 100C
74 12   52417EAGLE            152104    L N2       5TC 500B
74 12   52417TELESCOPE        152105    L N2       5TC 500B
74 12   52100BULLION KING     152107      N         TC 500A
74 12   60800BROOKLYNS D      152018    L N1      10TC  75B
74 12   60800BROOKLYNS F      152020    L N1      10TC  75B
74 12   60800BROOKLYNS G      152022    L N1      10TC  75B
74 12   60800BROOKLYNS H      152023    L N1      10TC  75B
74 12   60800BROOKLYNS I      152024    L N1      10TC  75B
74 12   60800BROOKLYNS J      152025    L N1      10TC  75B
74 12   60800BROOKLYNS K      152026    L N1      10TC  75B
74 12   60800BROOKLYNS L      152027    L N1      10TC  75B
74 12   608002ND TWIN CROSS   152032    L N2      10MC 200B
74 12   60800N MINERAL BRIDGE152033     L N2      10MC 200B
74 12   6 724N MINERAL BRIDGE152033     L N2       5TC 300B
74 12   60800WILLOW SWAMP     152095    L N2       5TL 100B
74 12   60800BLUE WILLOW      152096    L N2      25TC  90C
74 12   62400BATTLESHIP       152128   SS N2    2  5TR1000B
74 12   61000GOBBLERS KNOB    152151    L N2       5TL 200B
74 12   91500BROOKLYNS F      152020    L N2       5T     B
74 12   91500BROOKLYNS F      152020    L N2       5T     B
74 12   91400N MINERAL BRIDGE152033     L N2       5MR 700B
74 12  112417WILLOW SWAMP     152095    L N2       5TL 150B
74 12  112417BLUE POINT       152097    L N1       5ML  75C
74 12  112417BLUE POINT       152097    L N2       5TR 125B
74 12  122405MILL CREEK CIRQ 152       SS N2           400
74 12  122405PORPHRY BASIN    152      SS N2           300
74 12  131400RMP              152040   SS N2      25TL 100C
74 12  132417GENESEE S        152045   SS N3      10MR 350C
74 12  132417MCINTYRE GULCH   152087   SS N3      10T  350B
74 12  130800BLUE POINT       152097    L N1G     10TL  50B
74 12  132417OPHIR POND W     152126   SS N2       5MR 300B
74 12  132417BATTELSHIP       152128   SS N2       5TC1200B
74 12  132417BROWN MT AREA    152      SS N2
74 12  141200RED MT 3         152044   SS N2    2  5BC 100C
74 12  142405RED MT 1         152049   SS N3G   3 10M  350C
74 12  142417SILVER GULCH     152073   SS N2G      5ML 400C
74 12  150730BROOKLYNS D      152018      N         T     C
74 12  152405BROOKLYNS I      152024   SS N2      25TC 700C
74 12  150930BROOKLYNS J      152025   SS N3    2 50TC 900C
74 12  152405BROOKLYNS L      152027   SS N2      10TR 500B
74 12  152405BROOKLYNS M      152028   SS N2    2  5TL 350C
74 12  152405BROOKLYNS N      152029   SS N2    1  5TR 250B
74 12  150300RMP              152040   SS N1       5T   40C
74 12  152405SLIPPERY JIM     152061   SS N2G   2   TR 150A
74 12  152405E RIVERSIDE S    152062   SS N2       5ML 300B
74 12  1507301 RIVERSIDE S    152062      N               C 2  30
74 12  151045BLUE POINT       152097   SS N2    2 25MC 100C 3  60
74 12  152405BULLION KING     152107   HS N2    3  5TC 400B
74 12  152405MILL CREEK A     152108      N               C
74 12  152405MILL CREEK C     152110   SS N2    1 10MR 300C
74 12  152405MILL CREEK E     152112   SS N3    2 50MR 500C
74 12  151100MILL CREEK G     152114   SS N2    2  5MR 250B
74 12  151200SAM              152117   SS N2    2 10TF 150A
74 12  151200UTAH             152118   SS N1        MR  50B
74 12  152405IMOGENE          152119   HS N3      25TC 300B
74 12  151200BATTLESHIP       152128   SS N2    1  5TR 400B
74 12  152405CHAMPION         152144      N               B
74 12  15    MILL CREEK AREA 152       SS N2
74 12  152405PORPHERY BASIN   152      HS N2           500
74 12  152405COMMODORE GULCH 152       SS N3    3      350
74 12  152405MILL CREEK AREA 152       SS N3
74 12  152405MINERAL BASIN    152      HS N3    4    T 1000C
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74 12  152405PORPHERY BASIN  152       HS N3G   3          400C
74 12  152405PORPHERY BASIN  152       SS N3G   3          200
74 12  152405TRICO BASIN     152       SS N3    2     T   300B
74 12  160600CEMENT FILL     152010    SS N2         10TC1000B
74 12  162405BROOKLYNS F     152019       N                  C
74 12  160400WILLOW SW.SHLDR.152095    SS N2G   1     5TL 100C 1  20
74 12  160630WILLOW SWAMP    15209521  SSAE2    2    10TL 200B
74 12  161530WILLOW SWAMP    152095B11
74 12  161600WILLOW SWAMP    152095B1
74 12  162405EAGLE           152104    SS N2            TR 200A
74 12  160600MULESHOE        152106    SS N2              1500C
74 12  160600MILL CREEK A    152108       N                  C
74 12  18    WILLOW SWAMP    152095     L N1
74 12  18    BLUE WILLOW     152096     L N1
74 12  182417BLUE WILLOW     152096     L N2            TC 150C
74 12  182417BLUE WILLOW     152096     L N2            TC 150C             1
74 12  18    BLUE POINT      152097     L N1
74 12  202200BROOKLYNS C     152017    SS N2G   2    50TC 500C
74 12  202400BROOKLYNS G     152022    SS N3G   4    75TC1100C
74 12  202200N MINERAL BRIDGE152033    SS N2    2    10ML 250C
74 12  202417E GUADALUPE     152060       N
74 12  202417SLIPPERY JIM    152061     L N2               150
74 12  20    SILVER GULCH    152073     L N
74 12  20    W RIVERSIDE     152074     L N
74 12  20    W GUADALUPE     152075     L N
74 12  202300ROCKWALL        152101       N                                 1
74 12  202200TELESCOPE       152105    SS N3            TL2200C             1
74 12  202417MILL CREEK A    152108    SS N2         25MR 400C
74 12  20    MINERAL CK.AREA 152       SS N2G
74 12  202300PROSPECT GULCH  152       HS N4    5          300
74 12  211300ANVIL SHRINE    152001    SS N3G   2       TL 400C
74 12  212405ZUNI            152006    HS N3G           TL   C
74 12  212405CEMENT FILL     152010    SS N2    3       MC 400B
74 12  211000BENNY LONG      152014    SS N2    2      5MC 100B
74 12  210200BROOKLYNS A     152015    SS N3G   2    75TF 400C              1
74 12  210200BROOKLYNS B     152016    SS N3G   2    75TF 550C 2 100
74 12  210200BROOKLYNS F     152020    SS N3G   4    50MC 650C 1 150
74 12  210630BROOKLYNS H     152023    SS N3G   2    75TF 700C 1  60
74 12  210410BROOKLYNS I     152024    SS N3G   3    50TC 950C              1
74 12  210300BROOKLYNS K     152026    SS N3G   1    25TC 300C              1
74 12  210800BROOKLYNS L     152027    SS N2G   2    25TC 400C
74 12  210800BROOKLYNS M     152028    SS N3    3    75TF 400C
74 12  210200CEMETERY        152030    SS N2    2    25MF 300C
74 12  212405US BASIN        152035    SS N2            TL 400
74 12  210300MARMOT TOWN     152038    SS N2    2    10TC 100C
74 12  211450GENESSEE 5      152045    SS N3    3       TL 500C
74 12  212405FIRE            152079     L N2         75TC 300C
74 12  212405IRONTON         152082    SS N2G   1       TL 500B
74 12  212405IRONTON         152082    SS N3G   3    50TR1000C
74 12  212405TIDY            152083    SS N2G   2       TF 300B
74 12  211000DAISY HILL      152085    SS N3    3    75TF 400C
74 12  210700RICHMOND        152086    HS N4G   4    75T
74 12  210800GALENA LION DUN.152088    HS N3G   4    10TC1500C
74 12  210800GOVERNOR GULCH  152090    SS N2    3    10TF 600B
74 12  211030SNOWFLAKE       152098    SS N4    4   100TF 100C 6 250
74 12  210930ROCKWALL        152101    SS N2G   3    10TL 350B 4 150
74 12  210930ROCKWALL        152101    SS N2G   3    10TR 250B 5 350
74 12  212405EAGLE           152104    SS N2          5MC1500C
74 12  210740EAGLE           152104    SS N3    5    25TL1500C              1
74 12  210730BULLION KING    152107    SS N3    3    50TF2000C
74 12  210100ERNEST          152115    SS N3    2    75TF 300C
74 12  210100JULIO           152116    SS N3    2    50TC 500C
74 12  210200SAM             152117    SS N3G   3    50TF 900C
74 12  210100UTAH            152118    SS N2    2       TF 250C
74 12  210200IMOGENE         152119    HS N2G   4    10TR 600B
74 12  210200OUTLAW          152121    SS N2    2    50TC 300C
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74 12  210200TAVERN          152123    SS N3     3  75TF 900C
74 12  210200BURRO BRIDGE    152124    SS N2     2  25TC 200B
74 12  210300OPHIR POND F    152125    SS N2     2   5ML 300C
74 12  210930BISMARK         152127    SS N3G    3  75TF1900C
74 12  212405RED MT PASS WEST152       SS N2
74 12  212405CHAMPION BASIN  152       HS N3     3       300C
74 12  212405CORKSCREW GULCH 152       SS N3G    3       500
74 12  210500MILL CREEK AREA 152       SS N3     4       900
74 12  212405MINERAL BASIN   152       SS N3G    3       350
74 12  212405MINERAL BASIN   152       HS N3     5       700
74 12  210300OPHIR AREA      152       SS N3     3       500C
74 12  210300OPHIR AREA      152       SS N3     5      2000C
74 12  210100RMP N           152       SS N3G    3    TF 100C 3 100
74 12  222405N BARTON        152012    SS N3                C              1
74 12  221020BROOKLYNS J     15202541 SSAA2   M 2  10TR 600C
74 12  221015BROOKLYNS K     15202641  LAA2   F     5TR 200B
74 12  222405RED MT 3        152044    HS N3G       25TR 900C
74 12  222405RED MT 2        152047    SS N2     3   5MC 250C
74 12  221245SLIPPERY JIM    15206141
74 12  221245E RIVERSIDE     15206441 SSAA2   M          250
74 12  221245E RIVERSIDE     15206445
74 12  220500WILLOW SWAMP    152095    SS N3G       25TL 300C 5 200
74 12  220500BLUE POINT      152097    SS N2        10TL 100  4  50
74 12  220530WILLOW SWAMP    152097    SS N3G    3  50TC 400C10 100
74 12  222417FENCE           152099    SS N2          TR 100C
74 12  220500SILVER LEDGE MIN152100    SS N2          TL 225C 4  75
74 12  221345SILVER LEDGE MIN15210042 SSAA2G S 3    T  150C 2  30
74 12  221400ROCKWALL        152101    SS N2G    3   5TR 200B12 150
74 12  221000EAGLE           15210441 HSAA3GJM 5A 50TR2100C15 150
74 12  221010TELESCOPE       15210541
74 12  221010MULESHOE        15210641 SSAA2     3   5TL 400B
74 12  222417IMOGENE         152119    HS N3        75TL2250C
74 12  222405OPHIR POND F    152125    SS N3        50TL1300C
74 12  222405BATTLESHIP      152128    SS N4GJ   5  75TF2600C
74 12  222405US BASIN AREA   152       SS N2G    3       300C
74 12  222405PARADISE FACE   152       SS N4G    5 100TF1400C
74 12  232405WATER GAUGE     152002    SS N2     2  25TR1000B
74 12  232405CEMENT FILL     152010    SS N2         5MR 500C
74 12  231000BROOKLYN G      152022       N                 C
74 12  2324051ST TWIN CROSS. 152031    SS N3     2  75MF 600B
74 12  2324052ND TWIN CROSS. 152032    SS N3     2  75MF 600B
74 12  230900N MINERAL BRIDGE152033    SS N2        25ML 400C
74 12  230800LONGFELLOW      152039    SS N3G    3  50TC 225C
74 12  232417GENESSEE S      152045    HS N2     3  10MR 400C
74 12  232405RED MT 2        152047    HS N3        10TR 500C
74 12  232417RICHMOND        152086    SS N3     1  15TF1200
74 12  232417MCINTYRE GULCH  152087    SS N3     3  25TF 900C
74 12  232405KING            152091    SS N2     1  50TR 300C
74 12  230900BLUE POINT      152097    SS N3G    3  75TF 300C 6 100
74 12  232417MILL CREEK E    152112    SS N3     3  75MR 900C
74 12  232417SAN JUAN        152122    SS N2     1  10 C 400C
74 12  232000TAVERN          152123    SS N2     1  10ML 200B
74 12  232405DESTROYER       152129    SS N3     5  75TL2200C
74 12  232405CORKSCREW GULCH 152       SS N3     3    T 1200C
74 12  231800RIMCO FACE      152       HS N3     3  75TF 900C
74 12  232417TRICO BASIN     152       SS N3G    3    T  600C
74 12  242417E RIVERSIDE LEFT152065     L N2         5TC 200C
74 12  2405PORTAL            152120    SS N3     3  50TC 300C
74 12  240830RED MT PASS W   152       SS N1     1        75
74 12  271000N MINERALB RIDGE152033    SS N3     3  25TR1200C
74 12  271300BIG HORN        152036     L N1         5TC  40B
74 12  271100WILLOW SWAMP PT.152095    SS N3G    2  75TF 400C
74 12  271100BLUE POINT      152097    SS N1         5TC  80B              1
74 12  271100BLUE POINT      152097    SS N1         5TL  70B              1
74 12  27    MULAS AREA      152       SS N2             200
74 12  272405SNOWDEN MT AREA 152       SS N3     4       600
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74 12  292405BROOKLYNS G     152022     SS N2    1    5TR 400B
74 12  291000N MINERALB RIDGE152033     SS N3    3   25TL 900C
74 12  292405GOBBLERS KNOB   152151     SS N2
74 12  29    ENGINEER MT B   152160     SS N2    3        100B
74 12  29    LIME CREEK AREA 152        SS N2    2
74 12  302417GOBBLERS KNOB   152151      L N2
74 12  301500N CARBON        152    23 SSAE1G    2    T   75C
75 01   22417BROOKLYN C      152017     SS N1    1   10TC  50A
75 01   22417BROOKLYN D      152018     SS N1    1    5    50A
75 01   22405BROOKLYNS G     152022      L N1         5T   50A
75 01   22405BROOKLYNS I     152024      L N1         5T   50A
75 01   22405BROOKLYNS I     152024      L N1         5T   50A
75 01   22405TELESCOPE       152105      L N2         5TC 300B
75 01   22405MILL CREEK C    152110      L N2         5MC 200C
75 01   22417MILL CREEK E    152112     SS N3G   3 100TF  900C
75 01   22417BATTLESHIP      152128     SS N1    1    5TR  50A
75 01   22417MINERAL BASIN   152        HS N3    3   25TL1900C
75 01   41222MOTHER CLINE    152069      L N1                                1
75 01   62200LONGFELLOW      152039     SS N3    2   25MC 100C
75 01   60900SLIPPERY JIM    152061      L N2         5B  100
75 01   60900SLIPPERY JIM    152061      L N2
75 01   61030E RIVERSIDE     152064     SS N
75 01   60900W GUADALUPE     152075      L N1
75 01   60900WATER GAUGE     152075      L N1              150
75 01   62405IRONTON         152082     SS N2    1   10TL 150A
75 01   60900KING            152091     SS N2    1   25TC 100B
75 01   60600KING            152091     SS N3    1   75TR 350B
75 01   60500WILLOW SWAMP    152095     SS N1
75 01   60900WILLOW SWAMP    152095     SS N2    1   75MF 200B
75 01   60300BLUE WILLOW     152096     SS N1    1 100TF   50B
75 01   60300BLUE POINT      152097     SS N1      100 F   30
75 01   60300ROCKWALL        152101      L N1         5T   30T
75 01   60300ROCKWALL        152101      L N1         5T
75 01   60300ROCKWALL        152101      L N1         5T   30A
75 01   60430EAGLE           152104      L N1         5TL  50A
75 01   61900TELESCOPE       152105     SS N3                C               1
75 01   61930TELESCOPE       152105     SS N3                C               1
75 01   60130BATTLESHIP      152128     SS N2    2   25TR 200A
75 01   62300W LIME CREEK    152150
75 01   61205MINERAL BASIN   152        SS N2    1   75TF 150B
75 01   61205MINERAL BASIN   152        SS N2    1   75TF 150B
75 01   60300PORPHERY BASIN  152        SS N2    2   25TC 200B
75 01   71520CEMENT FILL     152010     SS N3                C 2 300
75 01   72417BROOKLYNS D     152018     HS N3    1   25TC 200B
75 01   72417BROOKLYNS E     152019     SS N2    2   50TF 200B
75 01   72417BROOKLYNS F     152020     SS N2    2   50TF 200B
75 01   72417BROOKLYNS G     152022     SS N2    2   50TF 200B
75 01   72417BROOKLYNS I     152024     SS N2    2   50TF 200B
75 01   72417BROOKLYNS J     152025     SS N2    2   50TF 200B
75 01   72417BROOKLYNS L     152027     SS N2    2   50TF 200B
75 01   72417CEMETERY        152030     SS N3    2 100TF  600C
75 01   71235E RIVERSIDE     15206448 SSAA3G         4      B
75 01   71300E RIVERSIDE LEFT152065     SS N1    1    5M   40C               1
75 01   71320MOTHER CLINE    152067     SS N                   3  30
75 01   71200WILLOW SWAMP    152095     SS N2    2   10TR
75 01   71300BLUE WILLOW     152096     SS N1              40C               1
75 01   71400BLUE POINT      152097     SSA04  M 2B100TR  300C 6  90
75 01   70300ROCKWALL        152101     SS N1    1    5TC  50C               1
75 01   71530TELESCOPE       152105     SS N3                C               1
75 01   72417SAM             152117     SS N1    1    5HR 100C
75 01   72417SAM             152117     SS N2    1    HL     C
75 01   72417PORTAL          152120     HS N3    3    ML   80C
75 01   72405SAN JUAN        152122     SS N3                C
75 01   70230W LIME CREEK    152151        N                 B               1
75 01   72405RUNOFF-100A     152        SS N3    1   75TF 100
75 01   81200CEMENT FILL     15201045
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75 01   81040BROOKLYN A      15201541 SSAA2   F 2     TL  300C
75 01   81040BROOKLYN C      15201741 SSAA2   M 2 100TR 400B
75 01   81040BROOKLYN C      15201741 SSAA2   M 3 100TL 400B
75 01   81100BROOKLYN F      15201941
75 01   81045BROOKLYN G      15202242 SSAA1     1   5TL  50A
75 01   81400BROOKLYN H      152023   SS N3                 C10   70
75 01   81100BROOKLYN J      15202541
75 01   81100BROOKLYN L      15202741 SSAA2   F 2     TR     B
75 01   81115EAGLE           15210444 HSAA2   M    10TL1500C
75 01   81115TELESCOPE       15210541
75 01   81115MULESHOE        15210641
75 01   82405MINERAL CK.AREA 152      SS N1     1 100TF   40C
75 01   90300WATER GAUGE     152002   SS N3     2 100TF1400B
75 01   90300S MINERAL ROAD  152003   SS N2     2  50MC 200B
75 01   90300PIT             152004   SS N2     1  25TC 600B
75 01   92000BROOKLYN C      152017   SS N2     2  50TL 400B
75 01   92000BROOKLYN D      152018   SS N      2  50TF 400B
75 01   92000BROOKLYN F      152020   SS N3     1  50MC 300C 3 30          1
75 01   90300U S BASIN       152035   HS N3G    5  25MF 400C
75 01   92405ITALIAN         152051   SS N3G    3  50TF1500C
75 01   91500E RIVERSIDE     152064   HS N2G    3  10MR1000B
75 01   90800E RIVERSIDE N   152065   SS N2     1  25TL 100B 3   90
75 01   90815E RIVERSIDE N   152065   SS N2   M
75 01   91400MOTHER CLINE    15206944 SSAA3   M 2  75TF 400B 3 300
75 01   90815SILVER POINT    152079   SS N2G    1  10TF 200B 2   30
75 01   91000W RIVERSIDE SMON152074   SS N4GJ   3 100TF1200C                  1
75 01   92417W GUADALUPE     152075   HS N3G    7   5TL 800B
75 01   92417IRONTON         152082   SS N3     2  75TF1500C
75 01   90300ROCKWALL        152101   SS N1     1   5TL  50B 2   15
75 01   90300EAGLE           152104   SS N3     2  50TC1200
75 01   90300MULESHOE        152105   SS N2     1  50TC 600B
75 01   90300MILL CREEK F    152112   SS N2     2  75TF 500B
75 01   90300ERNEST          152115   SS N3     3 100 F 400C
75 01   90300JULIO           152116   SS N4     3 100 F 600C
75 01   90300SAM             152117   SS N4     3 100TF1600C
75 01   90300UTAH            152118   SS N4     3 100TF 500C
75 01   90300IMOGENE         152119   SS N3           1900C
75 01   90300OUTLAW          152121   SS N4         TF     C
75 01   91200BISMARK         152127   SS N3     2  50TR1600C
75 01   90300BATTLESHIP      152128   SS N3     2  75TF     C
75 01   91030JENNIE PARKER N 15214043 SSAA3   P    85TF     B 3 150
75 01   91030JENNIE PARKER . 15214141 SSAA3   P    85TF     B10   25
75 01   91035PEACOCK         15214241 SSAA3   P    90TF1200C 5   50
75 01   91030CHAMPION        152144461
75 01   92405SPRINGS         152148   SS N3     1  75TF     C 3   30
75 01   92405E LIME CREEK    152149   SS N2G    1  50TC 150B 3 180
75 01   92405W LIME CREEK    152150   SS N2G    1  50MC 150B 3 300
75 01   92405W LIME CREEK    152150   SS N2G    1  50MC
75 01   92417GOBBLERS KNOB   152151   SS N2G    2  50TR 300C
75 01   92405DEER CREEK N    152153   SS N3     3 100    200B 7 150
75 01   92405DEER CREEK S    152153   SS N3     2    TR 150B 3   90
75 01   92405SWAMP           152154   SS N2     2 100 F     B
75 01   92405HENRY BROWN     152155   SS N4     2 100 F     B 3 140
75 01   92405COAL CREEK E    152157   SS M1     1  10TL  25B                  1
75 01   92405COAL CREEK WEST 152158    L N1     1 100MF  30B                  1
75 01   92405ENGINEER MT A   152159   SS N3     2 100TF     C
75 01   92405ENGINEER MTN B  152160   SS N3     2 100TF     C
75 01   92405ENGINEER MTN C  152161   SS N3     2 100TF     C
75 01   92405LIME CREEK AREA 152      SS N2G    2          300C
75 01   92405ENGINEER MT AREA152      SS N4     2 100TF1200C
75 01   92405N OF SPRING AREA152      SS N4G    3  75TF 900C
75 01  04     RICHMOND       152086   HS N3           TL1300B
75 01  100125BENNY LONG      152014   SS N4     3  75TF 200C 7 600
75 01  100300BLUE WILLOW     152096   SS N2     1  10TL  90B
75 01  101515EAGLE           152104   SS N3                 C 5   90
75 01  102417ENGINEER MT     152      SS N3     2 100TF     C
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75 01  10     SENTIAL PI S.     152                      1900
75 01  112100CEMENT FILL        152010   HS N3G    5  50TC2300B
75 01  112030BROOKLYNS A        152015   SS N2G    3  50TR 300C
75 01  112030BROOKLYNS C        152017   SS N3G    3  50TC 700C18 180
75 01  112300BROOKLYNS D        152018   SS N3G    3  25TC 600C
75 01  112030BROOKLYNS E        152019   SS N4G    5  75TF1300C14  50
75 01  110515BROOKLYN K         152026   SS N3               200  5  90
75 01  112100 1ST TWIN CROSS.   152031   SS N4     5  75TF1900C
75 01  112100 2ND TWIN CROSS.   152032   HS N3G    3  75TF1200C
75 01  112100N MINERAL BRIDGE152033   HS N4G    5 100TF1900C
75 01  110900ARCHIE             152034   SS N3G    3  50TF 250C
75 01  110830STUDY PLOT         152037   SS N4G    3 100TF 400C
75 01  110830MARMOT TOWN        152038   SS N4G    3  25TR 400C
75 01  110830LONGFELLOW         152039   SS N3     3 100TF 300C
75 01  112417E GUADALUPE        152060   HS N2G    3   5TL 600B
75 01  112405E GUADALUPE        152060   HS N3G    7  25MR1400B
75 01  112000E RIVERSIDE L      152065
75 01  111800SILVER POINT L     152070   SS N2                      5  30
75 01  111900SILVER GULCH       152073   HS N4GJ   5  75TL2400C 3 150
75 01  112000W RIVERSIDE L      152074   HS N4G    3  75TR2300C15 110
75 01  112100WILLOW SWAMP       152095   SS N2     3    MR    C
75 01  112230ROCKWALL N         152101   SS N2     2 100TR 150B 9 180
75 01  112230ROCKWALL S         152101   SS N3     2 100TR 100B 9 450
75 01  112230SILVER LEDGE MILL152102   SS N4     2 100TF1200C 9 450
75 01  112100SAM                152117   HS N4G    3 100TF1400C
75 01  112417GLADSTONE N        152138   SS N3        75TF 500C
75 01  111100DEER CREEK         152152    L N1         5MF  50B                      1
75 01  112417BANK SLIPS         152      SS N1G
75 01  112417E LIME CK.AREA     152      SS N2G    3     T  250C
75 01  112417SNOWDEN AREA       152      SS N2     4     T  400C
75 01  112100S RMP GULL.AREA    152      HS N2G    3    TF   75C
75 01  112417TURKS HEAD         152      HS N3     3         600
75 01  112100GREY COOPER GLCH152      HS N4G       6  1100C
75 01  122417PIT                152004   SS N3G    3  25TC 600C
75 01  122000CAMP               152008   SS N3     3  75TF1800B
75 01  120900LOWER CEMENT FIL152009   SS N2        25T  400B
75 01  120900BARTON S           152011   SS N           C
75 01  122405BARTON W           152012   SS N3                 B                     1
75 01  121000BLACKBURN          152013   SS N3G    3    TC     C 3  60
75 01  121600HENNY LONG         152014   SS N1     2          50                     1
75 01  120300BROOKLYNS J        152025   SS N3G    3  50TC1000C                      1
75 01  120300BROOKLYNS K        152026   SS N4G    3 100TF1000C 3  90
75 01  120300BROOKLYNS L        152027   SS N3G         TL 200C
75 01  120300BROOKLYNS M        152028   SS N5G    3 100TF1000C 9  90
75 01  120300N MINERAL BRIDGE152033   SS N4     5 100TF1900C
75 01  120900BIG HORN           152035   SS N3G    3  50TC 150C
75 01  121500PUTNEY PEAK N      152041   HS N4G    8  50TR 700C
75 01  120900GENNESSEE S        152045   HS N3G    5  75TF 700C
75 01  120900GENESSEE N         152046   SS N3G    3  75TF 500C
75 01  120300CORA BELL          152048   HS N3G    3  25MR 400C
75 01  120300RIPPLE             152050   SS N3     3  75TF 600C
75 01  122405SLIPPERY JIM       152061   SS N3G    3  25TR 600C 5  75
75 01  122405WHITE FIR          152072   SS N3G    5  75TL2200C
75 01  120300W GUADALUPE        152075   HS N2     2  75MF 200C
75 01  120300FULL MOON UPPER    152084   HS N3G    5  25TR 200B
75 01  120309FULL MOON UPPER    152084   HS N3G    5  25MR 300C
75 01  120300DAISY HILL         152085   SS N3     3 100TF 600C
75 01  120900G RIDGE FACE       152089   SS N3     2  75TF 400C
75 01  121500IDARADO BANK SLD152094   SS N1G             30  3  60
75 01  120300SILVER LDGE.MINE152100   SS N3     3  25TC 125B 9  60
75 01  120730EAGLE              152104   HS N3G    2  10TF1200C 6 120
75 01  120630MULESHOE           152106   HS N4G    7  90T 2400C20 300
75 01  120630BULLION KING       152107   HS N4G    7  90T 2600C
75 01  120300MILL CREEK E       152112   HS N4G    5  75TC1000C
75 01  120309MILL CREEK E       152112   HS N4G    5  75MF1000C
75 01  122405ERNEST             152115   SS N3     3  50TC 300C
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75 01  120300IMOGENE         152119   HS N4   3  75TL2000C 2  15
75 01  120300SAN JUAN        152122   SS N3   3  75TF    C
75 01  120300TAVERN          152123   SS N4   2 100TF    C
75 01  122405BURRO BRIDGE    152124   SS N3   3 100TF    C
75 01  122000OPHIR POND E    152125   SS N2   3  10ML1200C
75 01  120300BISMARK         152127   HS N3   6    TL2000C
75 01  120900BATTLESHIP      152128   HS N3G  3  35TC2200C
75 01  120300G I             152130   SS N3   3  75TF1200C
75 01  120300PICKLE BARREL   152131   SS N3   3  75TF1000C
75 01  120400DEADWOOD        152145   SS N3      TR      C 2  25
75 01  122405RMP N AREA      152      SS N2   3 100TF    C
75 01  122405RMP S AREA      152      SS N2G  3 100TF    C
75 01  120900LEFT BURRO BDGE 152      SS N3   3 100TF1000C
75 01  122417US BASIN AREA   152      HS N3   5    T  500A
75 01  120300MILL CREEK CIRQ.152      HS N4   5    T 1000C
75 01  120300RALSTON CREEK   152      HS N4   2  75T     C
75 01  131500ANVIL           152001   WL N2G       TR 300C
75 01  131500WHITE FIR       152072   HS N3G  2  10MR 300B
75 01  142417ANVIL           152001   WL N1G      5MC  50C
75 01  142417THIRTY          152005   WL N2G      5TL 100B
75 01  142417WATER GAUGE     152076   WL N2      50TL 200B
75 01  141500WILLOW SWAMP    152095   HS N2G  5  10TR 150B
75 01  151300HOPI            152007   SS N2G       ML 200B
75 01  151200SLIPPERY JIM    15206142
75 01  151150E RIVERSIDE     15206443
75 01  151353PORCUPOINE      15210341 HSAA4G M 53100TF1320C 8 150
75 01  151315EAGLE           15210446
75 01  151350TELESCOPE       15210544 HSAA4G M 32 75  1420C 6 330
75 01  161320CEMENT FILL     15201044
75 01  161255BROOKLYN A      15201541
75 01  161255BROOKLYN B      15201642
75 01  161500EAGLE           152104   HS N2   3  10MR1000B
75 01  161400CHAMPION        15214444
75 01  161445CHAMPION        15214442
75 01  211400MOTHER CLINE    152069   SS N1G  1   5MR  50B                1
75 01  211400SILVER POINT    152070   SS N1G  1   5MR  20B
75 01  211500SILVER LEDGE MIN152100   SS N1   1   5ML  20B                1
75 01  231500OLD S MINERAL RD152003   WL N2G  1  25TC 300B
75 01  231500PIT             152004   SL N2G  1  25TC 600B
75 01  231300WILLOW SWAMP    15209523 HSAE2G M 3 10TL 400B
75 01  261620WILLOW SWAMP    15209521 HSAF3G F 23 10TL 300B
75 01  271545COMMODORE GULCH 152   22 SSAA2  F 11 75TF 200C
75 01  280300HOPI            152007   SS N3        TF 400C
75 01  280730BLACKBURN       152013                        6 120
75 01  280900BROOKLYN F      152020   SS N2                B
75 01  280900BROOKLYN G      152022   SS N2   1    TL      B
75 01  280900BROOKLYN H      152023   SS N3   1    MF      C 5  90
75 01  280900BROOKLYN J      152025   SS N3G  2  75TF      C              1
75 01  280900BROOKLYN K      152026   SS N3G  2  75TF      C              1
75 01  2809001ST TWIN CROSS. 152031   SS N3   3    M       C
75 01  2809002ND TWIN CROSS. 152032   SS N3   3    TF      C
75 01  280900N MINERAL BRIDGE152033   SS N4   3 100TF      C
75 01  280300ARCHIE          152034   SS N2   2    M  100C
75 01  280300US BASIN        152035   SS N3   3    TC 900C
75 01  28    BIG HORN        152036                   80
75 01  281000LONGFELLOW      152037   SS N2G  3  25TL 180C
75 01  280900LONGFELLOW      152039   SS N3G  5    TF    C
75 01  280900RMP             152040   HS N5G  5 100TF 150C
75 01  280900NATIONAL BELL S 152042   HS N3   5    TR 400C
75 01  280900PED MT 3        152044   HS N3G  3    TC1400B
75 01  280300GENESSEE S      152045   SS N3G  3    TF 900C
75 01  280300GENNESEE N      152046   SS N3   3    TL 600C
75 01  280300CORA BELL       152048   SS N3G  3    TF    B
75 01  280300BROOKLYN GULCH  152054   SS N2   3  10ML 600B
75 01  280300W GUADALUPE     152075   SS N3   5    TL
75 01  281500WATER GAUGE     152076   SS N3   2  25TC1900C
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75 01  280300FULL MOON GULCH 152084   SS N2     3  10MR 800C
75 01  280300FULL MOON GULCH 152084   SS N3     3  10TR1200B
75 01  280300DAISY HILL      152085   SS N2     1  25T  300B
75 01  280300DAISY HILL      152085   SS N2     1  25T  300B
75 01  280300DAISY HILL      152085   SS N2     1  25T  900B
75 01  280300DAISY HILL      152085   SS N2     1  25T  300C
75 01  280900TWIN BRIDGES    152092   SS N2     3    TF  80C 3  60
75 01  28    WILLOW SWAMP    152095   HS N3     3    TL    C 3  60
75 01  28    BLUE POINT      152097   SS N4G    2 100TF    C 6 150
75 01  280900ROCKWALL        152101   SS N2               80  3  30
75 01  280900EAGLE           152104   SS N4     3  75TF    C 3 120
75 01  280900TELESCOPE       152105   SS N3     3  75TC    C
75 01  280730MULESHOE        152106   SS N3        90TF2100C
75 01  28    ERNEST          152115   SS N2     1    ML 200C
75 01  280300OUTLAW          152121   SS N3        90TC1400C
75 01  280300OPHIR POND W    152126   SS N3     3  25TC
75 01  280300BISMARK         152127   SS N3     5  75TL1400C
75 01  280900BATTLESHIP      152128   SS N2G    6  10ML 300B
75 01  280300SNOWSLIDE GULCH 152132   SS N4        25TC    C
75 01  280300PORPHERY BASIN  152      SS N3     3    ML
75 01  280900S OF WATER GAUGE152      SS N3          TL 400C
75 01  280900CHAMPION GULCH  152      SS N4G    3    MF    B
75 01  290935BROOKLYN E      15201943
75 01  290930BROOKLYN L      15202741
75 01  290930CEMETERY        15203042
75 01  291355E RIVERSIDE     15206446 HSAA3G M     10MR1500B
75 01  291420MOTHER CLINE    15206942 SSAA2     2  20TC 150C
75 01  291545W RIVERSIDE     15207444
75 01  291525WILLOW SWAMP    15209541 SSAA4  M 5  75TC 600C15 300
75 01  291525BLUE WILLOW     152096   SSAA4G F 5 100TF 100C 5 120
75 01  291010TELESCOPE       15210542
75 01  291005MULESHOE        15210543
75 01  302417SNOWSLIDE GULCH 152132   SS N2        25TR1200C
75 01  312405BROOKLYN I      152024   SS N3G       75T  200C
75 01  311045BLUE POINT      1520973  SSAU2  M 2A 10TR 200C 4  30
75 01  312405BATTLESHIP      152129   SS N3G    5  50MC    C
75 01  310900STRING ALONG    152133   SS N3       100TF1200C
75 02   11600WILLOW SWAMP    15209521 HSAE5G F 5B100TL 600C
75 02   11030SILVER LEDGE MIN152100    L N1         5    50B
75 02   11030SILVER LEDGE MIN152100    L N1         5    50B
75 02   12405EAGLE           152104   SS N1     5   5M  100B
75 02   12405MILL CREEK      152      SS N2G    5  50   400C
75 02   12405MILL CREEK      152      SS N4G       75  1200C
75 02   50300BROOKLYN F      152020    L N1     5   5TR 100B
75 02   50300BROOKLYN J      152025   SS N2     1   5TR 200B
75 02   51700EAST RIVERSIDE S152062   SS N2     2   5ML 900  7  50
75 02   51725EAST RIVERSIDE L152065   SS N2     1  50TC 400C12  75
75 02   50700ROCKWALL        152101   SS N1     1  10MR  20B
75 02   51300ROCKWALL        152101   SS N1     1  10TR  50B
75 02   51400EAGLE           152104   SS N2     2    MR 400B
75 02   51400EAGLE           152104   SS N2     2    ML 400B
75 02   50700RU IOUT         152      SS N1     1  10TL  50B
75 02   61200CAMP            152034    L N2         5TR1200C
75 02   61145EAST RIVERSIDE S15205249
75 02   61350EAST RIVERSIDE S15205242
75 02   61200EAGLE + TELESCOP152104   OL N2         5TC 200C
75 02   60900W LIME CREEK    152150   SS N2     1  25TC 200C
75 02   60900GOBBLERS KNOB   152151   SS N2     1  35T  250B
75 02   60900HENRY BROWN     152155   SS N2     1  10TC 350C
75 02   60900ENGINEER AT     152160   SS N2     1  10MC 200C
75 02   72417BROOKLYNS O     152018   SS N2     1    TC 300B
75 02   71500BROOKLYNS J     152025    L N2         5TC 300B
75 02   72417BROOKLYNS K     152026   SS N2     1   5TL 350B
75 02   71500BROOKLYNS L     152027    L N2         5TL 200B
75 02   716001ST TWIN CROSS. 152031   SS N2     1  10TR 275B
75 02   716001ST TWIN CROSS. 152031   SS N2     1  10TR 250B
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75 02   71000WILLOW SWAMP     152095    L N2          TL 250B
75 02   71000BLUE POINT       152097    L N2        10TF 150C
75 02   71500SILVER LEDGE MINI52100    SS N2     1  10TR 150C             1
75 02   71500ROCKWALL         152101A   LA02         5MC 200C
75 02   71100RMP AREA         152       L N1
75 02   81200BROOKLYNS K      152026   SS N2     1   5TC 200B
75 02   81200EAGLE + TELESCOP152104     L N2          TL 200C
75 02   81200EAGLE + TELESCOP152104     L N2          TR 150C
75 02   91900COAL CREEK W     152158   SS N1     1   5TC  30B             1
75 02   91900SNOWFLAKE(MOLAS)152       SS N1     1  10TL  20C             1
75 02  101500OLD S MINERAL RD152003     L N1          TC  50B
75 02  101100BENNY LONG       152014   SS N3     2 100TF1000C
75 02  101100BROOKLYN A       152015   SS N4     3 100TF     C
75 02  101500BROOKLYN C       152017   SS N2     1  50TF 200B
75 02  101100BROOKLYN C       152017   SS N3     3  75TF     C
75 02  101500BROOKLYN D       152018    L N1        10TC  50B
75 02  101100BROOKLYN D       152018   SS N4     3    TF     C
75 02  101100BROOKLYN E       152019   SS N3     3 100TF     C
75 02  101500N OF BROOKLYN G 152022    SS N1     2
75 02  100700BROOKLYNS L      152027   SS N2     3    ML     C
75 02  100700LONGFELLOW       152039   SS N2     1  10TL 250C
75 02  102100SLIPPERY JIM     152061    L N1
75 02  102100WATER GAUGE N    152076    L N1
75 02  102100TINY             152083   SS N2     1  25TR 200B
75 02  102100FULL MOON BASIN 152084    SS N3     1  25TF1000B
75 02  102100GALENA LION GLCH152088     L N2
75 02  102100GOVERNOR GULCH  152090     L N2
75 02  101300BLUE POINT       152097   SS N1     1   5TL  75B
75 02  101845EAGLE            152104   SS N3     2  75TF2000C12 150
75 02  101900TELESCOPE        152105   SS N2     2 100TF2000C 6 100
75 02  101900MULESHOE         152106   SS N2     2 100TF2000C
75 02  101900BULLION KING     152107   SS N2     1 100TF2000C
75 02  101500IMOGENE          152119   SS N3     2  50MC1400C
75 02  102100OPHIR POND E     152125   SS N2        10MC 200B
75 02  102100OPHIR POND W     152126   SS N2        10MC 200B
75 02  102100BISMARK          152127   SS N1     1    MC  50B
75 02  102100BISMARK          152127   SS N2     2  25TL 300B
75 02  101900BATTLESHIP       152128   SS N2     1    MR 500B
75 02  102100PICKLE BARREL    152131   SS N2     1  25MC 200B
75 02  100700DEER CREEK S     152153    L N1          ML  40C
75 02  101100COAL CREEK E     152157    L N1
75 02  101100COAL CREEK W     152158    L N1
75 02  100900ENGINEER MT B    152160   SS N3     2 100TF 600C
75 02  100900ENGINEER MT C    152161   SS N3     2 100TF 600C
75 02  101200RMP AREA         152       L N1
75 02  101415RAYS BANK SLIDE 152       SSA01     2     T  45C             1
75 02  101300IDARADO SUBSTAT.152       SS N2     2     T 100C
75 02  101900PROSPECT BASIN  152       SS N3     2    TF 300C
75 02  111120BROOKLYN E       15201941 SSAA3  M 2  50TR 700C12  90
75 02  111118BROOKLYN F       15202041 SSAA3  M 2  50TC1000C
75 02  111116BROOKLYN G       15202241 SSAA2    2  50TC1100C 6  60
75 02  111114BROOKLYN H       15202341 SSAA3  M 3  50TC1100C
75 02  111112BROOKLYN J       15202541 SSAA3G M 3  75TC1000C             1
75 02  111108BROOKLYN L       15202741 SSAA3G M 3  75TC1000C
75 02  111100CEMETERY         15203043
75 02  111530SLIPPERY JIM     15206141
75 02  111500E RIVERSIDE      15206449
75 02  111530E RIVERSIDE      15206441
75 02  111315WILLOW SWAMP     15209541 SSAA2  M 2  25TL 300C
75 02  111315WILLOW SWAMP     152095   SSA02G M 1  50TR 300C
75 02  111050TELESCOPE        15210542 SSAA3  M 3  75ML     C 2  90
75 02  111045MULESHOE         15210642 SSAA2  M 2  75TC     C
