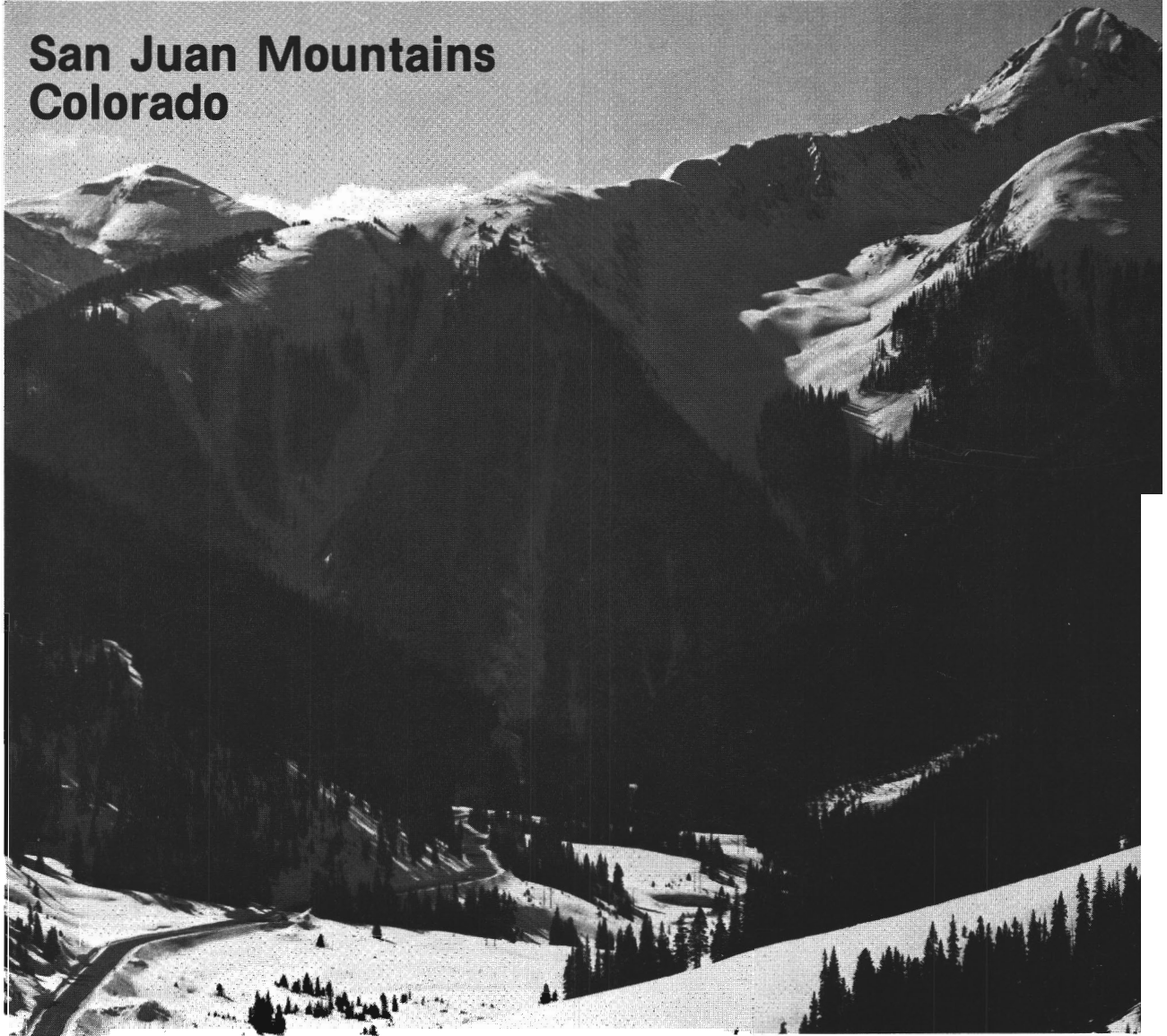


AVALANCHE RELEASE AND SNOW CHARACTERISTICS

**San Juan Mountains
Colorado**



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

UNITED STATES PROGRAM
ON MAN AND THE
BIOSPHERE



Unesco MAB Project 6

Occasional Paper No. 19, 1976
Report to the Bureau of Reclamation

1. REPORT NO. INSTAAR-14-06-D-7155-4		2. GOVERNMENT ACCESSION NO.		3. RECIPIENT'S CATALOG NO.	
4. TITLE AND SUBTITLE Avalanche Release and Snow Characteristics, San Juan Mountains, Colorado				5. REPORT DATE May 1976	
				6. PERFORMING ORGANIZATION CODE	
7. AUTHOR(S) Richard L. Armstrong and Jack D. Ives (Eds.)				8. PERFORMING ORGANIZATION REPORT NO. INSTAAR-14-06-D-7155-4	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Institute of Arctic and Alpine Research University of Colorado Boulder, Colorado 80309				10. WORK UNIT NO.	
				11. CONTRACT OR GRANT NO. 14-06-D-7155	
12. SPONSORING AGENCY NAME AND ADDRESS Division of Atmospheric Water Resources Mgt. Bureau of Reclamation Denver Federal Center, Denver, Colorado 80225				13. TYPE OF REPORT AND PERIOD COVERED Final Report April 1971-Sept. 1975	
				14. SPONSORING AGENCY CODE	
15. SUPPLEMENTARY NOTES					
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.					
17. KEY WORDS AND DOCUMENT ANALYSIS a. DESCRIPTORS-- avalanche, Colorado, snow, weather modification b. IDENTIFIERS-- c. COSATI Field/Group					
18. DISTRIBUTION STATEMENT Available from the National Technical Information Service, Operations Division, Springfield, Virginia 22151. No limitations				19. SECURITY CLASS (THIS REPORT) UNCLASSIFIED	
				20. SECURITY CLASS (THIS PAGE) UNCLASSIFIED	
				21. NO. OF PAGES 256	
				22. PRICE	



AVALANCHE RELEASE AND SNOW CHARACTERISTICS,
SAN JUAN MOUNTAINS, COLORADO

Final Report 1971 - 1975

May 1976

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

San Juan Avalanche Project
Institute of Arctic and Alpine Research
University of Colorado
Boulder, Colorado 80309

Prepared for:

Division of Atmospheric Water Resources Management
U.S. Bureau of Reclamation
Department of the Interior
Denver, Colorado 80225

Contract No. 14-06-D-7155

A contribution to the United States
Unesco Man and the Biosphere (MAB) Program Project 6:
Study of the impact of human activities on mountain
and tundra ecosystems

University of Colorado
Institute of Arctic and Alpine Research

Occasional Paper 19

ISSN 0069-6145



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

UNITED STATES FOREST SERVICE - Alpine Snow and Avalanche Project

Pete Martinelli
Ron Perla - currently with Environment Canada, Calgary
West Wide Data Network
Arthur Judson
Knox Williams

COLORADO DEPARTMENT OF HIGHWAYS

Tuffy Foster
Ray Ledford
Noel Peterson
Blaine Thompson
Lyn Watson

SAN JUAN COUNTY

Avalanche Schools
Sheriff Virgil Mason
John "Scotty" Jackson

E G AND G INC.

Synoptic Meteorological Data (Weather Forecasts)
Larry Hjermstad
Dick Medenwald
Art Ragno

WESTERN SCIENTIFIC SERVICES

Meteorological Data Exchange

SWISS FEDERAL INSTITUTE FOR SNOW AND AVALANCHE RESEARCH

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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 precede 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.

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Institute of Arctic and Alpine Research
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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

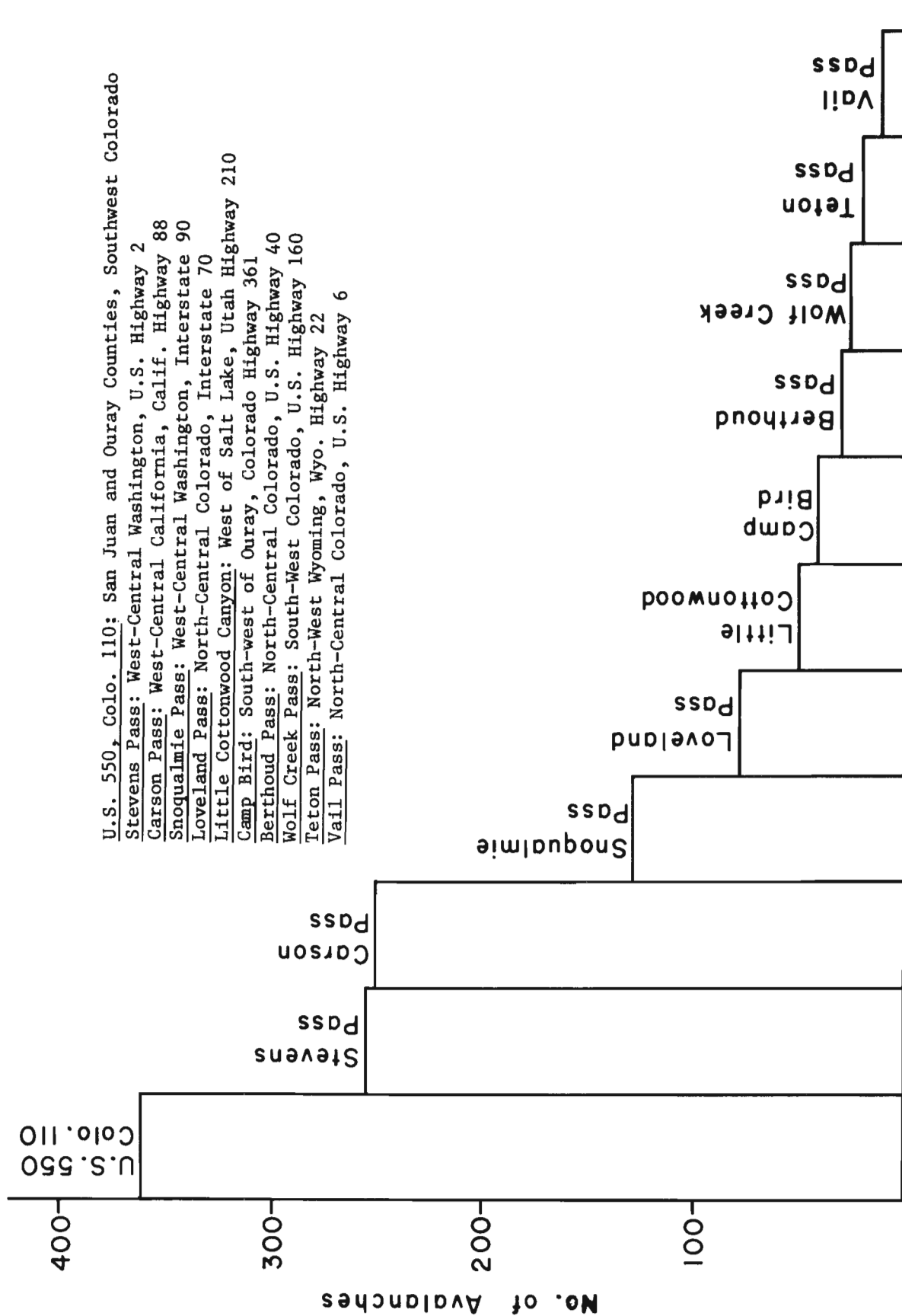
Information regarding the relationship between augmented winter precipitation and avalanche occurrence, that could in turn create economic and public safety problems, was considered a vital segment in analysis of the United States Bureau of Reclamation Project Skywater winter cloud-seeding experiment. 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 Iron-ton Park of the upper Uncomphagre drainage that form the main



U.S. 550, Colo. 110: San Juan and Ouray Counties, Southwest Colorado
 Stevens Pass: West-Central Washington, U.S. Highway 2
 Carson Pass: West-Central California, Calif. Highway 88
 Snoqualmie Pass: West-Central Washington, Interstate 90
 Loveland Pass: North-Central Colorado, Interstate 70
 Little Cottonwood Canyon: West of Salt Lake, Utah Highway 210
 Camp Bird: South-west of Ouray, Colorado Highway 361
 Berthoud Pass: North-Central Colorado, U.S. Highway 40
 Wolf Creek Pass: South-West Colorado, U.S. Highway 160
 Teton Pass: North-West Wyoming, Wyo. Highway 22
 Vail Pass: North-Central Colorado, U.S. Highway 6

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 engelmannii), 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.

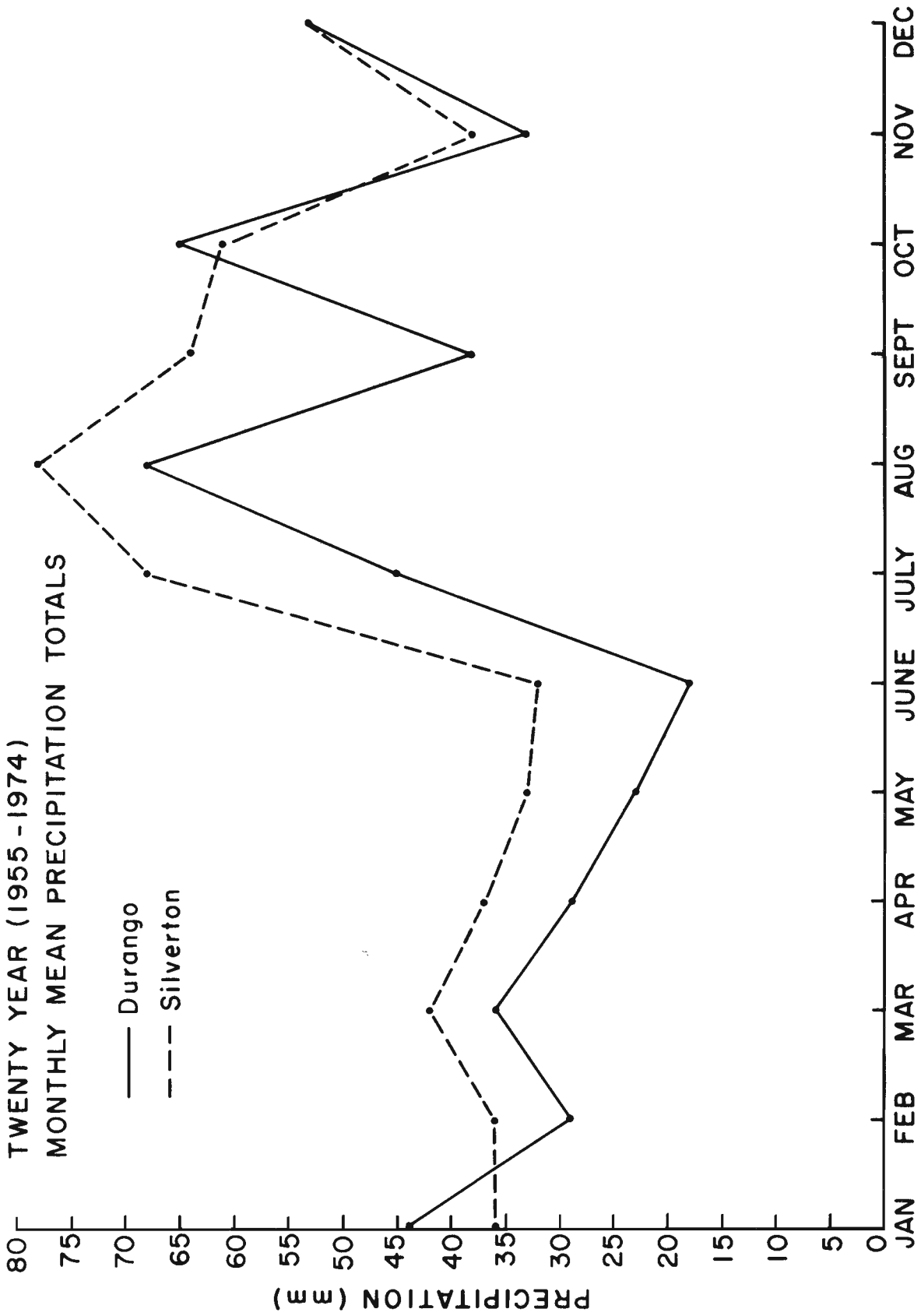


Figure 3. Twenty year monthly mean precipitation totals for Silverton and Durango, Colorado (1955-1974). Durango is located 85 km south of Silverton at an elevation of 2030 m.

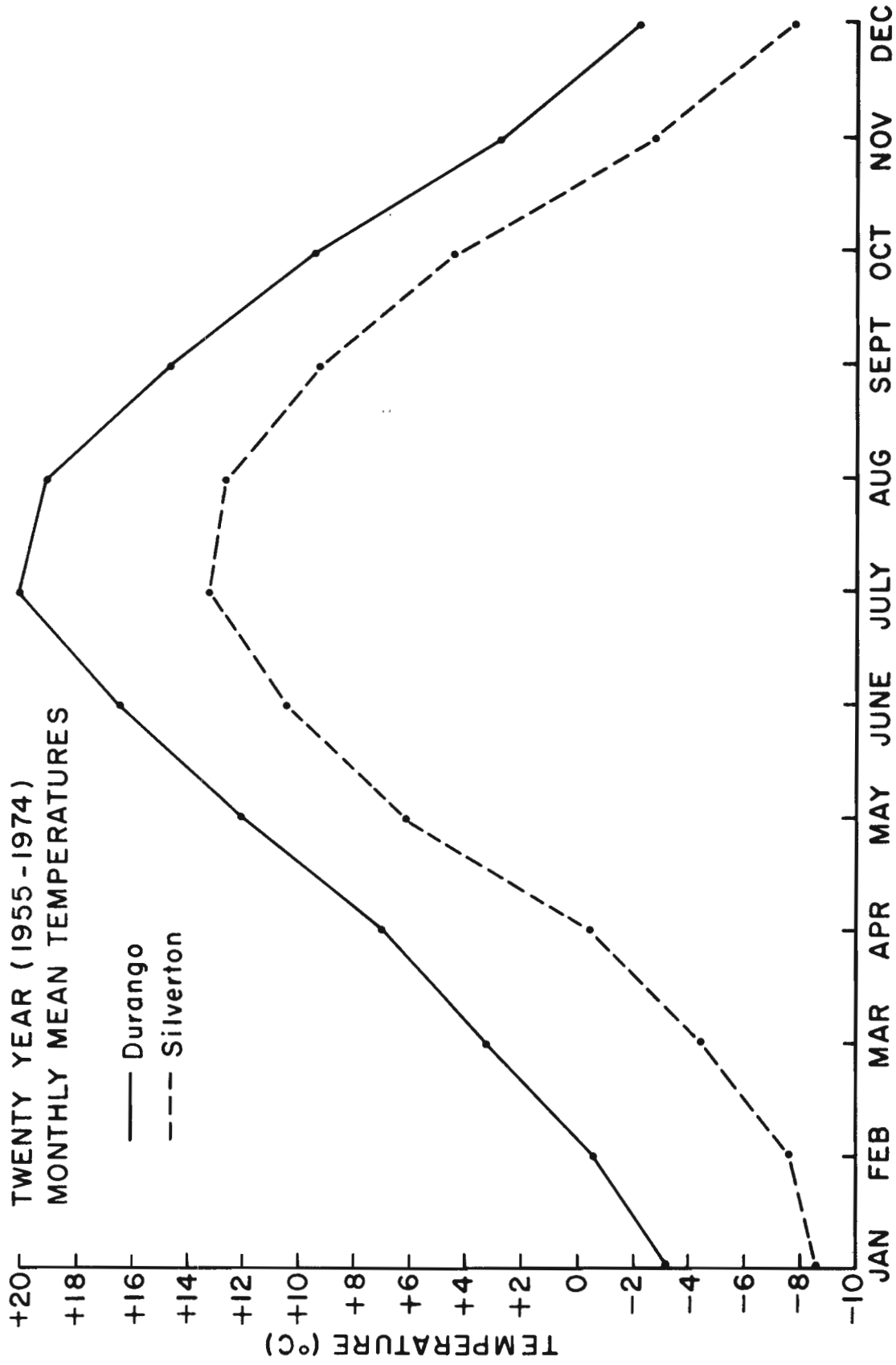


Figure 4. Twenty year monthly mean temperatures for Silverton and Durango, Colorado (1955-1974). Durango is located 85 km south of Silverton at an elevation of 2030 m.

to avalanche occurrence. They are: relatively low latitude (37°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 south-east 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 of 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

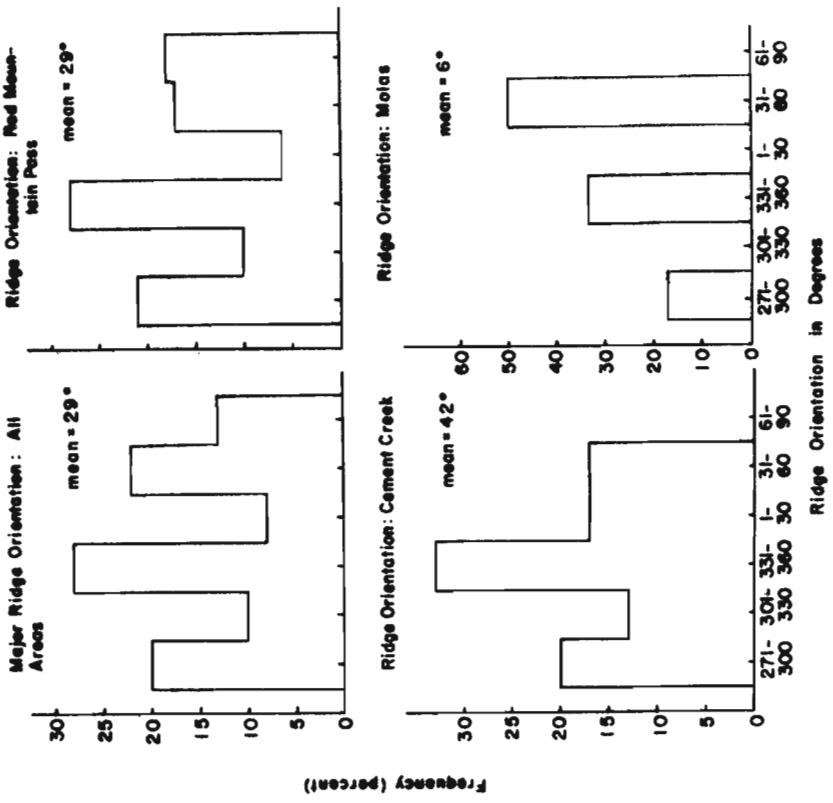


Figure 6

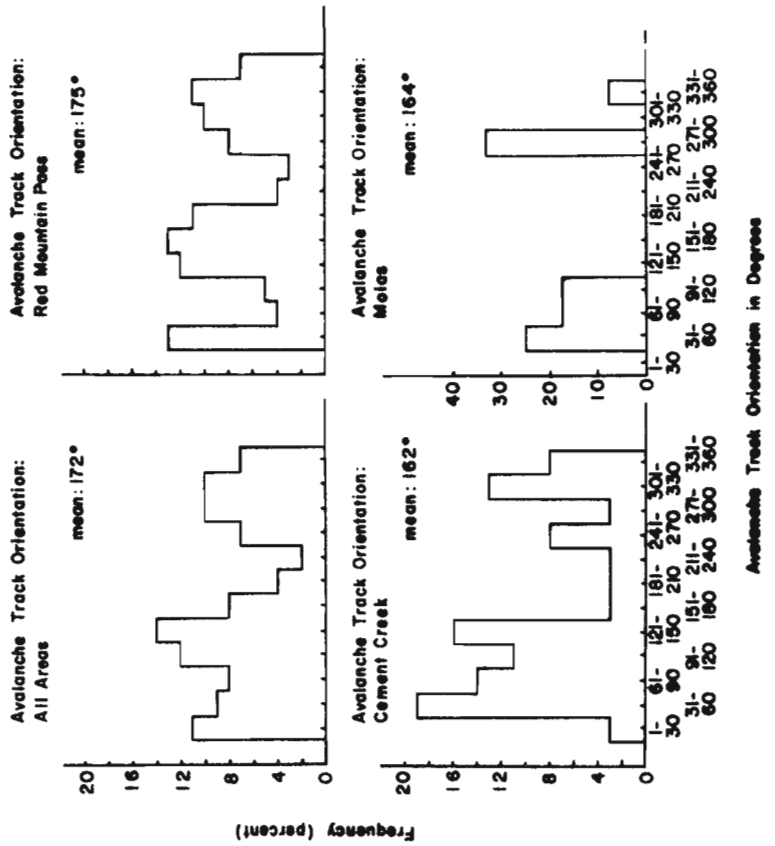


Figure 5. Histograms showing the orientation of the major ridge system for: a. the entire study area, b. the Red Mountain Pass portion of Highway 550, c. the Cement Creek road, and d. the Coal Bank Hill-Molas Pass portion of Highway 550. The ridge orientations have been calculated for 20 degree class 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).

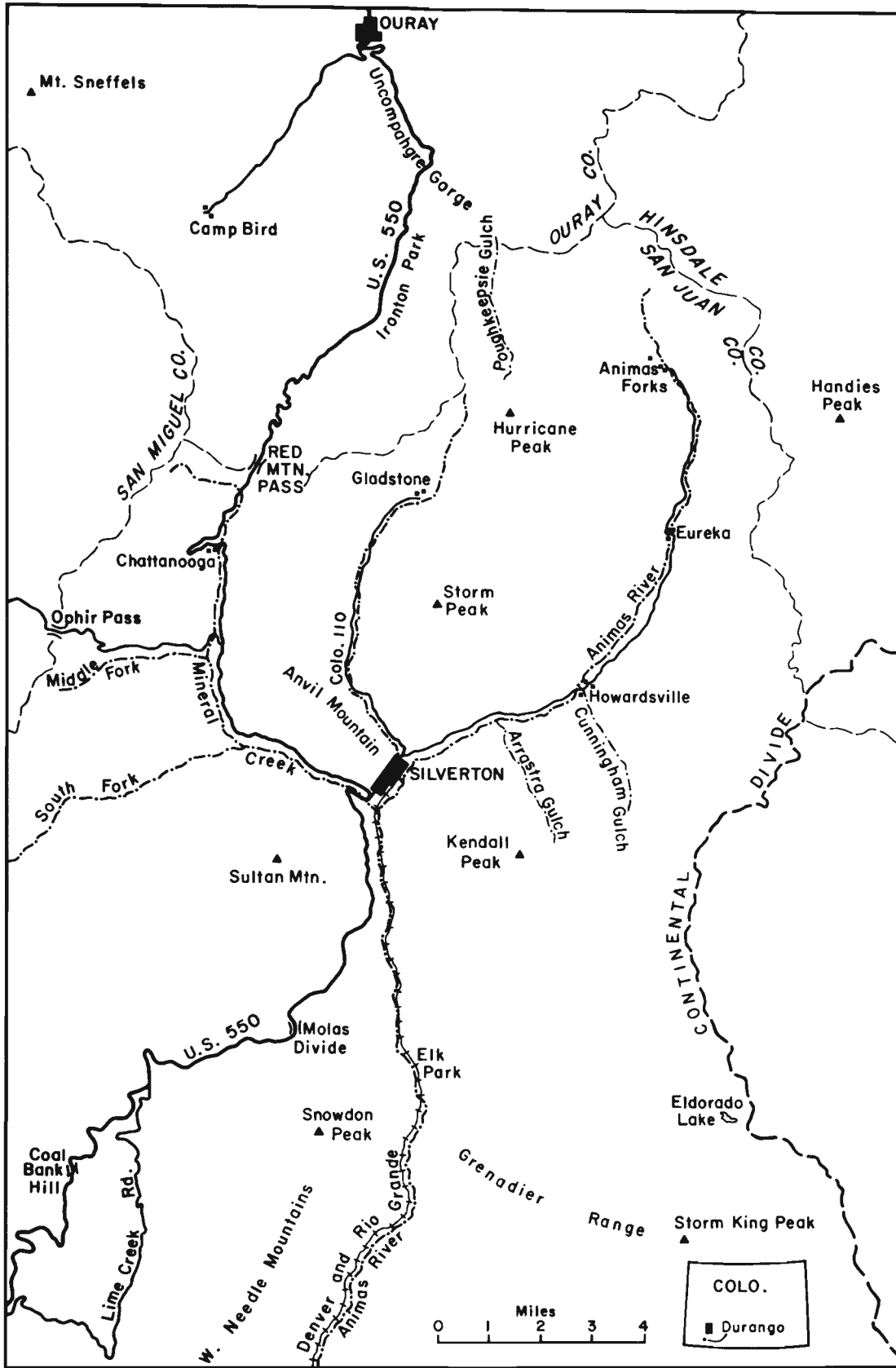


Figure 7. Location map of San Juan County, Colorado, 1975.

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.

Observation of internal snowpack evolution: 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	reduced data available	DATA REDUCTION 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) wind dir. (degrees)	weekly weekly	hourly hourly	0.5 m/sec nearest 10°
Carbon	3587	wind system	wind speed (m/sec) wind dir. (degrees)	monthly monthly	2 hr means 2 hr means	0.5 m/sec 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) relative humidity (%)	weekly not reduced	2 hr	0.5°C
		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
		net radiometer	snowpack water equivalent (mm) net all-wave radiation (cal/cm ²)	daily weekly	daily at intervals of 1.0 cm daily net value	1.0 mm 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	0.5cm 0.005 Mg/m ³
	interval snow board	3 hr interval new snow depth (cm) 3 hr interval new snow density (Mg/m ³)	3 hr 3 hr	0.5cm 0.005 Mg/m ³
Rainbow	3490	recording precipitation gauge	weekly	0.5mm
	hygrothermograph	air temperature (°C) relative humidity (%)	monthly not reduced	0.5°C
	wind system	wind speed (m/sec) wind dir. (degrees)	monthly monthly	0.5 m/sec nearest 20°
Silverton	2830	hygrothermograph	weekly not reduced	0.5°C
	recording precipitation gauge	snow-water equivalent (mm)	weekly	0.5mm
	microbarograph	air pressure (mb)	not reduced	
	master snow stake	total snowfall (cm)	daily	1.0cm
	24 hr snow board	24 hr new snow depth(cm) 24 hr new snow density (Mg/m ³)	daily daily	0.5cm 0.005 Mg/m ³
Molas	3225	hygrothermograph	weekly	0.5°C
	master snow stake	total snowfall (cm)	weekly	1.0cm
	24 hr snow board	24 hr new snow depth(cm) 24 hr new snow density (Mg/m ³)	daily daily	0.5cm 0.005 Mg/m ³

TABLE 2
1971-1975 INSTRUMENTATION NETWORK

Winter 1971-1972		
<u>Site</u>		
Pt. 12,325	wind system	Nov.-April
	thermograph	annual
Carbon	wind system	Oct.-March
RMPsss	precipitation gauge	Nov.-April
	hygrothermograph	Nov.-April
	thermistors-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

	<u>Site</u>	
RMPsss		
	precipitation gauge	Oct.-May
	hygrothermograph	Nov.-May
	thermistors-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. DAHCO4-75-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).

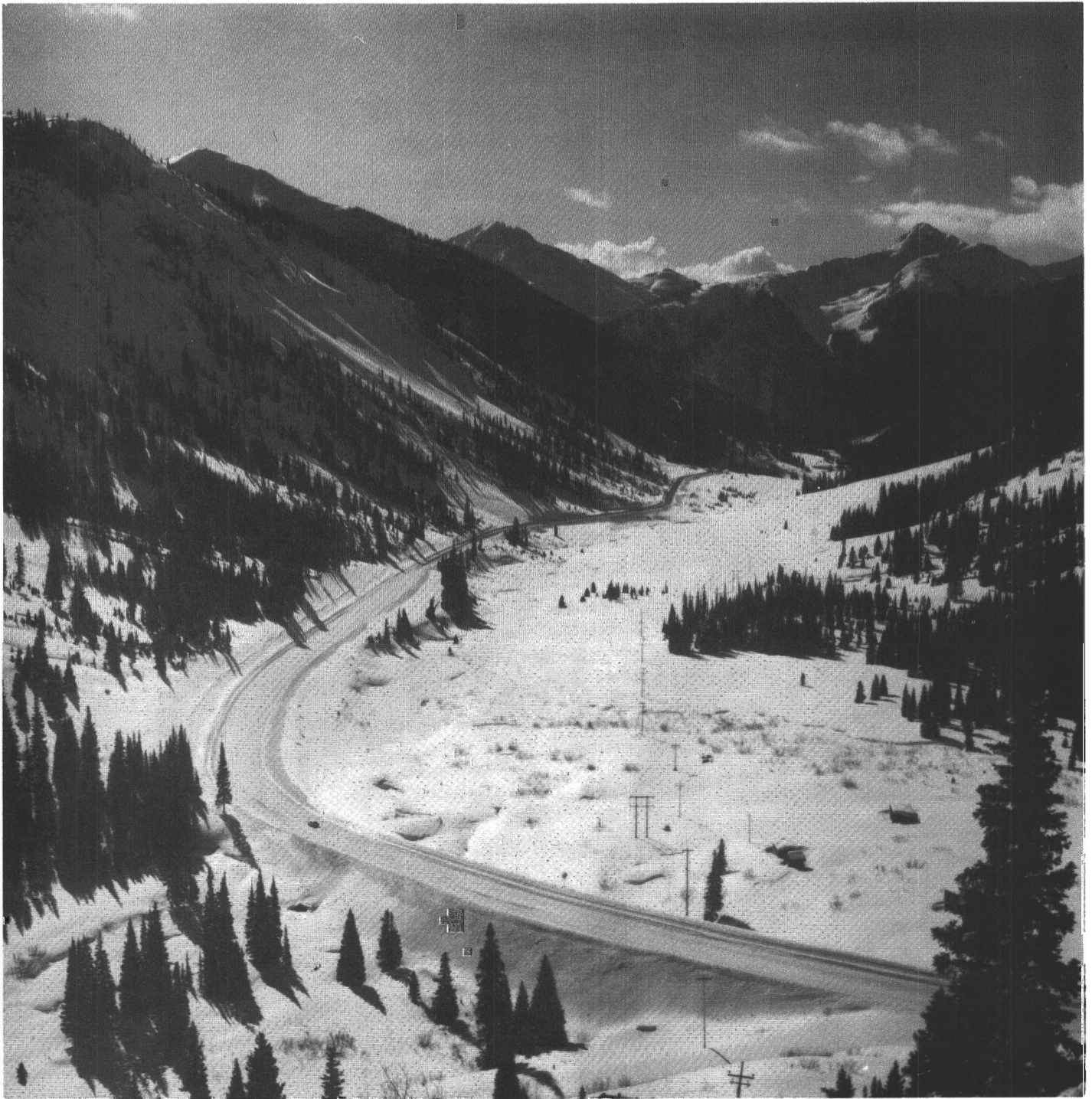


Plate 1. The view south along Highway 550 from below Red Mountain Pass. The Brooklyns avalanche paths threaten the highway from the east (left). From the opposite side several major paths, including Imogene, Bismark, and Battleship, cross the highway and damage timber on the reverse slope when they run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

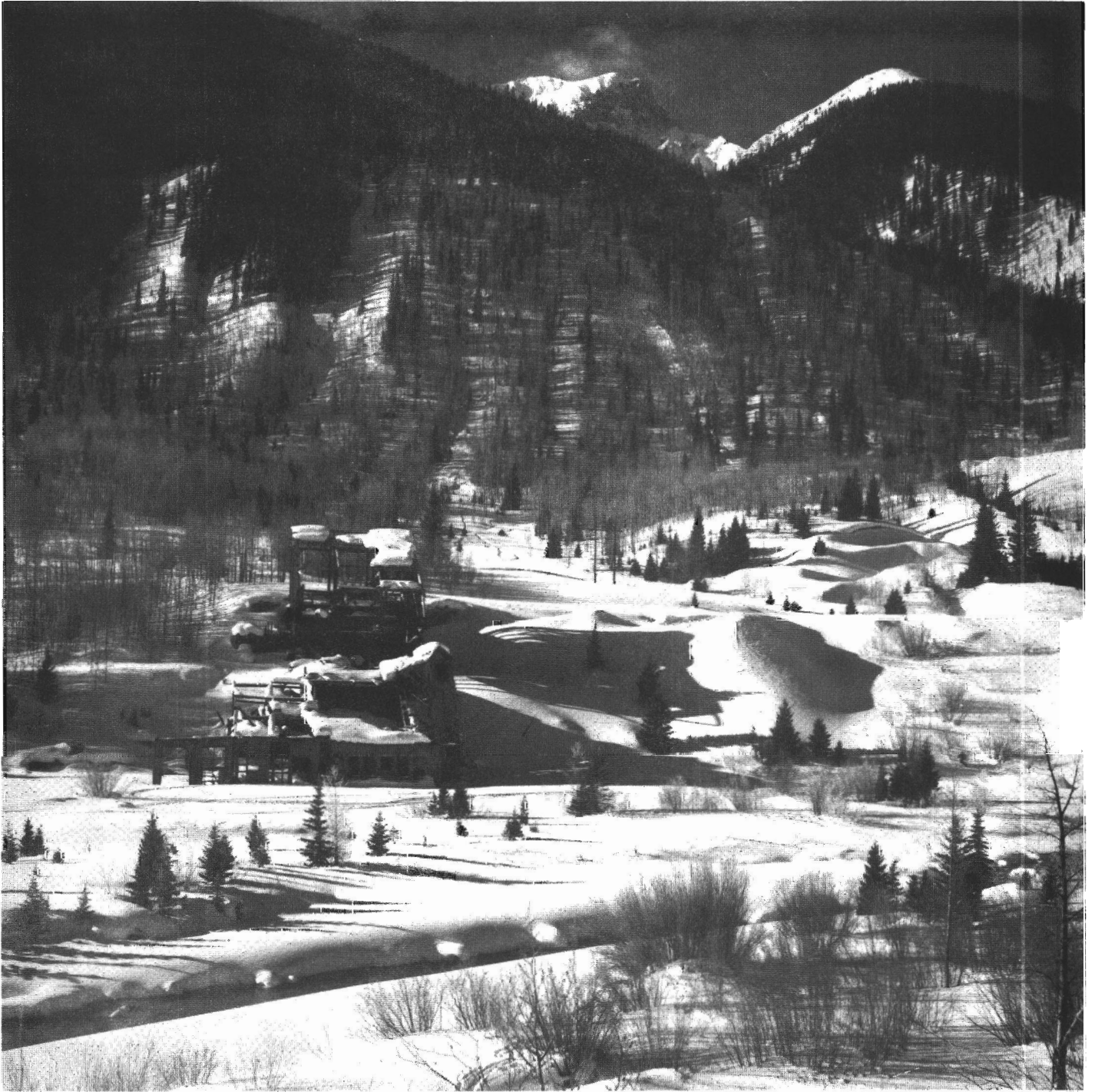


Plate 2. In contrast to the major avalanche paths, the linear vegetation shown here indicated repeated small scale wet snow avalanche activity. The derelict North Star Mill buildings in the center ground were not damaged by avalanche activity.



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 prevalent 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

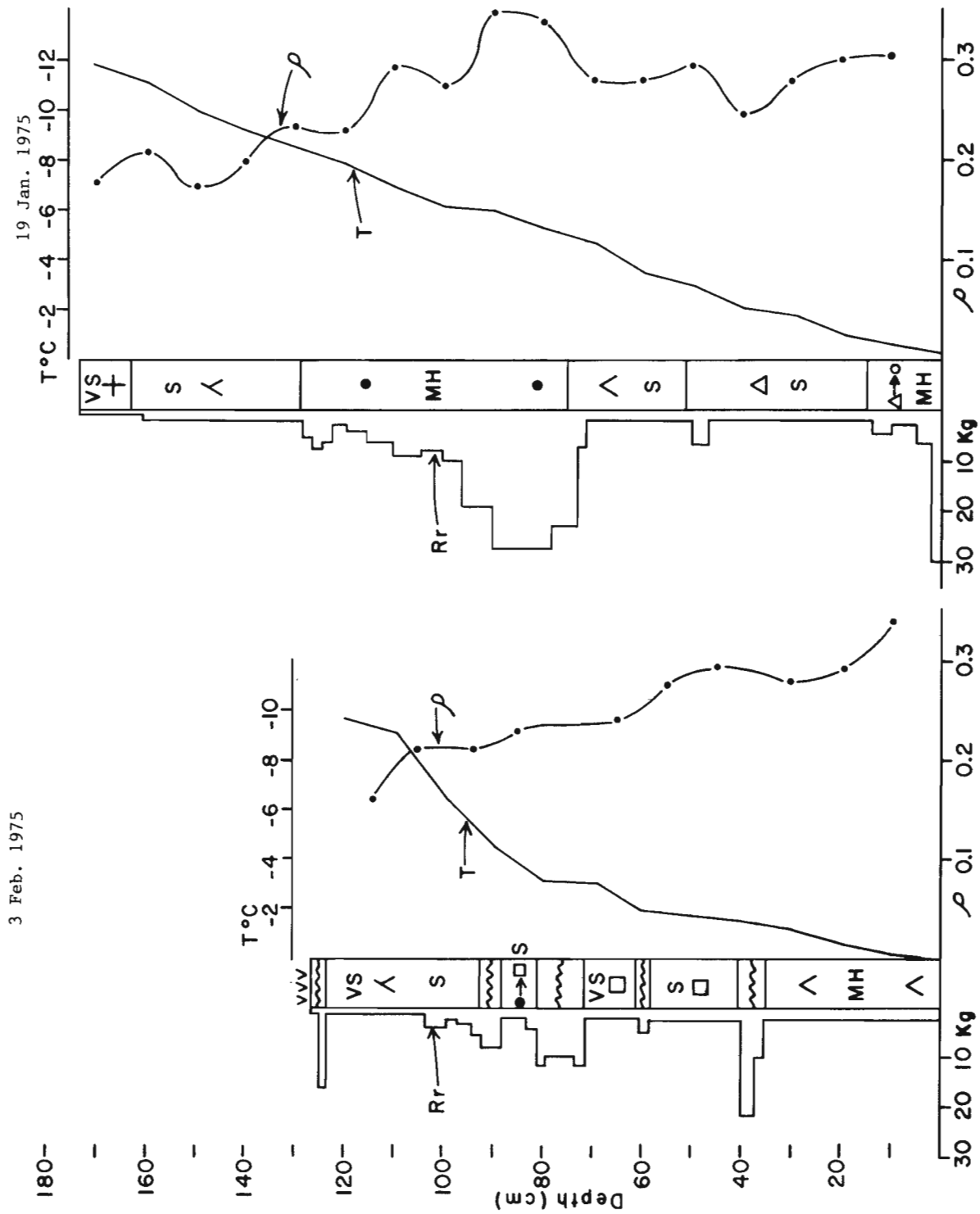


Figure 9. Two examples of typical San Juan snow stratigraphy. The profile on the left of the figure is from a south-facing slope and on the right is a north-facing slope. Both profiles are from the Red Mountain area at an elevation of 3550 m. See page 223 in Appendix 4 for symbol explanation.

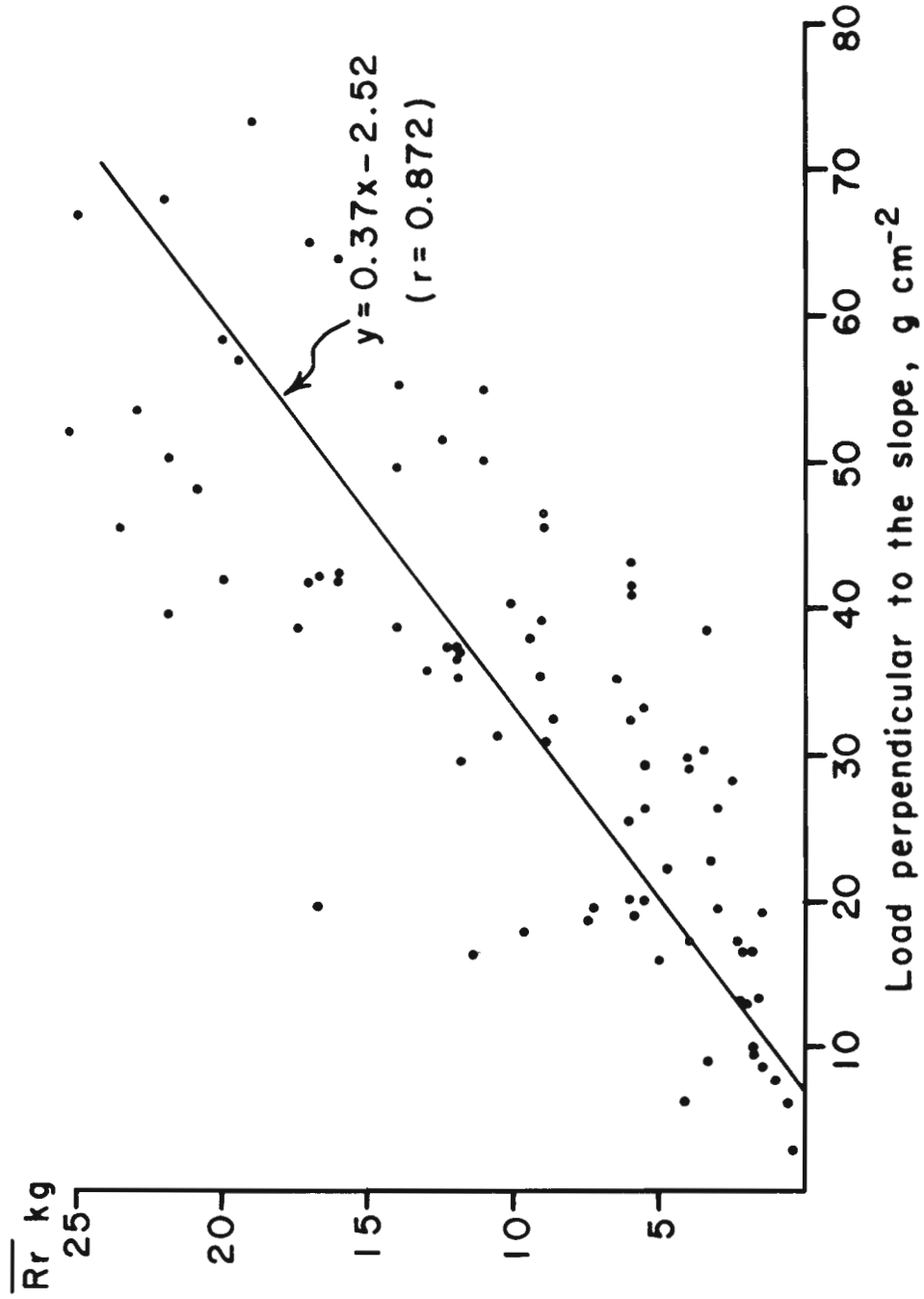


Figure 10. Mean snowcover ram resistance as a function of total compressive loading perpendicular to the ground surface at the base of the snowcover for 84 release zone profiles in the Red Mountain Pass area.

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 sub-freezing 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 prevalent type of release was thaw-induced and is the result of the introduction of melt water to sub-surface 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

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>
14	57	23	5	1

B. Type: percent

	<u>ss</u>	<u>hs</u>	<u>ws</u>	<u>dl</u>	<u>wl</u>
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

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>
6	49	31	12	2

E. Percent Reaching Highway 550 by Type

	<u>ss</u>	<u>hs</u>	<u>ws</u>	<u>dl</u>	<u>wl</u>
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 per year	average no. of events	avalanche path number	avalanche path name	frequency per year	average no. of events
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.

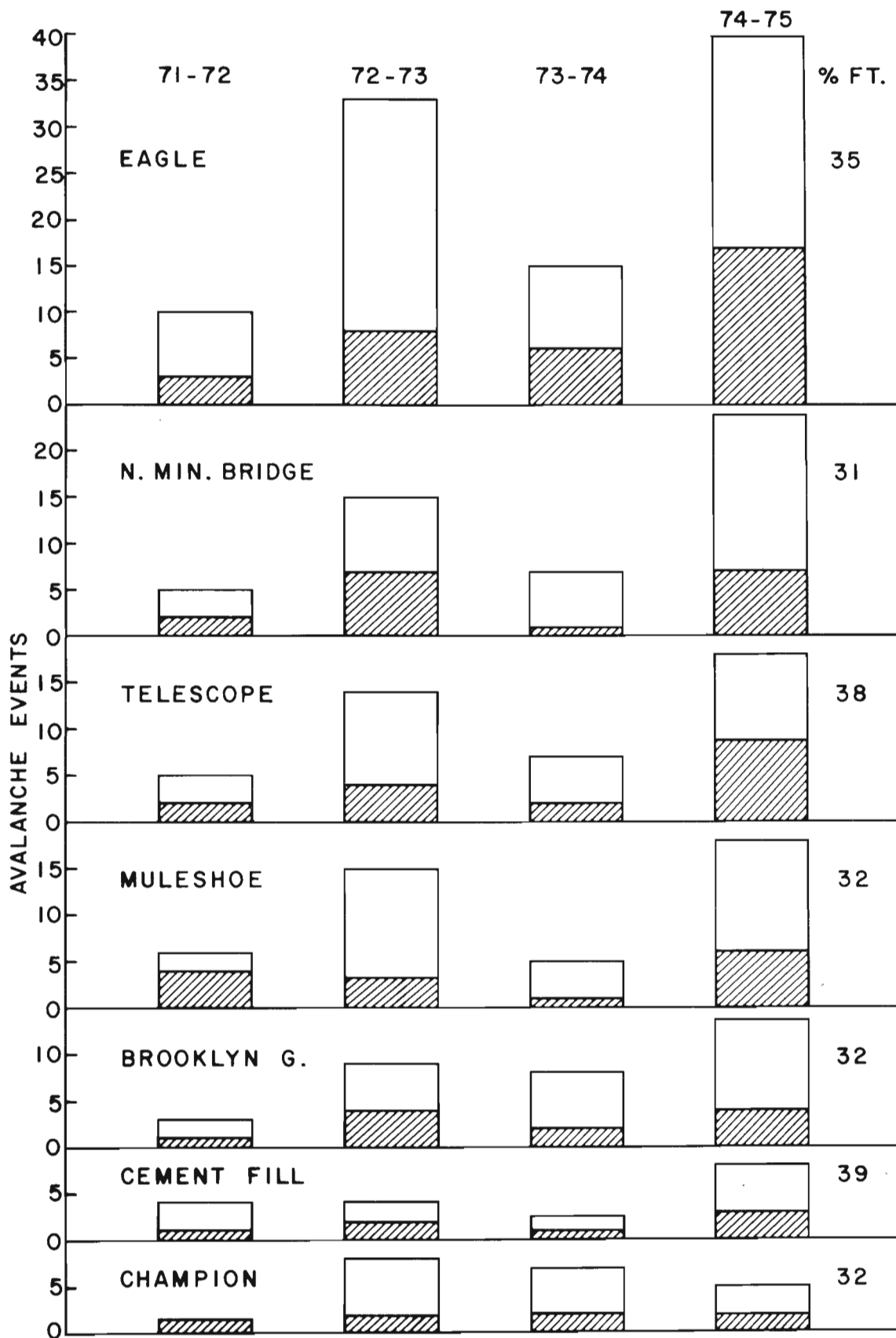


Figure 11. Relationship between the number of avalanche events reaching full track and the total number of observed events larger than size one for seven of the most active avalanche paths directly affecting Highway 550.