75 02  111600JENNIE PARKER N 15214041
75 02  111600JENNIE PARKER S 15214141
75 02  120300MILL CREEK AREA 152       SS N2     3     T 1500C
75 02  142417JENNIE PARKER N 152140     L N1
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75 02  142417CHAMPION        152144    L N1
75 02  142417GOBBLERS KNOB   152151    L N1
75 02  142417DEER CREEK N    152152    L N1
75 02  142417HENRY BROWN     152155   SS N1              5MC  50B
75 02  142417COAL CREEK E    152157    L N1
75 02  142417COAL CREEK W    152158    L N1
75 02  142417ENGINEER MT C   152161   SS N2              5MF 250B
75 02  152417200 TWIN CROSS. 152032   SS N2      1       5M  300
75 02  152000N MINERAL BRIDGE152033   SS N2      1        TR 300B
75 02  152000N MINERAL BRIDGE152033   SS N2      1        ML 300B
75 02  152000N MINERAL BRIDGE152033   SS N2      1        MC 300B
75 02  152000EAGLE           152104   SS N2      1       5ML 500B
75 02  152000TELESCOPE       152105   SS N2      1        MC 750B
75 02  152405MILL CREEK B    152109    L N2             10MR 600C
75 02  152417PROSPECT BASIN  152       L N2
75 02  162100LONG FELLOW     152039   SS N2      1      50TC 350B
75 02  160900BLUE WILLOW     152096    L N2             10TC 100C                1
75 02  160900BLUE POINT      152097   SS N2      1      10ML 100C                1
75 02  160910MILL CREEK AREA 152       L N2   F  A           350
75 02  170300BROOKLYNS I     152024   SS N2             25MC 600B
75 02  172417BROOKLYN K      152026   SS N3      2        TF 700C
75 02  170300WILLOW SWAMP    152095   SS N2      1      25TL 200B
75 02  170300EAGLE           152104   SS N2      1      10MR1200B
75 02  170300MULESHOE        152106   SS N2      1      10ML 700B
75 02  170300BULLION KING    152107   SS N2      1      25TC2000C
75 02  172405WATERFALL       152147   SS N2      1      50TR    C 2   30
75 02  172417E LIME CREEK    152149    L N1             25MR  50C
75 02  172417GOBBLERS KNOB   152151    L N2               TF 100B
75 02  172405DEER CREEK S    152153   SS N1      1      10TF  50B
75 02  172417DEER CREEK S    152153    L N1             50TC  50C
75 02  172405HENRY BROWN     152155   SS N2      1        TC 100B
75 02  172417COAL BANK       152156    L N1             50TF  50C
75 02  172405COAL CREEK F    152157   SS N1      1      10TL  30C
75 02  172417COAL CREEK F    152157    L N1             25TC  20B
75 02  172417COAL CREEK W    152158    L N1             75MF  20C
75 02  172417ENGINEER MT A   152159    L N1             25TF  50B
75 02  172417ENGINEER MT B   152160    L N1             50TF  50B
75 02  172405ENGINEER MT B   152160   SS N2      1 100TF 400C
75 02  172417ENGINEER MT C   152161    L N1             50TF  50B
75 02  172405ENGINEER MT C   152161   SS N2      1 100TF 400C
75 02  172417S FORK MIN.CREEK152      SS N2
75 02  172405KING SOLOMON    152      SS N3      3   75T 2700C 6   75
75 02  181105CEMENT FILL     15201045
75 02  181127BROOKLYNS A     15201541 SSAA3   M 3A 50TL     C                    1
75 02  181125BROOKLYNS B     15201641 SSAA4     3           C 9 300
75 02  181131BROOKLYNS C     15201741 SSAA3   M 2B 75TR     B
75 02  181140BROOKLYNS F     15201942
75 02  181133BROOKLYNS G     15202241 SSAA1   F 1A  5TR     A
75 02  181020CHAMPION        15214444 HSAA2     3
75 02  181415W LIME CREEK    15215041 SSAA2   F  A   TL     B
75 02  181350SWAMP           15215442 SSAA3     2  50TL     B
75 02  181355HENRY BROWN     15215542 SSAA1   F 2A 25TR     A
75 02  181500UNCOMPAGHRE GOR.152      DL N1
75 02  180300MILL CREEK CIRQ.152      SS N3GJ  2  75TL1300C
75 02  211500BMP S           152040   SS N2                  100
75 02  210300ERIVERSIDE LEFT 152065   SS N2      1  50TR 250C 2   30
75 02  210300W RIVERSIDE     152074   SS N3      3  25TL1900C                    1
75 02  210300E RIVERSIDE     152074   SS N3      3  25ML1900C                    1
75 02  210300W GUADALUPE     152075   HS N3      3  25TC2500C
75 02  211815EAGLE           152104   SS N3      1  50TR    C15   90
75 02  21    OPHIR ROAD W    152126   SS N3      2  25MF    C
75 02  212100OPHIR ROAD N    152126   SS N3      1  25MF    C
75 02  21    BATTLESHIP      152128   SS N2      2   5TC 900B
75 02  212100LIME CREEK W    152150   SS N2          5RL 175C
75 02  211500MINERAL BASIN   152      SS N2      2       600
75 02  210600SNOWDEN AREA    152      HS N3      3       450
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75 02  220330BENNY LONG      152014   SS N1      1    5TC  50C                1
75 02  221300SLIPPERY JIM    15206141
75 02  221200E RIVERSIDE     15206447
75 02  221130SILVER LEDGE MIN15210043
75 02  220030ROCKWALL        152101   SS N1      1   10TC  60B                1
75 02  221030EAGLE           15210443 SSAA2  M  1     TL    C
75 02  221030TELESCOPE       15210541 SSAA2  M 19   25TR 300B
75 02  221030MULESHOE        15210642 SSAA2  F  1   10TF 200A
75 02  221500COAL BANK #     152158   SS N1      3    5BC  40C 2  50
75 02  231500ZUNI            152006   HS N2      3    5TC 400B
75 02  230830LOWER CEMENT FIL152009   SS N2         25TL
75 02  230730CEMENT FILL     152010   HS N4      5   75T 2500C11 200
75 02  230300BROOKLYNS F     152020   HS N2      1   25TC1000B
75 02  230300BROOKLYNS I     152024   SS N2      2   10TC 600B
75 02  230300BROOKLYNS I     152024   SS N2      3   10TC 400B
75 02  230300BROOKLYNS J     152025   HS N2      2   10TC 500B
75 02  230300BROOKLYNS K     152026   HS N2      2   10MC 500B
75 02  230900E GUADALUPE     152069   HS N3      3   10ML1500C
75 02  230900WATER GAUGE N   152076   SS N2      2   25    500
75 02  230300EARTH           152078   SS N2      1   25TC 400
75 02  230300IRONTON         152082   SS N2      2    5TC 400B
75 02  230900MACINTYRE GULCH 152087   HS N3      3     T
75 02  230900GALENA LION GLCH152088   HS N2      3    5T  400B
75 02  230300GOVERNOR GULCH  152090   HS N3      3    5TC1500C
75 02  230300KING            152091   SS N2      1     MC 125
75 02  231345PORCUPINE       152103   HS N3      3   50TC1400C 8 100
75 02  230300EALGE           152104   HS N3      5   25TR2200C
75 02  230730MULESHOE        152105   HS N3      5   50TC2600C 8 200
75 02  231000BULLION KING    152107   HS N3      7   50
75 02  230300IMOGENE         152119   HS N3      3     TR2200C
75 02  230300BATTLESHIP      152128   HS N3      3     TC1500C
75 02  230900BASIN BATTLESHIP152128   HS N3G     5     T     C
75 02  231430N STAR          152137   HS N3G     6
75 02  230600CHAMPION        152144    S N2      2     TC 600C 3  20
75 02  230300KINO MINE       152146   HS H       5
75 02  230430WATER FALL      152147   HS N4            T 1000C12 120
75 02  230430SPRINGS         152148   HS N4          75T 1000C 9  70
75 02  231500E LIME CREEK    152149   WL N1           5BR  40
75 02  230400E LIME CREEK    152149   HS N2      2   25TL 200B 4 350
75 02  230400E LIME CREEK    152149   HS N2      1   25MR 150B 4 150
75 02  231500ENGINEER MT A   152159    L N2           5T  250
75 02  231300RT.OF TRICO BAS.152      HS N2
75 02  230900W LIME CK.AREA  152      HS N2      2         150
75 02  230900BEAR CREEK AREA 152      HS N3G     5
75 02  232405ENGIN.MT.E.FACE 152      HS N3      5     M 1500C
75 02  230600KENDALL AREA    152      HS N3      3
75 02  231200MILL CREEK AREA 152      HS N3                    C
75 02  230300MINERAL BASIN   152      HS N3      3         600
75 02  230300RIMCO FACE WILLW152      HS N3G     3   50TC 500C
75 02  231300RT.OF TRICO BAS.152      HS N3G
75 02  231300S MINERAL       152      HS N3      5
75 02  230300SULTAN MOLAS SHD152      HS N3            M  500C
75 02  231200TRICO BASIN     152      HS N3
75 02  232405TWILIGHT PEAK   152      HS N4      5        1900
75 02  241500ANVIL           152001   DL N2          25TC 300B
75 02  241500WATERGAUGE      152002   DL N2          25TC 900B
75 02  241400WATER GAUGE     152002   SS N2      2   25TL 600C
75 02  241500OLD S MINERAL RD152003   DL N2          25TC 300B
75 02  241400OLD S.MIN.ROAD  152003    L N2      2   25T  500C
75 02  241500PIT             152004   DL N2          10TC 200B
75 02  241400PIT             152004   SS N2      2   25TL 500C
75 02  241500HOPI            152007   DL N2          25TC 600B
75 02  241530HOPI            152007    L N2          50TR 400C
75 02  2414001ST TWIN CROSS. 152031    L N1           5M  300B
75 02  2415001ST TWIN CROSS. 152031   DL N2            TC 200B
75 02  241500E RIVERSIDE LEFT152065   SS N2      1             C                1
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75 02  241600SILVER POINT     152070    WL N2                  C 3   20
75 02  241500SILVER LEDGE MIN152100    WL N1     1  25TC   50B
75 02  241400BETWEEN 104+105 152104     L N2          B     B
75 02  242417SWAMP           152154    WL N2        25TL  200B
75 02  241400RMP SOUTH       152       SS N1     2    5M  100B
75 02  241400RUNOUT          152       SS N1     1   10M  100C
75 02  241500RUN OFF         152       HS N2     1  25TC  100B
75 02  241600UNCOMPAGHRE GOR.152       WL N2
75 02  250600SLIPPERY JIM    152061    WL N2          ML  100C
75 02  261100WILLOW SWAMP    15209543
75 03   11600THIRTY          152005    WL N2        10TR  600B
75 03   11600CAMP            152008    WL N3        75TR1000C
75 03   11600BROOKLYNS C     152017    WL N2         5TR  400B
75 03   11600BROOKLYNS D     152018    WL N2         5TC  400B
75 03   11600BROOKLYNS E     152019    WL N2        10TC  600B
75 03   11600BROOKLYNS F     152020    WL N2        10T   500B
75 03   11600BROOKLYNS G     152022    WL N2        10TR  600B
75 03   11600BROOKLYNS I     152024    WL N2         5TC  200A
75 03   11600BROOKLYNS L     152027    WL N2         5TL  300B
75 03   116001ST TWIN CROSS. 152031    WL N2         5TR  350B
75 03   116002ND TWIN CROSS. 152032    WL N2        10    400B
75 03   11600N MINERAL BRIDGE152033    WL N2        10    700B
75 03   11615MARMOT TOWN     152038    WL N2              100
75 03   11615LONGFELLOW      152039    WL N2              150
75 03   11400SLIPPERY JIM    152061    WL N1              100C
75 03   11400E RIVERSIDE L   152065    WL N2        10T   200C 2   20
75 03   11500DUNSMORE        152068    WL N2        25TC  250C                    1
75 03   11500JACKPOT         152071    WS N3G    2  50MC  150C 2   75
75 03   11600ROCKWALL        152101    WL N2                                      1
75 03   11600EAGLE           152104    WL N2          TL  300A
75 03   11600MULESHOE        152106    WL N2          TR  300A
75 03   11400JENNIE PARKER N 152140    WL N1         5T    50A
75 03   11400JENNIE PARKER S 152141    WL N1         5T    50A
75 03   11400CHAMPION        152144    WL N1         5T    50A
75 03   11400GOBBLERS KNOB   152151    WL N2         5TC  150B
75 03   11400SWAMP           152154    WL N2         5TL  100A
75 03   11400HENRY BROWN     152155    WL N2         5TR  100A
75 03   11400ENGINEER MT A   152159    WL N2         5TR  350B
75 03   11400ENGINEER MT B   152160    WL N2         5TC  150B
75 03   11400W LIME CK.AREA  152       WL N2              100
75 03   21200ANVIL           152001    WL N2          TC  250B
75 03   21200ANVIL           152001    WL N2          T   300B
75 03   21222ANVIL MT SHRINE 152001    WL N3  F       T   350C
75 03   21200WATER GAUGE     152002    WS N2     1   5TR  200B
75 03   21400BLUE WILLOW     152096    WL N1         5B    40C
75 03   21400BLUE POINT      152097    WL N1         5B    40C
75 03   21500GORGE AREA      152       WL N1
75 03   21400COMMODORE BASIN 152       WL N2              200B
75 03   60800US BASIN W      152035    SS N3     3  25TC  300C
75 03   62200RMP             152040    SS N1     2   5T    50B
75 03   60900MOTHER CLINE    152069    SS N2        25       B 3
75 03   62417DAISY HILL      152085     L N1
75 03   62417KING            152091     L N1
75 03   62417WILLOW SWAMP    152095     L N1
75 03   61135BLUE POINT      152097     LAU1         5TF   40B
75 03   60800BLUE POINT      152097    SS N2     1  25TC   80B 1    6
75 03   60600SILVER LEDGE MIN152100    SS N2     1   5TC  150B
75 03   61100MILL CREEK A    152104    SS N3                 C
75 03   60300ERNEST          152115    SS N2     1    ML
75 03   61400COAL BANK W     152158     L N1        25TF   35C                    1
75 03   62417PROSPECT BASIN  152        L N1
75 03   71030CEMENT FILL     15201971
75 03   71040CEMENT FILL     15201041
75 03   71115BROOKLYN G      15202241 SSAA2  M 1  25TC  300B
75 03   71400BROOKLYN H      152023    WL N2        10TC  200B
75 03   7    BROOKLYNS I     152025    WL N1
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75 03   7    BROOKLYNS K     152026   WL N1
75 03   71115CEMENTARY      15203042
75 03   71315E RIVERSIDE     15206449
75 03   7    WATER GAUGE N   152076    L N2       25TC 350C
75 03   71000FULL MOON GULCH 152084   SS N1    1   5TL  50A
75 03   7    BLUE WILLOW     152095   WL N1
75 03   71000BLUE POINT      152097   WL N1
75 03   71230ROCKWALL        152101   WL N2        5MR 100B 2  15
75 03   71115EAGLE           15210441 SSAA2  M 1  25TL    C
75 03   71115EAGLE           15210471
75 03   71115TELESCOPE       15210543 SSAA2  M 1  25TC    C
75 03   71030BATTLESHIP      15212842 SSAA2  F 2    TC 100A
75 03   70930SPRINGS         15214871  LA01       10TR  70A
75 03   70930W LIME CREEK    15215073
75 03   7    GORGE AREA      152      WL N1
75 03   7    IDARADO SNFSLIDE152      WL N1
75 03   90600BROOKLYN B      152016    L N2       25TR 100B
75 03   90600BROOKLYN B      152016    L N2       25TR 100B
75 03   90600BROOKLYN D      152018    L N2       25TC 125B
75 03   91000BROOKLYN D      152018    L N2
75 03   91100BROOKLYN J      152025   SS N2    1  50TC 200B
75 03   90600BROOKLYN L      152027    L N1       10TL  50B
75 03   916001ST TWIN CROSS. 152031   SS N2    1   5M  400B
75 03   916002ND TWIN CROSS. 152032   SS N2    1   5M  400B
75 03   91600N MINERAL BRIDGE152033   SS N2    1   5TC 400B
75 03   91430LONGFELLOW      152039    L N2             75
75 03   91600E RIVERSIDE L   152065   SS N2       25TC 250C 3 100
75 03   91600CLIFF           152067   WL N2        5TR 100C                     1
75 03   91000WILLOW SWMP.SHLD152095    L N1       25TC  50B                     1
75 03   90900BLUE WILLOW     152096    L N1       50    90                      1
75 03   91000BLUE POINT      152097   SS N2    1    TF  80B 3  90
75 03   90800SILVER LEDGE MIN152100   SS N1    1  10TL  50B                     1
75 03   91000ROCKWALL        152101   SS N1    1  50TF  50B 2  15               1
75 03   91630ROCKWALL        152101   SS N2    1   5TR 150B 2 100
75 03   91200EAGLE           152104   SS N2
75 03   90800MULESHOE        152106   SS N2
75 03   90900MINERAL BAS.AREA152      SS N2            150
75 03   91400RED MT S AREA   152      SS N2    1    T  100B
75 03   92100TRICO BASIN AREA152      SS N3         T  200C
75 03   90800CUTBNK.B/W 104-5152                                                1
75 03  101100SLIPPERY JIM    152061   DL N1             100
75 03  10    E RIVERSIDE     15206449
75 03  102100E RIVERSIDE L   152055    L N2        5TC 150C 3  45
75 03  102100MOTHER CLINE    152064    L N2       25MR 200B 3  45
75 03  111300BROOKLYNS B     15201673
75 03  110600ARCHIE          152034   SS N2    2  25TL 100C
75 03  110600US BASIN        152035   SS N3       25MC 100C
75 03  110600BIG HORN        152036    L N1      100    60C
75 03  110600RMP             152040    L N1
75 03  11    E RIVERSIDE     15206449
75 03  110600WILLOW SWMP SHLD152095    L N1         TR  60B                     1
75 03  112417WILLOW SWAMP    152095    L N1
75 03  110600WILLOW SWMP SHLD152095    L N2       25TL 150B
75 03  111100WILLOW SWMP SHLD1520958
75 03  110600BLUE WILLOW     152096    L N2      100TF  80C 6   3
75 03  111100BLUE POINT      152097    LA01                  2  30               1
75 03  112417BLUE POINT      152097    L N1
75 03  110600BLUE POINT      152097    L N2       90TF  90B 3  90               1
75 03  110600FENCE           152099   SS N1    1  25TR  30C
75 03  110600SILVER LEDGE MIN152100   SS N1    1  25TC  70B                     1
75 03  111830SILVER LEDGE MIN152100    L N2       25MR 200B 3  90
75 03  111230SILVER LEDGE MIN15210071 SSAL3  F 2  25TR 200B 6  75
75 03  111300SILVER LEDGE MIN15210071
75 03  110600ROCKWALL        152101   SS N1    1  50TF  70B                     1
75 03  110600ROCKWALL        152101   SS N1    1  50TF  70B 3   9
75 03  111300ROCKWALL        15210171 SSAL1    1  10TL 150B
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75 03  111300ROCKWALL          15210171 SSAL2    1  25TR 400B
75 03  111830EAGLE             152104    L N3       50TF2500C 3  45
75 03  110600TELESCOPE         152105   SS N2    1  25BF 200C
75 03  110600BULLION KING      152107    L N1       25
75 03  110600MILL CREEK B      152109   SS N2    1  90TC 300C
75 03  11    CHAMPION          1521443   LAA1
75 03  110600CLIFFS B/W104-5   152       L N2      100TF  90C
75 03  12    E GUADALUPE       152060    L N1            200B
75 03  12    E GUADALUPE       152060   SS N2            200
75 03  122417W RIVERSIDE       152074   SS N2    2   5ML 900C
75 03  12    WILLOW SWAMP      152095    L N2    5    TL 200B
75 03  121800WATERFALL         152147   SS N3    1  50TR 700B 4  70
75 03  121600E LIME CREEK      152149   SS N2       10     B    150
75 03  121500GOBBLERS KNOB     152151   SS N2        5ML 100B
75 03  121500S DEER CREEK      152153   SS N2    1   5TL 150B
75 03  121500S DEER CREEK      152153   SS N2    1  10TR 150B
75 03  121630SWAMP             152154   SS N2    1  10TC 300B
75 03  121630HENRY BROWN       152155   SS N2    1  50TC 250  4 200
75 03  120900ENGINEER MT A     152159   SS N3    1  50TF 450C
75 03  121500ENGINEER MT C     152161   SS N3    2  50ML 300C
75 03  12    COMMODORE GULCH 152         L N1
75 03  121500MULAS AREA        152      SS N1
75 03  12    GORGE + IRONTON 152
75 03  131200WILLOW SWAMP      152095   WL N1        5TR  50A
75 03  131200BLUE WILLOW       152096   WL N1        5M   50C
75 03  131200BLUE POINT        152097   WL N1        5ML  50C
75 03  131200ROCKWALL          152191    L N2        5ML 100B
75 03  131200COMMODORE BASIN 152        SS N2    1   5   300B
75 03  151500PIT               152004    L N2       10TC 650B
75 03  151500THIRTY            152005    L N3       25TC 500B
75 03  151500CAMP              152008   WL N2       10TR 400B
75 03  151500CEMENT FILL       152010   SS M1        3TL  50A
75 03  151500BROOKLYNS C       152017   DL N2       10T  300B
75 03  151500BROOKLYNS D       152018   DL N2       10T  300B
75 03  151500BROOKLYNS E       152019   DL N1       10T  300B
75 03  151500BROOKLYNS F       152021   DL N2       10T  100B
75 03  151500BROOKLYNS G       152022   DL N1       10T  300B
75 03  151500BROOKLYNS K       152025   DL N1       10T  300B
75 03  151500BROOKLYNS K       152025   DL N1       10T  300B
75 03  151500BROOKLYNS L       152027   DL N1       10T  300B
75 03  151500BROOKLYNS M       152029   DL N1       10T  300B
75 03  151500N MINERAL BRIDGE152033     DL N2        5MC 100T
75 03  151500N MINERAL BRIDGE152033     DL N2            200M
75 03  151500MULESHOE          152106    L N2
75 03  151500MILL CK CIRQUE    152      DL N2
75 03  162100RED MT 3          152044   HS N3    3  25MR 700B
75 03  162100CORA BELL         152048   SS N2    2  50TC 700B
75 03  162000E RIVERSIDE       152064   HS N3 J  4    TR2500C 4  90
75 03  162100BROWN MT AREA     152      HS N3    6     M 500B
75 03  170100W RIVERSIDE       152074   SS N3    2  25TL1900C
75 03  181430ANVIL MT S FACE 152091     WL M3       10TL 900C
75 03  18    E RIVERSIDE       15206449
75 03  18    MOTHER CLINE      15206942
75 03  181200PORCUPINE         15210341
75 03  181200EAGLE             15210471 SSAL2  F 1  10TR1300B
75 03  181200EAGLE             15210443
75 03  181200EAGLE             15210472
75 03  181200TELESCOPE         15211541 SSAA3    1  25TC1900B
75 03  18    JENNIE PARKER S 15214172
75 03  18    PEACOCK           15214241
75 03  18    CHAMPION          15214471
75 03  18    CHAMPION          15214441
75 03  18    DEADWOOD          15214572
75 03  191400WATER GAUGE       152002   WL N2       10   300B
75 03  191400OLD S MINERAL RD152003     WL N2       25TC 250B
75 03  191400LOWER CEMENT FIL152004     WL N2       10TC 400B
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75 03   191400BENNY LONG      152014   WL N2        10TC 100B
75 03   191400BROOKLYN B      152016   WL N2        25TC 400B
75 03   191400BROOKLYN C      152017   WL N2        25TC 400B
75 03   191400BROOKLYN D      152018   WL N2        25TC 400B
75 03   191400BROOKLYN F      152020   WL N2        25TC 400B
75 03   191400BROOKLYN G      152022   WL N2        25TC 400B
75 03   191400BROOKLYN H      152023   WL N2        25TC 400B
75 03   191400BROOKLYN I      152024   WL N2        25TC 400B
75 03   191400BROOKLYN J      152025   WL N2        25TC 400B
75 03   191400BROOKLYN K      152026   WL N2        25TC 400B
75 03   191400BROOKLYN L      152027   WL N2        25TC 400B
75 03   191400BROOKLYN M      152029   WL N2        25TC 400B
75 03   191400N MINERAL BRIDGE152033   WL N2        50TF 400B
75 03   191200WHITE FIR       152072    L N2        10TC1400B
75 03   191400EAGLE           152104   WL N2        10   400B
75 03   191000GOBBLERS KNOB   152151    L N2          TF 250B
75 03   191000ENGINEER MT C   152161    L N2          TF 250B
75 03   191400TWIN SLIDES     152      WL N2        50TF 350
75 03   201400DUNSMORE        152068    L N2             200C                    1
75 03   202417G RIDGE         152089   SS N2      1   TC 500B
75 03   210900ITALIAN         152051   SS N2          MR1200B
75 03   211300LAKE            152077   WL M3        50TC 450C
75 03   211300BISMARK         152127   SS N2          TL 300A
75 03   211300BISMARK         152127   SS N2          TC 100A
75 03   211300GORGE AREA      152      WS N3G     1   T  450C
75 03   231800E RIVERSIDE R   152063   SS N2      1 25MC 200C 1  10
75 03   24     E RIVERSIDE    15205445
75 03   242417WILLOW SWAMP    152095   SS N2         2TL 200B
75 03   252230CHAMPION        152144   SS N2        25MC 200B 1  25              1
75 03   261100BROOKLYNS C     152017   SS M1      1  5TL 100A
75 03   261100BROOKLYNS D     152018   SS N2        25TR 600B
75 03   260800SLIPPERY JIM    152061   SS N2      1 10BL 300C
75 03   260900E RIVERSIDE     152064   SS N2      1  5BF 200C 6  90
75 03   260900MOTHER CLINE    152069   SS N2      1 25MF 250C 3  90
75 03   260900SILVER GULCH    152073   SS N2      1 10MC 500C
75 03   260900W RIVERSIDE     152074   SS N2      1 10MC 400C
75 03   260400BLUE POINT      152097   SS N2      2100TF 200C 6  30
75 03   260400BLUE POINT      152097    L N2       100TF 200C
75 03   262417MILL CREEK D    152111   SS N4      3 75MF 800C
75 03   260900MONUMENT        152      SS N2      1 50TC 200C
75 03   260900RALSTON CREEK   152      SS N2      1 25TC 500B
75 03   271300E RIVERSIDE S   15205446
75 03   271430JENNIE PARKER N 15214042
75 03   271430JENNIE PARKER S 15214141
75 03   271430PEACOCK         15214242
75 03   271445CHAMPION        15214442 SSAA2          TR
75 03   271200COAL CREEK      152158   SS N1      1 10TF  45C                    1
75 03   271100ENGINEER MT     152159   SS N3      2 75TF 450B
75 03   271100ENGINEER MT     152160   SS N3      2 80TF 500C
75 03   271100ENGINEER MT     152161   SS N3      1 80TF 500C
75 03   281050BROOKLYNS G     15202241 SSAA2    F 1 10TC 600B
75 03   281050BROOKLYNS L     15202741
75 03   280900SLIPPERY JIM    152061    L N2         5BC 100C
75 03   281230E RIVERSIDE     15206445
75 03   281230MOTHER CLINE    15206941  LAA2    F   10TC 200C 3  30
75 03   281230MOTHER CLINE    15206941  LAA2    F   10TC 200C 3  30
75 03   281230MOTHER CLINE    15206941  LAA2    F   10TC 200C 3  30
75 03   281300SILVER POINT    152070    L N1
75 03   280900WHITE FIR       152072   SS N3      1 25TR1200C
75 03   280900W GUADALUPE     152075    L N2         5RC 100C
75 03   281100BLUE POINT      1520974   LAU2    F   75TC 250C 3  30
75 03   280940ROCKWALL        152101    L N2    F    5MR 150B
75 03   280930EAGLE           152104    L N2         5BL 150C
75 03   281040EAGLE           15210441 SSAA2    F 1  5TR 100B
75 03   281040EAGLE           15210441  LAA2         5TC 100B
75 03   281030TELESCOPE       15210541 SSAA2    F 1 10TC 900B
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75 03  280900GORGE AREA      152         L N1
75 03  280900MONUMENT        152         L N1           TC 125C
75 03  280830MILL CREEK AREA 152        SS N2          10T  400B
75 03  301300PIT             152004      L N2          10TC 400B
75 03  301300THIRTY          152005      L N2          10TL 400B
75 03  301300OLD S MINERAL RD152033      L N2           5TL 250B
75 03  301300EARTH           152078     WL N2          25TC 500C
75 03  301400PORCUPINE       152103      L N2           5RL 150C                 1
75 03  301400H/W 104 + 105   152         L N2          10TF 150B
75 03  301400UPPR.MILLCK.AREA152         L N3            T  500B
75 04   11500WILLOW SWAMP    152095     SS N2       2  25TR 250B
75 04   11130BLUE POINT      152097      L N2          10TL 150C 3  40           1
75 04   11000BUCKWALL        152101      L N2           5ML 100C 2  30           1
75 04   12405SNOWSLIDE GULCH 152132     SS N3          50TL    C
75 04   12417SNOWSLIDE GULCH 152132     SS N3          50TL    B
75 04   11500CHAMPION        152144        N2                                    1
75 04   11600SWAMP           152154     SS N2           5TC 200B
75 04   11630HENRY BROWN     152155     SS N3       2 100TF 350C 6 500
75 04   41400ANVIL SHRINE    152001     WL N2            T  350B
75 04   41500OLD S MINERAL RD152033     WL N1          10T  350B
75 04   41500PIT             152004     WL N2           5T  350B
75 04   41400E RIVERSIDE S   152062      L N2          25TC 300C 3  50
75 04   41400E RIVERSIDE L   152065      L N2          10TC 350C 3 100
75 04   41200WILLOW SWAMP    152095      L N2
75 04   41400JENNIE PARKER N 152140     WL N2           5TR 200B
75 04   41200GOBBLERS KNOB   152151     WL N2           5TC 200B
75 04   61200GOBBLERS KNOB   152151     WL N2           5TC 200B
75 04   61200HENRY BROWN     152155     WL N2           5TR 150B
75 04  110900BROOKLYNS D     152018      L N2           5TC 300B
75 04  110900BROOKLYNS E     152019      L N2           5TR 300B
75 04  110900BROOKLYNS G     152022      L N2           5TL 650B
75 04  121300ANVIL           152001      L N2            T  500B
75 04  121200E LIME CREEK    152149      L N2           5M  100C 2  30
75 04  121200W LIME CREEK    152150     SS N2       1   5M  100C
75 04  121230SWAMP           152154     SS N2       1   5TC 200B
75 04  121230HENRY BROWN     152155     SS N2       2  10TL 100C 5 200
75 04  121200ENGINEER A      152159     SS N2       1  50T  400C
75 04  121200ENGINEER B      152160     SS N2       1  25T  400B
75 04  121200ENGINEER C      152161     SS N2       1  25T  400B
75 04  131300ANVIL           152001      L N2            T  500B
75 04  131700HOPI            152007     WL N2          10TC 600B
75 04  13     CAMP           152008      L N3       2  50TR1200B
75 04  130500BROOKLYNS B     152016     SS N2       1  10TF 300B
75 04  131200BROOKLYNS D     152018      L N2       1  10TC 400B
75 04  130500BROOKLYNS E     152019     SS N2       2  10TR 600B
75 04  13     BROOKLYNS E    152019     WL N2           5TR 600B
75 04  130300BROOKLYNS F     152020     SS N3       2  90T 1000C                 1
75 04  130300BROOKLYNS G     152022     SS N2       1  75T  700B
75 04  131115BROOKLYNS H     152023     SS N2       1  10TC 600B
75 04  131300BROOKLYNS I     152024     SS N2       1  10TC 600B
75 04  131300BROOKLYNS L     152027     SS N2       1  10TC 400B
75 04  131300BROOKLYNS M     152028     SS N2       1  10TC 400B
75 04  130300TWIN CROSSINGS  152031     SS N3       1  10TR 400B
75 04  130300N MINERAL BRIDGE152033      L N2          25   600B
75 04  130300N MINERAL BRIDGE152033     SS N2       1  25   600B
75 04  130800US BASIN        152035     SS N2           5TR 300B
75 04  130500MARMOT TOWN     152038      L N1
75 04  130500LONGFELLOW      152039      L N1
75 04  130500RED MT 3        152044     SS N2           5TL 500B
75 04  130500GENESSEE 5      152045     SS N2            TL 400B
75 04  130300RED MT 2        152047     SS N2          15   700B
75 04  130300RED MT 2        152047      L N2          10   700B
75 04  130300RED MT 2        152047     SS M2       2  10MR 400B
75 04  130500E GUADALUPE     152060      L N1
75 04  131200SLIPPERY JIM    152061      L N2
75 04  130500E RIVERSIDE     152064      L N1
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75 04  131330E RIVERSIDE L   152065  WL N2      10TR 300C 2  60
75 04  130500E RIVERSIDE L   152065  SS N3   2  50MF 300C 7 150
75 04  130500N EMERGENCY PHON152066  SS N2   1  50M  100C 4  75                1
75 04  130500MOTHER CLINE    152069  SS N3   1 100TF 400C 5 800
75 04  130500WHITE FIR       152072   L N1
75 04  130500SILVER GULCH    152073   L N1
75 04  130500W GUADALUPE     152075   L N1
75 04  130500WATER GAUGE N   152076   L N1
75 04  131200WATER GAUGE N   152076   L N2
75 04  130500DAISY HILL      152085   L N1
75 04  130500GALENA LION GLCH152088   L N1
75 04  130500GOVERNOR GULCH  152090   L N1
75 04  130500GOVERNOR GULCH  152090   L N1
75 04  130500KING            152091   L N1
75 04  130500KING            152091   L N1
75 04  130500WILLOW SWAMP    152095   L N2      10TL 300B
75 04  13    BLUE WILLOW     152096   L N2       5T  200C                      1
75 04  130500BLUE POINT      152097   L N1
75 04  130300BLUE POINT LEFT 152097  SS N2   1  10T  200C 5 100                1
75 04  131200SILVER LEDGE MIN152100   L N2
75 04  130500ROCKWALL        152101  SS N2   1  10TR 150C 2 250
75 04  131200ROCKWALL        152101   L N2
75 04  130500PORCUPINE       152103   L N2       5BF 125C 2  40                1
75 04  130300EAGLE           152104  SS N2   2  10TL1900B
75 04  131130EAGLE           152104   L N2       5MR 600B
75 04  13    TELESCOPE       152105  SS N2   2  20TR 200B
75 04  13    MULESHOE        152106  SS N3   1  50TF2000B
75 04  13    BULLION KING    152107  SS N3   2  75TF2400C
75 04  130300MILL CREEK A    152108  SS N2      25  1000C
75 04  130300MILL CREEK B    152109  SS N2      25  1000C
75 04  130300MILL CREEK C    152110  SS N2      25  1000C
75 04  130300MILL CREEK D    152111  SS N2      25  1000C
75 04  130300MILL CREEK E    152112  SS N2      25  1000C
75 04  130300MILL CREEK F    152113  SS N2      25  1000C
75 04  130500BATTLESHIP      152128   L N1
75 04  130500PICKLE BARREL   152131   L N1
75 04  131200E LIME CREEK    152149   L N2
75 04  131200W LIME CREEK    152150   L N2
75 04  131200GOBBLERS KNOB   152151   L N2
75 04  130300ENGINEER A      152159   L N2   5        100B
75 04  130300ENGINEER A      152159  SS N2   5        300B
75 04  130300ENGINEER B      152160  SS N2   1  10TC 300B
75 04  130300ENGINEER C      152161  SS N2   1  10TC 300B
75 04  130500RED MIN.PASSAREA152      L N1
75 04  130500RUBY CLIFFS     152      L N1
75 04  131200MONUMENT        152      L N2
75 04  131300TURKS HEAD AREA 152     SS N2   2     T  200B
75 04  131200UNCOMPAGRE GORGE152     WL N2
75 04  130300MINERAL BAS.AREA152     SS N3   2     T  300C
75 04  132417TWILIGHT PK.AREA152     SS N4      75T     C
75 04  142405TWILIGHT PK.AREA152     SS N4      75T     C
75 04  15    BROOKLYNS D     152018  WL N2      25TF 450B
75 04  151600BROOKLYNS J     152025  WL N2       5TR 500B
75 04  151430E LIME CREEK    152149  WL N1        TC    C 2   5
75 04  182100EAGLE           152104   L N2      10TL1800B
75 04  182100TELESCOPE       152105   L N2      10TR1200B
75 04  181500MULESHOE        152106   L N2       5TC 500B
75 04  182100MULESHOE        152106   L N2      10TC1600C
75 04  182100MILL CREEK F    152112  SS N2   2  25TC1000C
75 04  181500MILL CREEK G    152114     N2              C                      1
75 04  181900COMMODORE GLAREA152     SS N2   2           600
75 04  182417PROSPCT BAS.AREA152     SS N3   3     TF1000C
75 04  181900TRICO BASIN AREA152     SS N3   2     T 1200C
75 04  191200ANVIL           152001  WL N2        TL 700B
75 04  191300N MINERAL BRIDGE152033   L N2       5TL 700B
75 04  191600SILVER POINT    152070  WL N2              B 6  50
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75 04  191200WILLOW SWAMP    152095    L N2        5TL 150B
75 04  191300BLUE POINT      152097    L N2       10TR 200                            1
75 04  191200EAGLE           152104    L N2        5TR 450B
75 04  201200BROOKLYNS B     152016    L N2        5TC 300B
75 04  201200E GUADALUPE     152060   WL N2        5MC 300B
75 04  201200WHITE FIR       152072    L N2       10TL1000B
75 04  201200SILVER GULCH    152073    L N2        5ML 400B
75 04  222417SLIPPERY JIM    152061   WL N2       10MF 175C
75 04  231300G RIDGE         152089   WL N2       10TC 250B
75 04  241400OLD S MINERAL RD152003   WL N2       10TC1000B
75 04  241600BROOKLYN G      152022   WL N3G      25TL 300B
75 04  241600BROOKLYN J      152025   WL N2       10TC 650B
75 04  241600N MINERAL BRIDGE152033   WL N2        5MC 350B
75 04  241400E GUADALUPE     152060   WL N2        5ML 400B
75 04  240600MOTHER CLINE    152069   WS N2G    2 10TR 200C 5  80
75 04  241200WHITE FIR       152072   WL N2        5TL 500B
75 04  241200SILVER GULCH    152073   WL N2        5ML 500B
75 04  241300W RIVERSIDE     152074   WL N2        5ML1400B
75 04  241200WATER GAUGE N   152076   WL N2       10MC 300C
75 04  241200DAISY HILL      152085   WL N2        5TR 200B
75 04  241400BLUE WILLOW     152096   WL N2       10TC 100C 1  20                     1
75 04  242417BLUE POINT      152097   WL N2       10TL 200C 1  20                     1
75 04  241200ROCKWALL        152101   WL N1                                           1
75 04  240950ROCKWALL        152101   WL N2        5ML 100B 4  80
75 04  241330PORCUPINE       15210341
75 04  241330EAGLE           15210443 WLAA3G F    10TC2100C 4 300
75 04  241330TELESCOPE       15210541
75 04  251630MOTHER CLINE    152069   WS N2G      50   300B                           1
75 04  251700MOTHER CLINE    152069   WS N2G                                          1
75 04  251700MOTHER CLINE    152069   WS N2G                                          1
75 04  251830MOTHER CLINE    152069   WS N2G        M  300B 6 100 1 1 1   1 1
75 04  251200HENRY BROWN     152155   WL N2        5ML 150C 1  10                     1
75 04  25    ENGINEER MT A   152159   WL N2        5TC 300B
75 04  280600RED MT I        152047    L N2         TC 400B
75 04  280500KING            152091    L N3     1 50TF 300B
75 04  280600BLUE POINT      152097    L N2       75TF    B 3  15                     1
75 04  280900BLUE PT         152097    L N2         TC 150C 1  10
75 04  280300MILL CREEK C    152110      N2
75 04  3015001ST TWIN CROSS. 152031   WL N2       10TC 300B
75 04  301200ROCKWALL        152101   WL N2        5M  100B                           1
75 05   21600EAGLE           152104   WL N2       10T  700B
75 05   21600MULESHOE        152106   WL N2       10T  700B
75 05   51045BLUE POINT      152097    L N2       10TL 200C 2  60
75 05   62405WILLOW SWAMP    152095   SS N2     1 10TL 200B
75 05   62417MILL CK F       152113      N2
75 05   72405WILLOW SWAMP    152095    L N2        5TL 150B
75 05  112417ENGINEER MTN C  152161   WS N2     1 10MC 100B
75 05  131400SILVER LEDGE MIL152102   WL N2G       5M  150B                           1
75 05  141400MCINTYRE GL     152087   WL N3G    5 10TC1000B
75 05  141500OPHIR PONG W    152126   WL N2       10TL 600B
75 05  151400EAGLE           15210443
75 05  151410TELESCOPE       15210541
75 05  152417ENGINEER MTN    152      WS N3     5   M  400C
75 05  152417ENGINEER MTN    152      WS N3G    5   M  400C
75 05  162417COLONY          152053   WS N3G    5 25MC2000C
75 05  162417E GUADALUPE     152060   WS N3G    8 25TL2600B
75 05  171600PEACOCK         152142   WL N3G      75TC 700B10  70
75 05  302417MILL CK D       152111   WS N3     1 25TR 300B
75 05  302417MILL CK F       152112   WS N3     1 25TR 400B
75 05  302417SNOWSLIDE GL    152132   WS N3     1 50TC1300B

                AVALANCHE OCCURRENCES, STATION 153, 1974-75

74 11  112417WESTERN         153033   SS N2     2  5MC 300B
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74 11   292417ARCADE          153008   HS N2        5TC 200B
74 12   142405IDAHO GULCH     153004   HS N2    3    MR 200B
74 12   232405IDAHO GULCH     153004   SS N2       10TR    B
74 12   272417DENVER          153001                    600C
74 12   272417RIO GRANDE      153002                    400B
74 12   292405WESTERN         153003   SS N2    3   5TR 600B
74 12   292405WESTERN         153003   HS N3    5  10TC1200B
75 01   122405RIO GRANDE      153002   HS N2    5     M 200B
75 01   122405IDAHO GULCH     153004   HS N3       25TC 900B
75 01   151500RIO GRANDE      153002   HS N2G        MC 400B
75 01   2809008TH STREET      153005   SS N3                 C
75 01   2809009TH STREET      153006   SS N3                 C
75 01   280900ARCADE          153008   SS N3
75 01   311100IDAHO GULCH     153004   SS N3    3  25TL3500C
75 02   230730DENVER          153001   SS N3    3  50T 1200C
75 02   230600RIO GRANDE      153002   SS N3
75 02   230900IDAHO GULCH     153004   SS N1         T  700B
75 03   242417KING SOLOMON IV 153      HS N4    7  60MF2600C
75 04   131300BOULDER MT      153      SS N2    2        200
75 05   172417ARCADE          153008   WL N2G       5MR 450B
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AVALANCHE OCCURRENCES, STATION 157, 1974-75