TABLE 8

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

<u>Total Layer Thickness (cm)</u>	<u>^</u>	<u>□</u>	<u>•○</u>	<u>+λ</u>	<u>Total</u>
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
<u>Percent</u>					<u>(No. of Profiles)</u>
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)
<u>Temperature Gradient Snow</u>	<u>Equi-Temperature Metamorphism</u>		<u>New and Partially Metamorphosed Snow</u>		
<u>Beginning</u>	<u>Advanced</u>	<u>(Increasing Grain Size)</u>		<u>(Decreasing Grain Size)</u>	
□	^	•○		+λ	

Table 9 contains statistics from 53 fracture-line profiles.

TABLE 9

FRACTURE-LINE CHARACTERISTICS 1971-1975

<u>Characteristics</u>	<u>Percent</u>
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
<hr/>	
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° to 55° , there is a pronounced peak of avalanche occurrence between 35° and 40° . This pattern is further supported by INSTAAR data with 49 percent of the 53 fracture-line profiles located on slopes between 34° and 41° and 72 percent located between 30° and 45° . The range of the total sample was 25° to 48° . 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

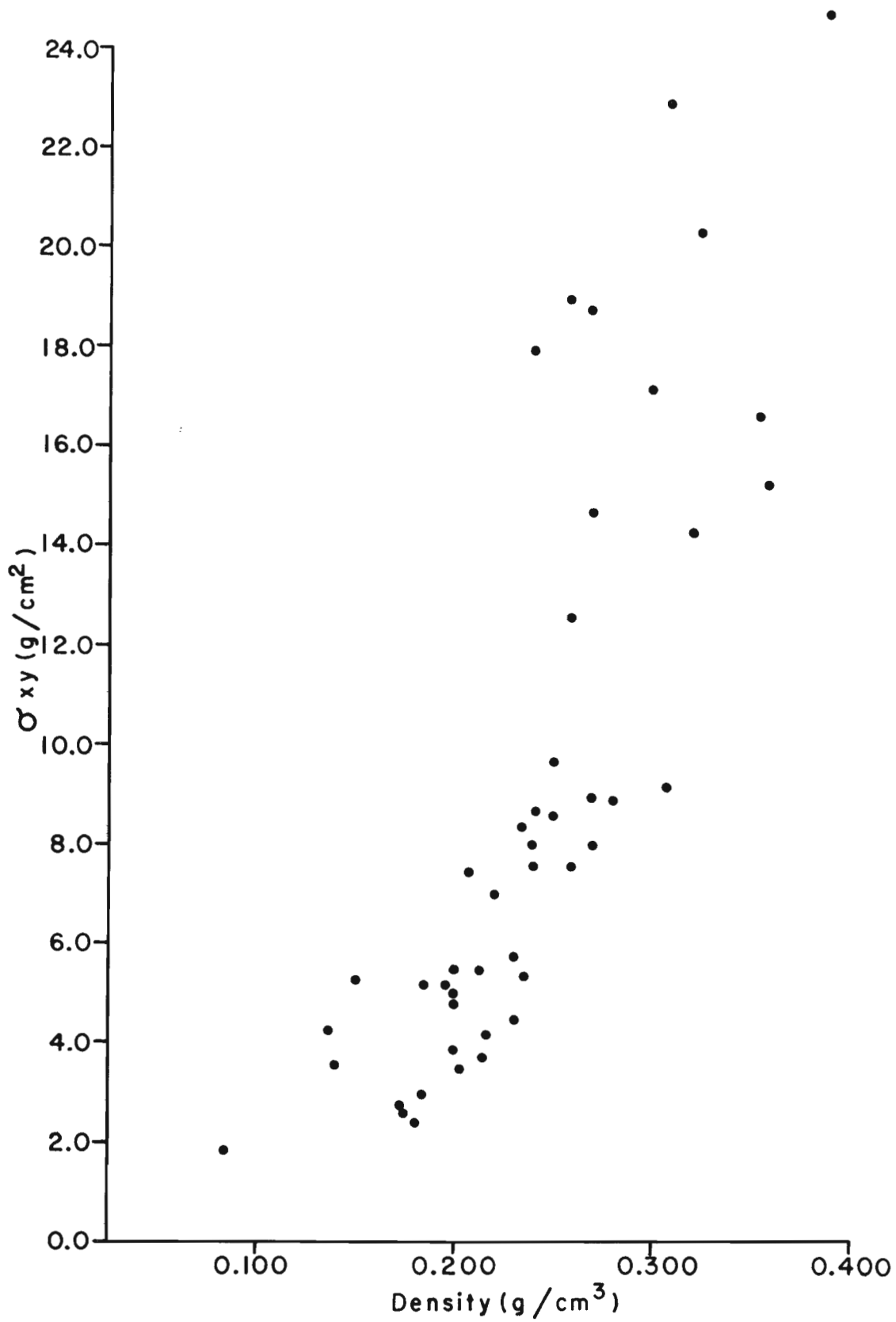


Figure 12. The relationship between snow slab shear stress at the point of failure (fracture line) and the density of the 5.0 cm layer (lubricating layer) at the base of the slab for 46 fracture line profiles.

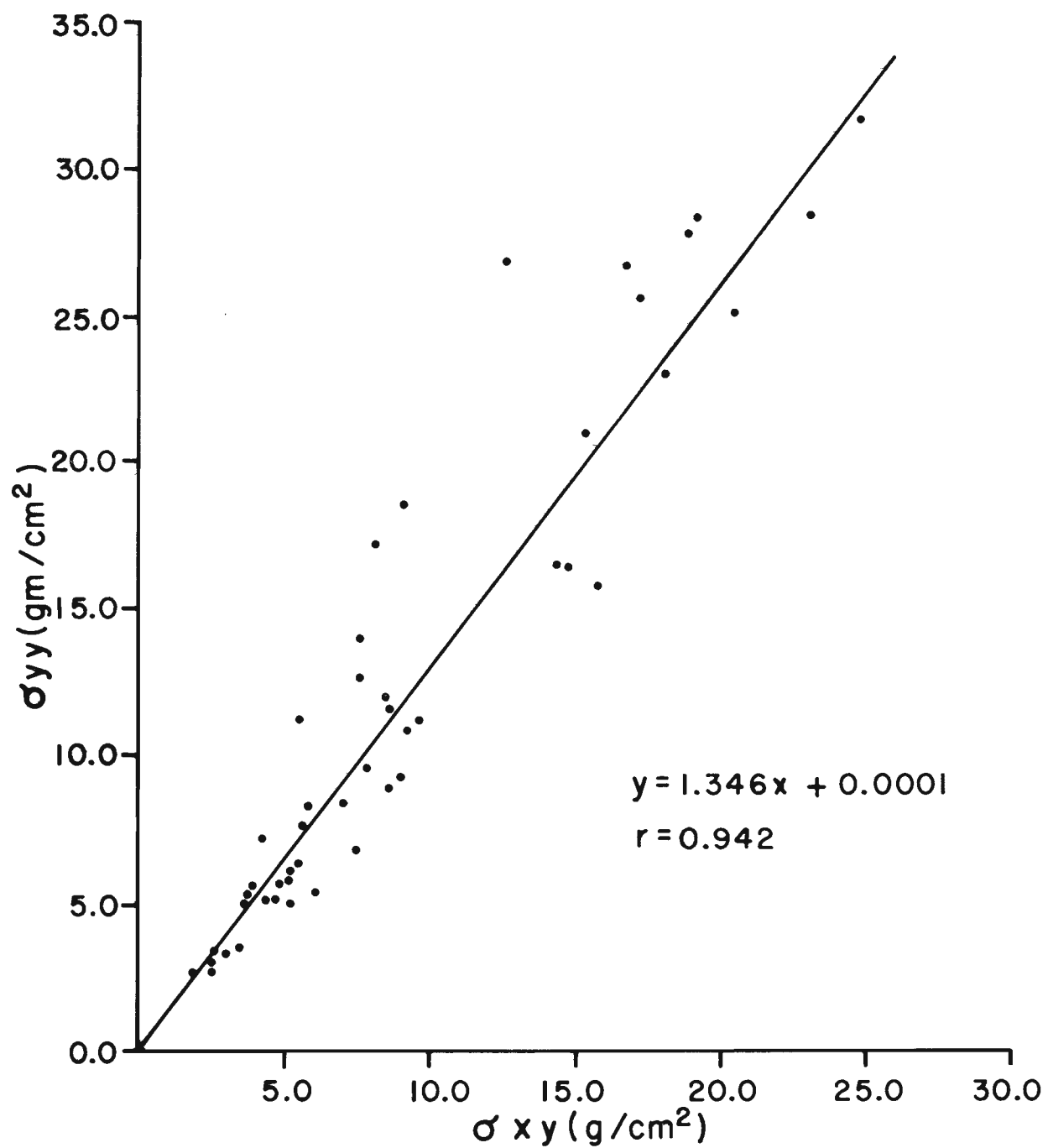


Figure 13. The Coulomb-Mohr relationship of shear stress vs. normal stress (internal friction) for 47 fracture line profiles.

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

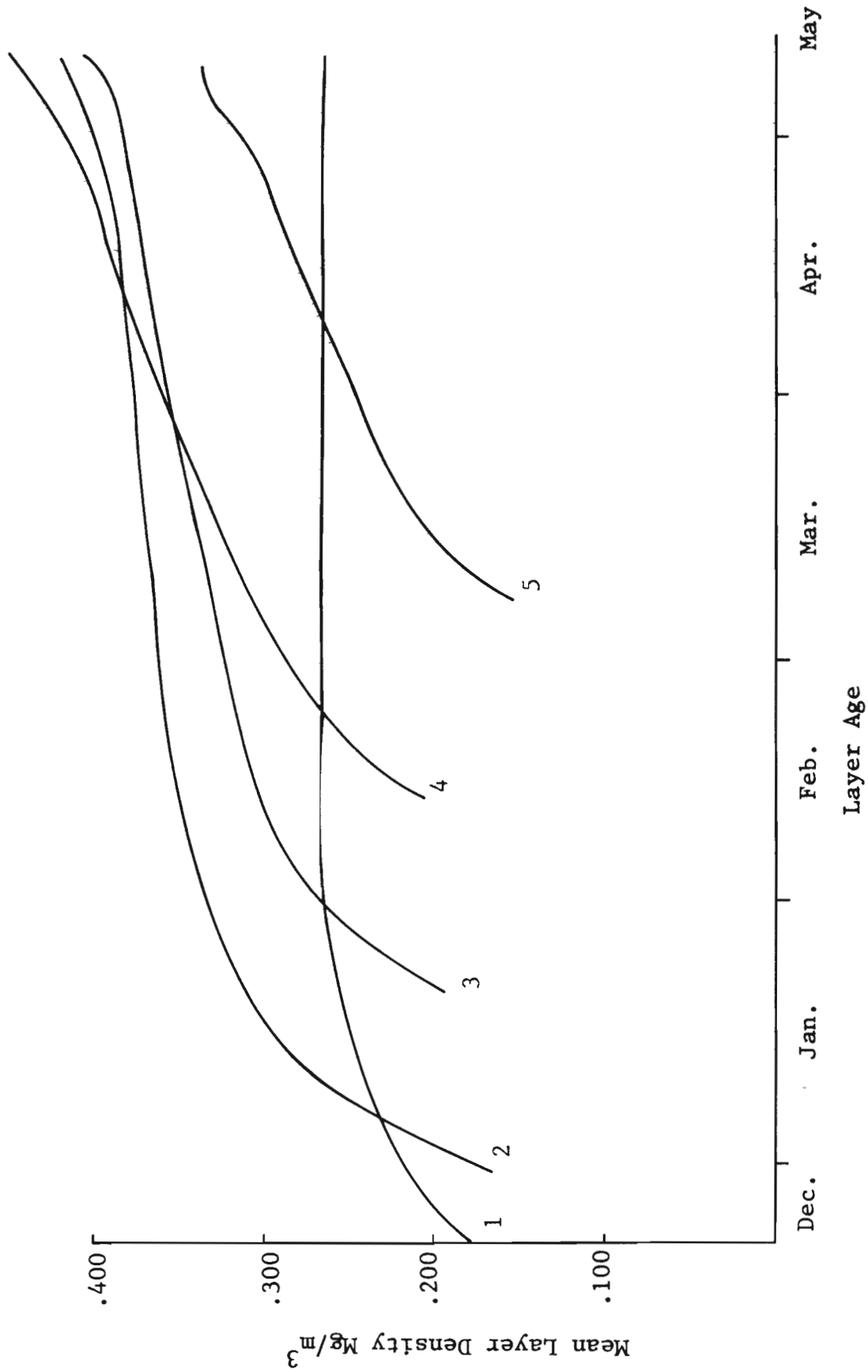


Figure 14. Snow layer densification rates at the Red Mountain Pass study site, 1973-1974. Layer number one is composed entirely of temperature-gradient snow. The remaining layers did not experience significant temperature-gradient metamorphism.

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

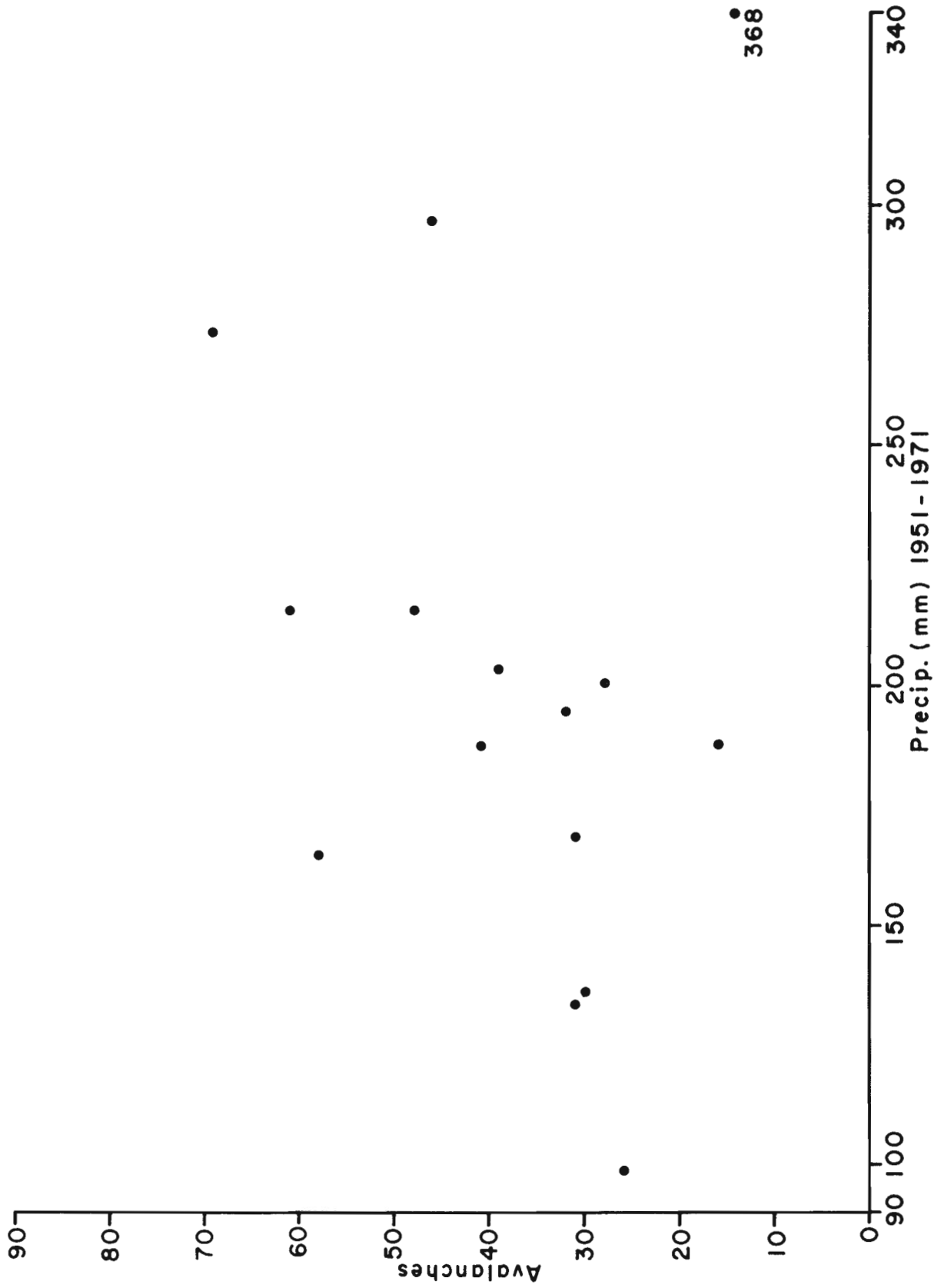


Figure 15. Relationship between the total number of avalanches reaching Highway 550 and total winter precipitation (mm water equivalent) for fifteen winter seasons within the period 1951-1971. Precipitation data is from the Soil Conservation Service, Red Mountain Pass site; avalanche data from Colorado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

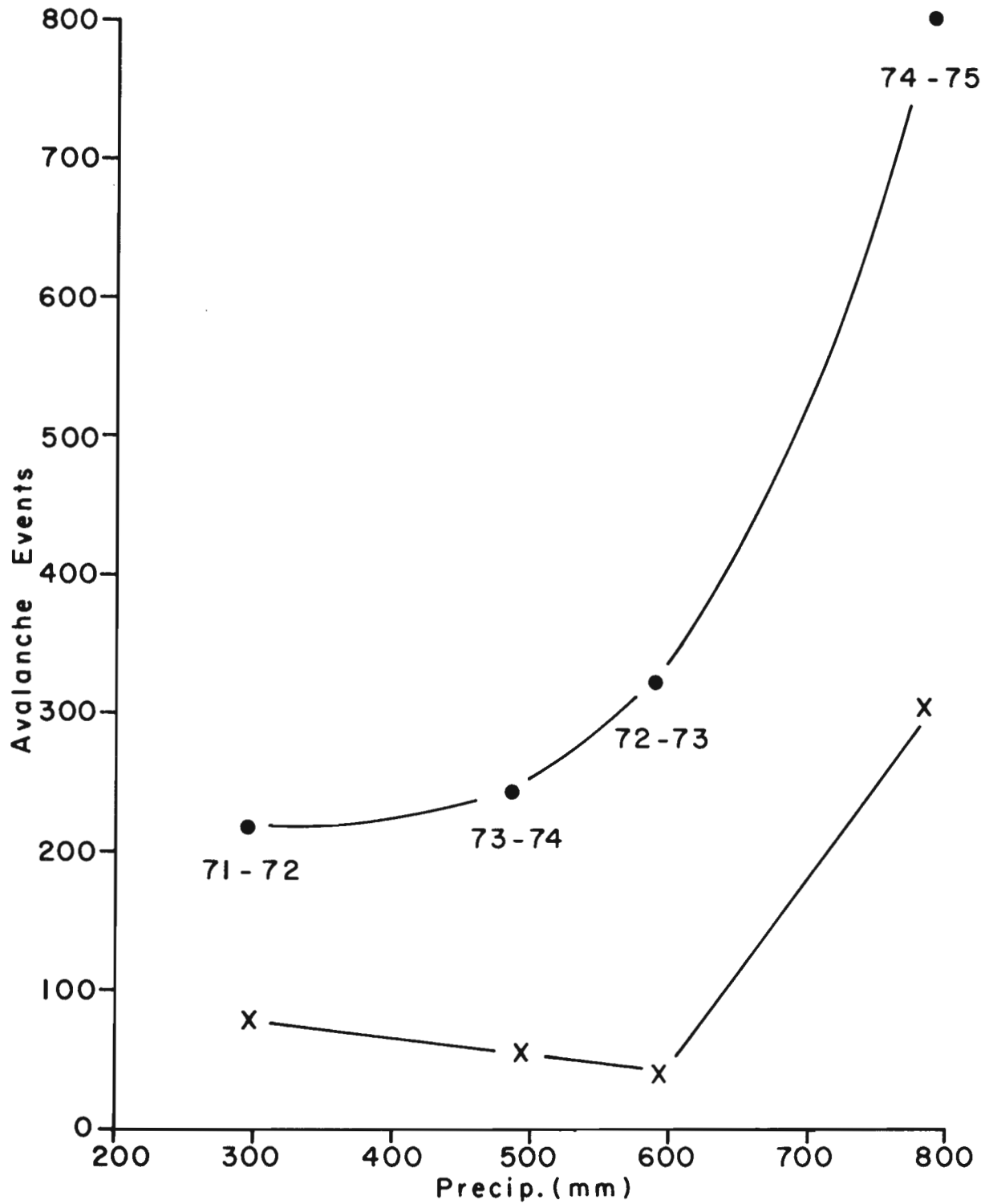


Figure 16. Relationship between total winter precipitation (mm water equivalent) to March 31, and total number of avalanches observed during the four winter seasons 1971-1975. Upper data points include all avalanches larger than size one; lower data include only events larger than size two.

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

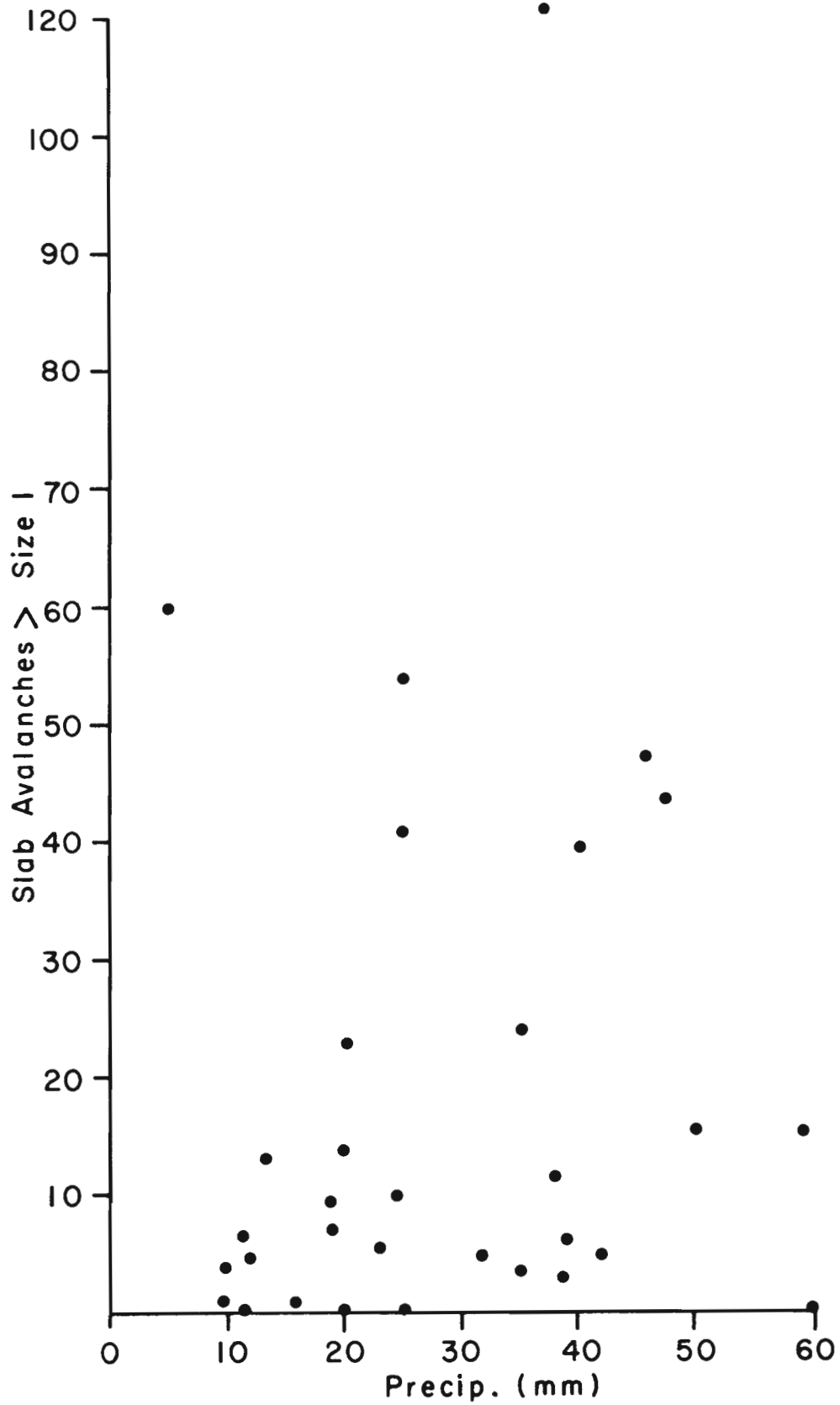


Figure 17. Relationship between individual storm precipitation totals (mm water equivalent) and number of observed slab avalanches larger than size one during the 1974-1975 winter.