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74 11   241400BOULDER GULCH F 157      SS N2    2  25TF1200C
74 12    32417BOULDER GLCHAREA157      SS N3G   2    M 1000C
74 12   142405IRENE AREA      157      HS N2         TR 400B
75 01    92405RIO GRANDE      153002   SS N3       50      C
75 01    92405IDAHO GULCH     153004   SS N2        5B  300C
75 01    91155IRENE           15700543
75 01    91155IRENE           15700541 SSAA2  P      TR
75 01    90200IRENE           157005   SS N2          M
75 01    90200IRENE           157005   SS N2          B
75 01    9    IRENE           157005   SS N3G
75 01    90300BAD NUMBER      157013   SS N
75 01    90300ERIE            157014   SS N
75 01    90300MICHIGAN        157015   SS N
75 01    90300FAIRVIEW        157016   HS N3    3  25TF1500C
75 01    90300BEATLES         157017   SS N
75 01    90300STONES          157018   SS N
75 01    90300WHO             157019   SS N3G   3  75TC 900C
75 01    90300CREME           157020   SS N3G   3  50TC 500C
75 01    90300GEORGIA GULCH   157021   SS N
75 01    90300STUMP           157022   SS N
75 01    90300DUMP S          157025   SS N3G   1  75T  300C
75 01    90300W JUMP A        157028   HS N3       75TL1000C12  60
75 01    90300W JUMP B        157029   HS N4    3    TF1000C15 120
75 01    90300MOGUL           157030   HS N3    3  50ML 900C12 160
75 01    9    BIG COLORADO    157032   SS N3    3  75T 1400C
75 01    92000HALF TRACK      157038   SS N3       75T  900C
75 01    90300DRY GULCH S     157039   HS N3    3  75TF1400C
75 01    90300ILLINOIS GULCH  157044   HS N3    5  10T 1500
75 01    90300FLORENCE        157      SS N3    3  75TF 700C 2   30
75 01   112417ARCADE          157008   HS N3    5  50TL2000C
75 01   112417MINNESOTA GULCH 157010   HS N4G       5TC1000B
75 01   112000BEATLES         157017   SS N4G   5  75TF 900C
75 01   112000STONES          157018   SS N3G   3  75TL 900C
75 01   111124UMDUMP N        157026   SS N3    3  25MR 400C
75 01   112000DRY GULCH N     157027   HS N3    3  25TL 900C
75 01   112417MOGUL           157030   HS N2    3  10TL 300B
75 01   112417STRING          157034   SS N4    3 100T  900C
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75 01  112417ROPE             157033    SS N4       100TF 400C
75 01  112417RAYE             157040    SS N2     3  10M  200C
75 01  112417GRASSY GULCH     157043    SS N3
75 01  112417SWAYSEA BASIN    157       SS N3
75 01  112000WOGGINS SLIDE    157       SS N4G    3  75T      C 6 200
75 01  120300HENRIETTA GULCH  157004    SS N3     3  50TL1200B
75 01  120300RED POINT S      157008    SS N4       100TF     C 4  60
75 01  120300RED POINT N      157009    SS N2        50       B
75 01  120300ERIE             157014    SS N4G    3  75T 1100C 7 150
75 01  120300MICHIGAN         157015    SS N4G    3 100T 1000C 3  20
75 01  120300FAIRVIEW         157016    HS N3G    3  25TL1400C
75 01  120300THREAD           157033    SS N2               200B
75 01  121203ZZF JUMP         157036    SS N4     3 100T  900C 6 100
75 01  120300S E JUMP         157037    SS N4       100T  600C
75 01  120300HILLBOARD        157042    HS N3G    5  25TF1400C 3  75
75 01  120300FAIRVIEW R.SLIDE157        SS N1G    3    TF  75C 3 200
75 01  121100HANCOCKGLCH.AREA157        HS N4G    9    T
75 01  122405S.SHOULL.OHIO,PK157        HS N4     5       1000C
75 01  281150BERTRAMSVILLE    157    11 SSAS3  F  5 100TF  75C
75 02  100800FAIRVIEW         157016    SS N2     3    MR     C
75 02  100800S HANCOCK GULCH  157       SS N2     3    TF     C
75 02  10     PORCUPINE       157       HS N3        75T 1300C
75 02  172417FAIRVIEW         157016    SS N3        50TF1200C
75 02  172417BEATLES          157017    SS N2     2  75TF     C
75 02  172417STONES           157018    SS N2     2  75TF     C
75 02  172417WHO              157019    SS N2     2  75TF     C
75 02  172417CREME            157020    SS N2     2  75TF     C
75 02  172417DRY GULCH N      157027    SS N3                 C
75 02  17     ARASTRA GULCH   157       HS N3     3     R 300
75 02  191015IRENE            15700545  SSAA2  F 2A    TR 200A
75 02  191030DRY GULCH N      15702741  HSAA4G M 6R 90TF1500C12  90
75 02  200400CREME            157020    SS N2     1    TF 200B
75 02  201245DRY GULCH N      15702743  SSAA2  F       TR 500B
75 02  201250W JUMP A         15702441  SSAA3     3    TF     C
75 02  201250W JUMP B         15702942
75 02  201255MOGUL            15703044
75 02  212405BOULDER GULCH    157       HS N3     2     M 2000C
75 02  230900IRENE            157005    HS N3          TL1600B
75 02  230900FAIRVIEW         157016    HS N3     3  10TR1400C
75 02  230300BILLBOARD        157042    HS N3     3  10TC1500B
75 02  230900BONITA BASIN     157       HS N3     2        1000
75 02  230900BONITA BASIN     157       HS N3     5         650
75 02  230300LITTLE GIANT BAS157        HS N3     5         400C
75 02  230300PORCUPINE        157       HS N3              1800
75 03   60900MINNESOTA GULCH  157010    SS N2     3   SML  750B
75 03   60900UPPER CEMENT CK  157       SS N3     3    T   300B
75 04   60300WESTERN          153003    SS N2     2   STC  700B
75 04  131400MINNESOTA GULCH  157010    SS N3     1   ST   600B
75 04  131400GEORGIA GULCH    157021    SS N2     1   SML  100B
75 04  131400BILLBOARD        157042    SS N2     1   SM   300B
75 04  232417GALENA MT        157       WL N2              1200
75 04  241400KING SOLOMON I   157       WL N2G         SMR 600B
75 04  241600PORCUPINEB-VILLE157        WL N3G           T  400B
75 05  152417ARRASTRA GL      157       WS N3G    6      T 2000C
75 05  152417GALENA MTN       157       WL N3G           T 1500B
75 05  152000HEMATITE         157       WS N3G    8  25TL3000C
75 05  152417KING SOLOMON I   157       WL N3G          ML 400C
75 05  162417TOM MOORE        157       WS N5G    6  75TC1000C
75 05  171600ASPEN            157       WS N3G    4     TC 400C
75 05  172417BOULDER GL       157       WS N3G    6     TL2000B
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APPENDIX 3

AN EXAMPLE OF DATA FROM AN AVALANCHE ATLAS FOR SAN JUAN COUNTY, COLORADO: L. MILLER, B.R. ARMSTRONG AND R.L. ARMSTRONG

The following includes a description of the methods and terminology employed in the preparation of an Avalanche Atlas for San Juan County, INSTITUTE OF ARCTIC AND ALPINE RESEARCH Occasional Paper Number 17, 1976. An example of data from one avalanche path is also included.

An explanation of the terms used follows:

MAPS:

All maps are 7½' USGS topographic reproductions with a scale of 1" = 2000'. Each avalanche path is outlined and numbered. Arrows within a path indicate observed directions of flow of avalanche material. The outlines are only a rough boundary of the path and do not indicate absolute limits for land use planning purposes. These limits can only be established by a detailed ground study of the path in question.

PHOTOGRAPHS:

Photographs were taken with a 35 mm camera from a light aircraft. Only low level oblique photographs were taken. Each path is outlined on the photograph and numbered.

AVALANCHE SUMMARY SHEETS:

Path name(s): The common name or names currently used are given. Where more than one name is currently used, all are included.

Path reference number: All paths have been cataloged with a reference number which allows it to be placed in a computer for easy retrieval. The first three digits signify the station. The remaining three refer to the avalanche path. (A station number is a National Forest Service classification number for a highway, mine, or a town. A single station may include more than one zone).

Zone: A zone is a region of geographic similarity; for example the deep valley from Silverton to Gladstone (Cement Creek) is considered a single zone.

Area: This category groups paths with similar release characteristics.

Map number: Each map in the atlas is numbered. This number appears on all avalanche summary sheets to which it applies.

Photograph number: Each photograph is numbered. This number appears on all avalanche summary sheets to which it applies.

Specifications:

Elevations and vertical fall: Elevations and vertical fall are taken directly from 1:24,000 scale maps.

Path lengths: Path lengths are computed as the sum of the individually calculated lengths for each of the three segments of the avalanche path.

Number of starting zones: The number of starting zones are obtained from maps and field observations. In cases where the number of starting zones is difficult to obtain due to the complexity of terrain the term multiple is used.

Starting zone: The starting zone is the section of the path where the initial rupture of the snowpack occurs and the avalanche begins its downward course.

Track: The track is that section of the path that funnels or guides the mass of falling snow from the starting zone to the runout zone.

Runout zone: The runout zone is the section of the path where an avalanche comes to rest. This is the hazard zone principally because it is frequently characterized by valley bottom slopes which provide some of the few areas in mountains that have slopes gentle enough for construction purposes.

Slope, track, and runout angles: The angles for the starting, track, and runout zones were all calculated from map data and measurements taken from the maps by a scaled ruler.

Acreages: Acreages were calculated from data taken from maps by ruler.

Mean widths: Mean widths were measured on the maps.

Tree line: The tree line data were obtained from maps and field observations. The letter (B) indicates below timberline; (A) indicates above timberline.

Terrain and vegetation cover: Subjective descriptions of the terrain and vegetation of the paths are given including topographic features, vegetation cover and location.

HISTORY:

The history of each avalanche path is described in the following three categories:

I. Historical data for the period 1875-1938(B. Armstrong, 1976, Century of Struggle Against Snow - A History of Avalanche Hazard in San Juan County, Colorado.)

II. Data collected by the Colorado Highway Department for period 1951-1971
Data obtained from personal communications with Louis Dalla, Durango, Colorado; Herman Dalla, Silverton, Colorado; and James Bell, Silverton, Colorado, for period 1938-1971.

III. Data collected by the San Juan Avalanche Project, INSTITUTE OF ARCTIC AND ALPINE RESEARCH, University of Colorado, for period 1971-1975.

AVALANCHE SUMMARY SHEET

PATH NAME ('s): Eagle

Path Reference Number: 152104 Zone: IV Area: 6

Map Number: 3 Photograph Number: 16,17

SPECIFICATIONS:

Top Elev.: 12600' Bottom Elev.: 10400' Vertical Fall: 2200'

Length of Path: 4565' Number of Starting Zones: 3

	Starting Zone		Track	Runout Zone
Slope Angle	41°		31°	14°
Area Acres	11	Mean Width	500'	Area Acres 35
		Length	2332'	
Tree Line	Above		Below	Below

TERRAIN AND VEGETATION COVER:

Starting Zone: Broad open slope, smooth cliffs

Track: Upper portion: broad open slope with broad v-shaped drainages; Lower portion: drainages narrow to single v-shaped gully. Light coniferous, grass and bare ground

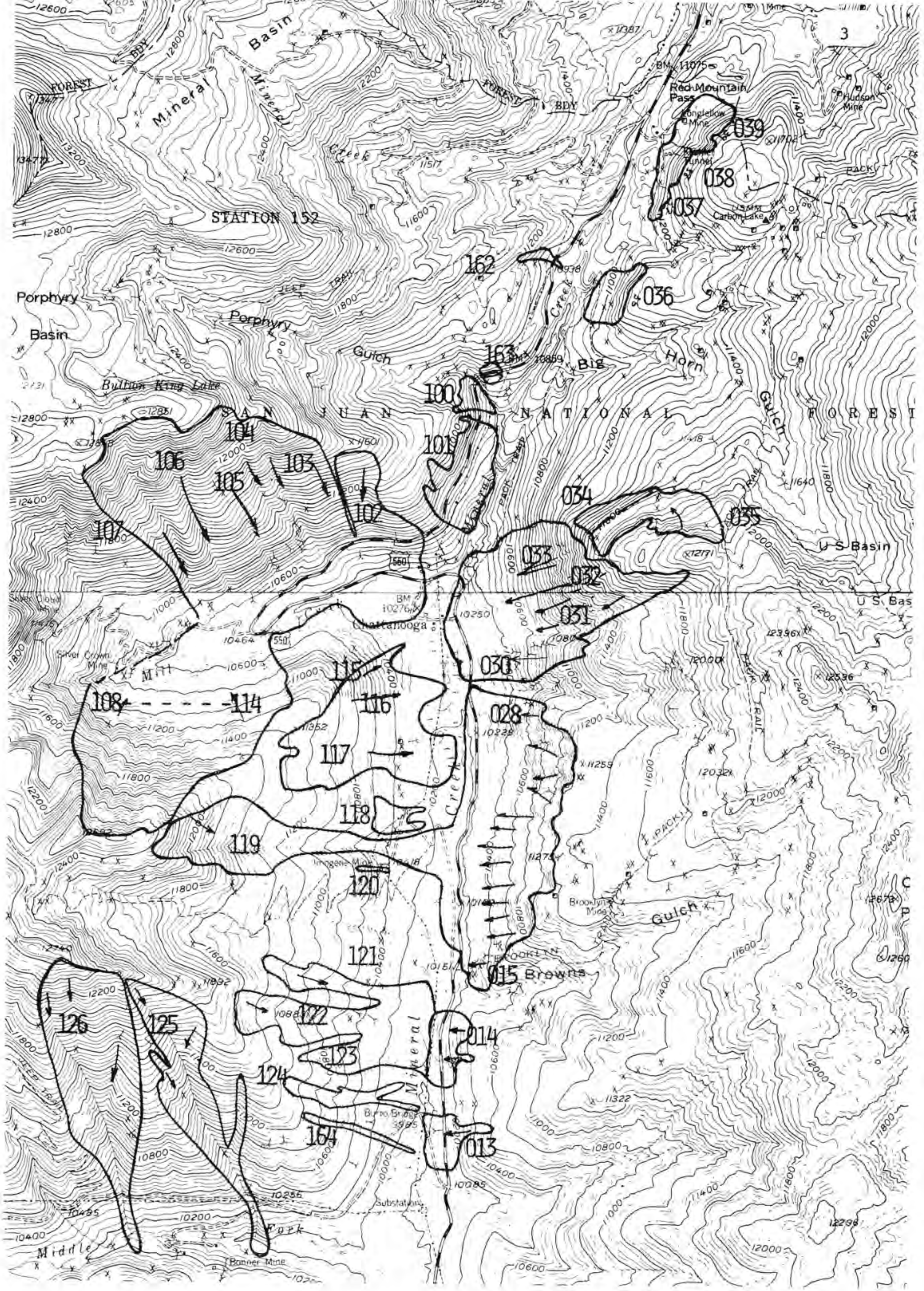
Runout Zone: Broadening fan, light coniferous, willows and grass

HISTORY:

Prior to 1951 — I. In March, 1884, the town of Chattanooga was struck by an avalanche from Independence Mt., northwest of town, which destroyed four buildings. The Independence mining claim is located in the Eagle slide path.

1951-1971 — II. crossed highway: 35
during the winter of 1951-1952, the Eagle ran 6 times

1971-1975 — III. events: 99
highway: 27
full-track: 38


Mineral Basin
Mineral Creek
FOREST BDY
STATION 152
Red Mountain Pass
Longfellow Mine
Hudson Mine
Carbon Lake
Porphyry Basin
Porphyry Gulch
Bullion King Lake
SAN JUAN NATIONAL FOREST
Big Horn Gulch
Creek
JEEP TRAIL
PACK TRAIL
U S Basin
Silver Cloud Mine
Silver Crown Mine
Mill
Chattanooga
550
Imogene Mine
Brooklyn Mine
Gulch
BROOKLYN
Browns
Burro Bridge
Substation
Middle Fork
Bonner Mine
Mineral
039
038
037
036
162
163
100
101
102
103
104
105
106
107
034
035
033
032
031
030
108
114
115
116
117
118
119
120
028
121
122
123
124
164
125
126
015
014
013
12600
12800
12400
12200
12000
11800
11600
11400
11200
11000
10800
10600
10400
10200
BM 11075
BM 10276
10250
10464
10228
10151
10085
10256
10495
10859
10938
11255
11275
11322
11640
12171
12336
12536
12296
11352
11892
12032
13477
11387
11517
11601


17
107
106
104
103
105
102

APPENDIX 4

FRACTURE LINE PROFILES

The following crystal-type symbols are used:

Unmetamorphosed New Snow

+	No Wind Action
⇸	Wind Action
V	Surface Hoar

Equi-temperature Metamorphism

λ	Beginning	[Decreasing]
⌀	Advanced	[Grain Size]
•	Beginning	[Increasing]
○	Advanced	[Grain Size]

Temperature-gradient Metamorphism

□	Beginning
Λ	Partial
Δ	Advanced

Melt-Freeze Metamorphism

〰	Sun Crust

Layer Hardness

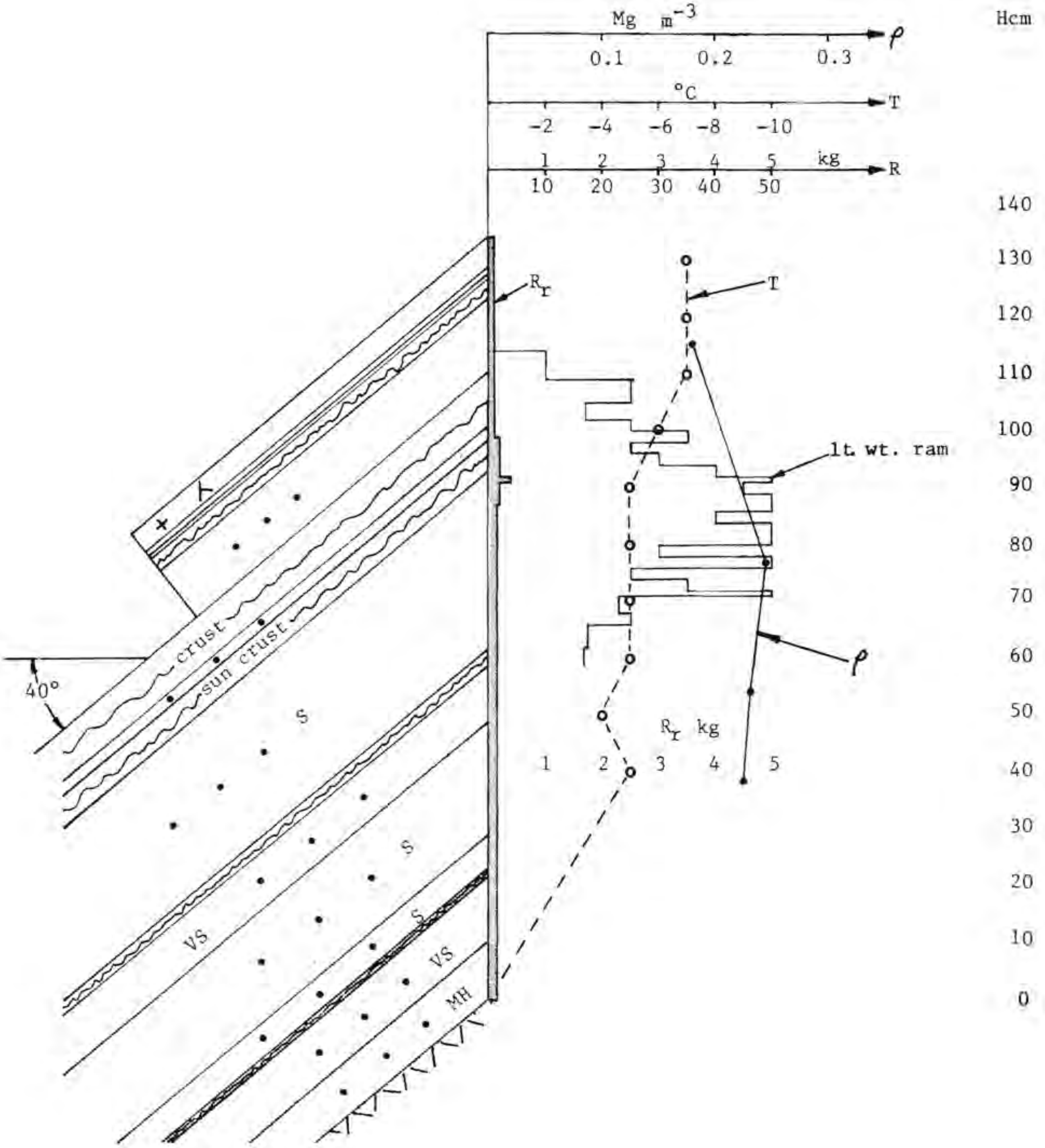
VS	Very Soft
S	Soft
MH	Medium Hard
H	Hard
VH	Very Hard

Crystal Size

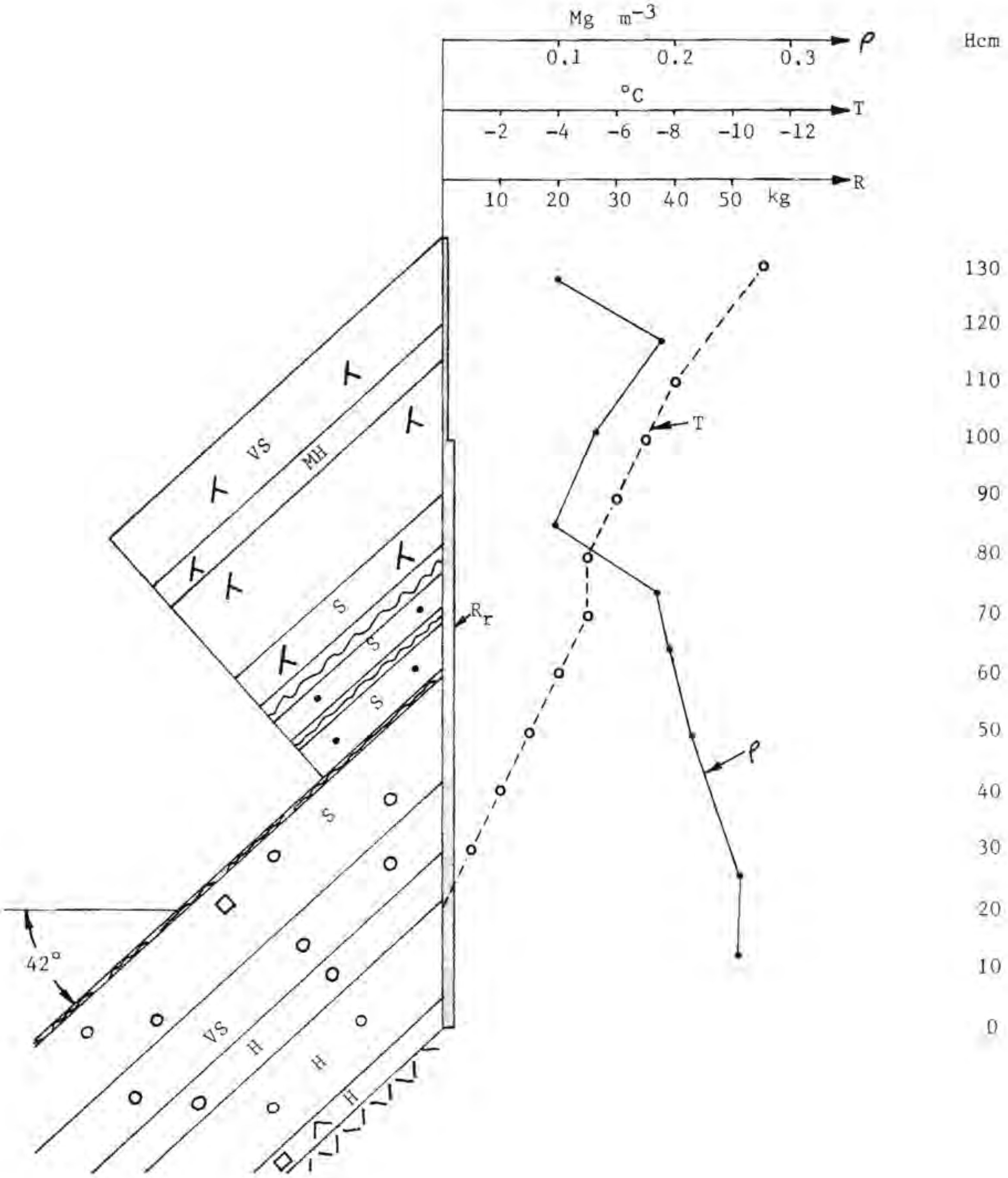
Provided as diameter in mm; e.g. 1.0-1.5 mm

⟶ Indicates transition between two crystal types.

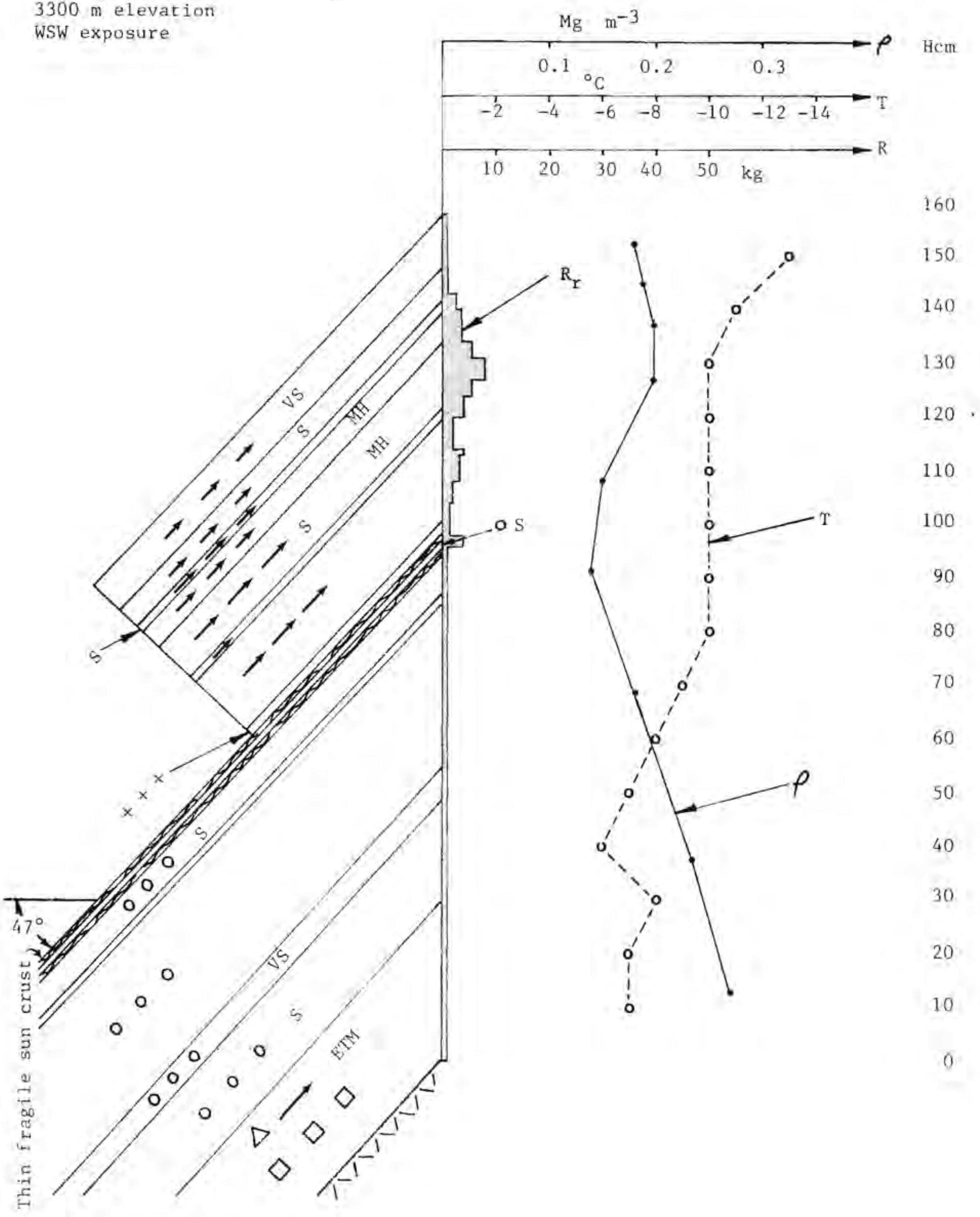
FRACTURE LINE PROFILE #1
1/2 mile SW of Red Mountain Pass
November 26, 1972
SS-N-1-O (November 26, 1972)
3600 m elevation
ESE exposure

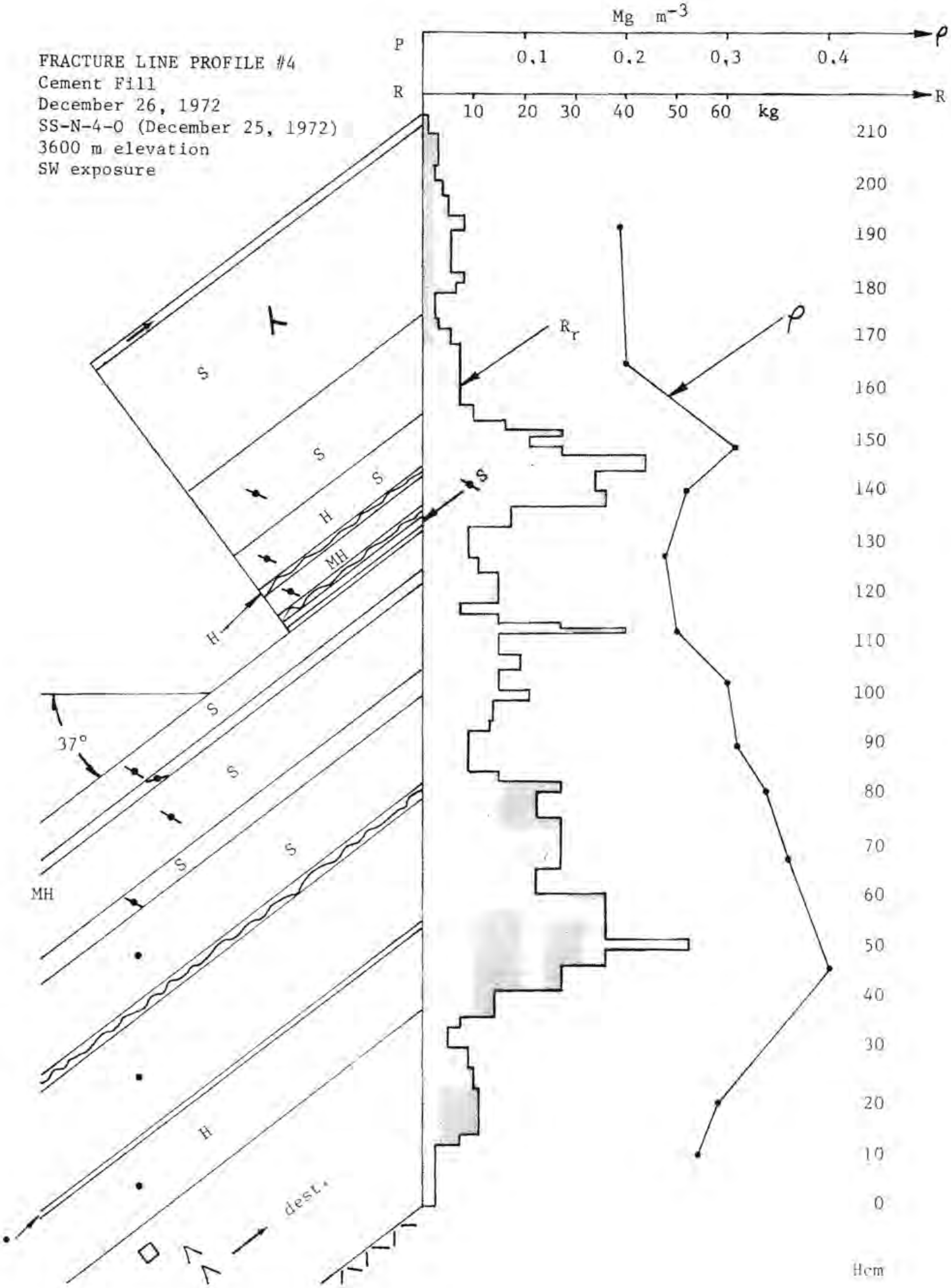


FRACTURE LINE PROFILE #2
Willow Swamp
December 6, 1972
SS-AA-3-O (December 5, 1972)
3400 m elevation
E exposure



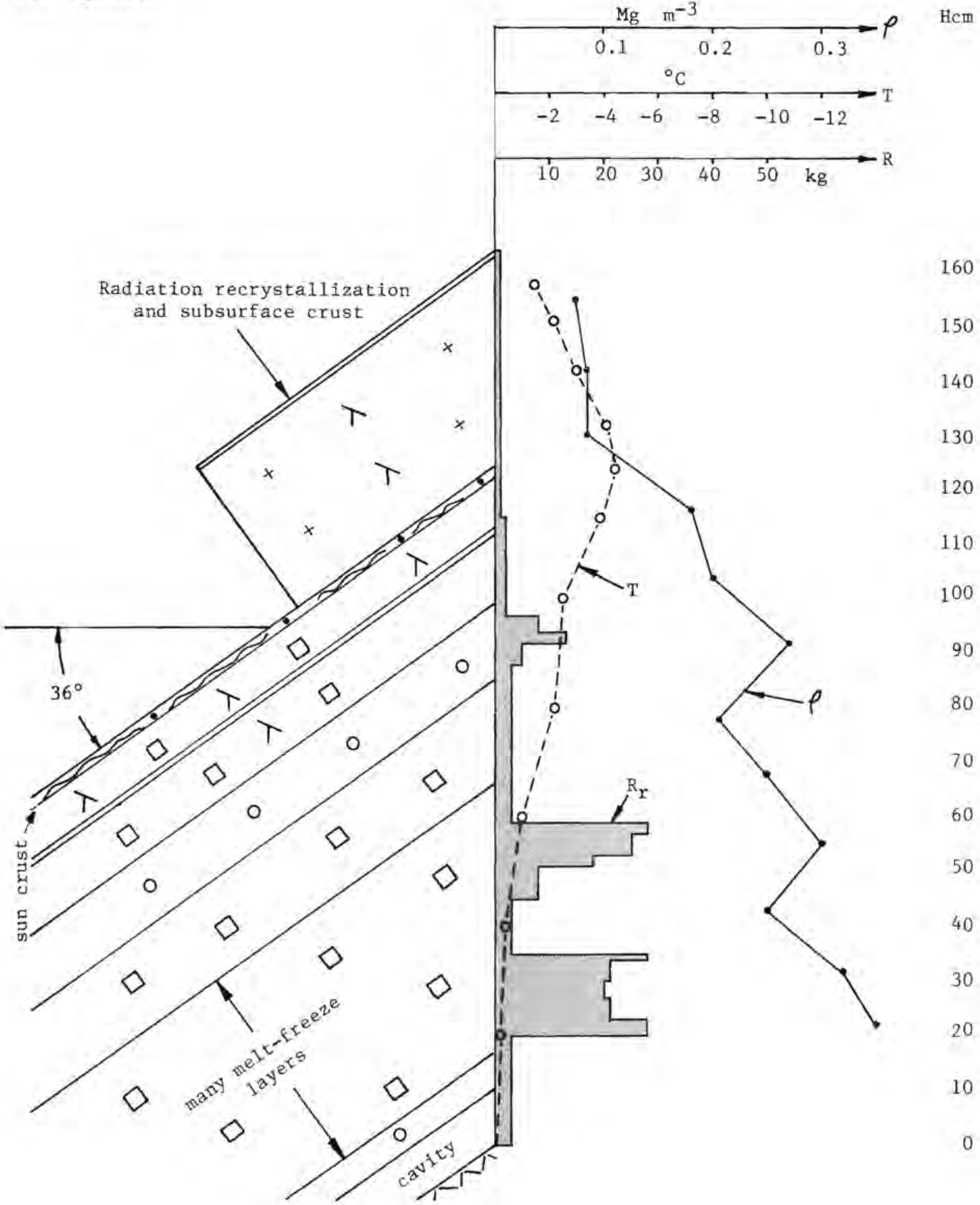
FRACTURE LINE PROFILE #3
No. Mineral Bridge
December 6, 1972
SS-N-2-0 (December 5, 1972)
3300 m elevation
WSW exposure



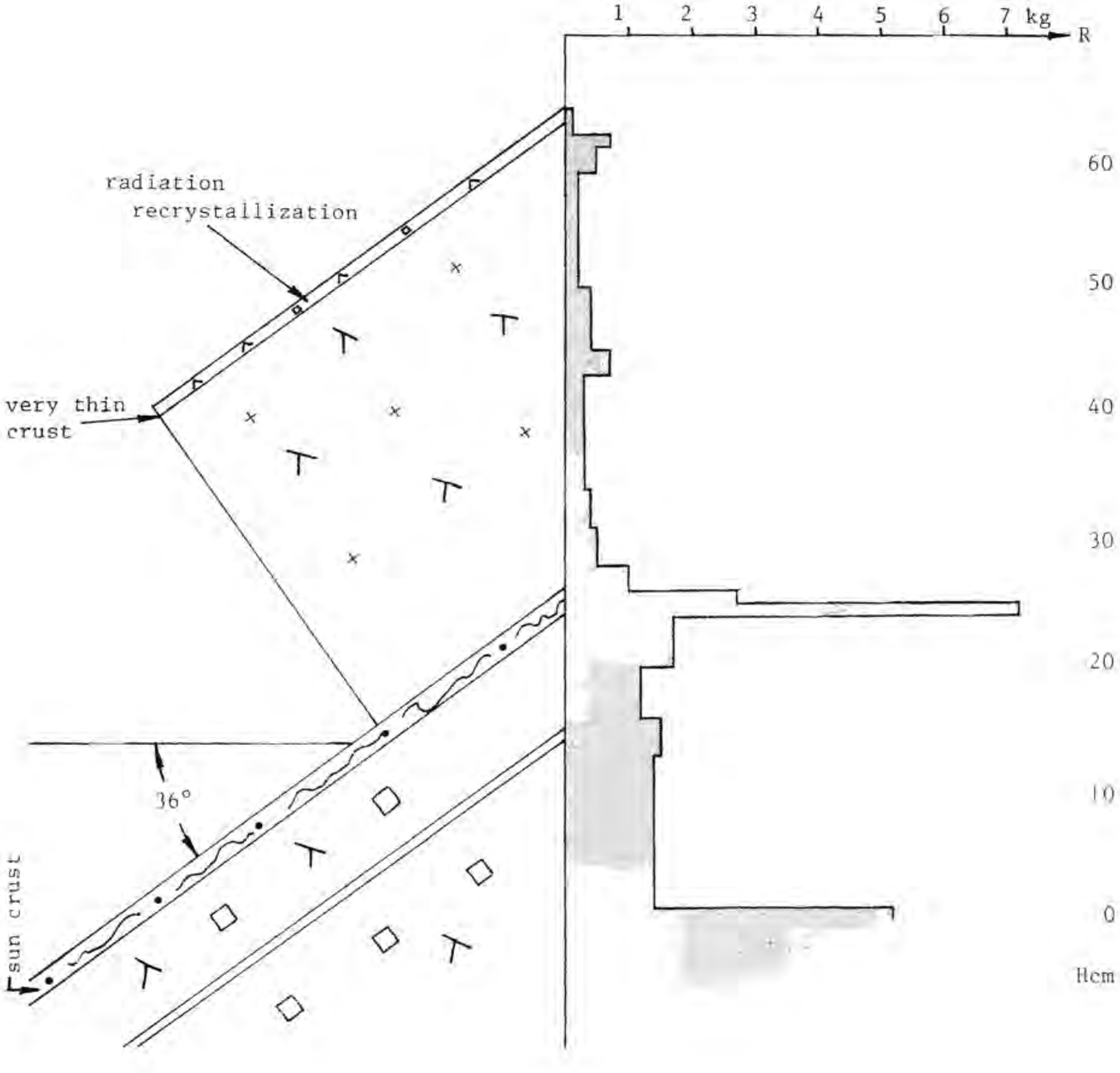


FRACTURE LINE PROFILE #4
Cement Fill
December 26, 1972
SS-N-4-0 (December 25, 1972)
3600 m elevation
SW exposure

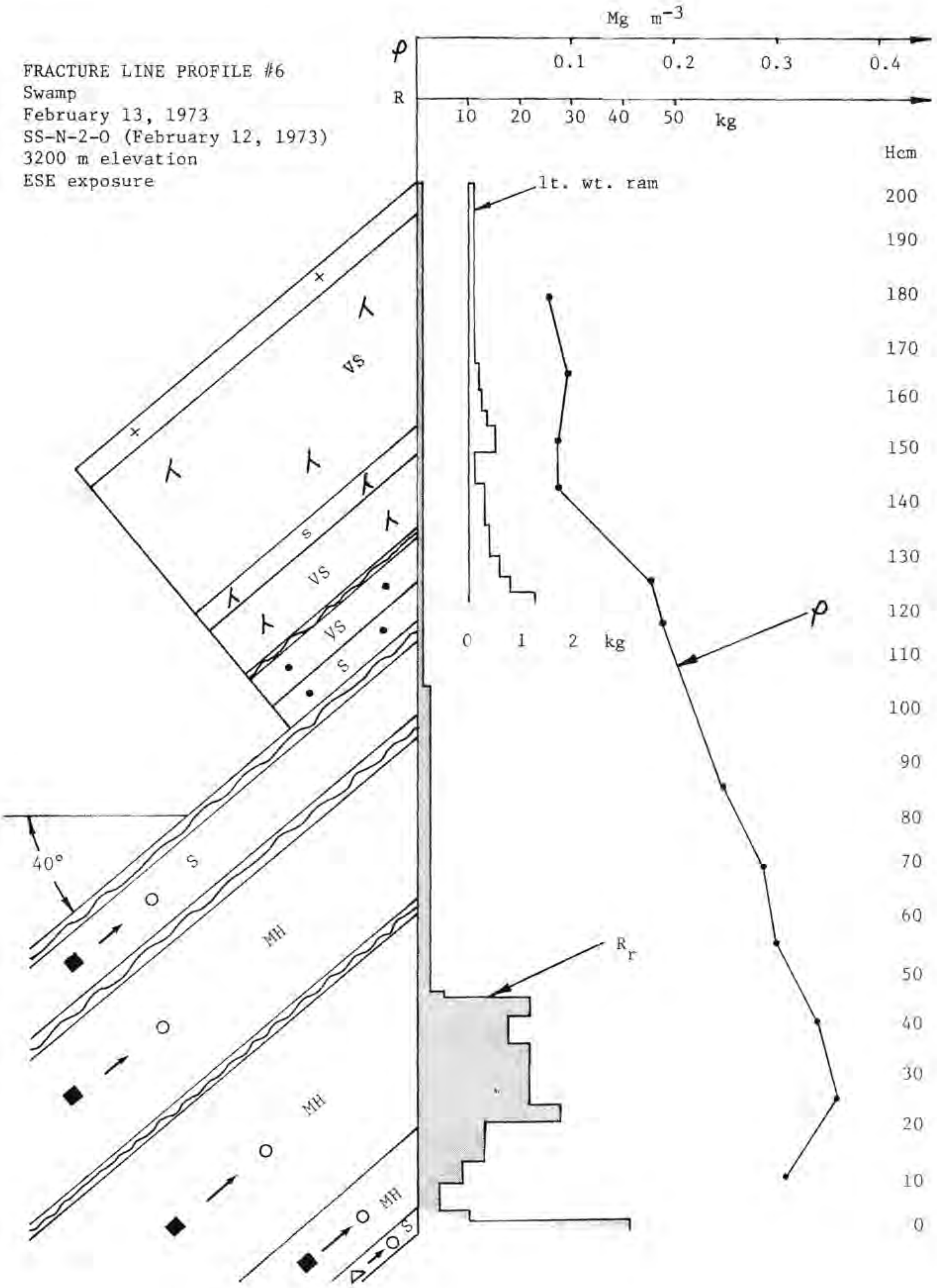
FRACTURE LINE PROFILE #5
Engineer A
January 6, 1973
SS-N-4-O (January 5, 1973)
3400 m elevation
SE exposure



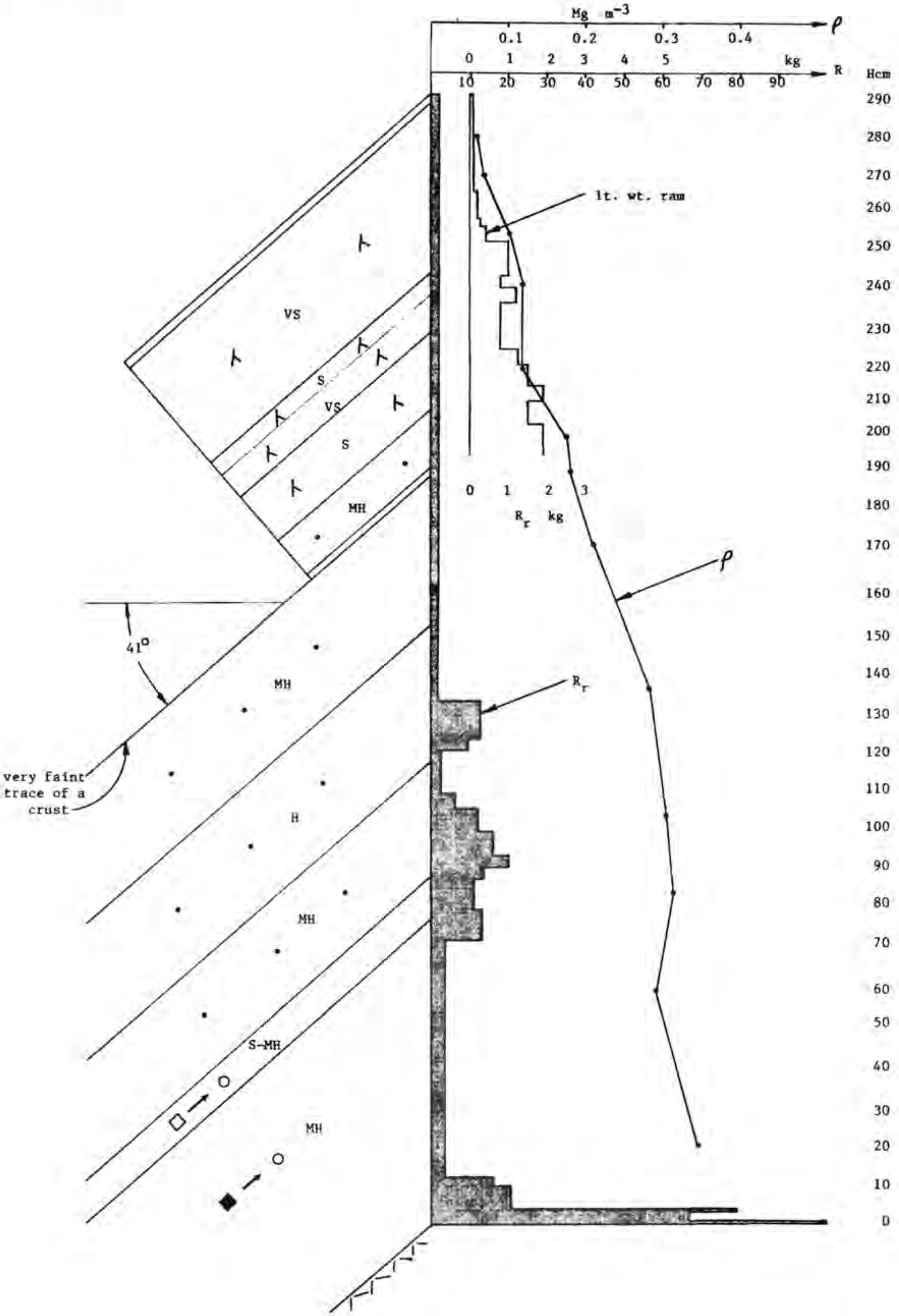
FRACTURE LINE PROFILE #5
Engineer A
January 6, 1973
Light-Weight (100 g) Ram Profile



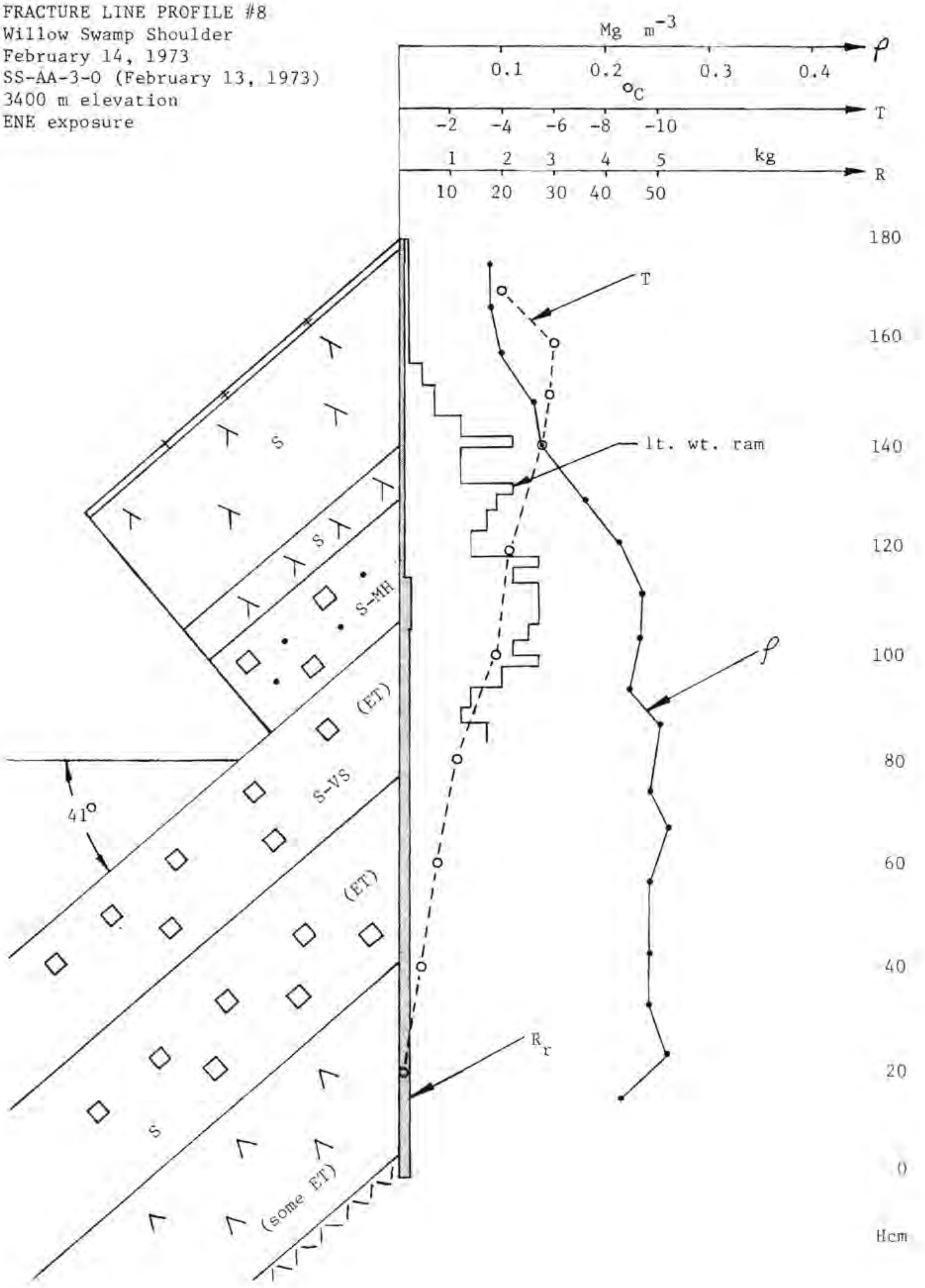
FRACTURE LINE PROFILE #6
Swamp
February 13, 1973
SS-N-2-O (February 12, 1973)
3200 m elevation
ESE exposure



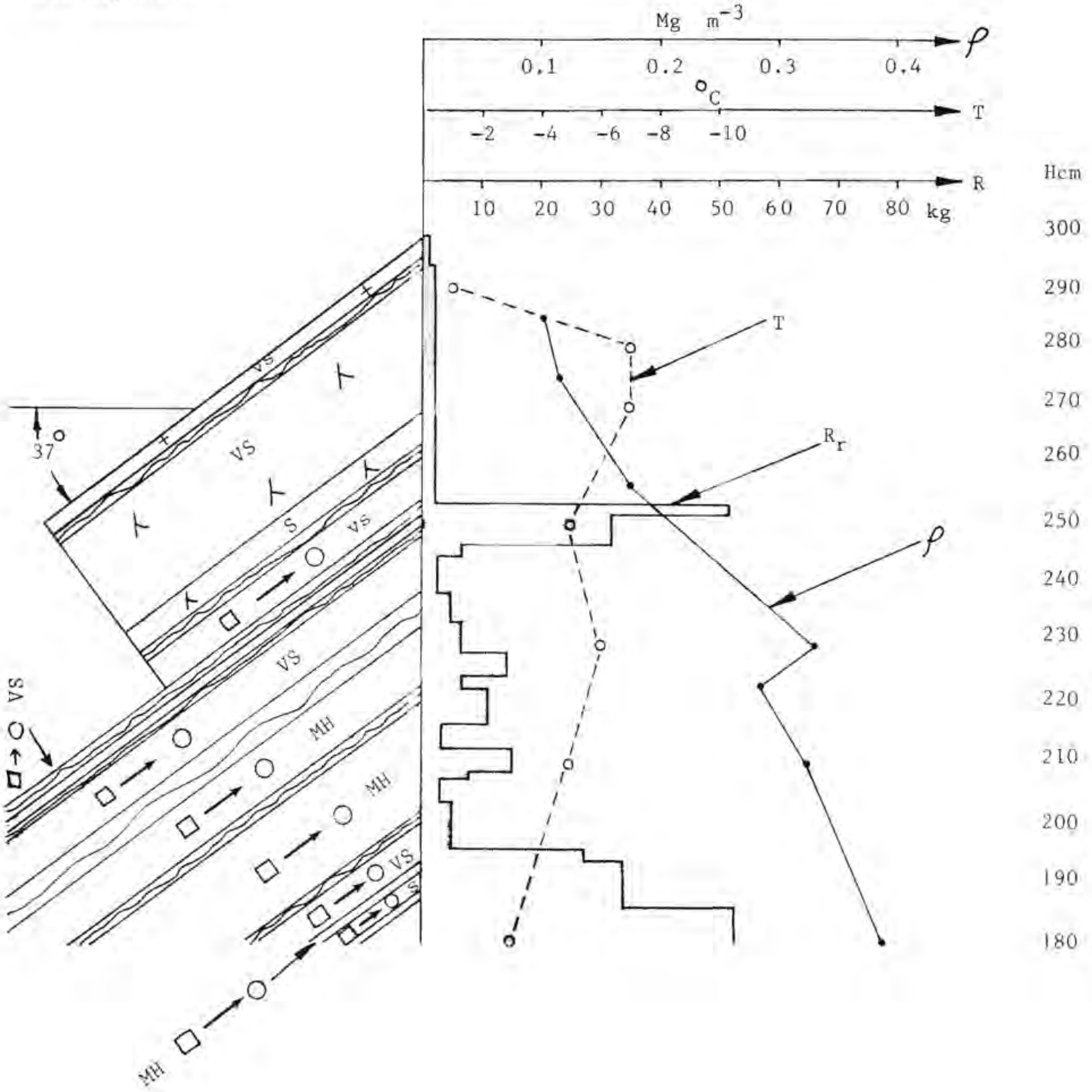
FRACTURE LINE PROFILE #7
North Shoulder of Potato Hill, Coal Bank Area
February 13, 1973
SS-N-2-0 (February 13, 1973)
3300 m elevation
N exposure