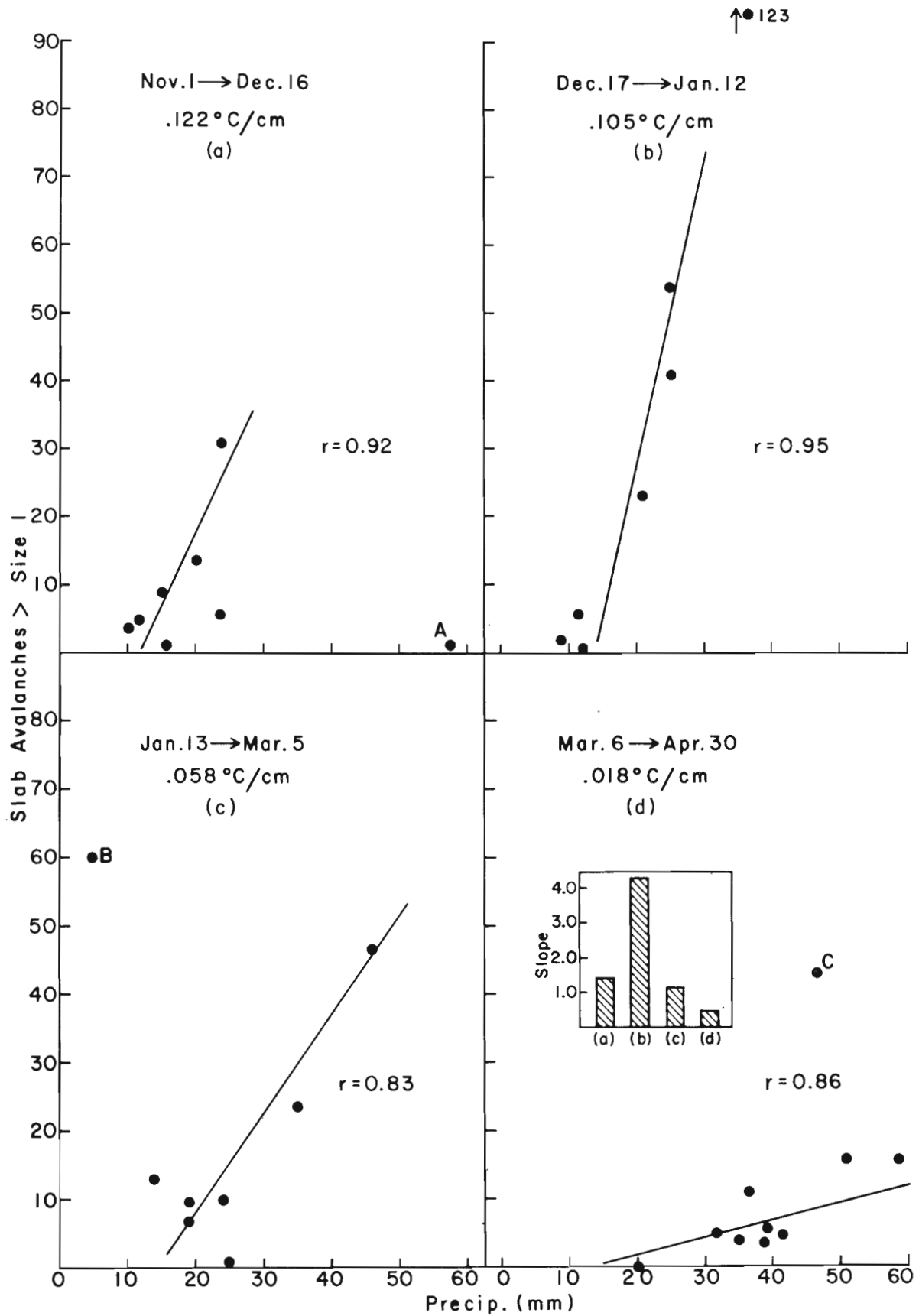


Figure 18. Relationship between individual storm precipitation totals and number of observed slab avalanches larger than size one subdivided into four periods according to progressive changes in snow structure for the 1974-1975 winter.

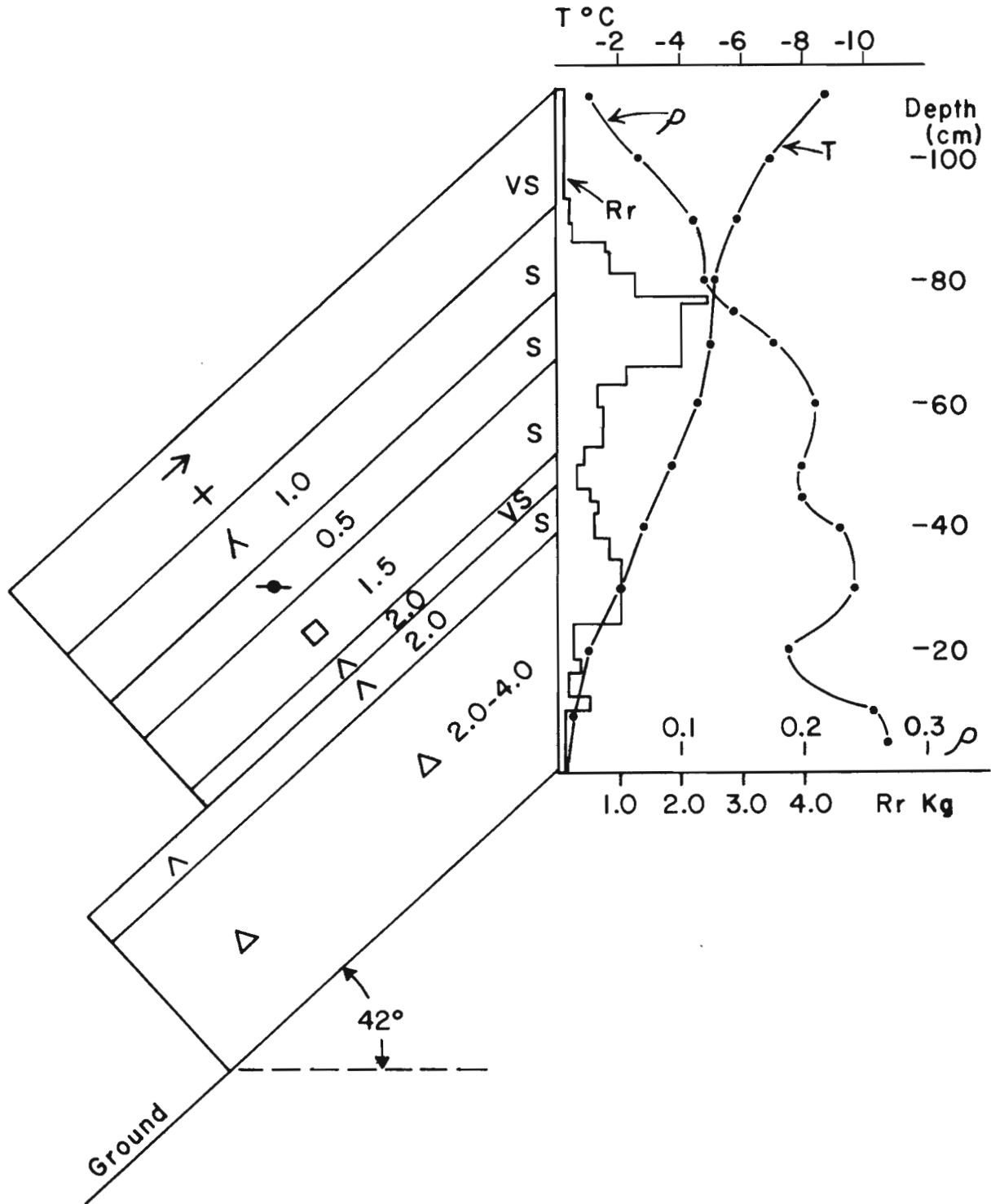


Figure 19. Fracture line profile data obtained from a soft-slab, artificial (artillery), size two event which ran to the ground on 22 Dec., 1974. The path is the Silver Ledge Mine (152100) with a slope aspect of 40° true.

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 preceding 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 preceding 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.

*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 omitted, 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 Examined	% Accuracy 24 hr. eval.	Number of Index Days (evaluated)				
			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 conscientiously 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 definitely 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°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	FGST 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	FGST 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	FGST 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	FGST right on
Dec 31	Full-track artificial releases possible in Muleshoe Group	Eagle A 3 150 Telescope A 2 100	FGST right on
Jan 5	Natural releases to run full-track.	Brooklyns G 15 250 Eagle 3 50 Porcupine 3 50 Rockwall 8 100	FGST right on
Jan 6	Artificial releases possible, running full-track	Brooklyns C A 2 75 East Riverside A 5 70 15 80	FGST right on
Jan 7	Artificial releases possible, running full-track	Brooklyns C A 1 25 Silver Ledge A 4 75	FGST right on
Jan 8	No natural slides	Willow Swamp 11 200	FGST 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

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

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

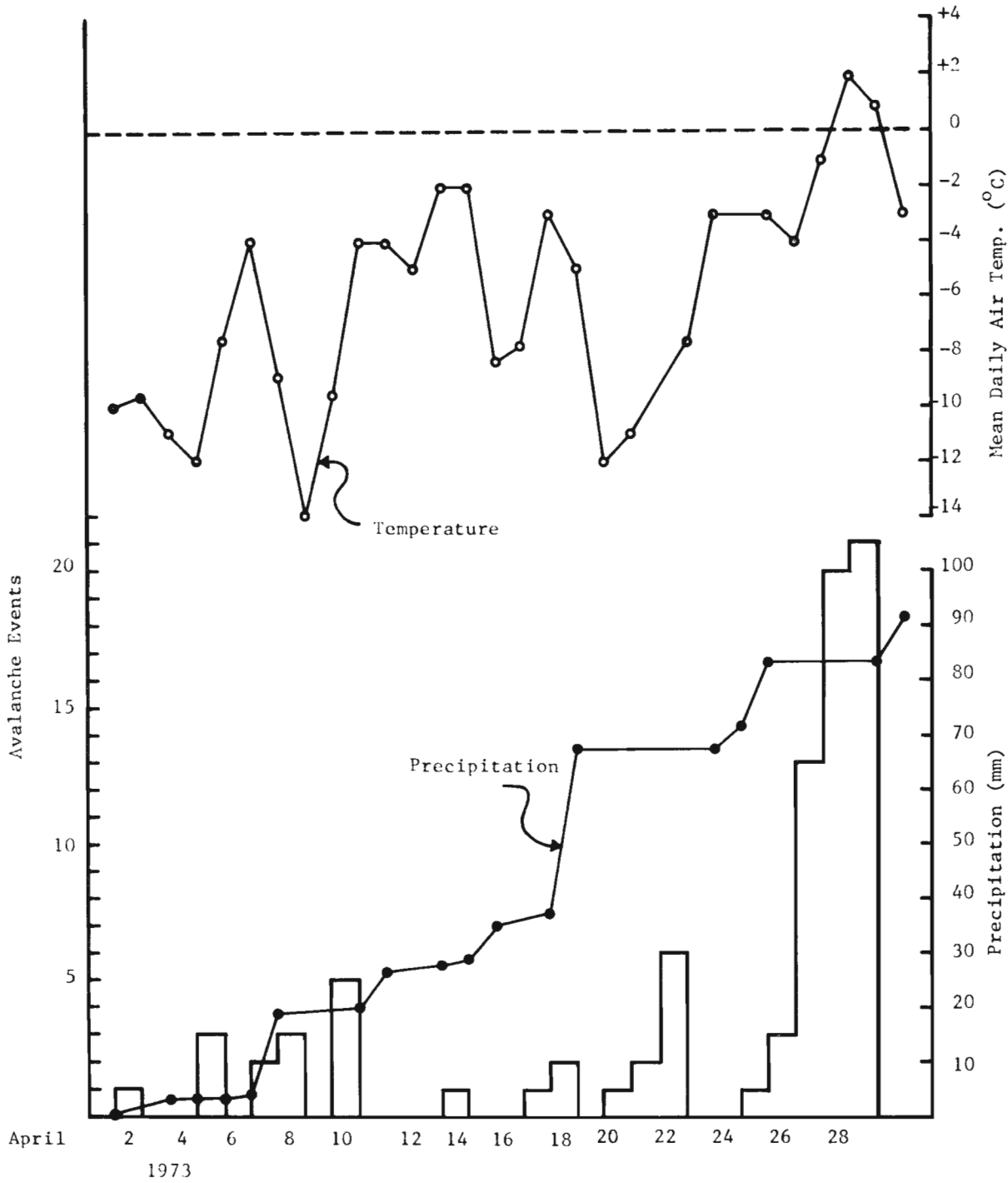


Figure 20. Wet snow avalanche events observed during April, 1973 compared to precipitation (mm) and mean daily air temperature ($^{\circ}\text{C}$) recorded at Red Mountain Pass.

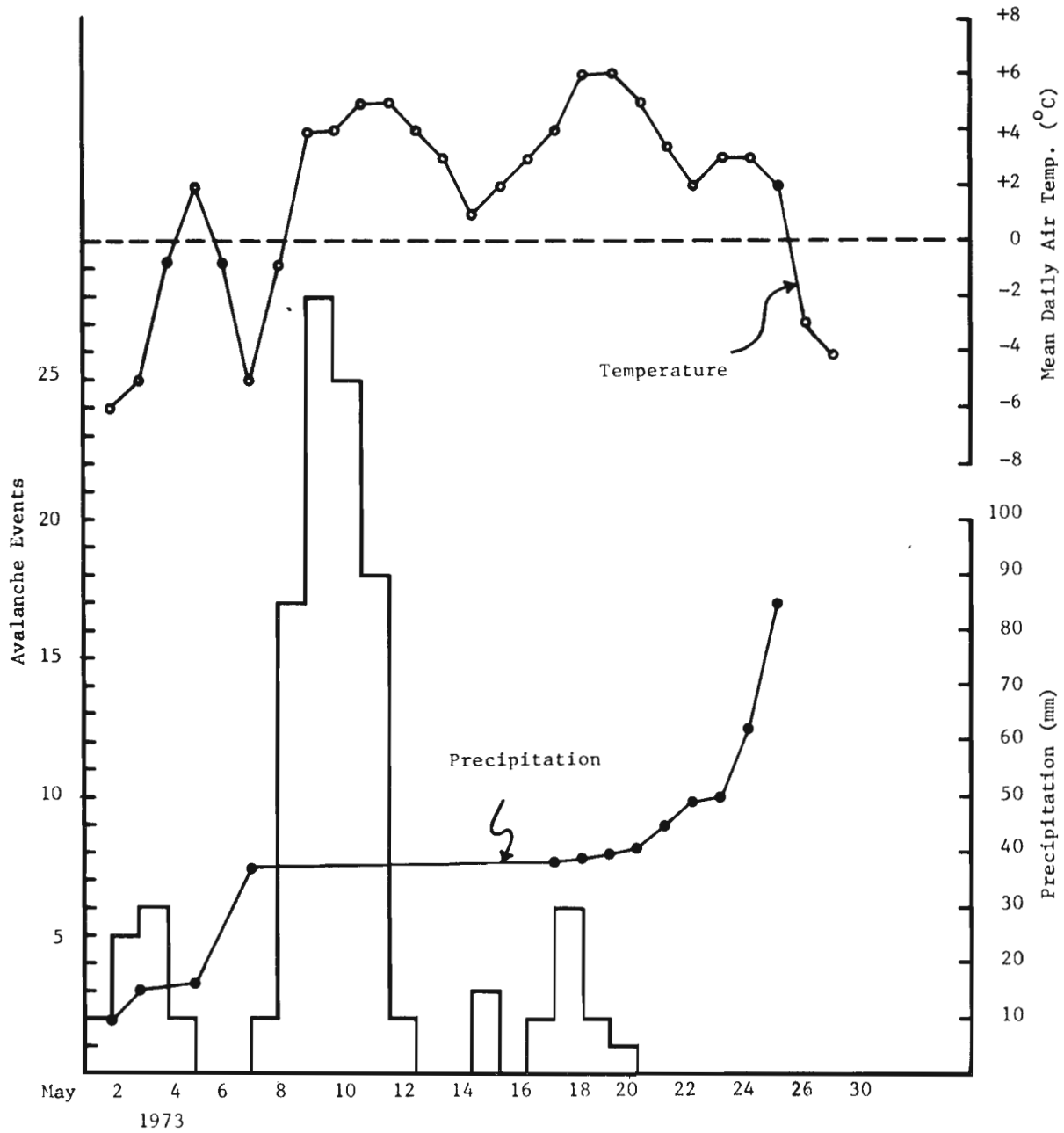


Figure 21. Wet snow avalanche events observed during May, 1973 compared to precipitation (mm) and mean daily air temperature ($^{\circ}\text{C}$) recorded at Red Mountain Pass.

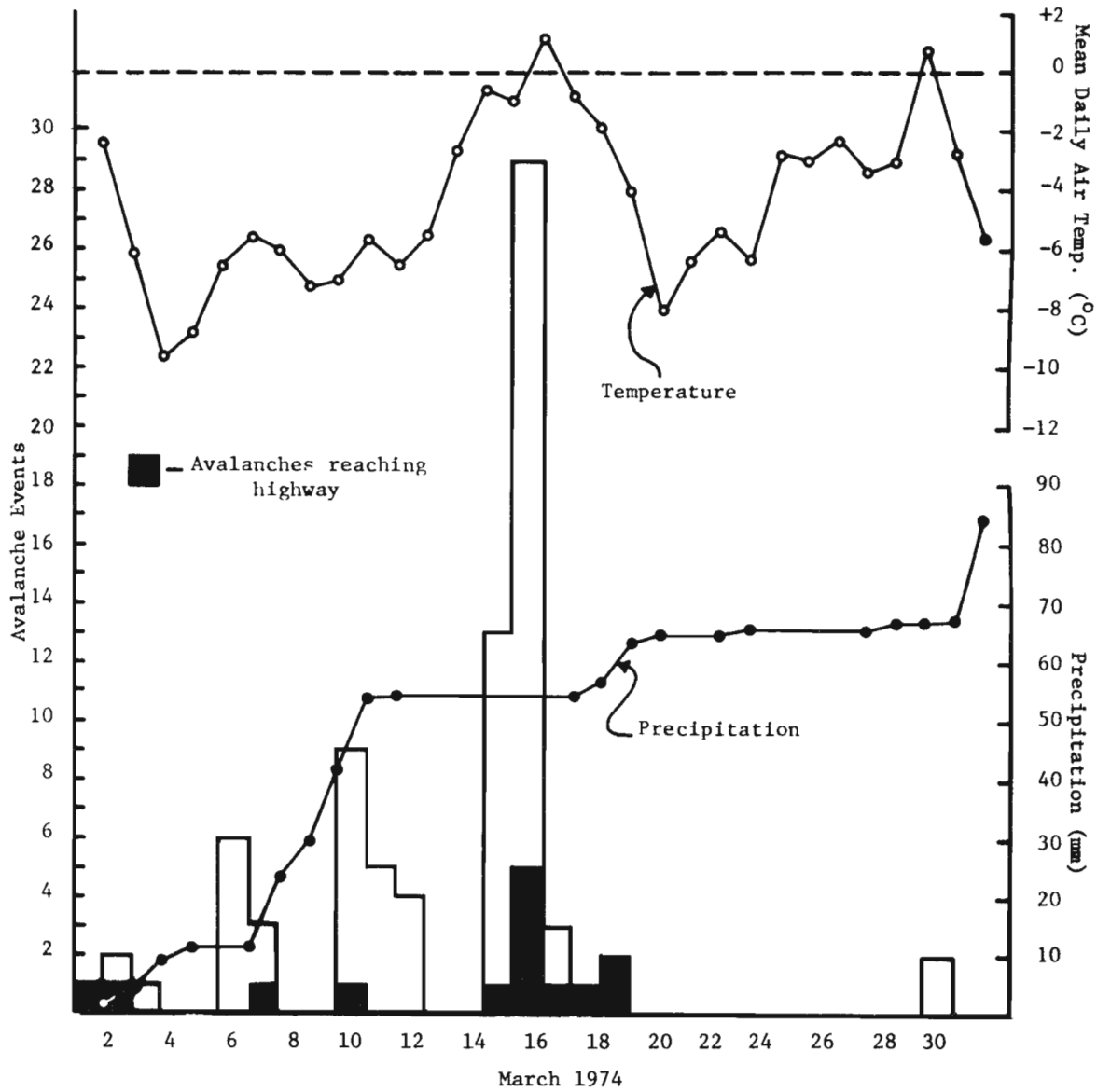


Figure 22. Wet snow avalanche events observed during March, 1974 compared to precipitation (mm) and mean daily air temperature ($^{\circ}\text{C}$) recorded at Red Mountain Pass.

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.

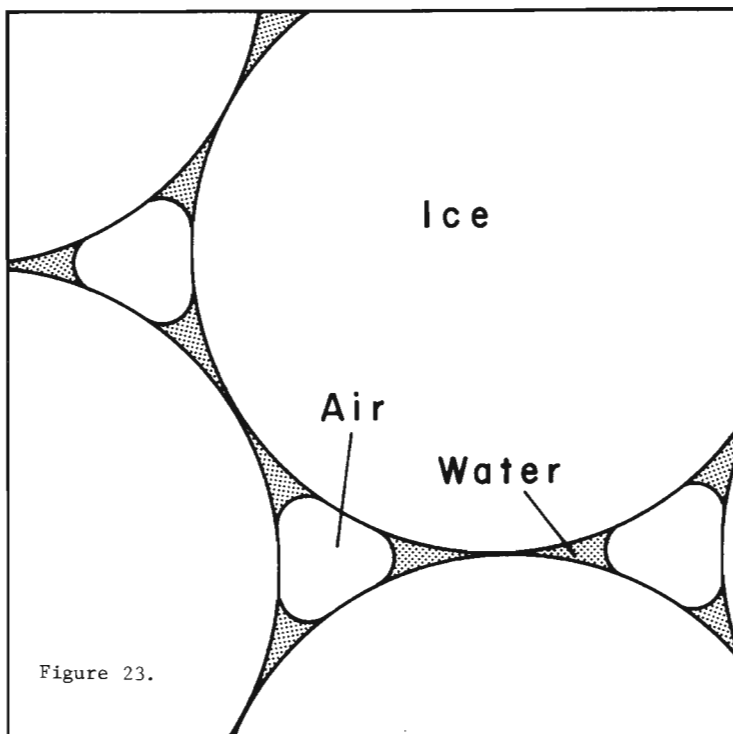
While increased solar energy is the cause of higher air temperatures, the effect of direct radiation is low on a snowcover with an albedo of 90 percent or greater. This value, however, drops to approximately 60 percent when the snow becomes wet. Also, some short-wave radiation penetrates 10-20 cm into 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.

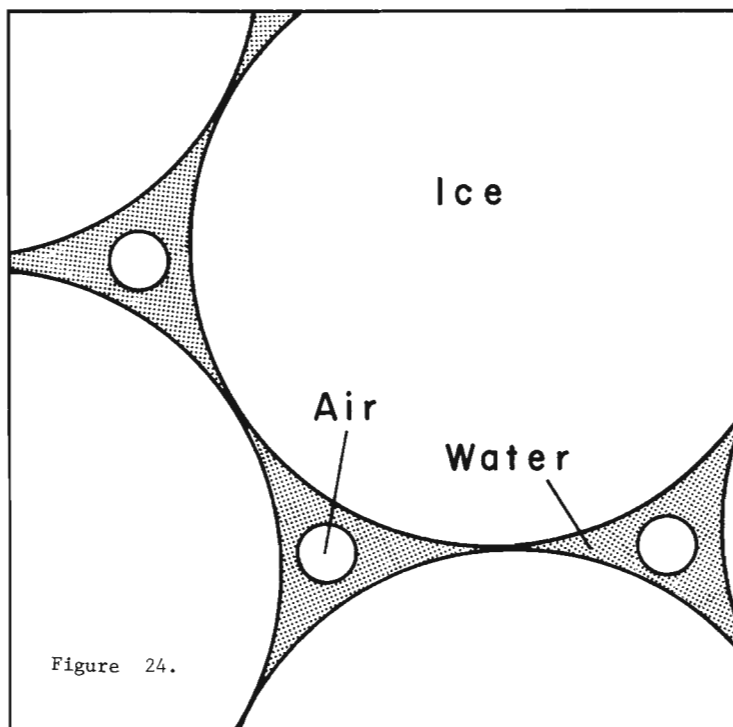
The metamorphism, strength, and densification of wet snow are controlled by the small temperature gradients between the grains. In order to describe these processes, Colbeck (1974) has categorized the saturation regimes in wet snow as either pendular or funicular, i.e., low or high saturation respectively. 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.



Pendular Regime



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/cm²) 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

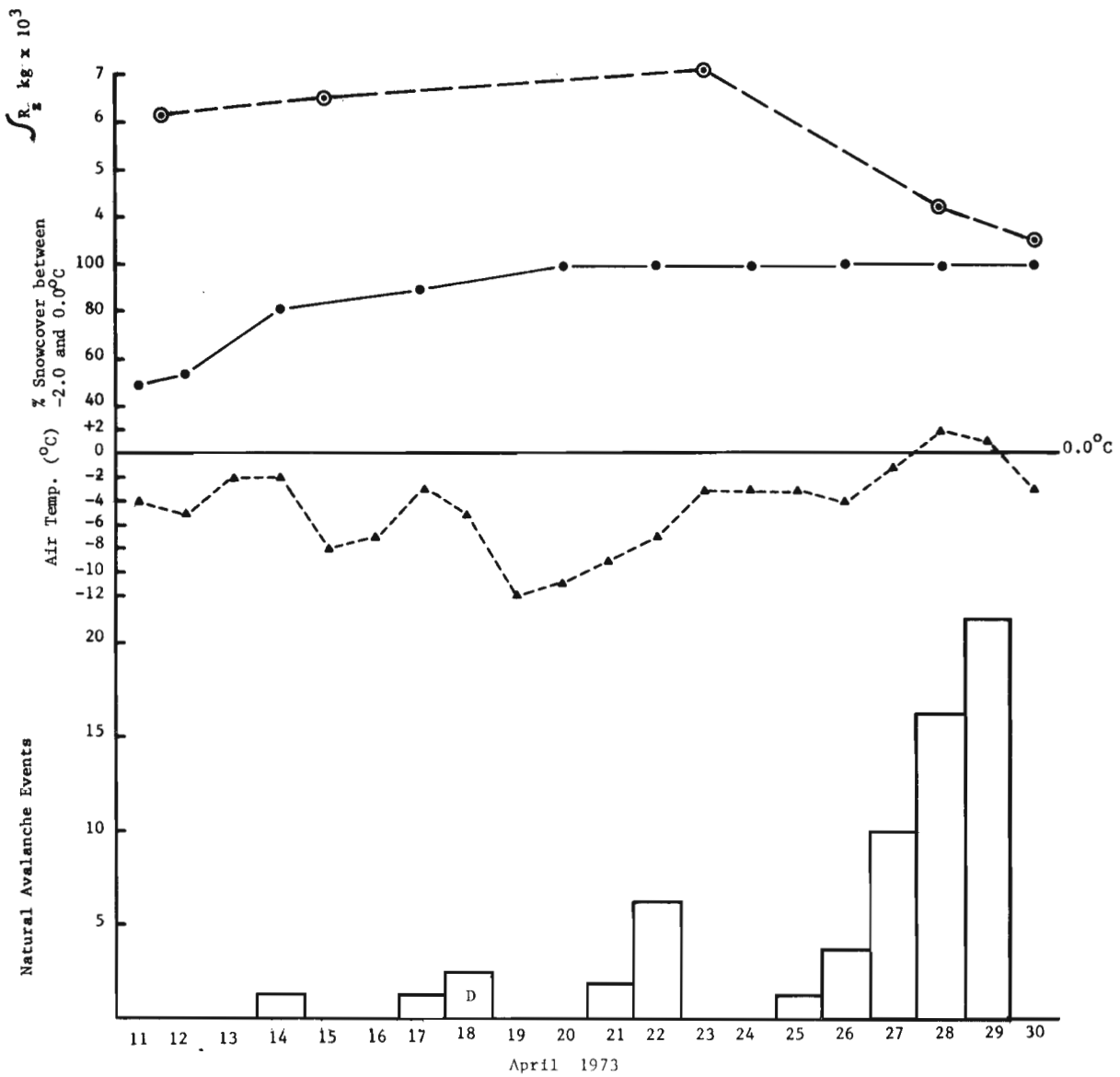


Figure 25. A comparison of integrated ram resistance, percent of snowcover between -2.0°C and 0.0°C , and mean daily air temperature ($^\circ\text{C}$) at Red Mountain Pass and observed natural wet snow avalanche events during April, 1973. (D = dry snow event)

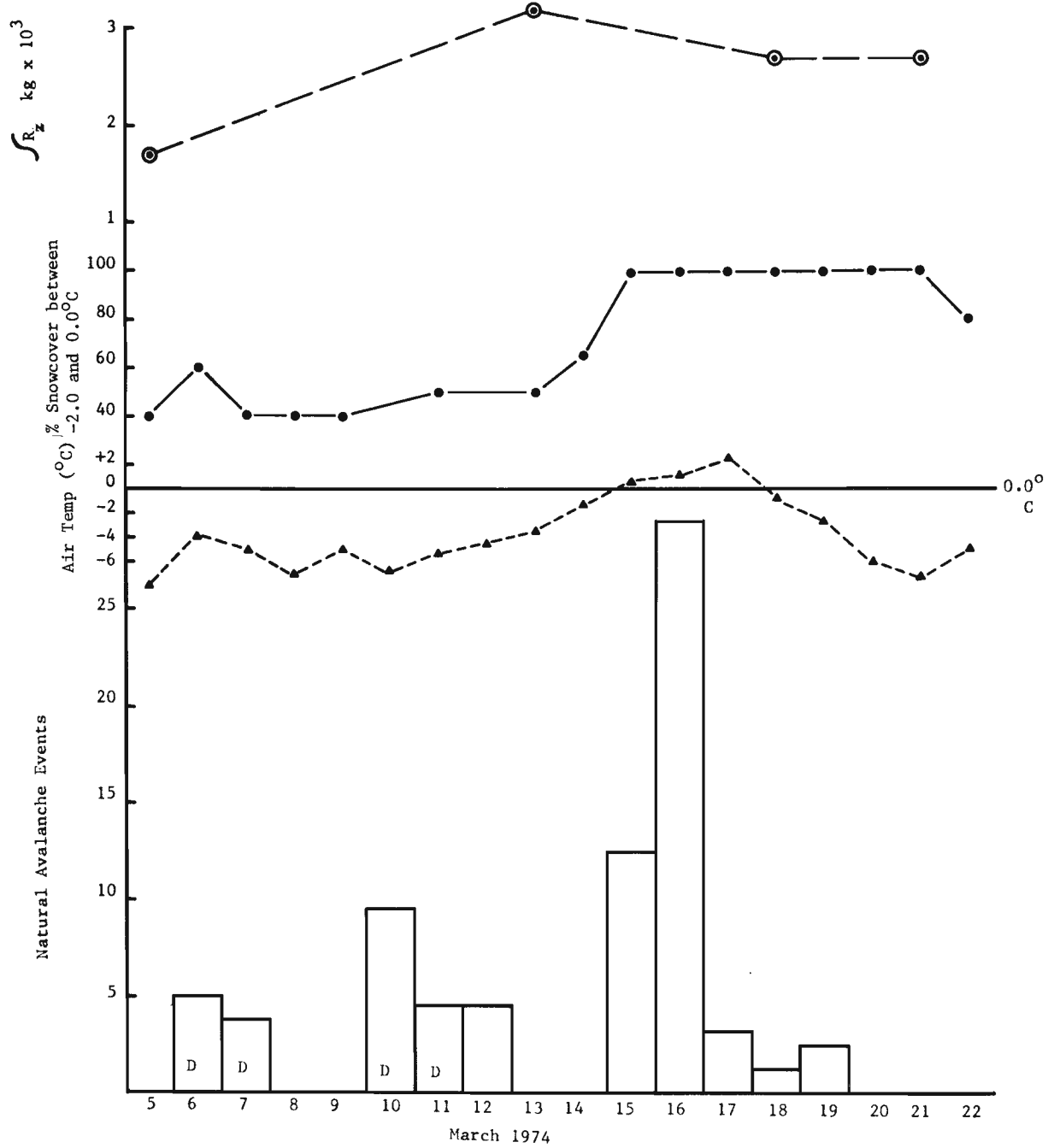


Figure 26. A comparison of integrated ram resistance, percent of snowcover between -2.0°C and 0.0°C , and mean daily air temperature ($^\circ\text{C}$) at Red Mountain Pass and observed natural wet snow avalanche events during March, 1974. (D = dry snow event)

avalanche activity on Engineer Mountain as a precursor 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 preceding 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.

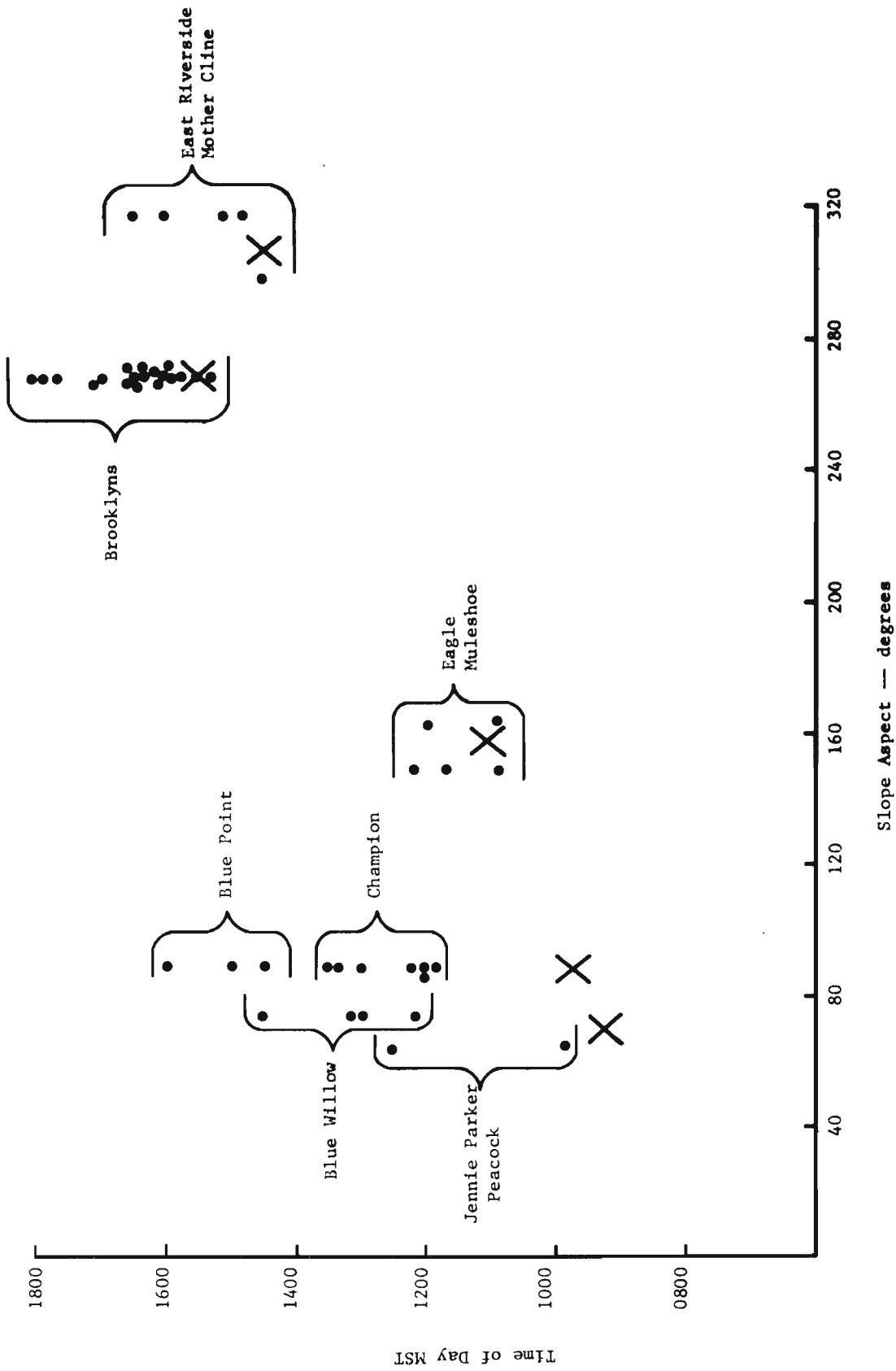


Figure 27 Wet snow avalanche events grouped by slide path as a function of slope aspect and time of day.

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 preceded 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

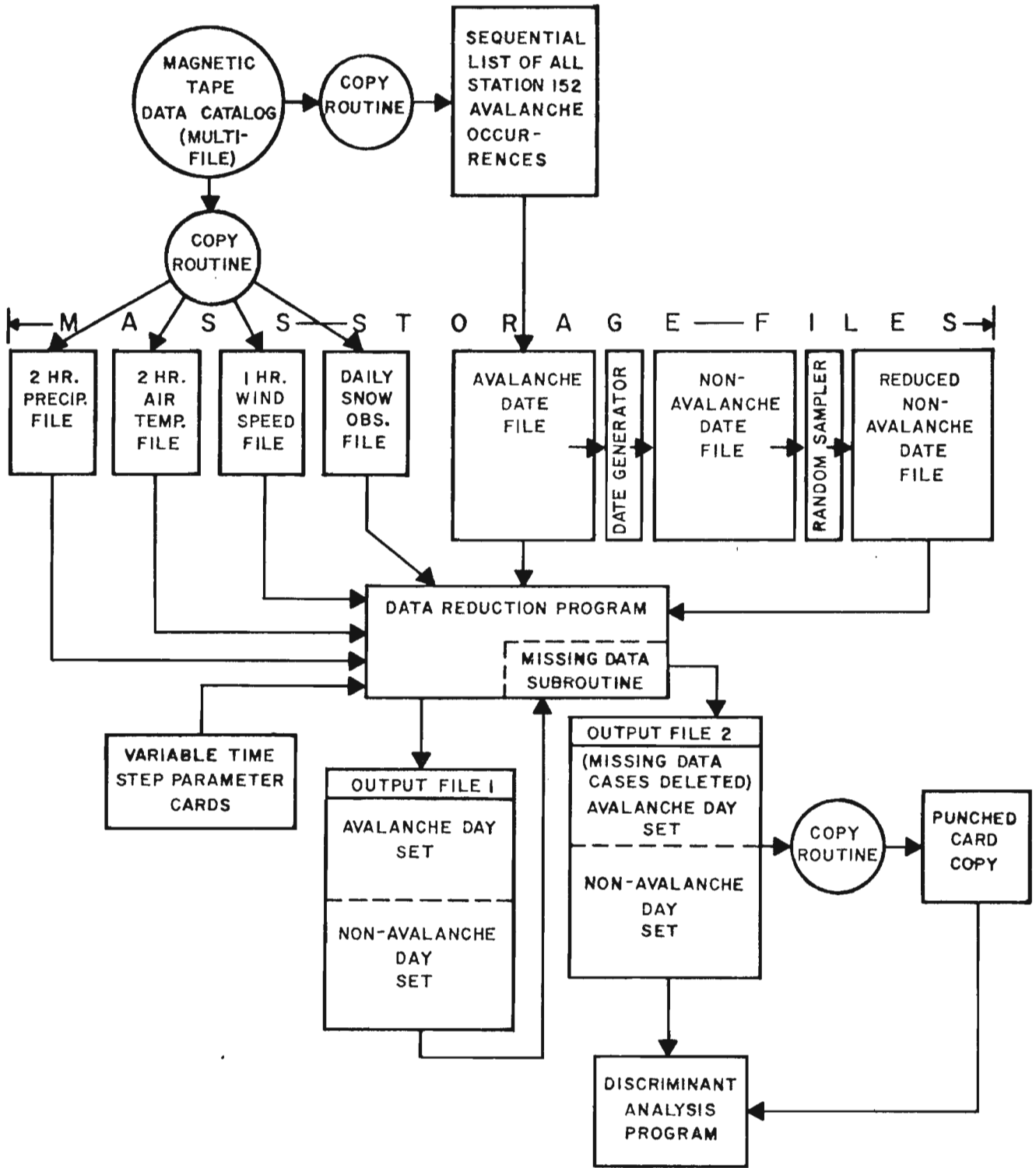


Figure 28.

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 ($^{\circ}\text{C}$).
5	Mean 2hr. air temperature during same period as (2) above, ($^{\circ}\text{C}$).
6	Maximum 2hr. air temperature in same period as (2) above, ($^{\circ}\text{C}$).
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	Einsinktiefte reading (standard ram) at 0800 hr. on avalanche or non-avalanche day (cm).

* $N = 2, 3$ 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:

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

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

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

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 non-linear 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),

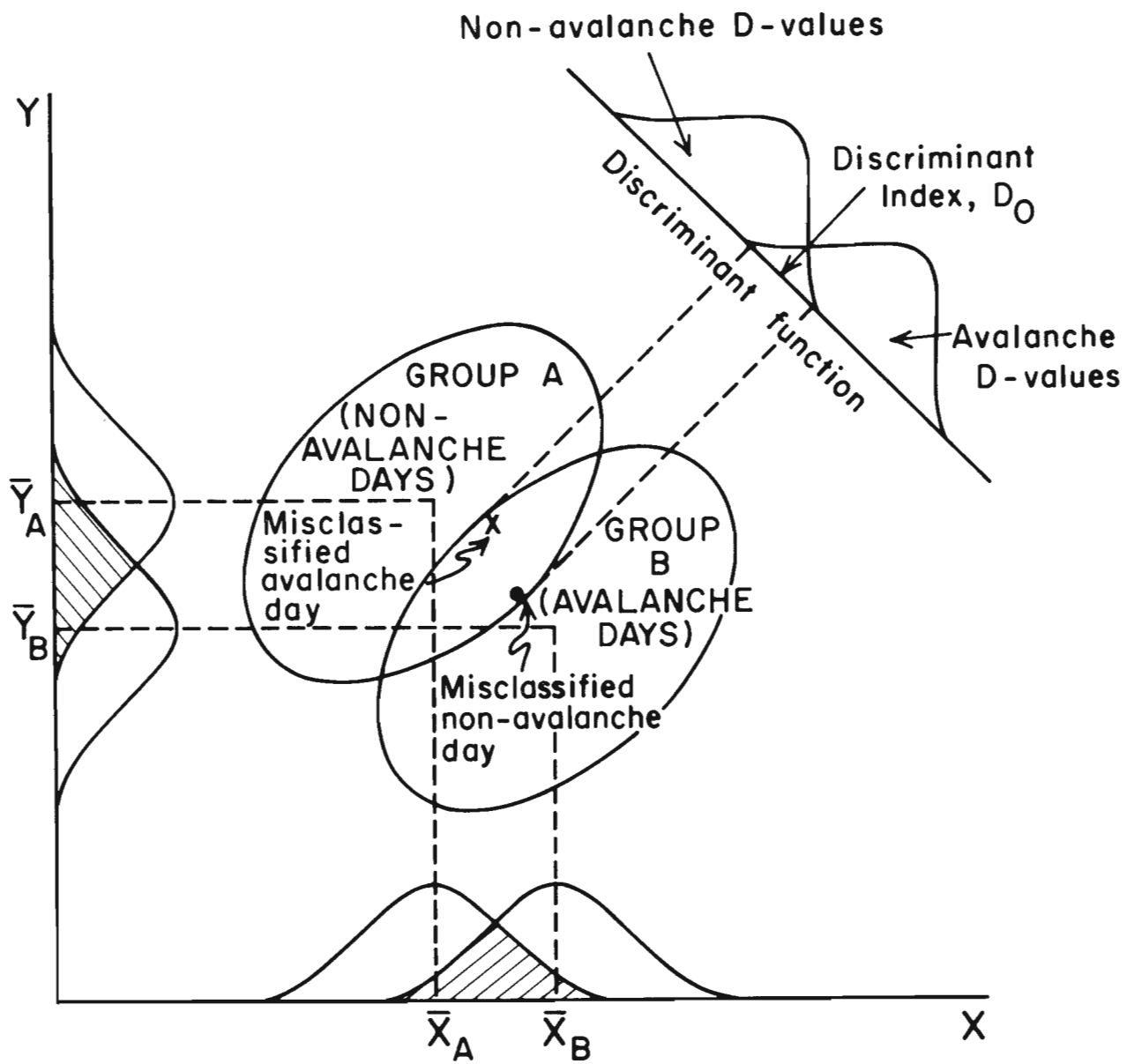


Figure 29.

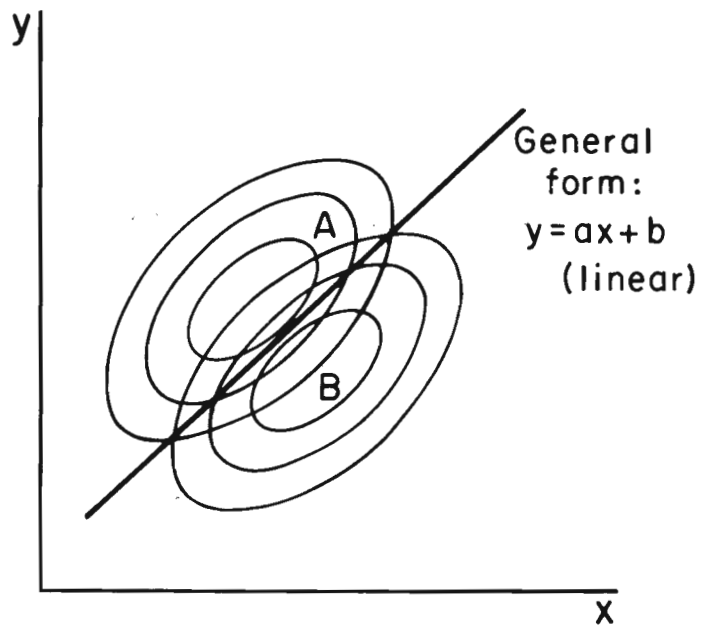


Figure 30(a)

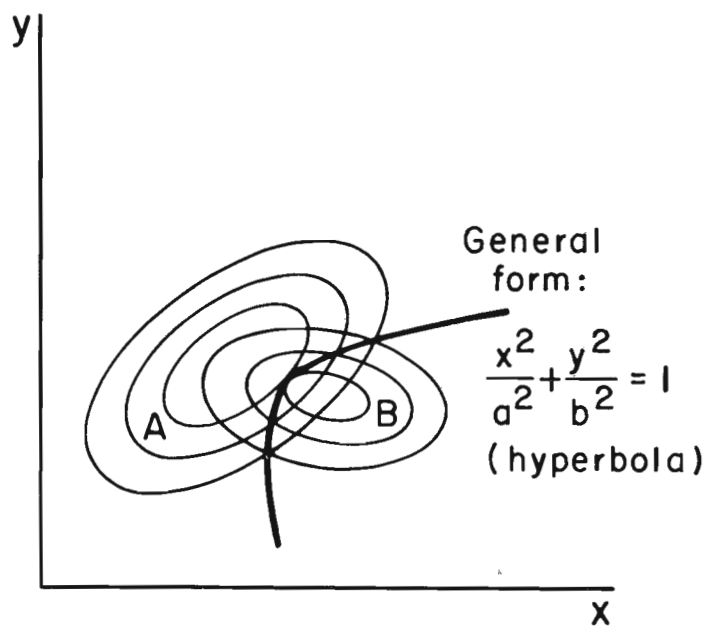


Figure 30(b)

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

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

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:

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

where λ_i is the i th coefficient of the discriminant function and \bar{A}_i and \bar{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:

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

In this two-dimensional example, the \bar{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:

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

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

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:

$$D = \lambda_1 X_1 + \lambda_2 X_2 + \dots + \lambda_k X_k \quad (7)$$

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		Percentage misclassified		Variables included	
			Aval.	Non-aval.	Avalanche	Non-avalanche		
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

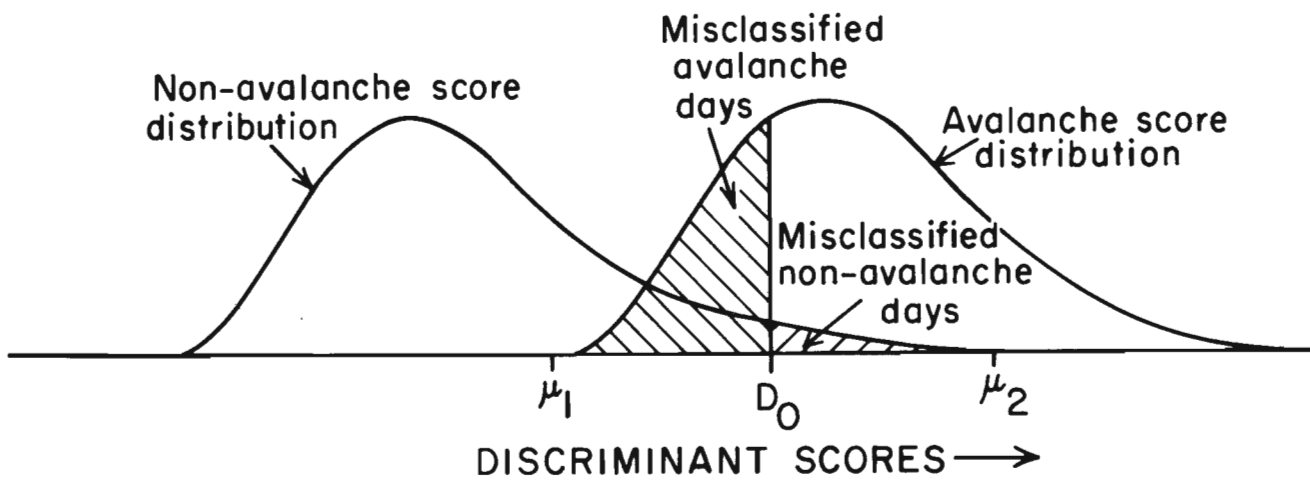


Figure 31(a)

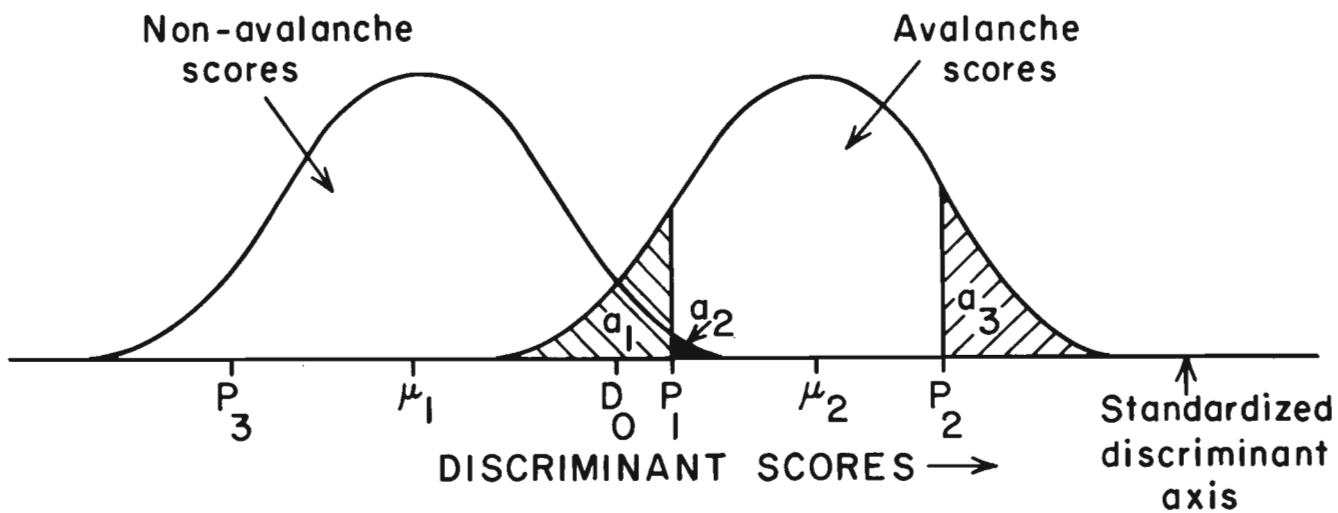


Figure 31(b)

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:

$$X_i^* = \ln(X_i + 1) \quad (8)$$

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-avalanche 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

<u>Sample Sizes</u>		<u>Percentage of Days Misclassified</u>		<u>Variables Selected</u>
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.