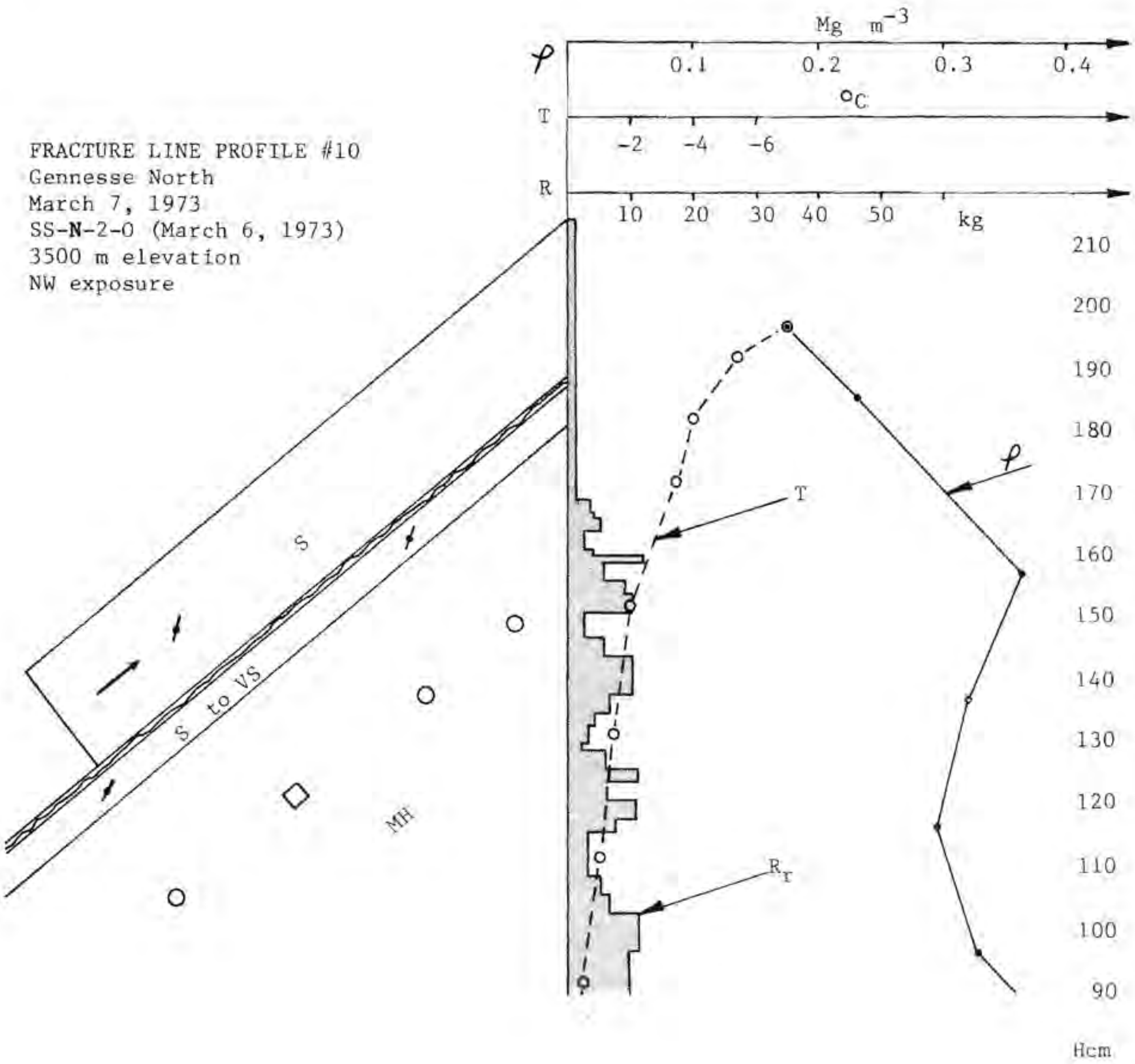


FRACTURE LINE PROFILE #8
Willow Swamp Shoulder
February 14, 1973
SS-AA-3-O (February 13, 1973)
3400 m elevation
ENE exposure



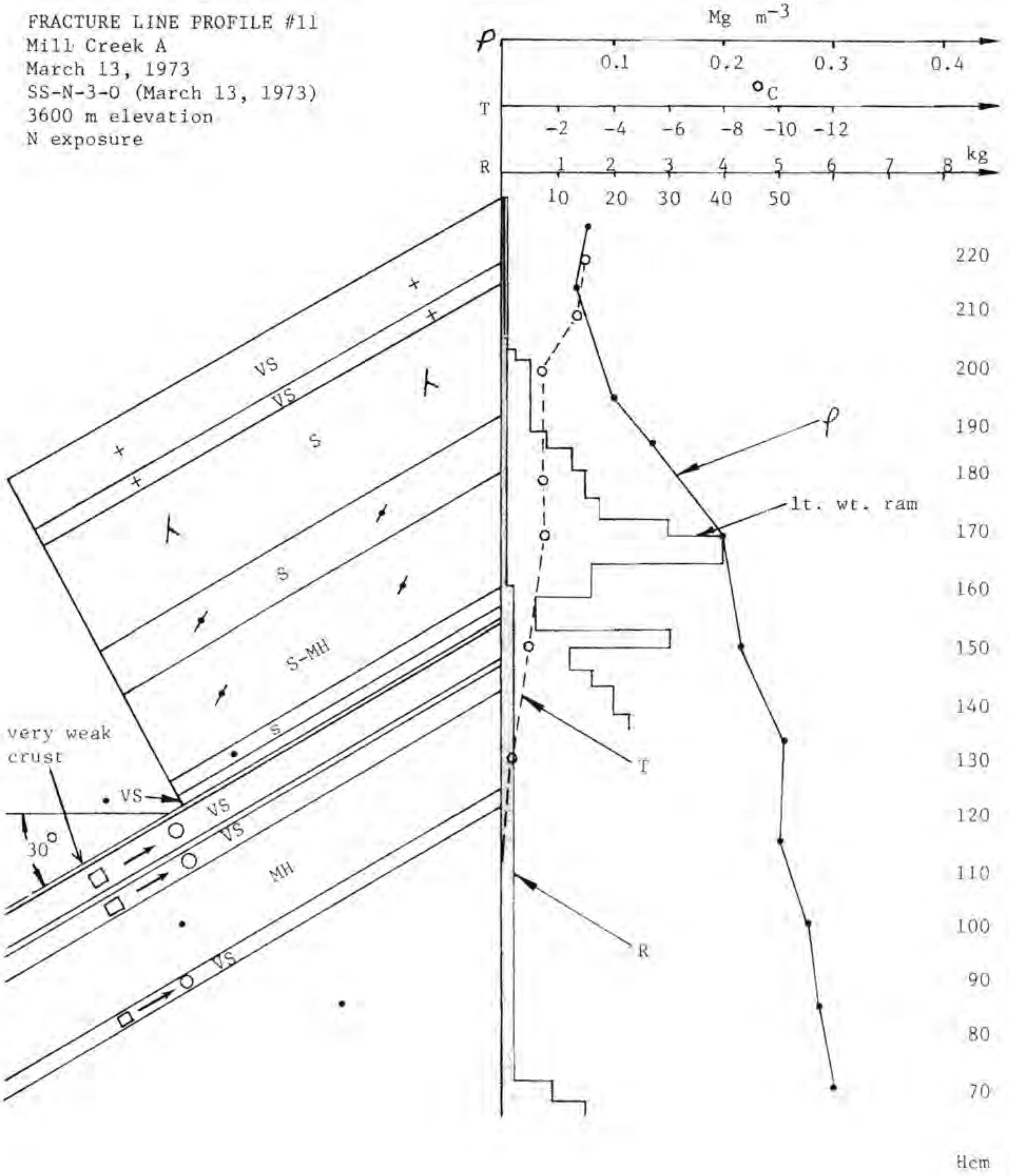
FRACTURE LINE PROFILE #9
Eagle
February 14, 1973
SS-AA-2-0 (February 13, 1973)
3800 m elevation
ESE exposure

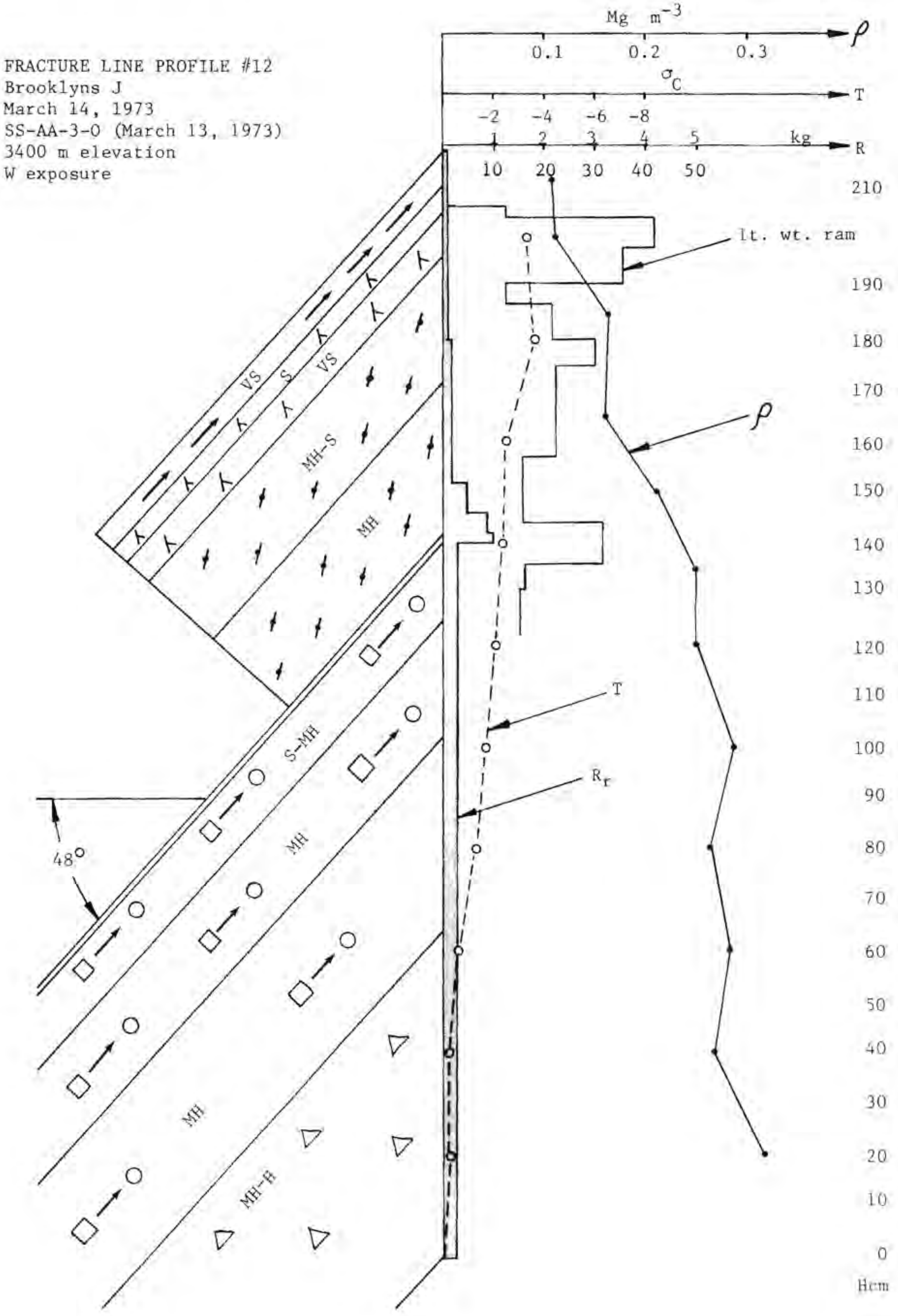




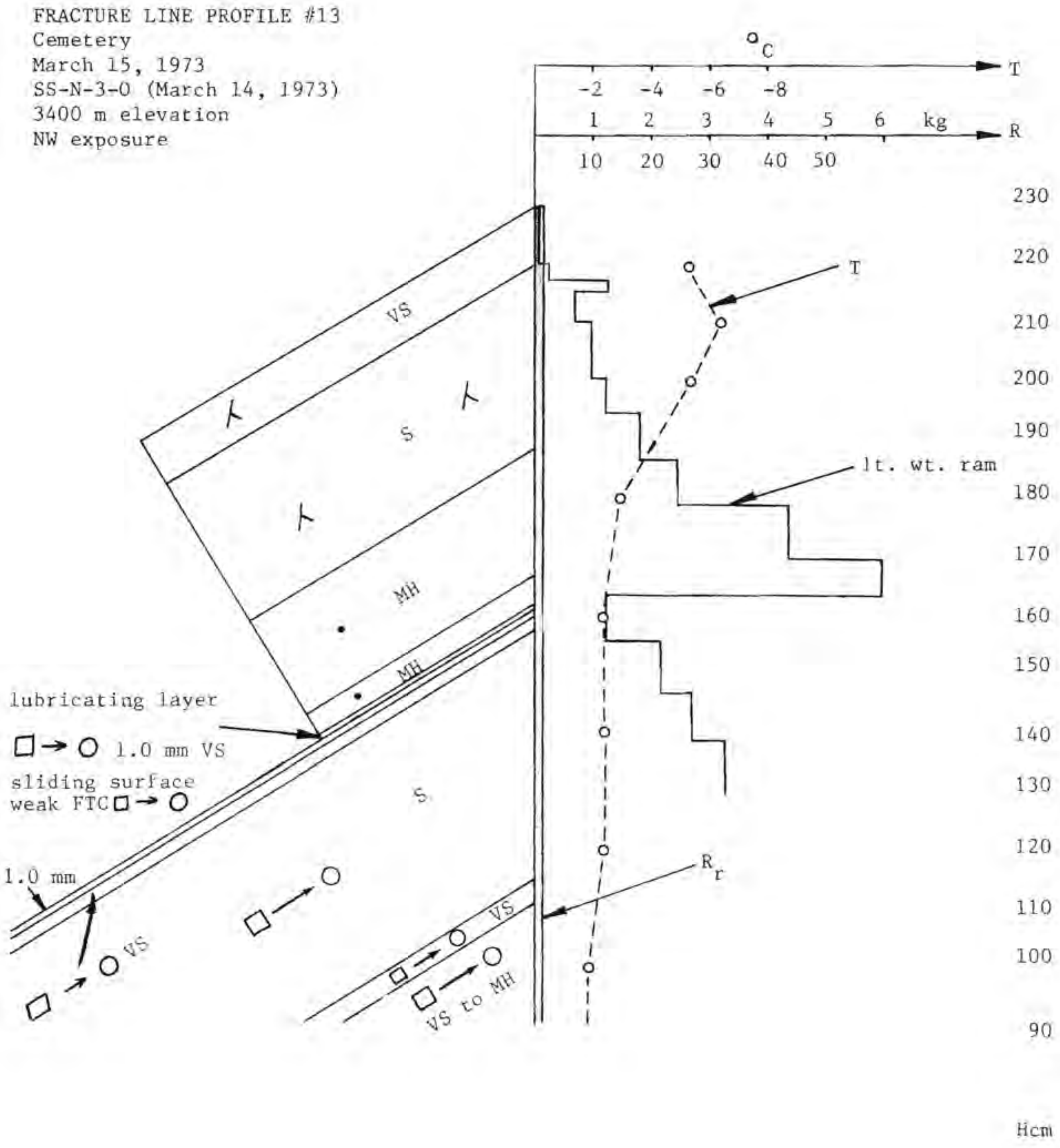
FRACTURE LINE PROFILE #10
Gennesse North
March 7, 1973
SS-**N**-2-0 (March 6, 1973)
3500 m elevation
NW exposure

FRACTURE LINE PROFILE #11
Mill Creek A
March 13, 1973
SS-N-3-0 (March 13, 1973)
3600 m elevation
N exposure



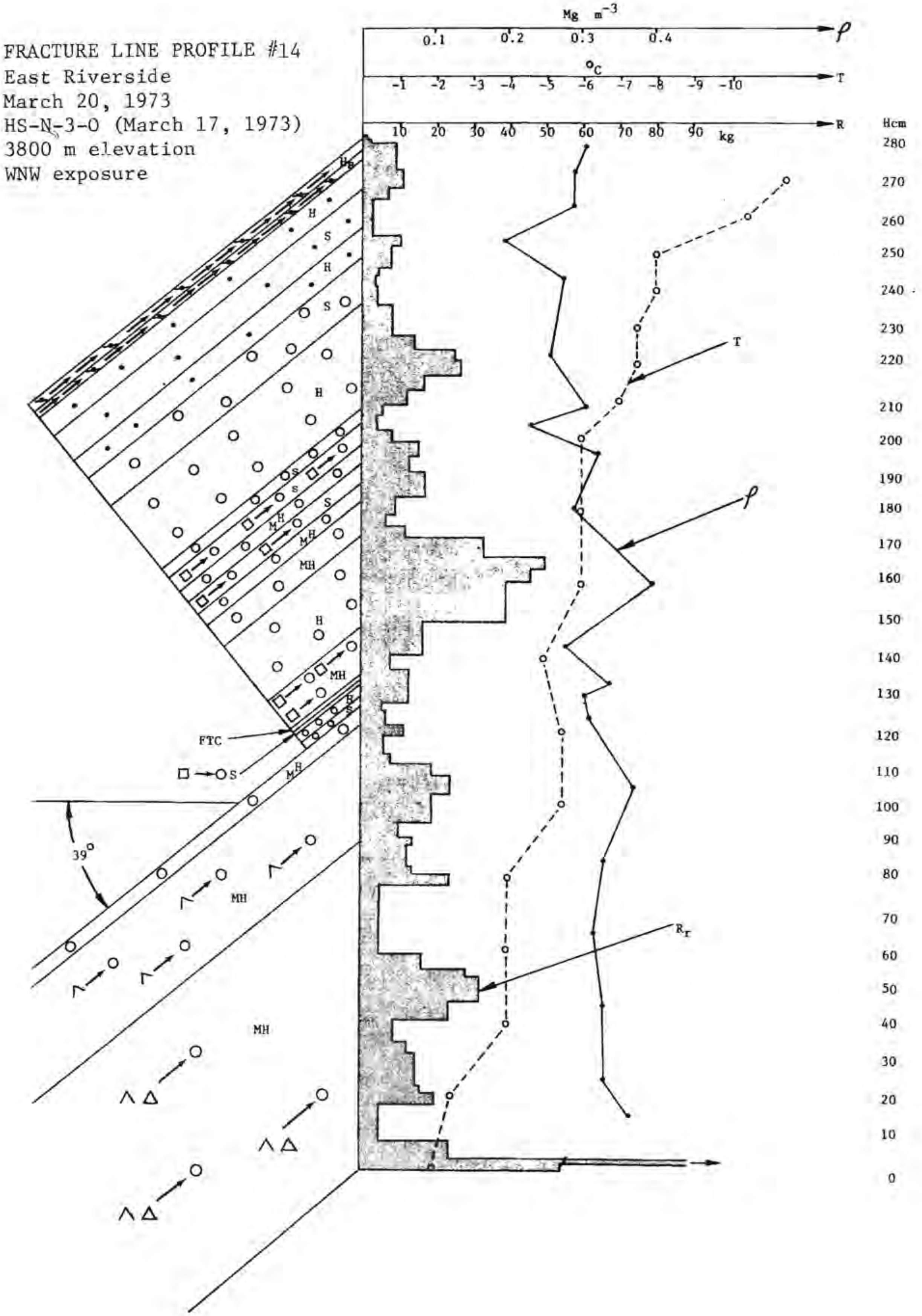


FRACTURE LINE PROFILE #12
Brooklyns J
March 14, 1973
SS-AA-3-0 (March 13, 1973)
3400 m elevation
W exposure

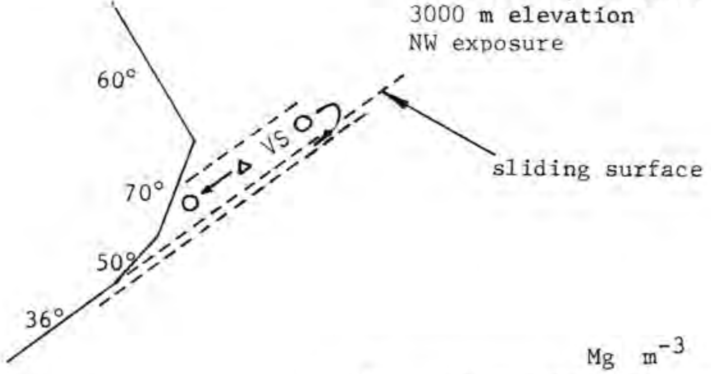


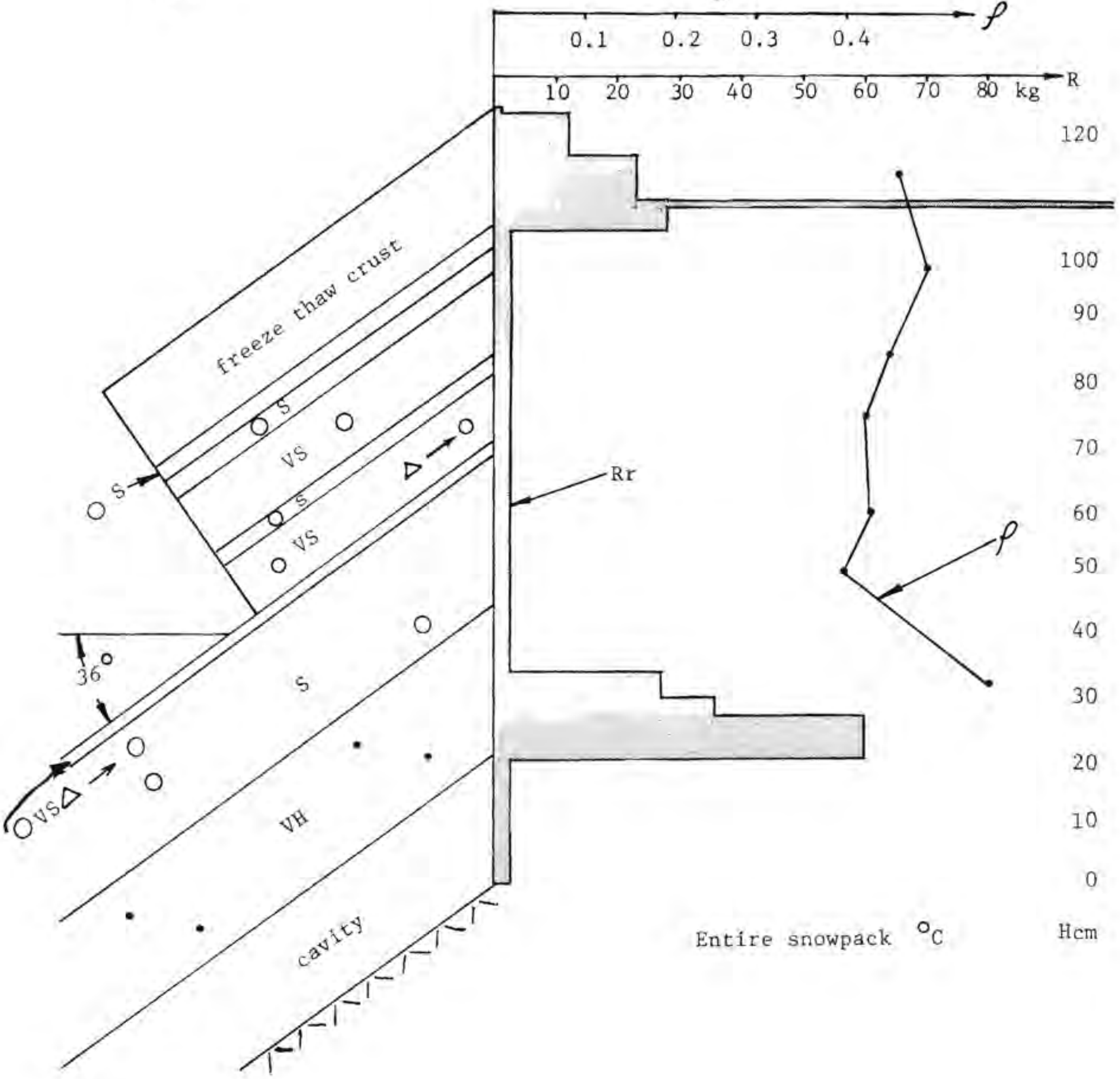
FRACTURE LINE PROFILE #13
Cemetery
March 15, 1973
SS-N-3-0 (March 14, 1973)
3400 m elevation
NW exposure

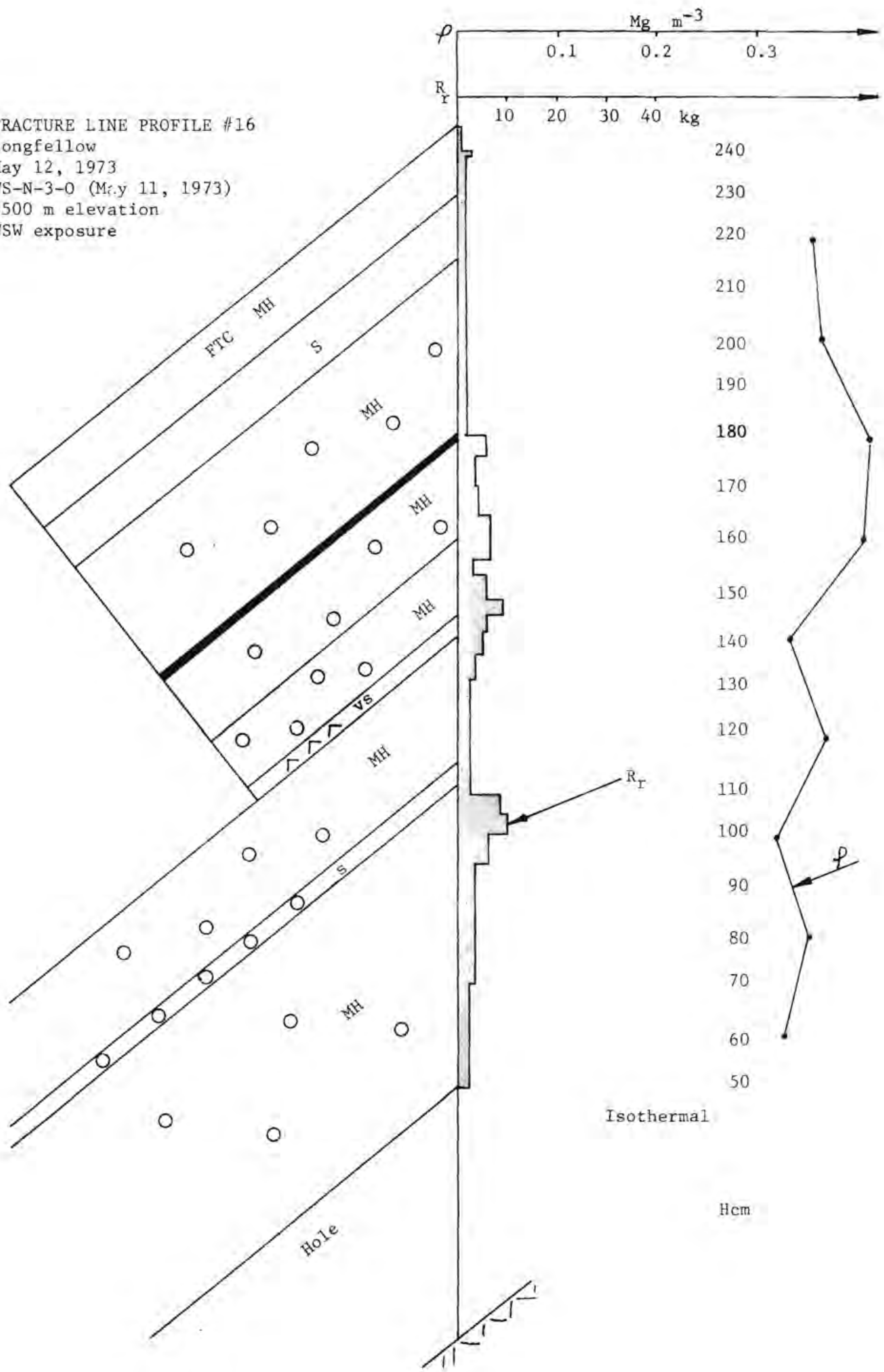
FRACTURE LINE PROFILE #14
East Riverside
March 20, 1973
HS-N-3-O (March 17, 1973)
3800 m elevation
WNW exposure



FRACTURE LINE PROFILE #15
Kendall Mountain North of Idaho Gulch
April 14, 1973
WS-N-1-0 (April 13, 1973)
3000 m elevation
NW exposure