<u>Sample Sizes</u>		<u>Percentage of Days Misclassified</u>		<u>Variables selected</u>
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:

$$\{\lambda\}^* = \frac{\{\lambda\}}{\delta} \quad (9)$$

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

$$D^* = \lambda_1^* X_1 + \lambda_2^* X_2 + \dots + \lambda_r^* X_r \quad (10)$$

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:

$$\Delta = (p_2 - \mu_2) = (1 - a_3) \quad (11)$$

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:

$$\Delta' = -(p_1 - \mu_1) = a_2 \quad (12)$$

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:

<u>14 December 1975:</u>	45 loose releases, magnitude 1
	1 soft slab release, magnitude 1
	<u>7</u> loose releases, magnitude 2
	TOTAL: <u>53</u> 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)
```

```
COPYRF(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 knowledgeable with the system before writing on the tape.

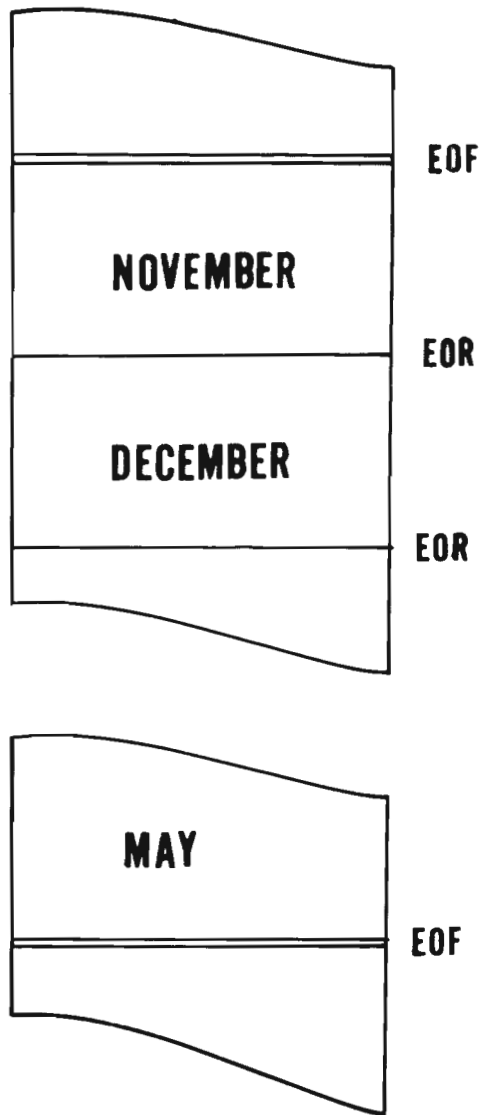


Figure A.1

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 Iron-ton 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: Einsinktiefereading, 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: Einsinktiefereading, 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 CI 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

```

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          PROGRAM PRELIM(INPUT,OUTPUT,TAPE1,TAPE2,TAPE3,TAPE4,TAPE5,TAPE6,
          ITAPE7)
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/SAMSIZE(3),NVAR,NGROUP,NC(3)
000003      DIMENSION OFMT(8),ITAPE(2),LABEL(8),VLABEL(90),TITLE(16),OPTION(3)
000003      INTEGER YEAR,DAY,SAMSIZE,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 TAPES. 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,(SAMSIZE(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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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(I)
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 I 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 0
IF EVENTS LESS THAN OR EQUAL TO*,I3,* DAYS FROM START OF FILE IS*,
2I3//)
000315      10 NC(LLOOP)=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=N
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

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

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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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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=NTAPE(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

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

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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

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      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