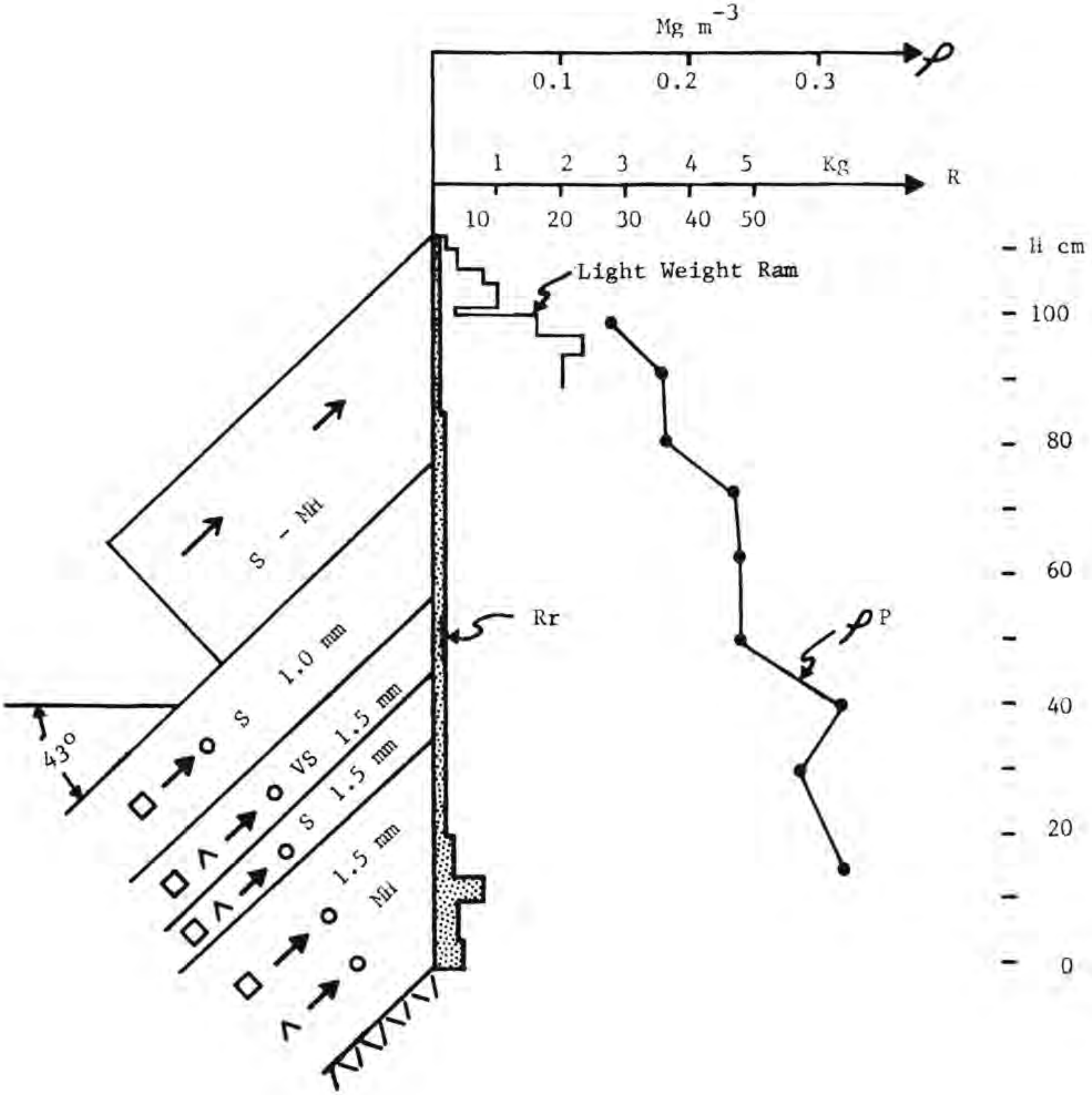




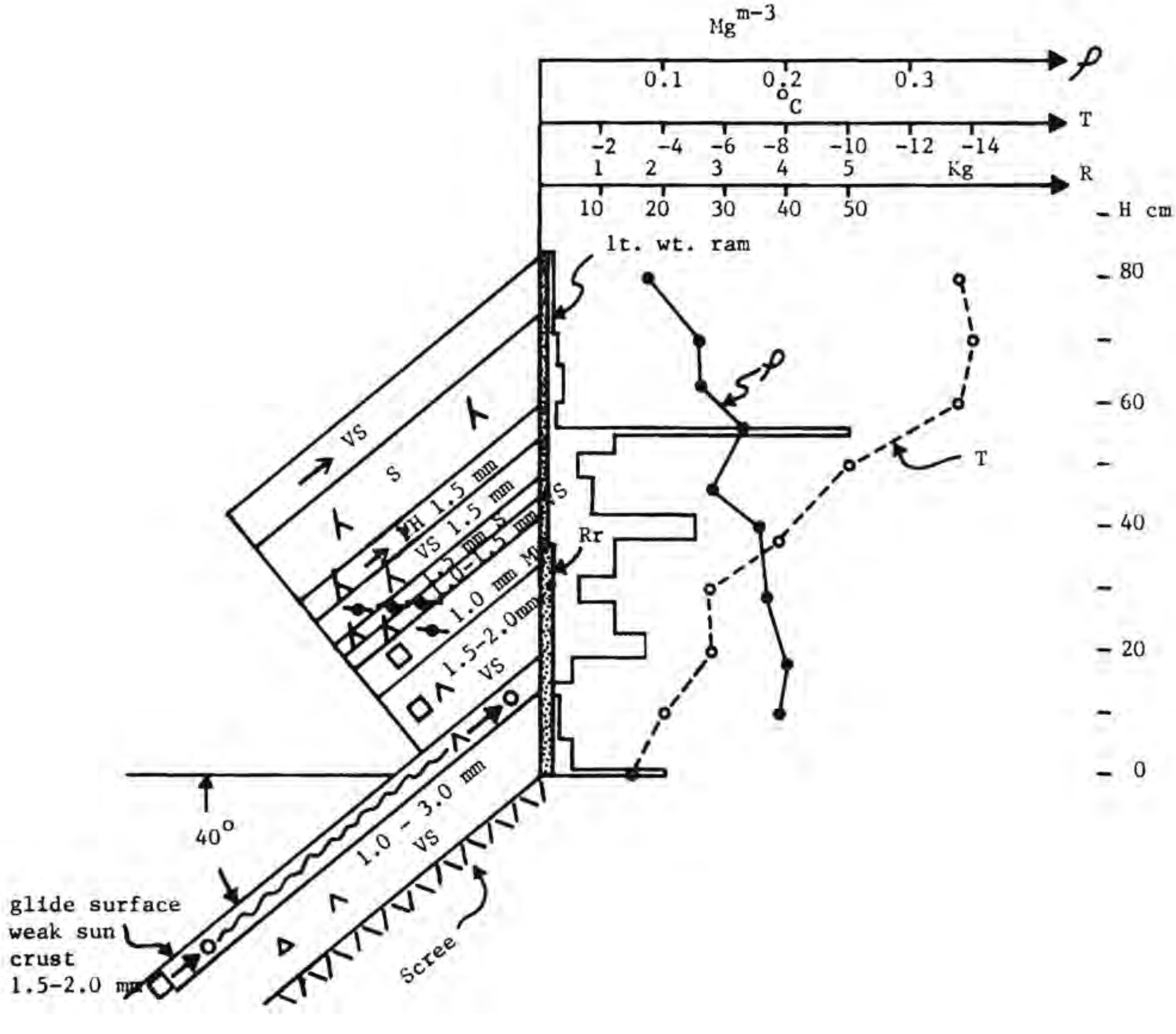


FRACTURE LINE PROFILE #16
Longfellow
May 12, 1973
WS-N-3-0 (May 11, 1973)
3500 m elevation
WSW exposure

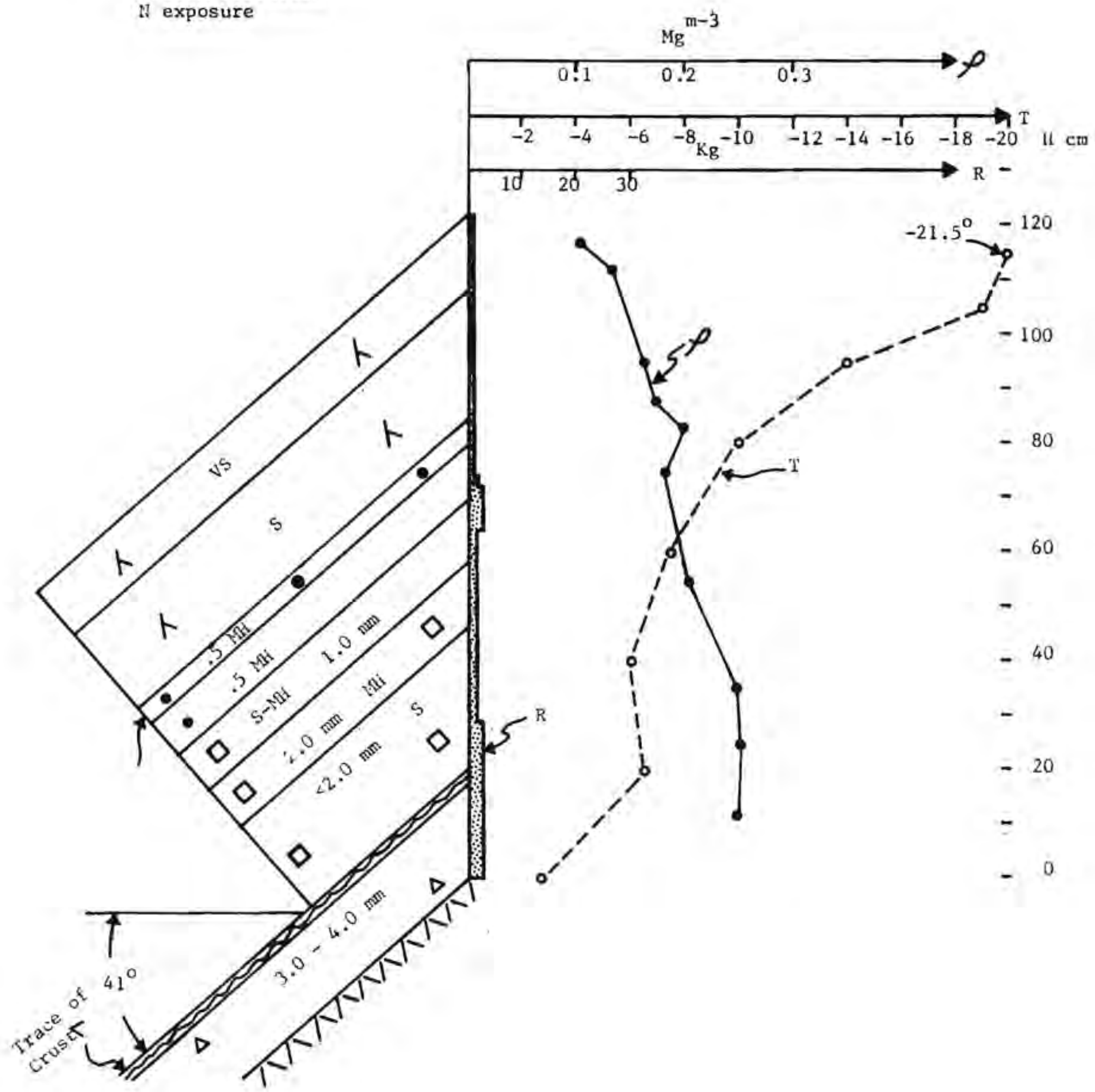
FRACTURE LINE PROFILE #17
Willow Swamp Shoulder
December 28, 1973
SS-N-2-O (Dec. 28, 1973)
3400 m elevation
E N E exposure



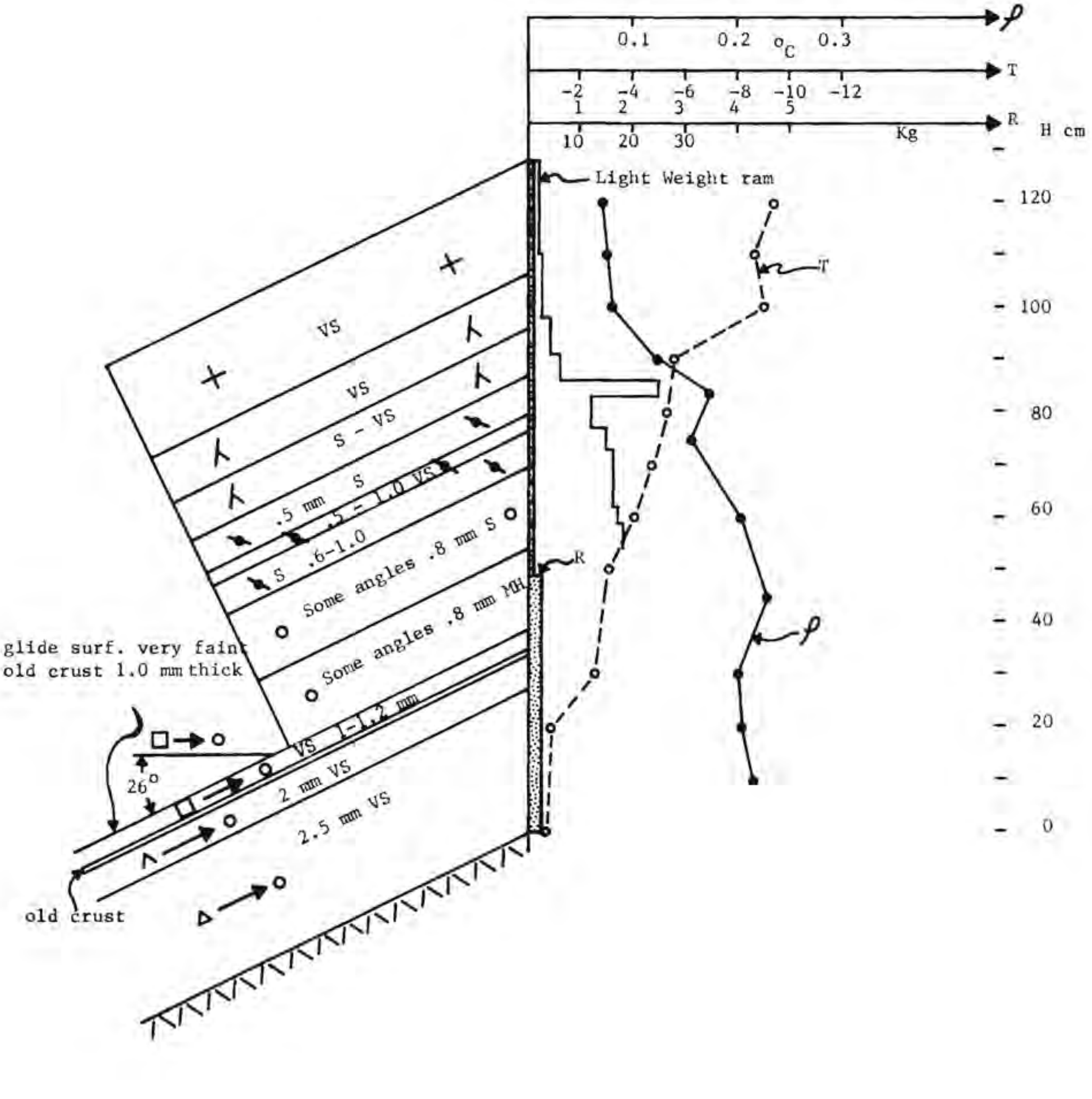
FRACTURE LINE PROFILE #18
Brooklyns E
December 31, 1973
SS-AA-2-OG (Dec. 31, 1973)
3400 m elevation
W exposure

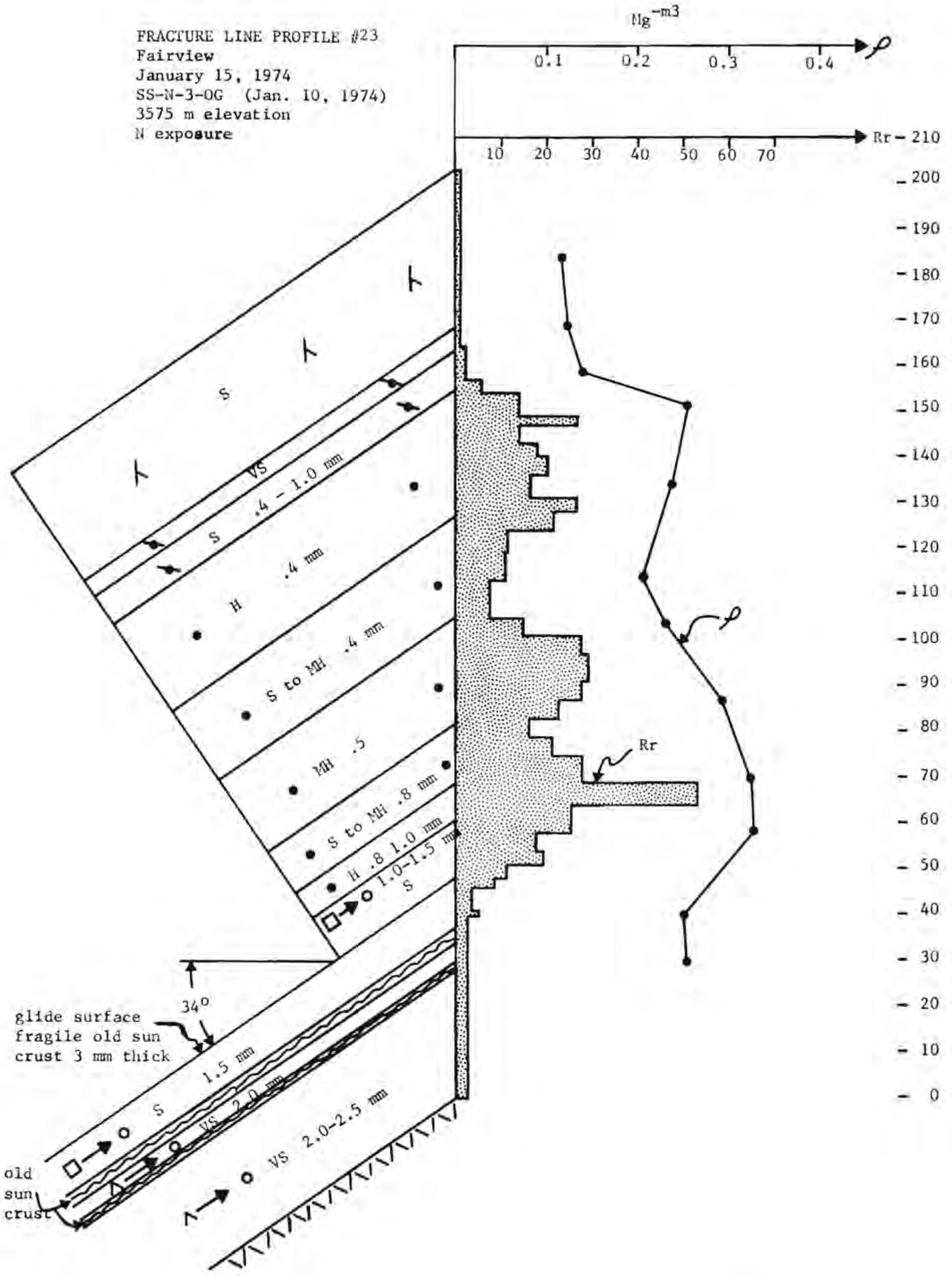


FRACTURE LINE PROFILE # 19
North Carbon Test Slope
January 3, 1974
SS-AE-3-OG (Jan. 3, 1974)
3500 m elevation
N exposure

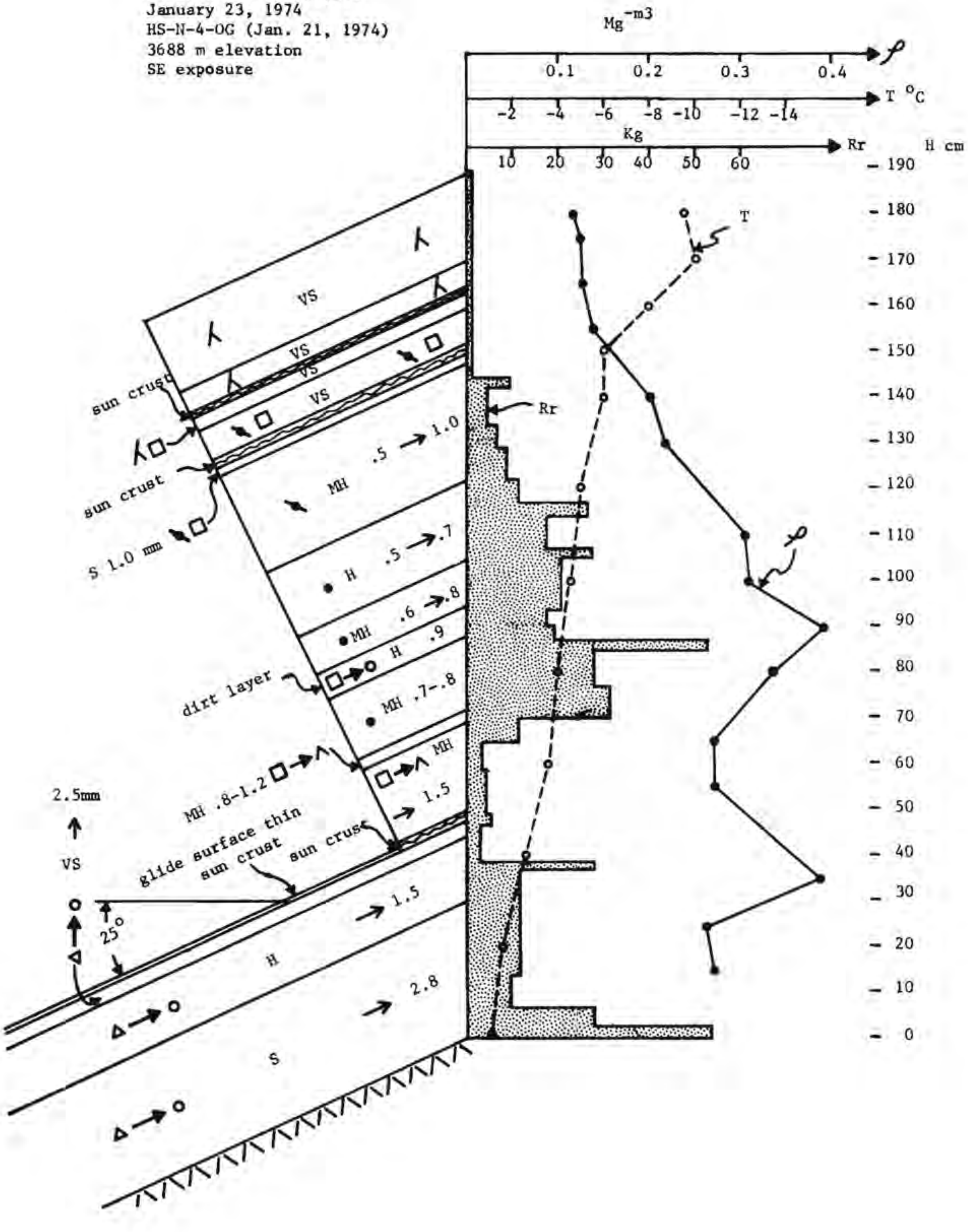


FRACTURE LINE PROFILE #22
Cement Creek - Bunker Hill
January 9, 1974
SS-N-2-OG (Jan. 9, 1974)
3000 m elevation
ESE exposure

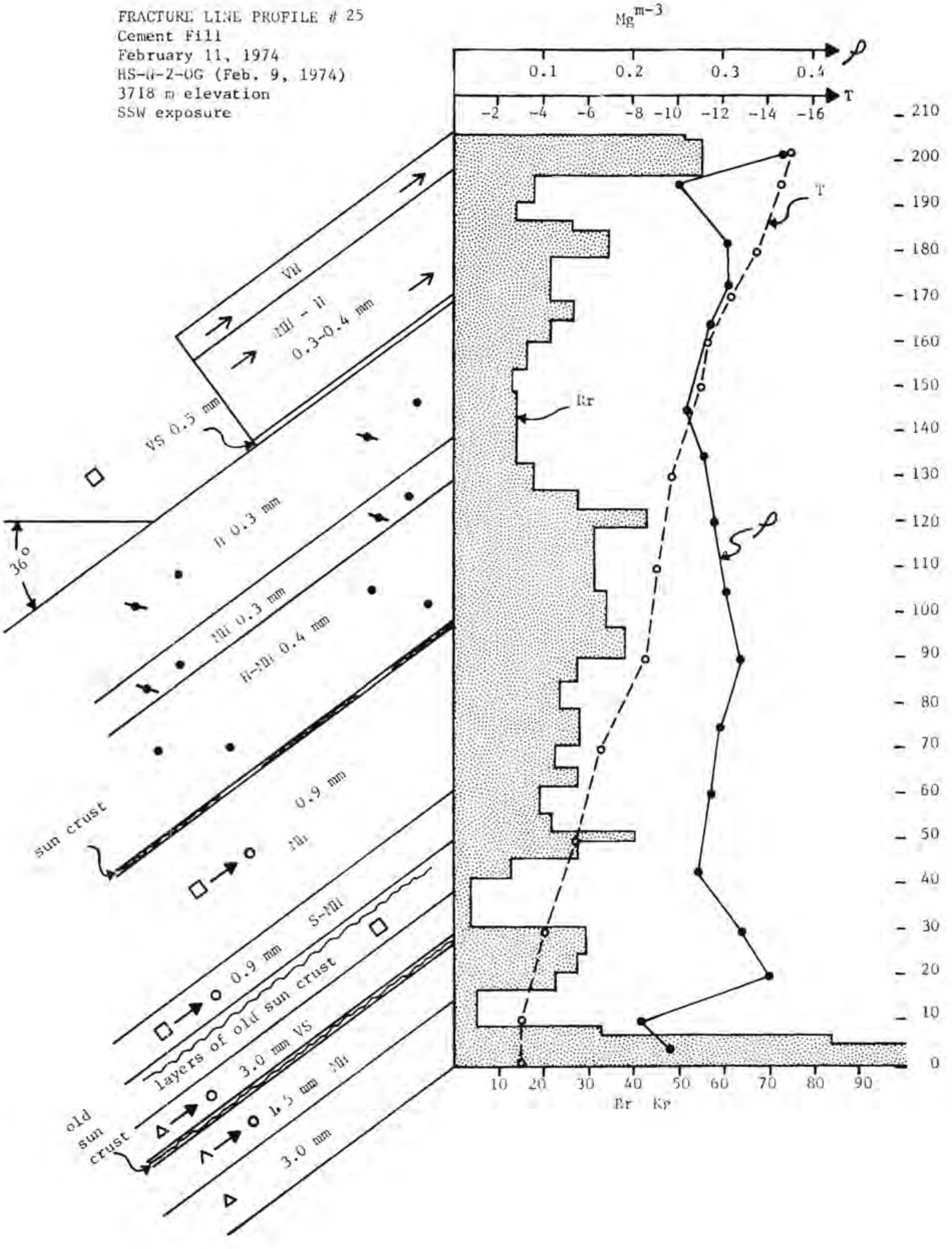


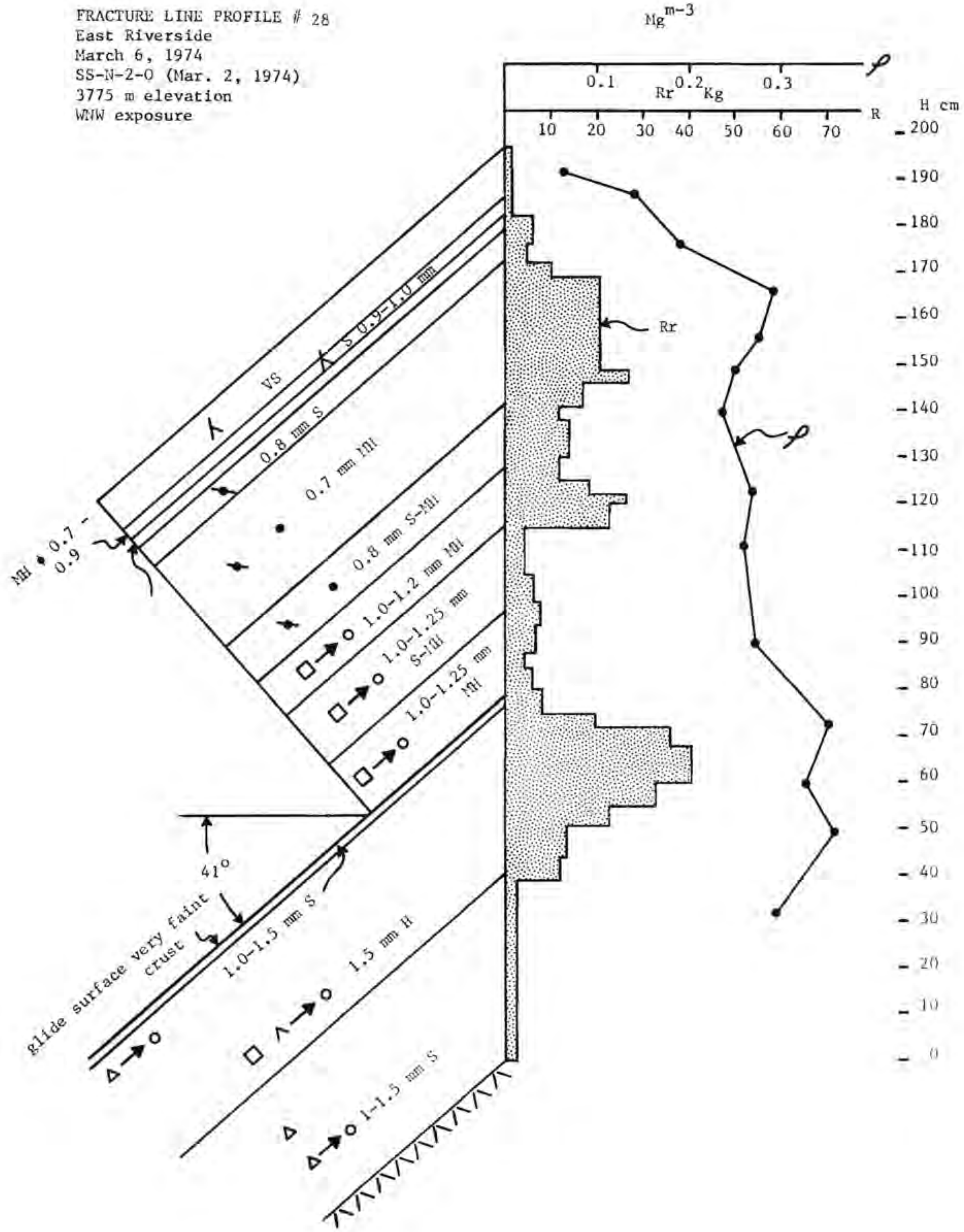

FRACTURE LINE PROFILE #23
Fairview
January 15, 1974
SS-N-3-OG (Jan. 10, 1974)
3575 m elevation
N exposure
Mg^{-m3}
0.1
0.2
0.3
0.4
ρ
10
20
30
40
50
60
70
Rr – 210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
S
VS
S
.4 - 1.0 mm
H
.4 mm
S to MH .4 mm
MH .5
S to MH .8 mm
H .8 1.0 mm
1.0-1.5 mm
S
ρ
Rr
34°
glide surface
fragile old sun
crust 3 mm thick
S
1.5 mm
VS 2.0 mm
VS 2.0-2.5 mm
old
sun
crust

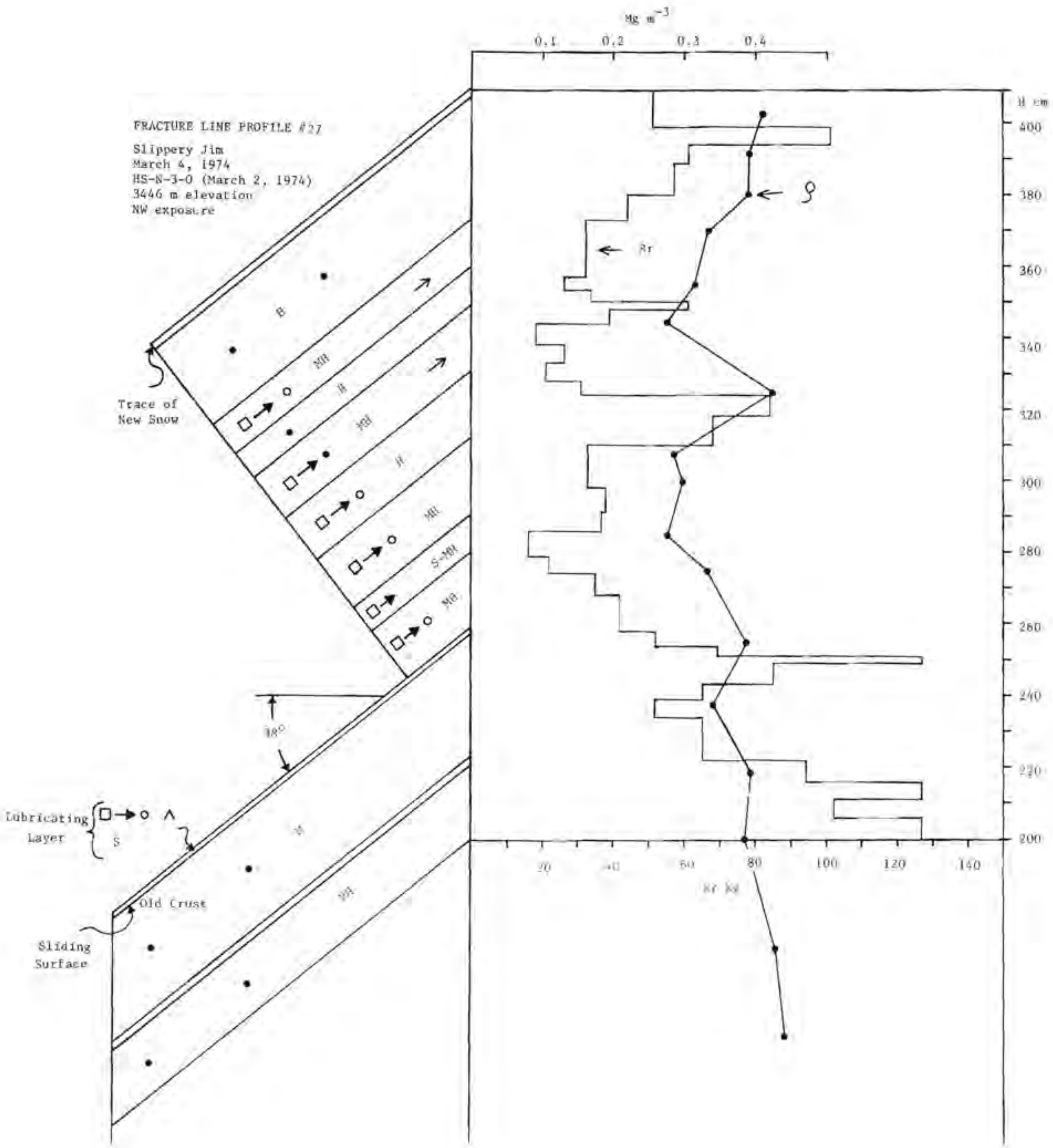
FRACTURE LINE PROFILE #24
NE Shoulder Pt. 12,325
January 23, 1974
HS-N-4-OG (Jan. 21, 1974)
3688 m elevation
SE exposure



FRACTURE LINE PROFILE # 25
Cement Fill
February 11, 1974
HS-N-2-OG (Feb. 9, 1974)
3718 m elevation
SSW exposure

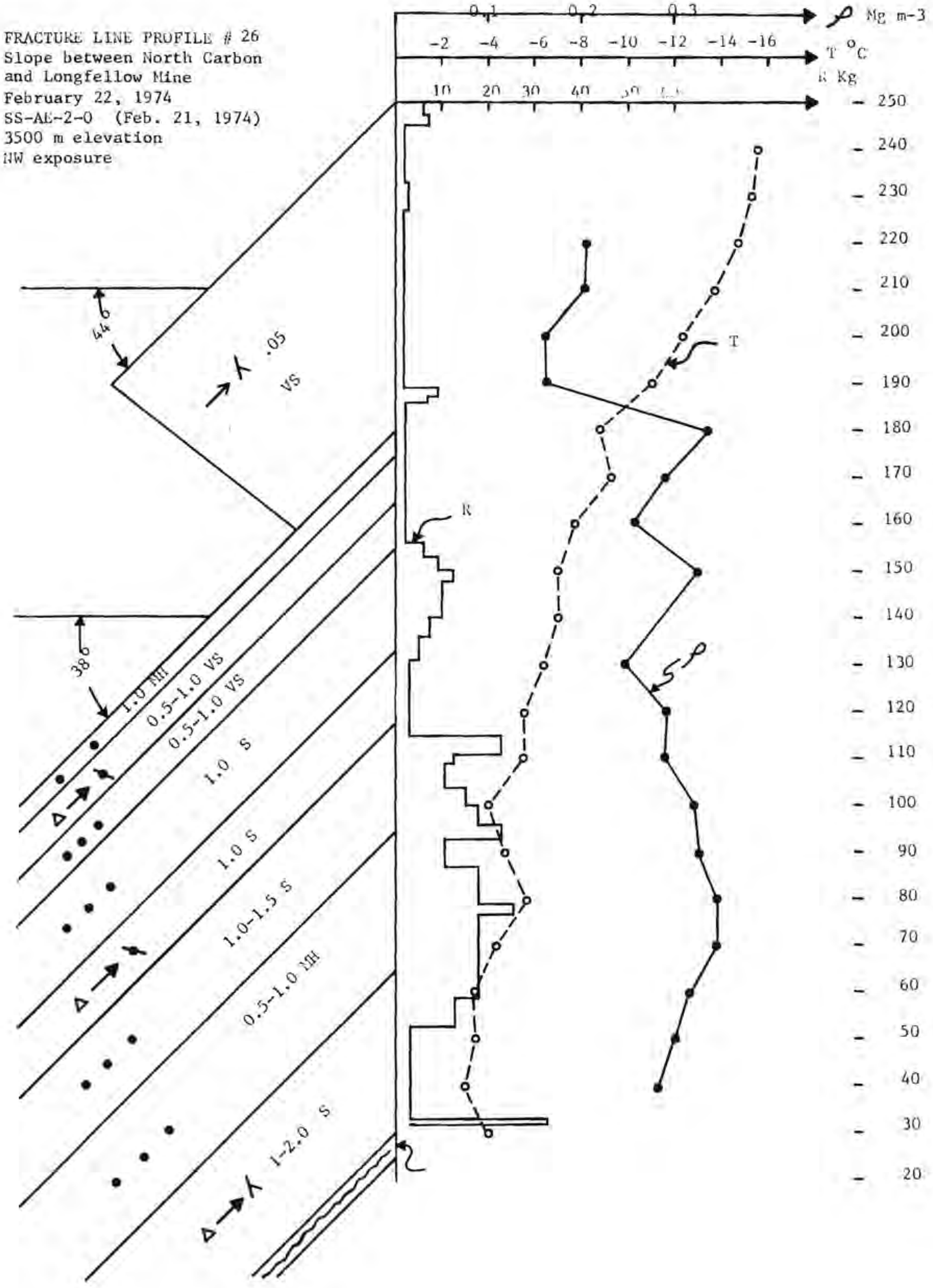



FRACTURE LINE PROFILE # 28
East Riverside
March 6, 1974
SS-N-2-O (Mar. 2, 1974)
3775 m elevation
WNW exposure
Mg m-3
ρ
0.1
Rr 0.2 Kg
0.3
R
10
20
30
40
50
60
70
H cm
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Rr
ρ
VS
S 0.9-1.0 mm
0.8 mm S
0.7 mm MH
0.8 mm S-MH
1.0-1.2 mm MH
1.0-1.25 mm S-MH
1.0-1.25 mm MH
MH ● 0.7 - 0.9
41°
glide surface very faint crust
1.0-1.5 mm S
1.5 mm H
1-1.5 mm S



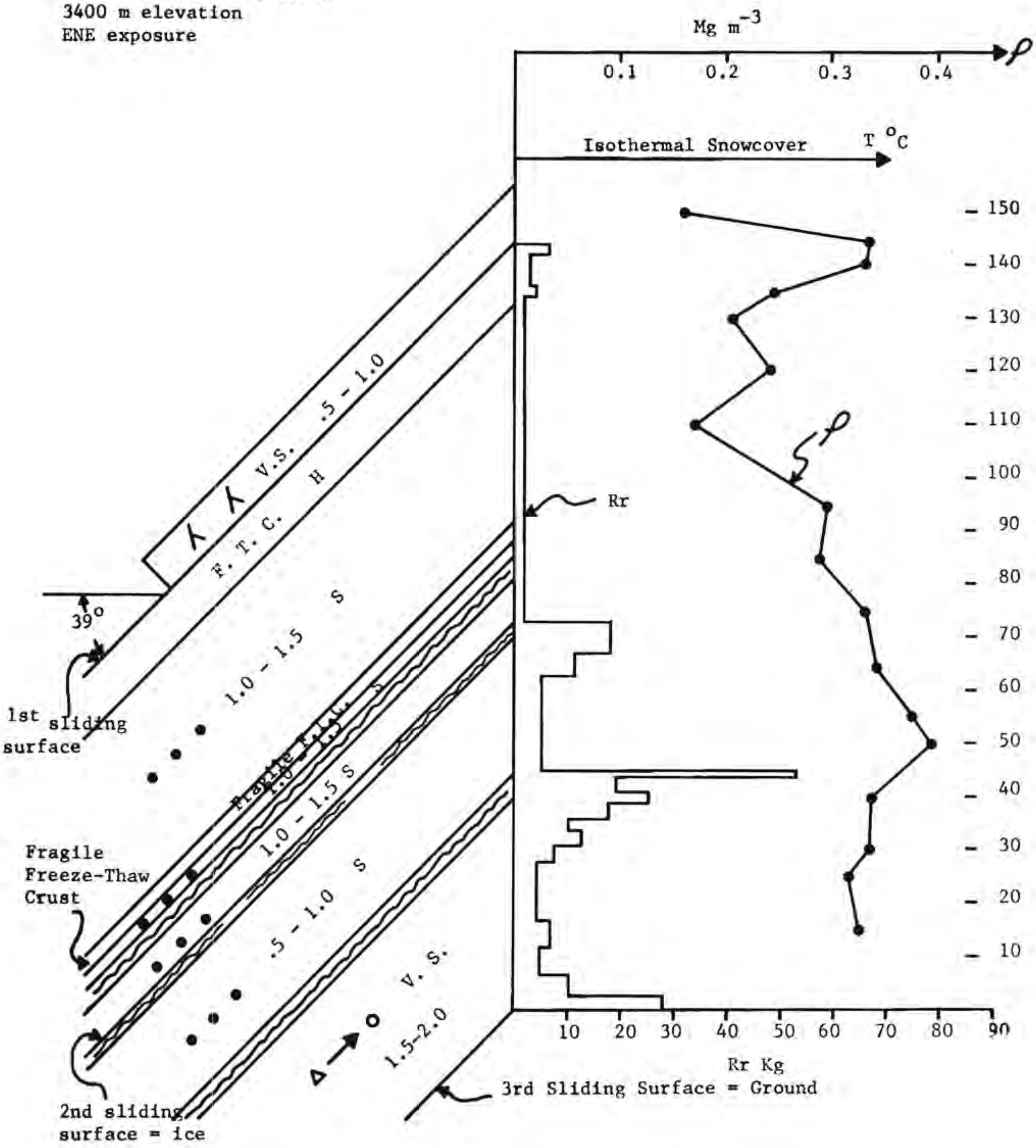
FRACTURE LINE PROFILE #27

Slippery Jim
March 4, 1974
HS-N-3-O (March 2, 1974)
3446 m elevation
NW exposure

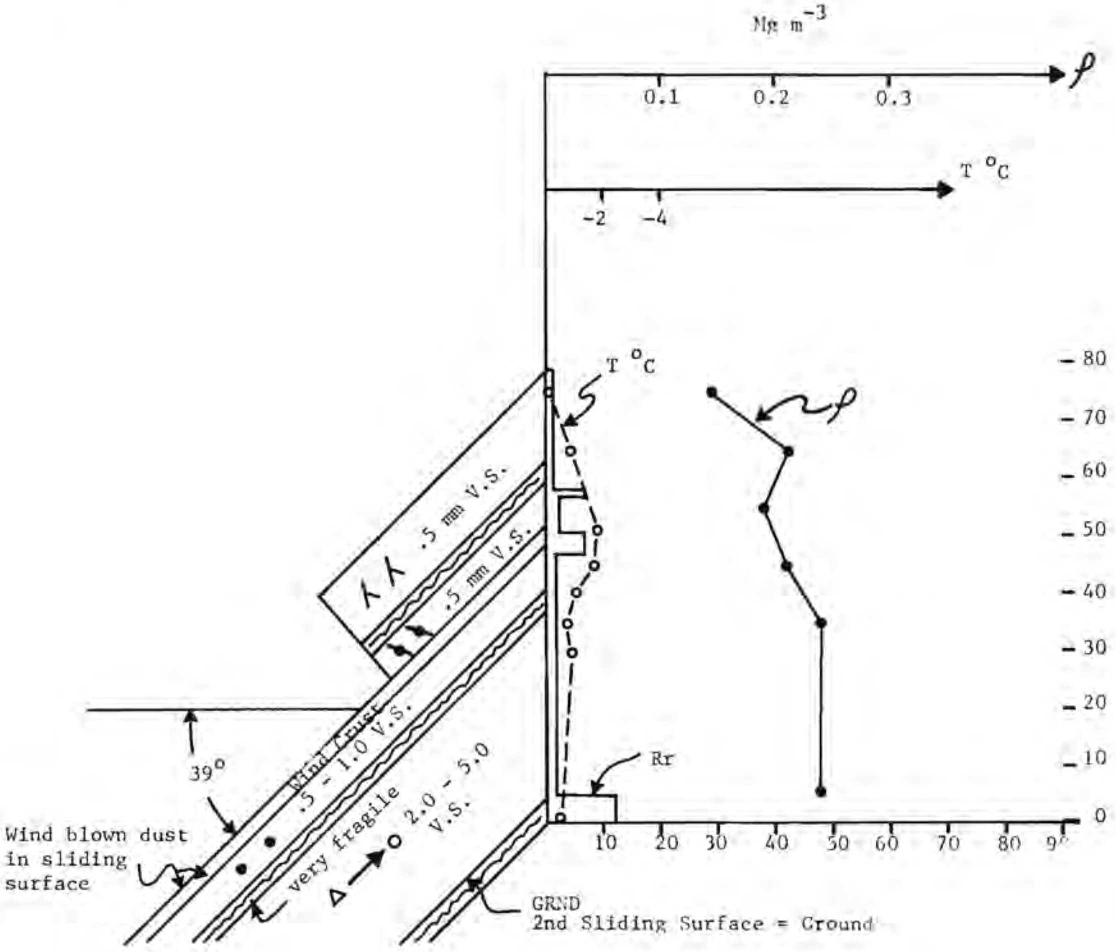


FRACTURE LINE PROFILE # 26
Slope between North Carbon
and Longfellow Mine
February 22, 1974
SS-AE-2-0 (Feb. 21, 1974)
3500 m elevation
NW exposure

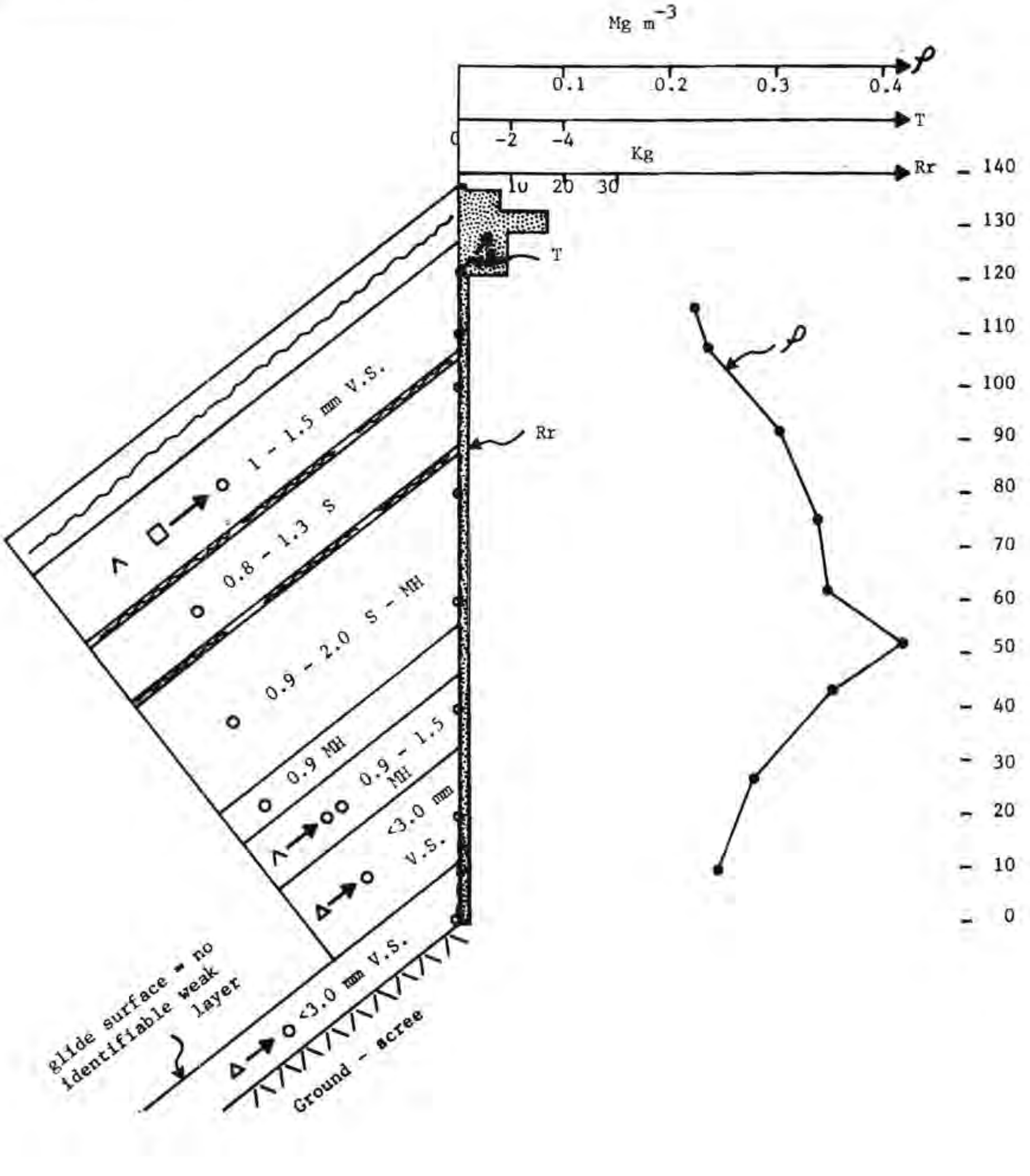
FRACTURE LINE PROFILE #29
Willow Swamp Shoulder
March 11, 1974
SS-N-2-G (Mar. 10, 1974)
3400 m elevation
ENE exposure



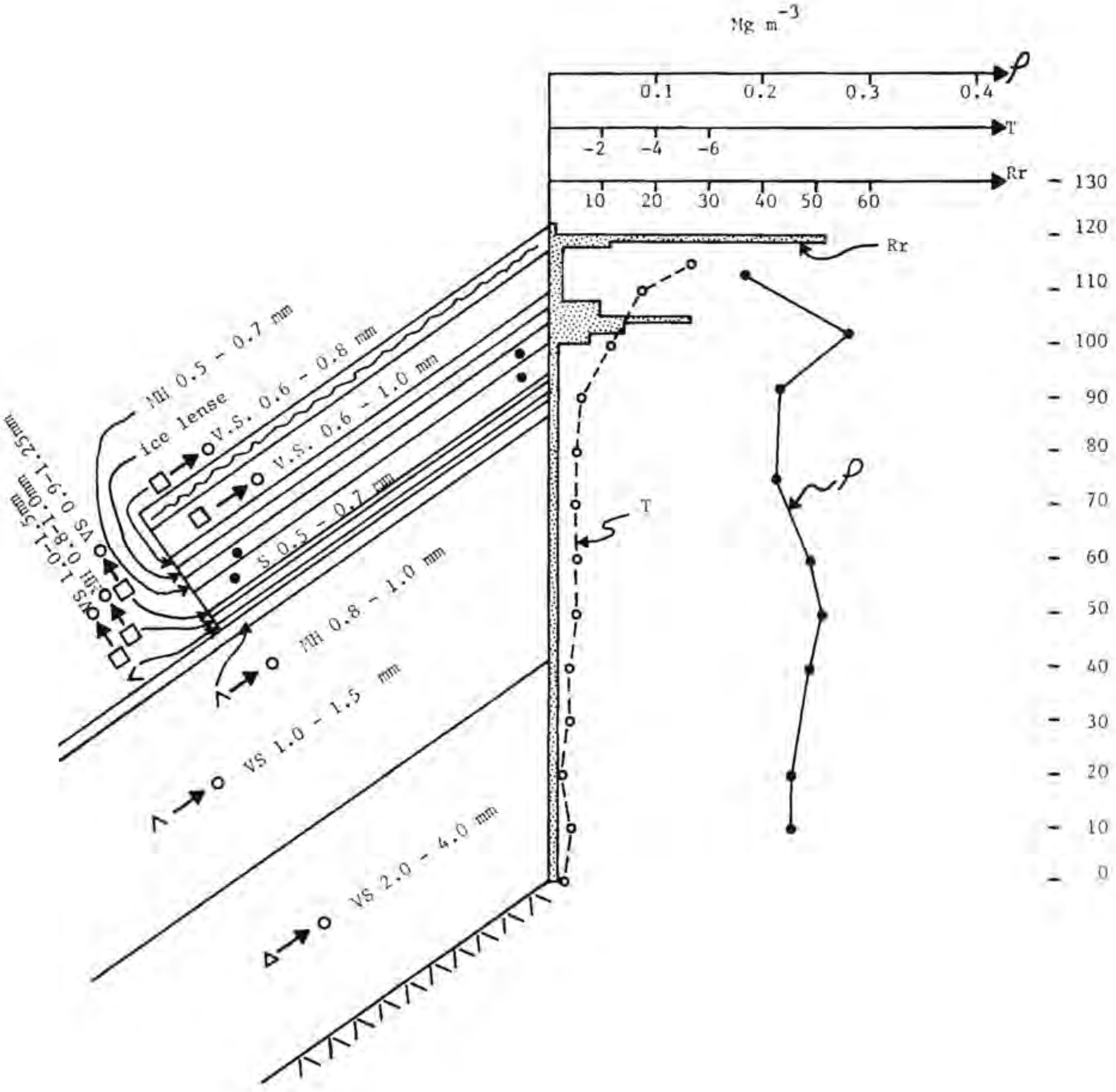
FRACTURE LINE PROFILE # 30
Ernest
March 12, 1974
SS-N-3-G (Mar. 10, 1974)
3350 m elevation
E exposure



FRACTURE LINE PROFILE #31
Second Twin Crossing
March 17, 1974
WS-N-3-O (Mar. 16, 1974)
3416 m elevation
WSW exposure



FRACTURE LINE PROFILE # 32
Cemetery
March 18, 1974
SS-N-2-O (Mar. 16, 1974)
3300 m elevation
NW exposure



INSTITUTE OF ARCTIC AND ALPINE RESEARCH
OCCASIONAL PAPERS

Numbers 1 through 5 are out of print. A second edition of Number 1 is available from the author. Numbers 2, 4, and 5 are available from National Technical Information Service, U.S. Department of Commerce. For details, please write to INSTAAR.

6. *Guide to the Mosses of Colorado.* By W.A. Weber. 1973. 48 pp. Order from the author, University of Colorado Museum, Boulder, Colorado 80309. $2.50.
7. *A Climatological Study of Strong Downslope Winds in the Boulder Area.* By W.A.R. Brinkmann. 1973. 228 pp. Order from the author, Institute for Environmental Studies, University of Wisconsin, 1225 West Dayton Street, Madison, Wisconsin 53706.

†8. *Environmental Inventory and Land Use Recommendations for Boulder County, Colorado.* Edited by R.F. Madole. 1973. 228 pp. 7 plates. $6.00.

†9. *Studies of Climate and Ice Conditions in Eastern Baffin Island.* 1971-73. By J.D. Jacobs, R.G. Barry, R.S. Bradley, and R.L. Weaver. 1974. 77 pp. $3.00.

†10. *Simulation of the Atmospheric Circulation Using the NCAR Global Circulation Model With Present Day and Glacial Period Boundary Conditions.* By J.H. Williams. 1974. 328 pp. $4.75.

11. *Solar and Atmospheric Radiation Data for Broughton Island, Eastern Baffin Island, Canada, 1971-73.* By J.D. Jacobs. 1974. 54 pp. (Out of print.)
12. *Deglacial Chronology and Uplift History: Northeastern Sector, Laurentide Ice Sheet.* By A.S. Dyke. 1974. 113 pp. (Out of print.)

†13. *Development of Methodology for Evaluation and Prediction of Avalanche Hazard in the San Juan Mountains of Southwestern Colorado.* By R.L. Armstrong, E.R. LaChapelle, M.J. Bovis, and J.D. Ives. 1975. 141 pp. $4.75.

†14. *Quality Skiing at Aspen, Colorado: A Study in Recreational Carrying Capacity.* By C. Crum London. 1975. 134 pp. 3 plates. $5.50.

†15. *Palynological and Paleoclimatic Study of the Late Quaternary Displacements of the Boreal Forest-Tundra Ecotone in Keewatin and Mackenzie, N.W.T., Canada.* By H. Nichols. 1975. x + 87 pp. $4.00.

†16. *Computer Techniques for the Presentation of Palynological and Paleoenvironmental Data.* By M. Nichols, M. Eccles, and H. Nichols. 1976 (in press).

†17. *Avalanche Atlas: San Juan County, Colorado.* By L. Miller, B.R. Armstrong, and R.L. Armstrong. 1976. 260 pp. 60 plates. $4.25.

†18. *Century of Struggle Against Snow: A History of Avalanche Hazard in San Juan County, Colorado.* By B.R. Armstrong. 1976 (in press).

†19. *Avalanche Release and Snow Characteristics, San Juan Mountains, Colorado.* Edited by R.L. Armstrong and J.D. Ives. 1976 (in press).

†20. *Landslides Near Aspen, Colorado.* C.P. Harden. 1976 (in press).

†Order from INSTAAR, University of Colorado, Boulder, Colorado 80309. Orders by mail add 65 cents.

Occasional Papers are a miscellaneous collection of reports and papers on work performed by INSTAAR personnel and associates. Generally, these papers are too long for publication as journal articles, or they contain large amounts of supporting data that are normally difficult to publish in the standard literature.

A stylized "ankh," the ancient Egyptian sign for life, has been incorporated into the symbol of the Program on Man and the Biosphere (MAB).