```

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SUBROUTINE T1200(Q,JNF,NPT)
COMMON/IFORMAT/NDAY(3),NTAPE(3),ITN,BUFF(24),JJ
DIMENSION Q(24),JNF(4)
MX=(NPT/2)+1 $ J=0
DO 1 K=MX,NPT
J=J+1
1 BUFF(J)=Q(K)
CALL SETEOR(ITN,0)
READ(ITN,JNF) (Q(I),I=1,NPT) $ MX=NPT/2
DO 2 K=1,MX $ J=J+1
2 BUFF(J)=Q(K)
RETURN
END

```

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SUBROUTINE CASELIM
COMMON SAMSIZ(3),NVAR,NGROUP,NC(3)
DIMENSION A(3),B(20)
REWIND 4 $ REWIND 5 $ PRINT 20
20 FORMAT(1H1)
L=0
DO 1 K=1,NGROUP $ KK=0 $ PRINT 30,K,NVAR
30 FORMAT(/2X,*INPUT DATA FOR GROUP*,I2,* CASES WITH MISSING DATA EL
IMINATED*/2X,*NUMBER OF VARIABLES IS*,I2/)
L=L+1 $ NCASES=NC(L)
DO 2 J=1,NCASES $ READ(4,100) A,(B(I),I=1,NVAR) $ MD=0
100 FORMAT(3I3,15F5.1)
DO 3 N=1,NVAR $ IF(.NOT.B(N)) 4,5
4 GO TO 3
5 MD=MD+1
3 CONTINUE $ IF(MD.GT.0) GO TO 2 $ WRITE(5,100) A,(B(I),I=1,NVAR)
PRINT 10, A,(B(I),I=1,NVAR) $ KK=KK+1
10 FORMAT(2X,3I4,5X,15F5.1)
2 CONTINUE $ PRINT 40,K,KK
40 FORMAT(/2X,*REMAINING SAMPLE SIZE IN GROUP*,I2,*==*,I3)
1 CONTINUE
RETURN
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.SPFED 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	5.0	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	3.8	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	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	0.3	14.5
74	12	16	16.5	5.5	3.0	-14.4	-12.4	-10.5	8.1	2.7	13.8
74	12	18	6.0	4.5	2.0	-10.2	-10.9	-.5	9.8	2.6	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	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	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	2.8	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

APPENDIX D

DISCRIMINANT FUNCTION COEFFICIENTS FROM COMBINED SEASONS 1971-75

<u>1: Dry Season</u>				
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
<u>2: Wet Season</u>				
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 Instruments, 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 successfully 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 ¹³⁷Cs, 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 formatting 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. Cobalt⁶⁰ 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 $+50^{\circ}\text{C}$ 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

Date	Mean Density (Mg/m^3)		Water Equivalent (mm)		Standard Deviation of Density Values at 5.0 intervals
	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
	<u>Mean Deviation</u>		<u>Mean Deviation</u>		
	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.

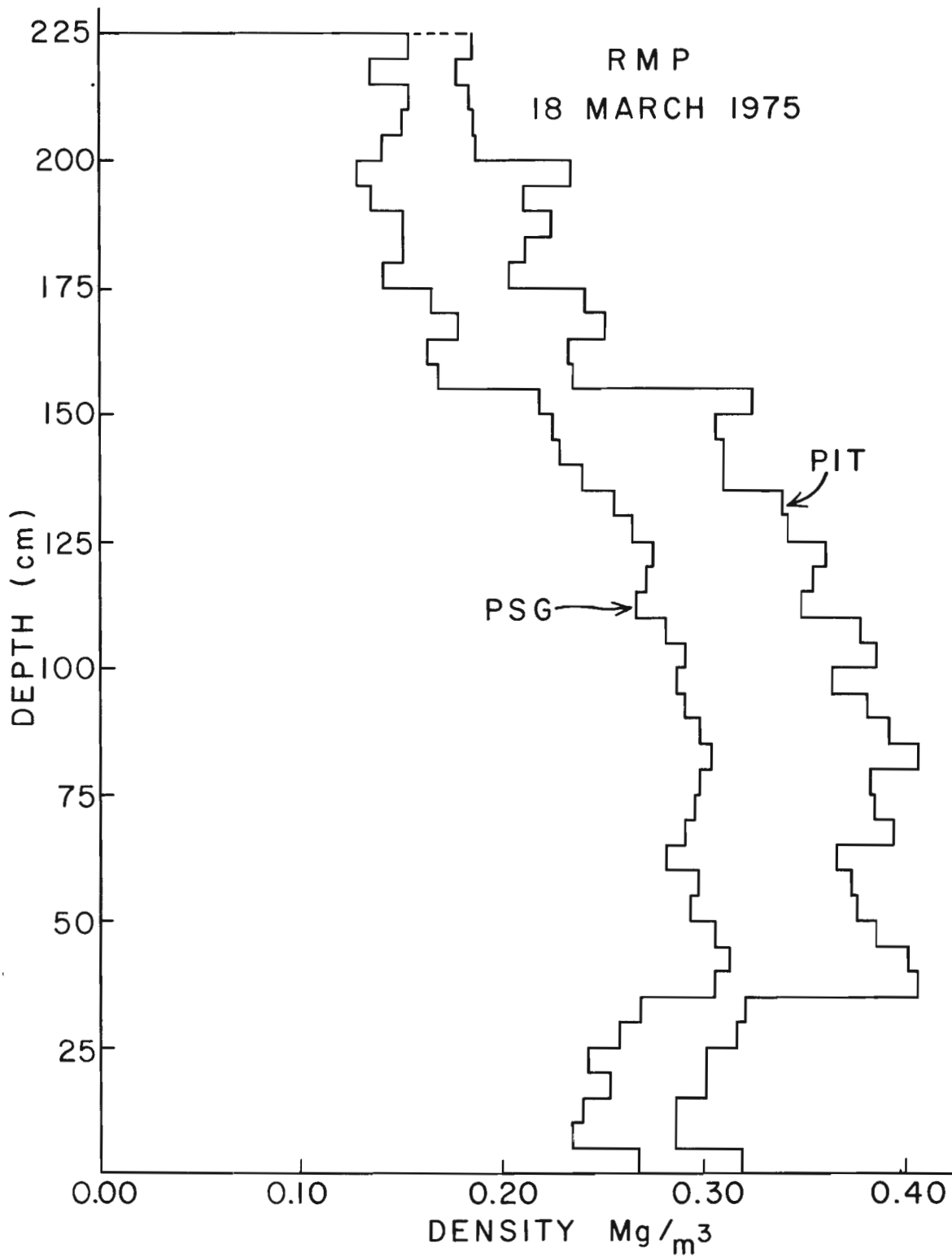


Figure 32. A comparison of snowpit and profiler density data for field calibration purposes.

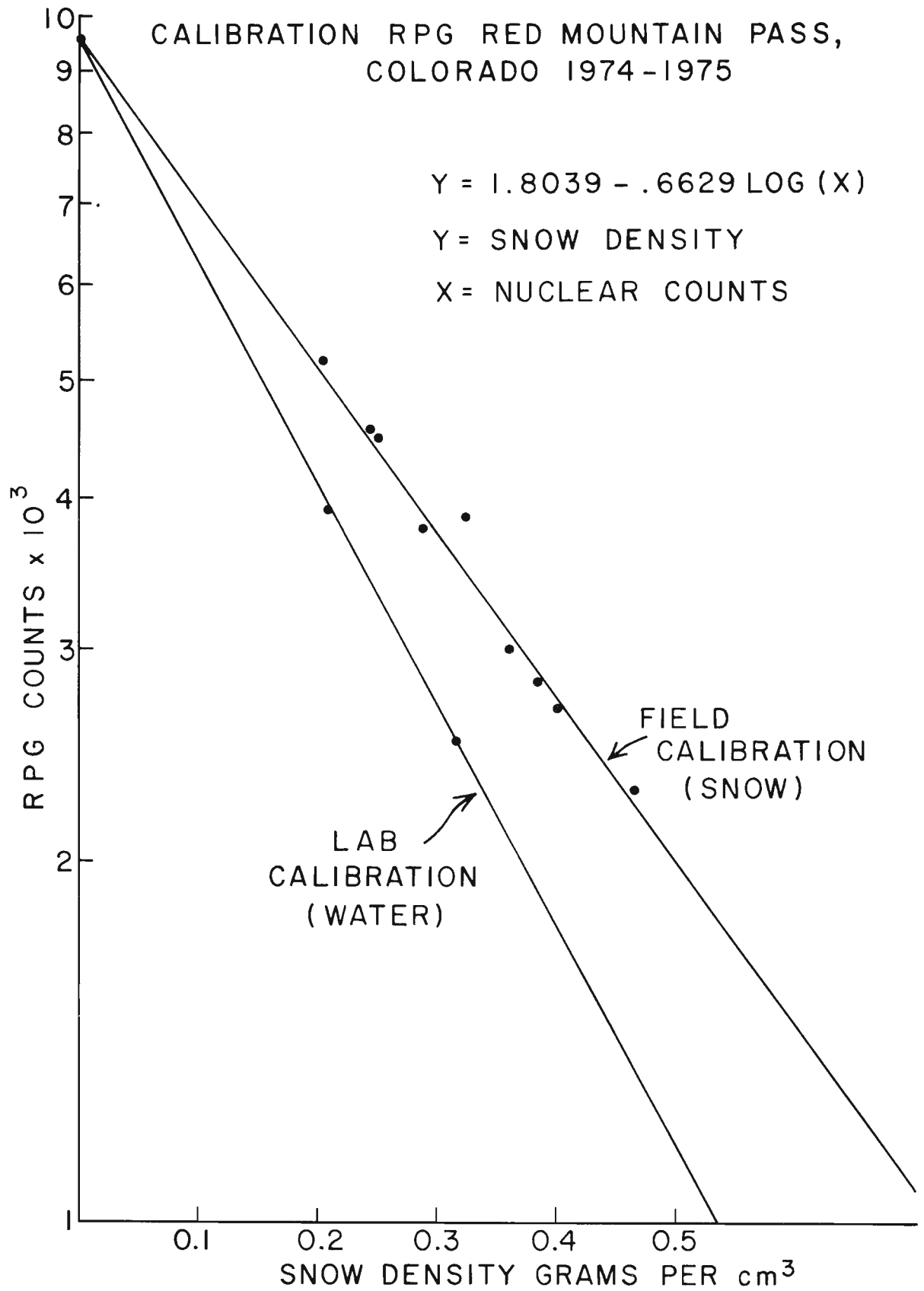


Figure 33. The corrected profiler calibration data based on field calibration in snow compared to laboratory calibration in water.

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 $0.1^{\circ}\text{C}/\text{cm}$), 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

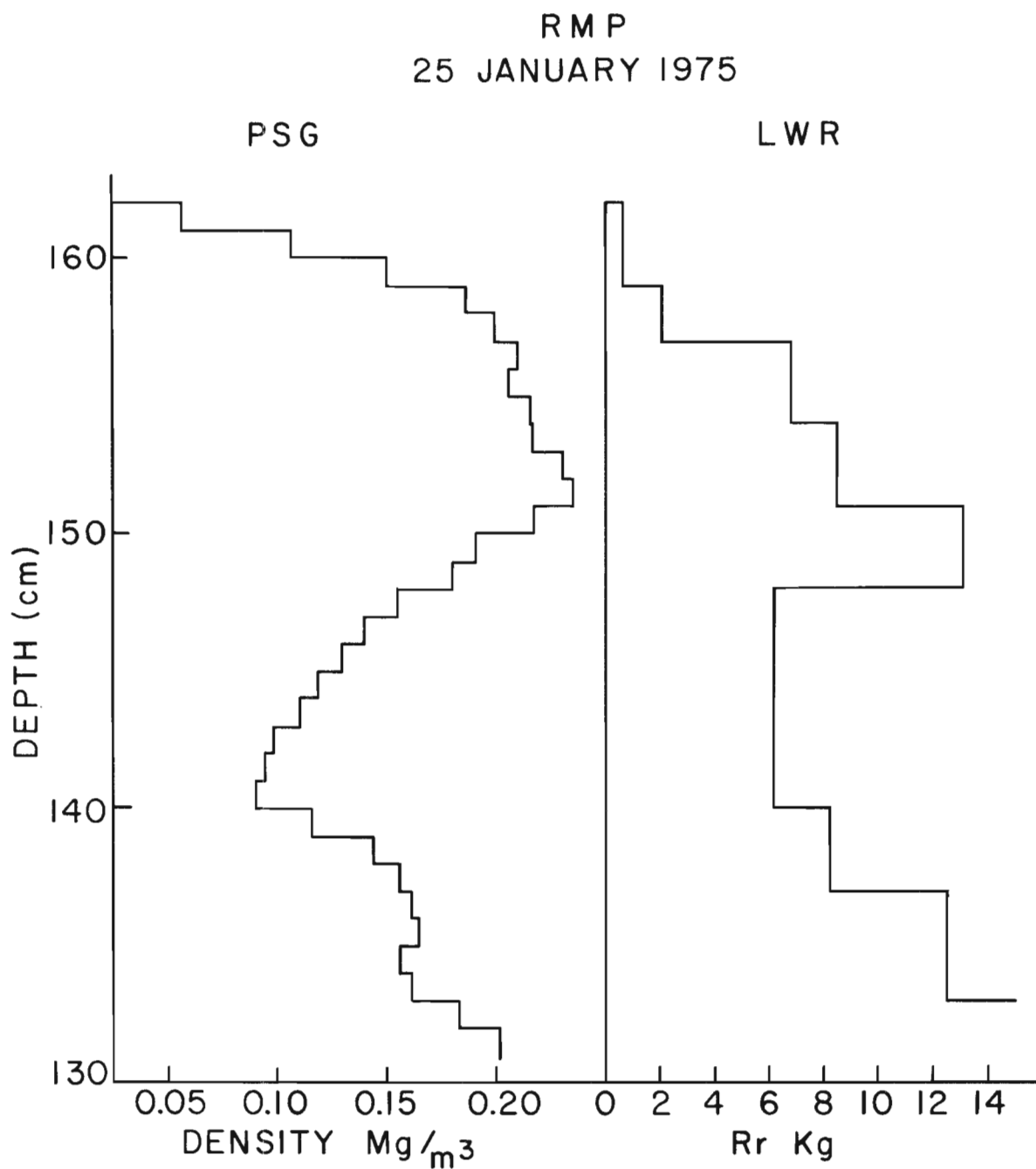


Figure 34. Comparison of stratigraphy provided by profiler density values and light-weight rammsonde (0.1 kg.) strength data. The weak, low density layer is a new snow accumulation in the absence of wind. Above this layer is a stronger, higher density slab deposited during a period of relatively high 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 mid-winter 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 ramsonde data in Figure 36 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.

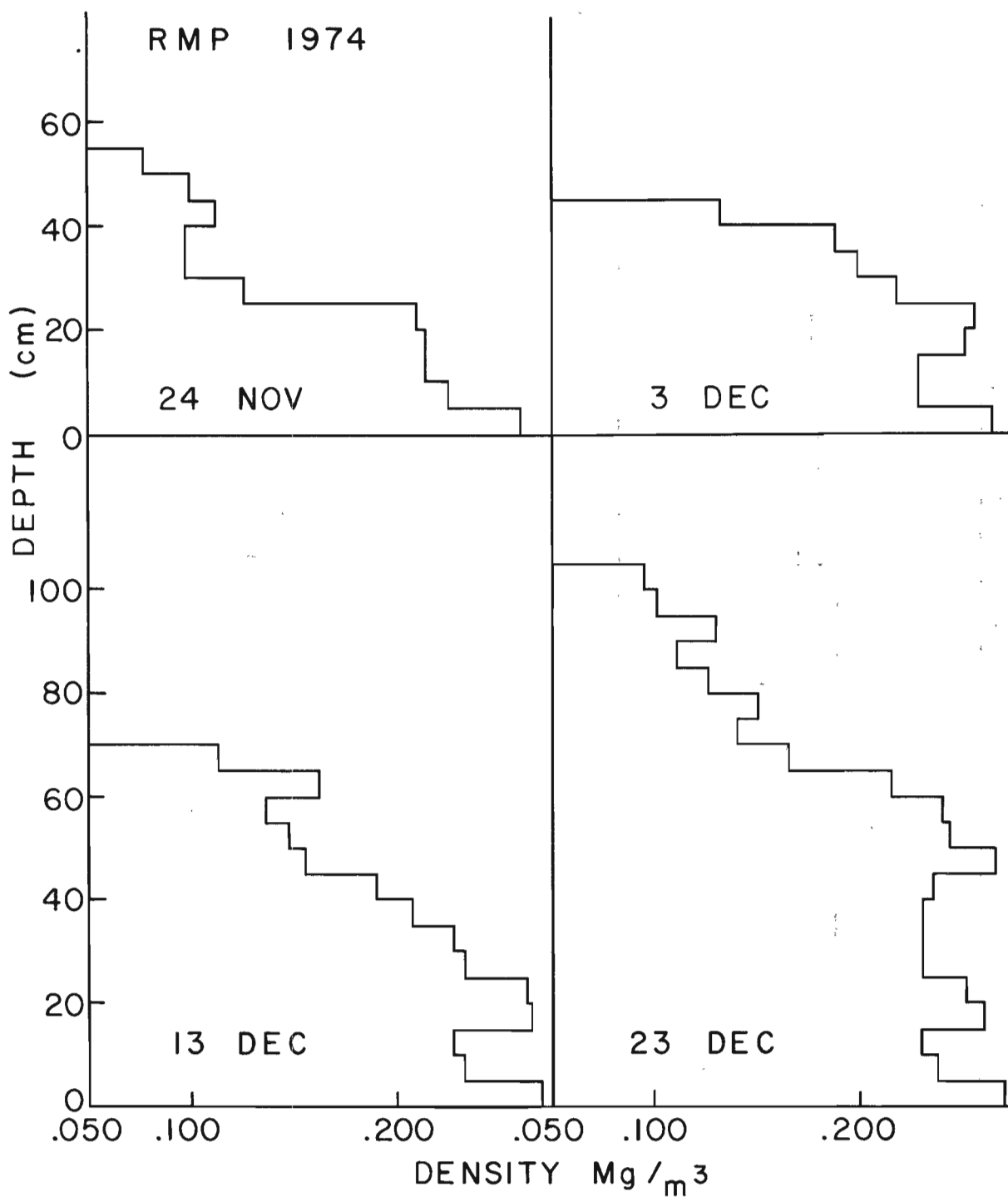


Figure 35. Sequential development of a structurally weak temperature-gradient layer at the base of the snowcover as monitored by profiling snow gauge density values.

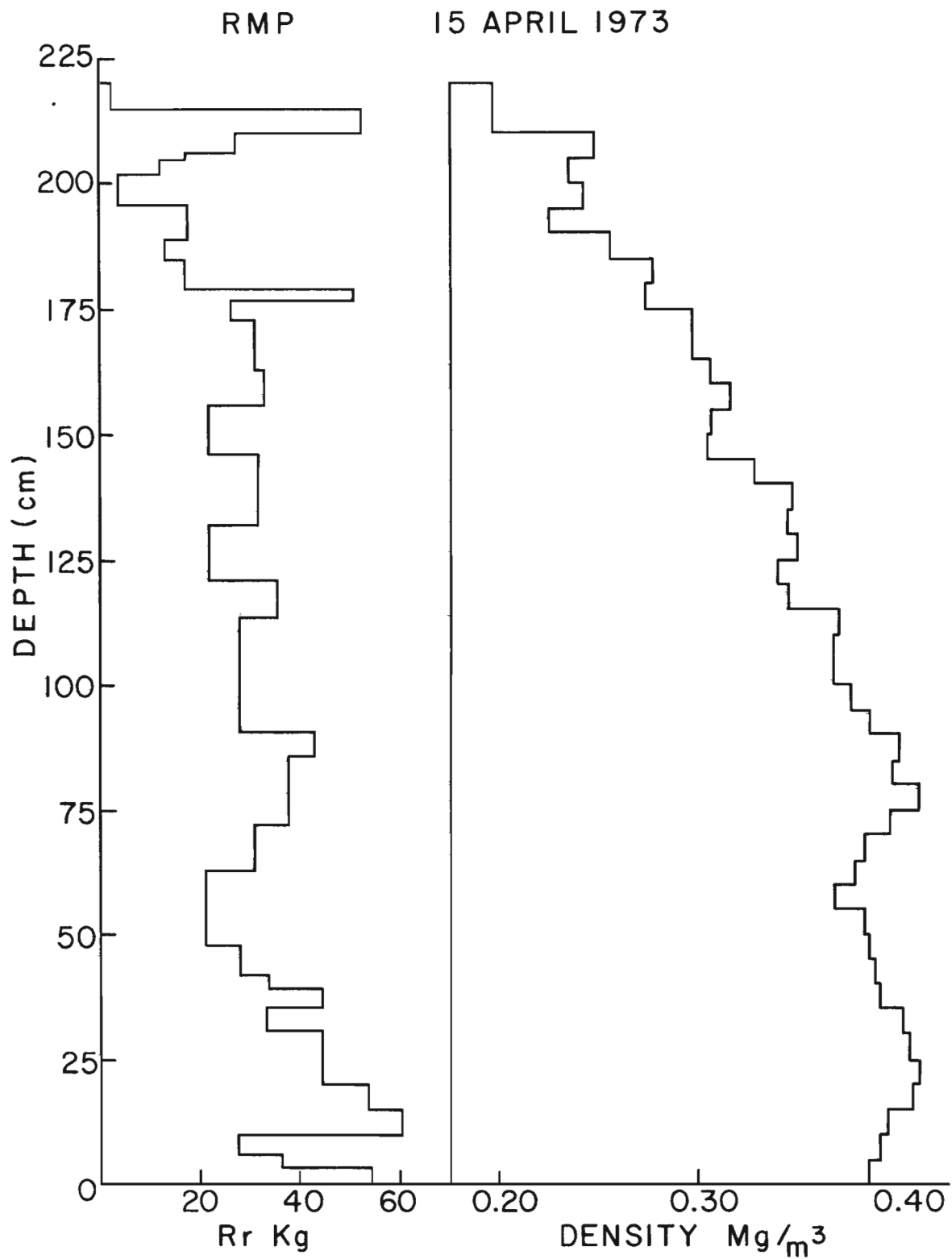


Figure 36. Comparison of rammsonde strength data and profiler snow density values within a mature snowcover.

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

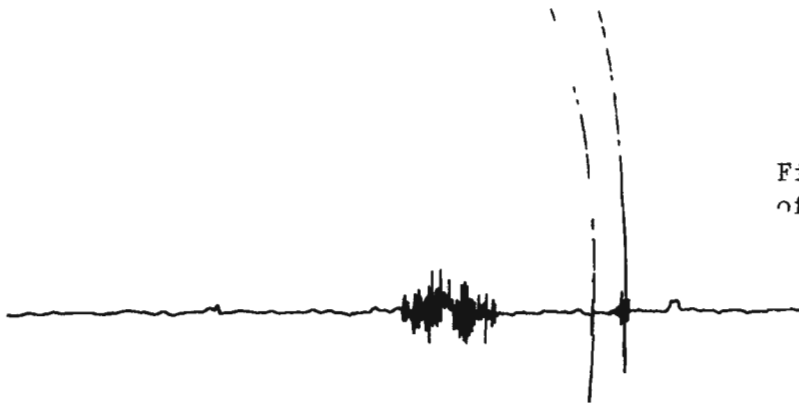


Figure 37. Drum record of December 5 avalanche.

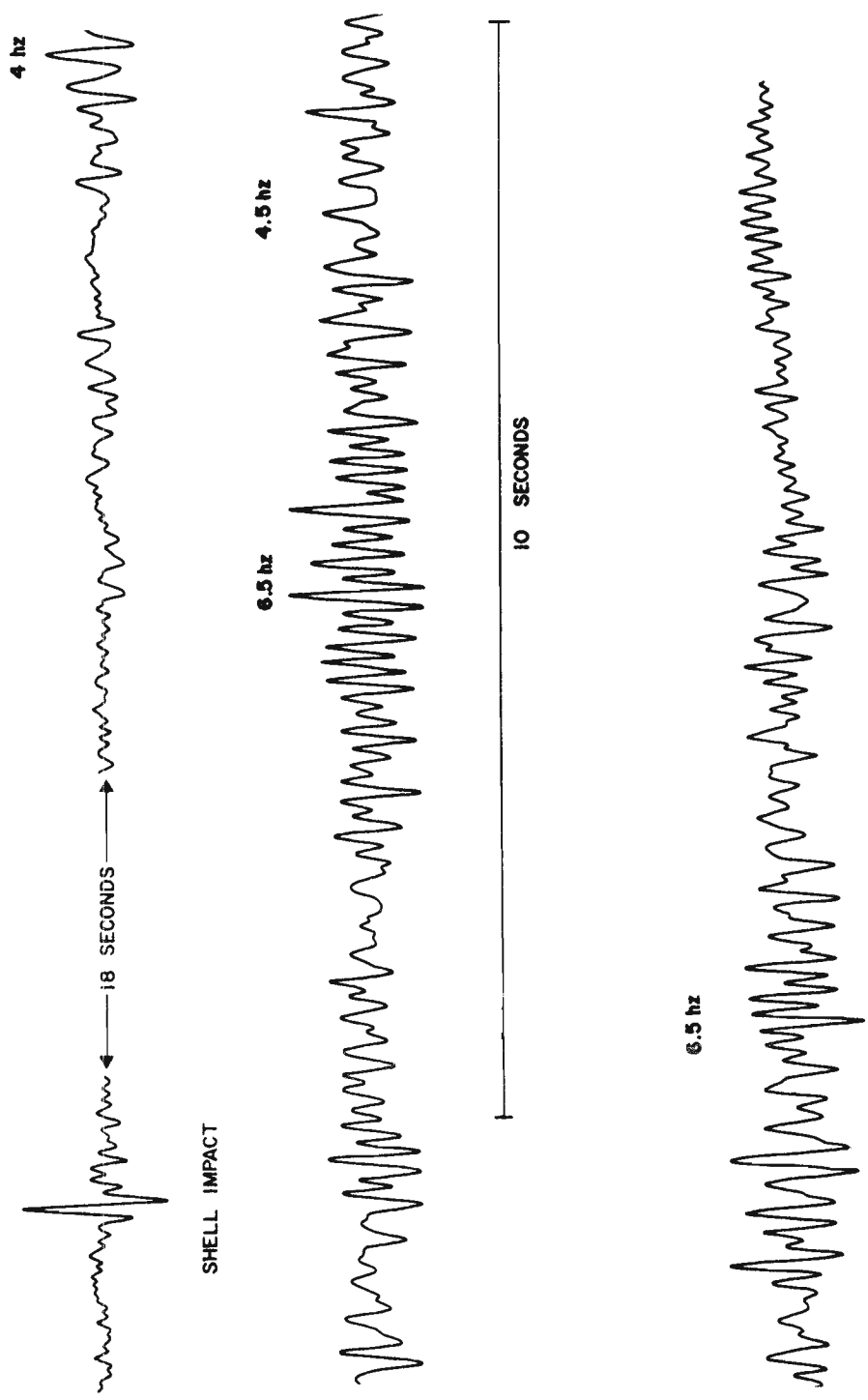


Figure 38. Tape playback of December 5, 1972 avalanche.

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.

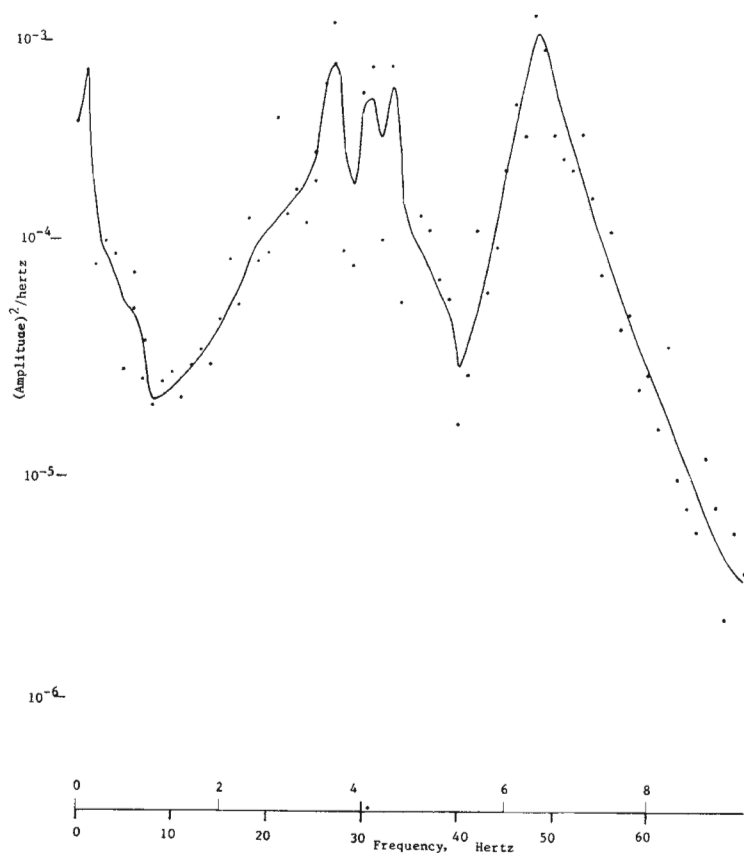


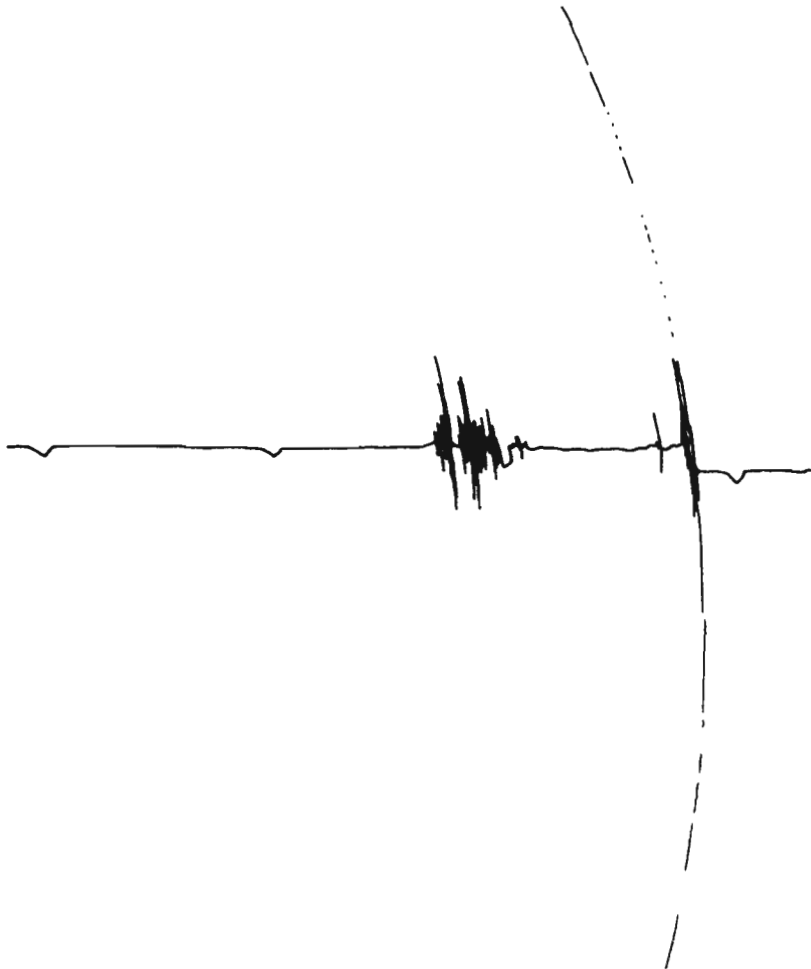
Figure 39. Power spectrum of December 5, 1972 avalanche.

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 absence 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.

REFERENCES

- Akitaya, E., 1974: Studies on depth hoar. Institute of Low Temperature Science, Hokkaido University, Series A, No. 26, 1-67.
- Armstrong, B., 1976a: Century of struggle against snow: a history of avalanche hazard in San Juan County, Colorado. University of Colorado INSTAAR Occasional Paper No. 18 (in press).
- Armstrong, B., 1976b: A history of avalanche hazard in Ouray County, Colorado. University of Colorado INSTAAR Occasional Paper (in preparation).
- Armstrong, R. L. et al., 1974: Development of methodology for evaluation and prediction of avalanche hazard in the San Juan Mountains of southwestern Colorado. University of Colorado INSTAAR Occasional Paper No. 13. 141 pp.
- Bader, H. et al., 1939: Snow and its metamorphism. Translation 14, U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire. 313 pp.
- Bois, P., Obled, C., and Good, W., 1974: Multivariate data analysis as a tool for day-by-day avalanche forecast. Paper presented at the International Symposium on Snow Mechanics, Grindelwald, Switzerland, 1974 (in press).
- Bovis, M. J., 1976: Statistical forecasting of snow avalanches, San Juan Mountains, southern Colorado. Journal of Glaciology (in press).
- Colbeck, S. C., 1974: Grain and bond growth in wet snow. Paper presented at the International Symposium on Snow Mechanics, Grindelwald, Switzerland, 1974 (in press).
- Hoel, P. G., 1971: Introduction to mathematical statistics. Wiley, New York. 409 pp.
- Hope, K., 1968: Methods of multivariate analysis. Gordon and Breach, New York. 288 pp.
- Ives, J. D., Harrison, J. C., and Alford, D. L., 1972: Development of methodology for evaluation and prediction of avalanche hazard in the San Juan Mountain area of southwestern Colorado. Interim Report for the Division of Atmospheric Water Resources Management, Bureau of Reclamation. 88 pp.
- Ives, J. D., Harrison, J. C., and Armstrong, R. L., 1973: Development of methodology for evaluation and prediction of avalanche hazard in the San Juan Mountain area of southwestern Colorado. Interim Report for the Division of Atmospheric Water Resources Management, Bureau of Reclamation. 122 pp.

- Ives, J. D. et al., 1976: Natural hazards in mountain Colorado. *Annals of the Association of American Geographers*, 66(1): 129-144.
- Judson, A. and Erikson, B., 1973: Predicting avalanche intensity from weather data: a statistical analysis. U.S. Department of Agriculture Forest Service Research Paper, RM-112. 12 pp.
- LaChapelle, E. R., 1965: Avalanche forecasting - a modern synthesis. International Association of Scientific Hydrology, Publication No. 69, International Symposium on Scientific Aspects of Snow and Ice Avalanches, Davos, Switzerland, April 1965, 350-356.
- LaChapelle, E. R. et al., 1975: Alternate methods of avalanche control. 1974-75 Interim Report prepared for Washington State Highway Commission by Geophysics Program and Department of Civil Engineering, University of Washington, Seattle, Washington. 158 pp.
- LaChapelle, E. R., and Armstrong, R. L., 1976: Snowcover, temperature and metamorphism patterns in the San Juan Mountains of southwestern Colorado. University of Colorado INSTAAR Occasional Paper (in preparation).
- Mellor, M., 1968: Avalanches. Cold Regions Science and Engineering, Part III: Engineering, Section A3: Snow Technology, U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire. 215 pp.
- Miller, L., Armstrong, B. and Armstrong, R. L., 1976: Avalanche atlas: San Juan County, Colorado. University of Colorado INSTAAR Occasional Paper No. 17. 233 pp.
- Perla, R. I. and Martinelli, M., Jr., 1976: Avalanche handbook. U.S. Department of Agriculture Forest Service Handbook No. 489. 235 pp.
- Rhea, O., 1970: In Installation and operation of an opportunity recognition and cloud seeding system for operational weather modification research in Colorado. Phase I. Comprehensive Field Report. EGG Environmental Services Corporation. Prepared for U.S. Bureau of Reclamation, Denver, Colorado.
- Smith, J. L., Willen, D. W., and Owens, M. S., 1965: Measurement of snowpack profiles with radioactive isotopes. *Weatherwise* 18: 246-251.
- Smith, J. L., Willen, D. W., and Owens, M. S., 1967: Isotope snow gauges for determining hydrologic characteristics of snowpacks. In *Isotope Techniques in the Hydrologic Cycle*, American Geophysical Union, Geophysical Monograph Series 11: 11-21.
- Smith, S.D., 1971: Avalanche track geomorphology in the San Juan Mountains of southwestern Colorado. Unpublished NSF sponsored summer research paper.
- U.S. Forest Service, 1961: Snow avalanches: a handbook of forecasting and control measures. U.S. Department of Agriculture Handbook No. 194. 84 pp.

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 $.077 \text{ Mg/m}^3$. 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 ($^\circ\text{C}$) within the snowcover at the Red Mountain Pass study site appears in Figure 45. The

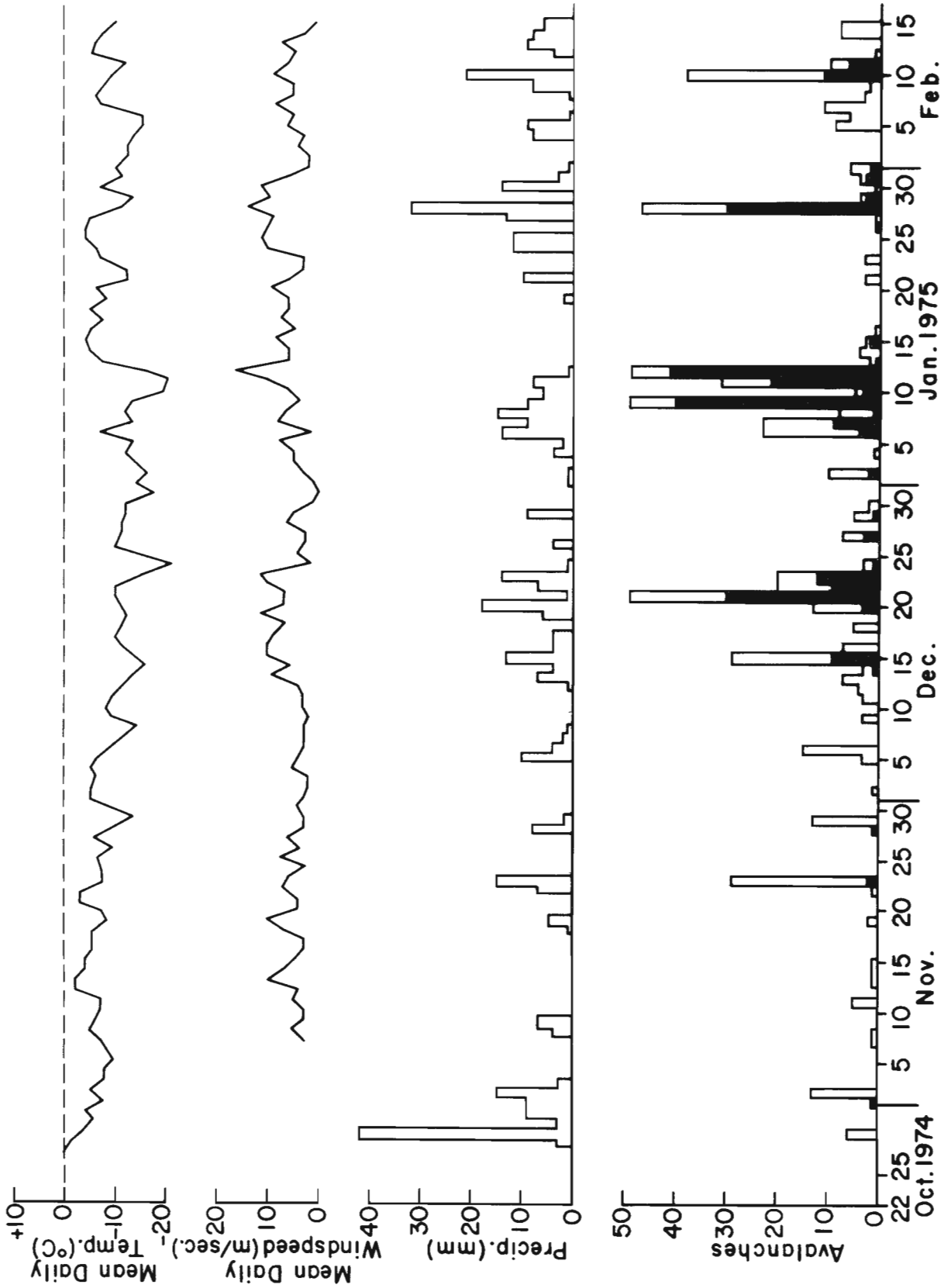


Figure 41. A diagram showing the variation in mean daily air temperature ($^{\circ}\text{C}$) and precipitation (mm of water equivalent) measured at the Red Mountain Pass study site, wind speed (meters per second) measured at Pt. 12325 and daily totals of observed avalanches for the period 22 October,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

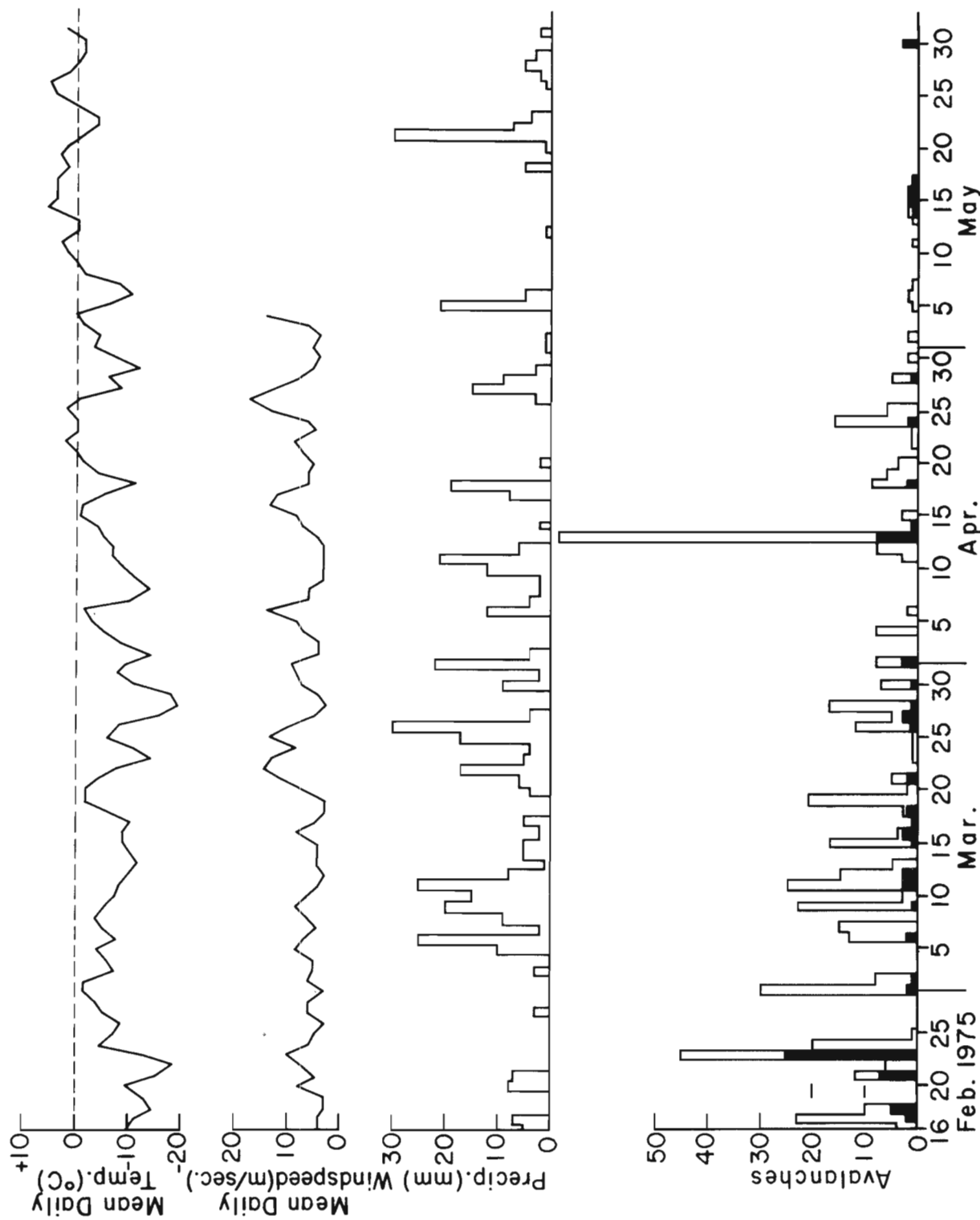


Figure 42. A diagram showing the variation in mean daily air temperature ($^{\circ}\text{C}$) and precipitation (mm of water equivalent) measured at the Red Mountain Pass study site, wind speed (meters per second) measured at Pt. 12325 and daily totals of observed avalanches for the period 16 February,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

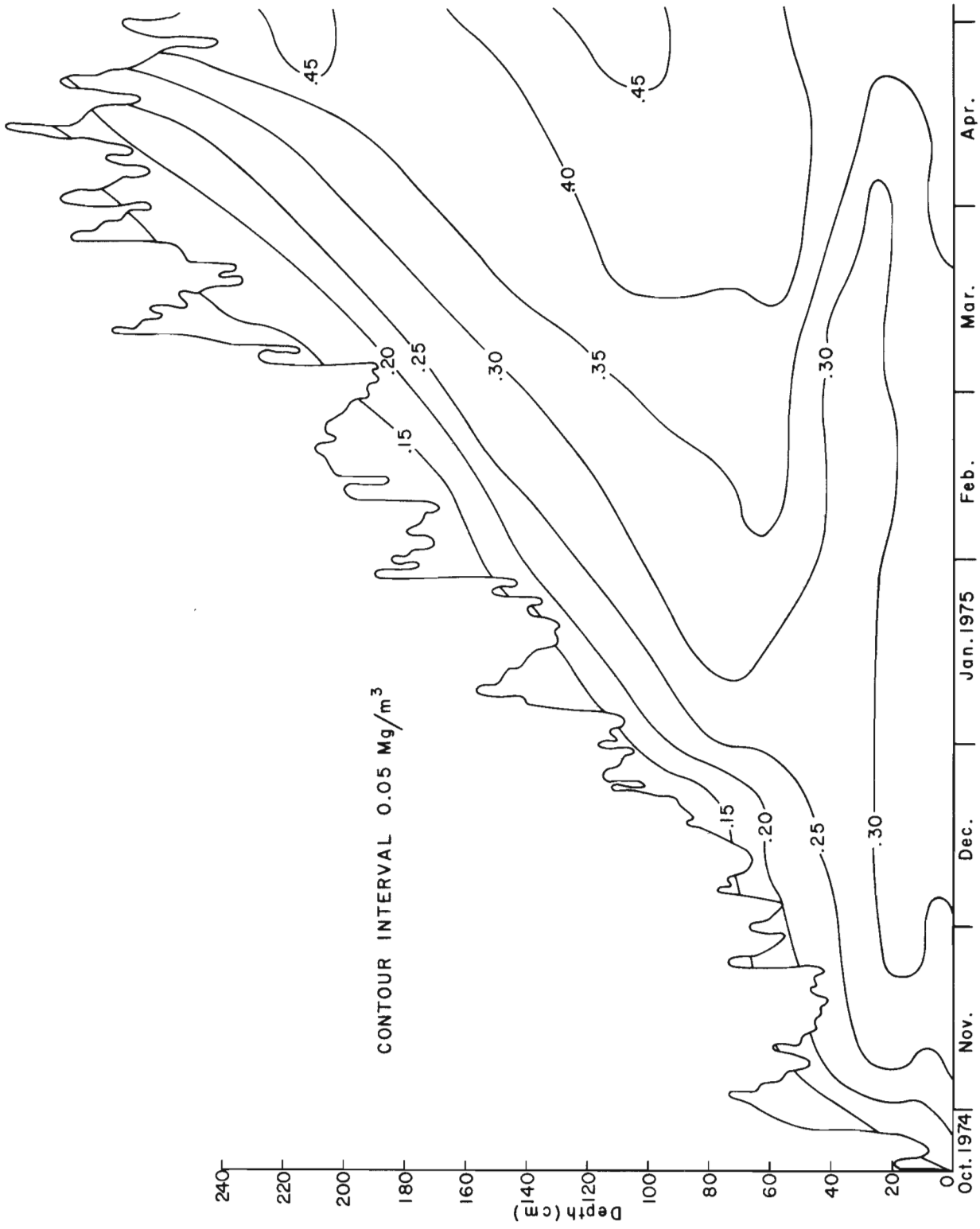


Figure 43. A time-stratigraphic diagram of density variations (Mg/m³) at the Red Mountain Pass study site for the period 15 October, 1974 through 30 April, 1975.

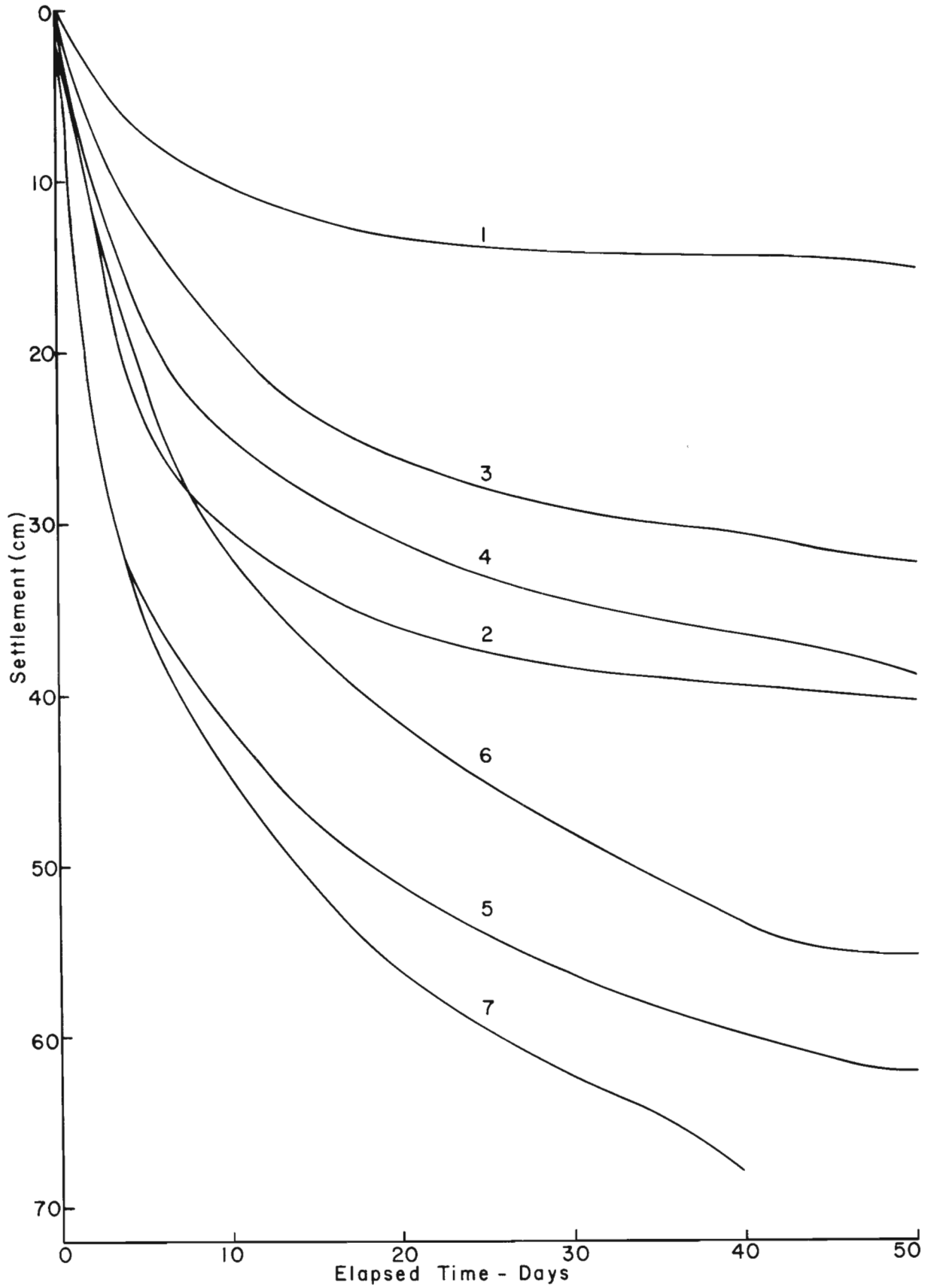


Figure 44. Initial settlement rates at seven points within the snowcover at the Red Mountain Pass study site, 1974-1975. Number 1 is representative of the early winter snowcover, numbers 2 through 4 are mid-winter and 5 through 7 are early spring conditions.

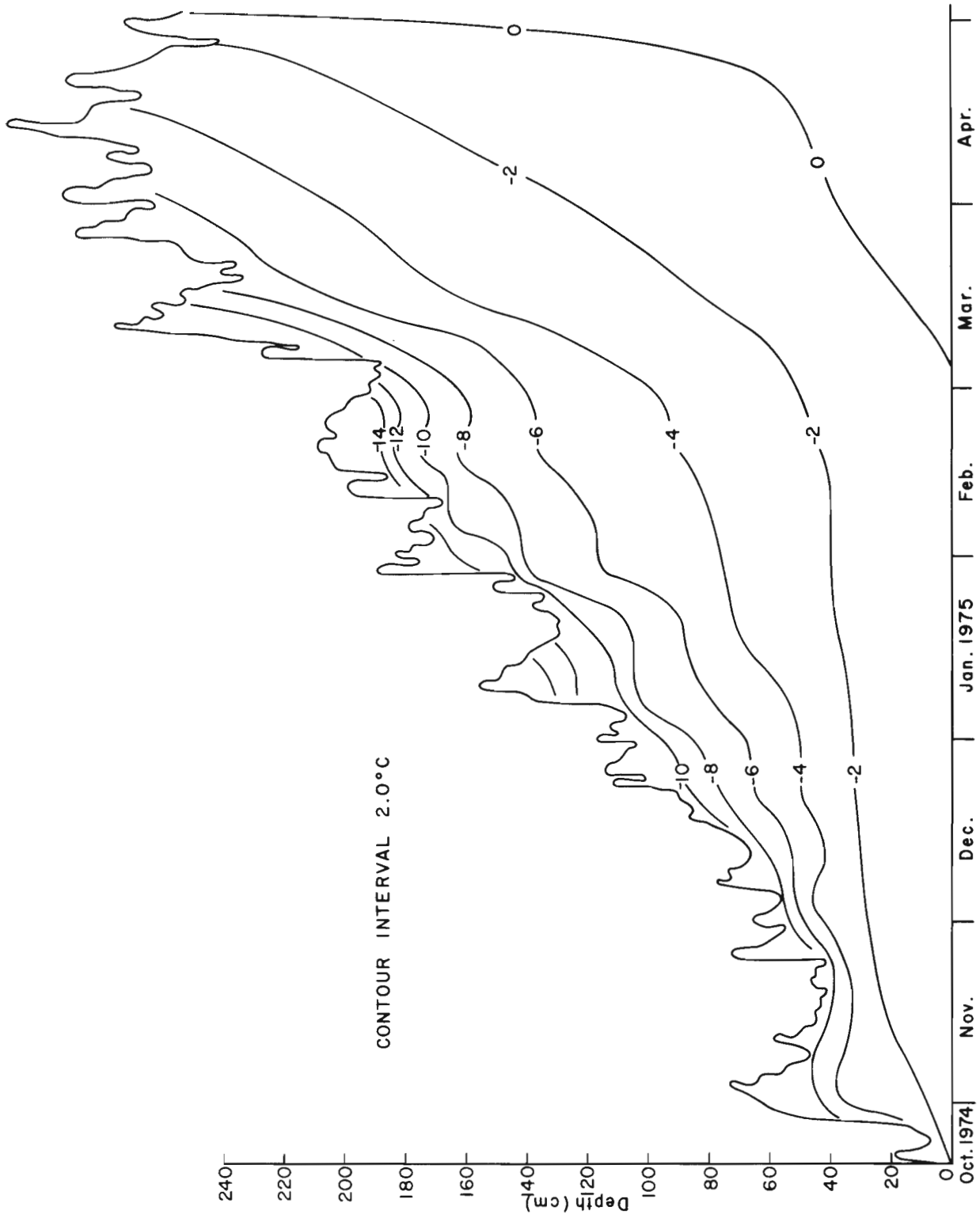


Figure 45. A time-stratigraphic diagram of temperature variations ($^{\circ}\text{C}$) within the snowcover at the Red Mountain Pass study site for the period 15 October, 1974 through 30 April, 1975.

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 preceding 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.

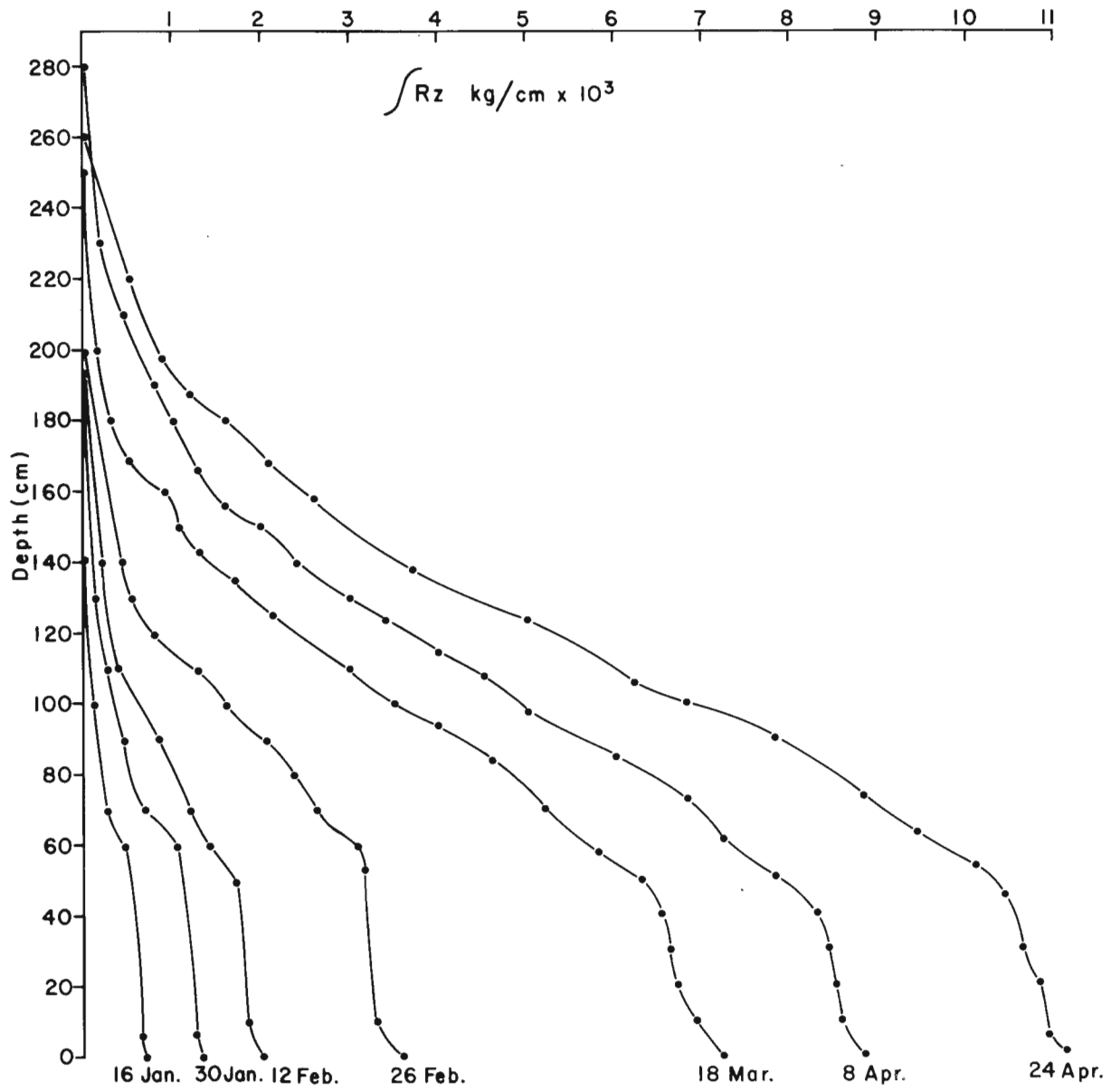


Figure 46. Integrated rammsonde resistance curves for seven selected dates at the Red Mountain Pass study site during the 1974-1975 winter.

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

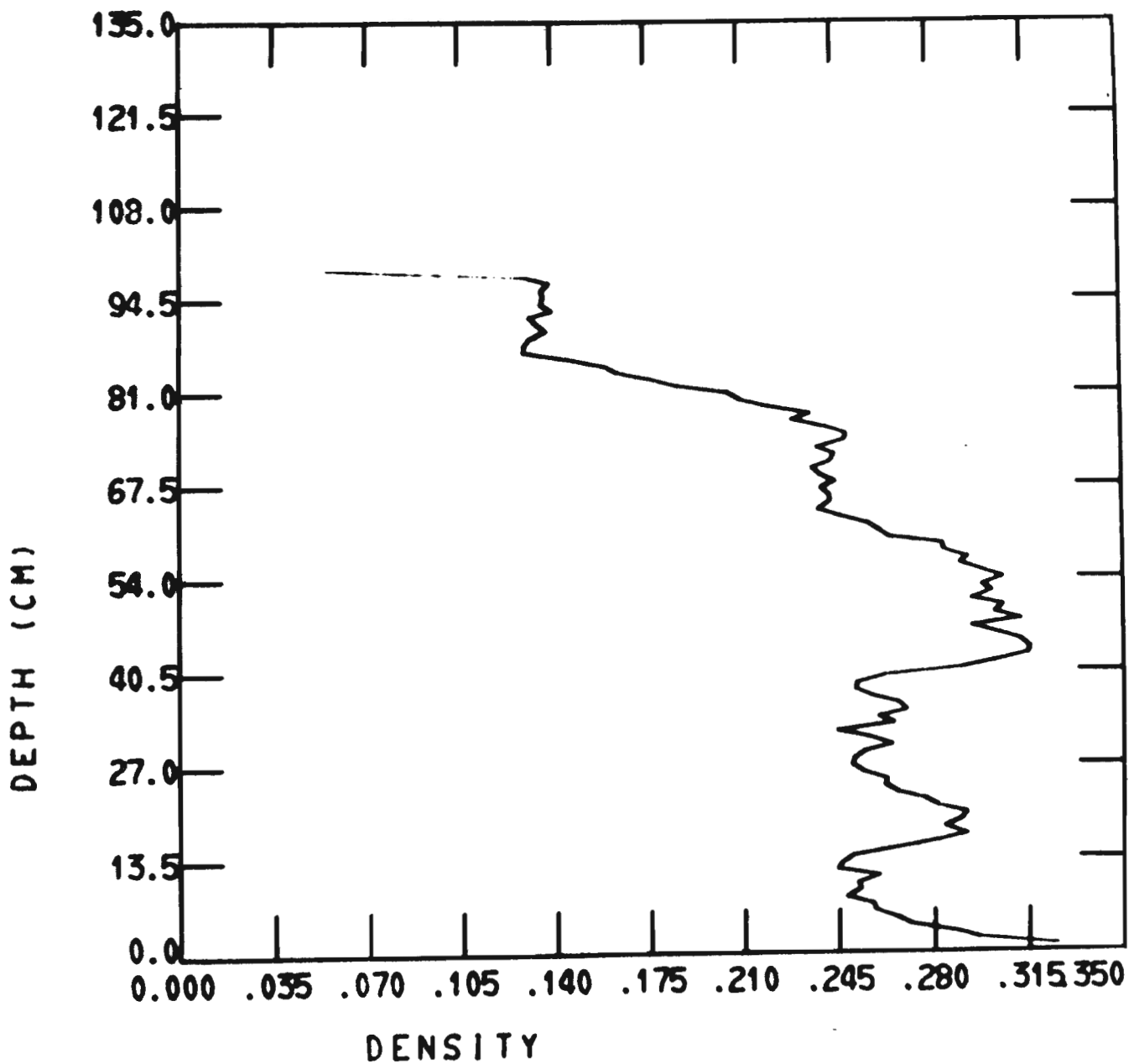


Figure 47. An example of stratigraphic density values (Mg/m^3) at 1.0 cm intervals at the Red Mountain Pass study site on 2 January, 1975. Data are obtained from an isotopic profiling snow gauge.

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 preceded 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°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 $+7.5^{\circ}\text{C}$) 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°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 $.098 \text{ Mg/m}^3$, 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

	<u>Nov</u>	<u>Dec</u>	<u>Jan</u>	<u>Feb</u>	<u>Mar</u>	<u>Apr</u>
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

	<u>Nov</u>	<u>Dec</u>	<u>Jan</u>	<u>Feb</u>	<u>Mar</u>	<u>Apr</u>	<u>May</u>
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

	<u>Nov</u> (18-30 only)	<u>Dec</u>	<u>Jan</u>	<u>Feb</u>	<u>Mar</u>	<u>Apr</u> (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

	<u>Nov</u>	<u>Dec</u>	<u>Jan</u>	<u>Feb</u>	<u>Mar</u>	<u>Apr</u>	<u>May</u>
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	<p>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.</p> <p>2 = Small, relative to the avalanche path</p> <p>3 = Medium</p> <p>4 = Large</p> <p>5 = Major or maximum</p>
Running surface	44	<p>0 = Avalanche ran on old snow surface in the starting zone.</p> <p>G = Avalanche ran to ground in the starting zone.</p>
Motion	46	<p>S = Sliding, occurs when snow breaks loose and moves downslope without rolling or tumbling.</p> <p>F = Flowing or tumbling motion; snow whether granular or in blocks, moves along the snow or ground surface in a rolling, turbulent motion.</p> <p>M = Mixed airborne and ground motion.</p>
Slab depth	48	Estimate of height of fracture line, measured at right angles to the slope, to the nearest foot.
Layers	49	<p>A = Avalanche involves only new snow</p> <p>B = Avalanche penetrates deeper and includes old snow layer or layers.</p>
Percent	51-52	Percent of total avalanche path affected.
Starting zone	53-54	<p>Starting area when avalanche is viewed from below:</p> <p>T, M, B = top, middle, bottom</p> <p>L, C, R = left, center, right, of the midline of path.</p>

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.

year	month	day	time	avalanche path	station number	path number	control	type	trigger timing surface	motion	slab depth layers	percent	starting zone	vertical fall	location of debris center line depth	length of center line
AVALANCHE OCCURRENCES, STATION 152, 1971-72																
71	11	16	1300	BLUE POINT	152097			L	N20			25T		200C		
71	11	16	1300	MILL CK E	152112			SS	N20		2A	25M		400B		
71	11	16	1300	MILL CK F	152113			SS	N20		2A	50T		1200B		
71	11	16	2417	BISMARK	152127			SS	N20		3B	40T		1000B		
71	11	16	2417	BROOKLYNS	152			SS	N20		2A	5T		300B		
71	11	16	2417	BROOKLYNS	152			SS	N20		2A	5T		300B		
71	11	16	2417	BROOKLYNX	152			SS	N20		2A	5T		600B		
71	11	17	2405	1ST TWIN CROSSNG	152031			L	N10				M			
71	11	17	2405	NO MINERAL BRDGE	152033			L	N10				M			
71	11	17	2405	SUS BASIN W	152035			SS	N20				T			
71	11	17	2405	JENNIE PARKER SOI	152141			L	N10				T		B	
71	11	17	2405	SPRINGS	152148			SS	N20		1		M		C	
71	11	17	2405	W LIME CK	152150			L	N10				B			
71	11	17	2405	GOBBLERS KNOR	152151			SS	N2G				TL			
71	11	17	2405	HENERY BROWN	152155			L	N10				M			
71	11	18		MILL CK B	152109			SS	N20				M			
71	11	18	2417	BATTLESHIP	152128			L	N10				T			
71	11	18		COAL CK W	152158			WL	N1G				T			
71	11	18		ENGINEER MTN B	152160			L	N10							
71	11	18		ENGINEER MTN C	152161			L	N10							
71	11	20	2417	1ST TWIN CROSSNG	152031			WL	N10				T			
71	11	20	2417	NO MINERAL BRDGE	152033			WL	N20				T			
71	11	20	2417	NO MINERAL BRDGE	152033			WL	N20				T			
71	11	20	2115	BLUE POINT	152097			L	N20		A	20T		200C		
71	11	20	2417	TELESCOPE	152105			WL	N2G		B	5T		500B		
71	11	22	2405	BROOKLYNS	152			WL	N2G		B	5T		600B		
71	11	22	2405	BROOKLYNS	152			WL	N2G		B	5T		600B		
71	11	22	2405	BROOKLYNS	152			WL	N2G		B	5T		600B		
71	11	22	2405	BROOKLYNS	152			WL	N2G		B	5T		600B		
71	11	28	2405	RIVERSIDE S.	152062			L	N20		A	10T		300C		
71	11	28		MILL CK F	152113			SS	N2G		2B	20T		400C		
71	11	28	2405	BATTLESHIP	152128			SS	N20		2B	5T		1000B		
71	11	29	2405	SUS BASIN W	152035			SS	N3G		3A	50T		400C		
71	11	29	2405	MOTHER CLINE	152069			SS	N2G		1R	5M		300B		
71	11	29	2405	KING	152091			SS	N20		1R	5T		150R		
71	11	29	2405	WILLOW SWAMP	152095			L	N10		B	10T		75B		
71	11	29	2405	BLUE POINT	152097			SS	N20		B	80T		200C		
71	11	29	2405	BULLION KING	152107			SS	N20		2B	5M		500B		
71	11	29	2405	SAM	152117			SS	N20		2B	5M		300B		
71	11	29	2405	SAM	152117			SS	N20		2B	5M		100R		
71	11	29	2405	BISMARK	152127			SS	N20		2B	30T		800B		
71	11	29		W LIME CK	152150			L	N10							
71	11	29	2405	GOBBLERS KNOR	152151			L	N20		B	5T		100R		
71	11	29		ENGINEER MTN A	152159			L	N20							
71	11	29		ENGINEER MTN B	152160			L	N20							
71	12	02		BROOKLYNS B	152016			L	N10							
71	12	02		SAM	152117			SS	N20		1		M	100B		
71	12	02		BATTLESHIP	152128			L	N10							
71	12	02		ENGINEER MTN B	152160			L	N10							
71	12	04		BROOKLYNS G	152022			L	N10				T			
71	12	04		BROOKLYNS H	152023			L	N10				T			
71	12	04		2ND TWIN CROSSNG	152032			SS	N20		A		M	250C		
71	12	04		NO MINERAL BRDGE	152033			L	N10				T			
71	12	04	2405	LONGFELLOW	152039			SS	N10		A					
71	12	04	2417	LONGFELLOW	152039			L	N10							
71	12	04		LONGFELLOW	152039			L	N10				T			
71	12	04		RMP	152040			L	N10				T			
71	12	04		CORA BELL	152048			L	N10				M			
71	12	04		E GUADALUPE	152060			L	N10				T			
71	12	04		SLIPPERY JIM	152061			L	N10				M			
71	12	04		W GUADALUPE	152075			L	N10				T			

71 12	042405	WILLOW SWAMP	152095	L N10	A			
71 12	04	BLUE POINT	152097	L N10		M		
71 12	042405	TELESCOPE	152105	L N20	A	5		
71 12	04	HULLION 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 KNOR	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	081430	BROOKLYNS R	15201641	LAA1			75	
71 12	081430	BROOKLYNS D	15201841	SSAA2		T	600	
71 12	08	BROOKLYNS G	152022	L N2		M	200	
71 12	081430	BROOKLYNS I	15202441	SSAA2	2	T	600	
71 12	08	NO MINERAL BRDGE	152033	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	3STR	1600	
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	GOVERNOR GULCH	152090	HS N30	5	TL	1000	
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	081400	EAGLE	15210442	HSAA2	4	M	900	
71 12	081400	EAGLE	15210441	HSAA2	4	T	1100	
71 12	08	EAGLE	152104	HS N20	3	M	900	
71 12	08	TELESCOPE	152105	HS N20	3	M	800C	3 50
71 12	081400	MULESHOE	15210641	HSAA2		T	900	
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	IMUGENE	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 KNOR	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	152124	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	TL	2000	
71 12	141100	BROOKLYNS C	15201741	SSAA20	M 3A	5TC	900C	50
71 12	141055	BROOKLYNS F	15201941	SSAA20	M 3A	40TR	1000C	100
71 12	141055	BROOKLYNS F	15202040	SSAA20	M 3A	40TR	1000C	50
71 12	141050	BROOKLYNS G	15202241	SSAA20	M 3A	50TR	1000C	100
71 12	141050	BROOKLYNS H	15202340	SSAA20	M 3A	30TC	1000C	100
71 12	141315E	RIVERSIDE	15206442	SSAA20	M 4B	5TR	1500C	10 150
71 12	141300E	RIVERSIDE	15206445	SSAA30	M 5B	30TR	2000C	8 200
71 12	141325E	RIVERSIDE	15206445					
71 12	141130W	WILLOW SWAMP	15209541	SSAA20	S 1A	5TR	100A	
71 12	141130W	WILLOW SWAMP	15209541	SSAA3G	M 4B	40TL	400C	

71 12	141140	BLUE POINT	15209741	SSAA36	M	3B100TC	400C	5	250	
71 12	141045	EAGLE	15210442	SSAA20	M	2A 10TR	400B			
71 12	141040	EAGLE	15210441	SSAA20	M	3A 30TC1	200C			
71 12	141036	MULESHOE	15210641	SSAA20	M	1A 10TL	400B			
71 12	141035	MULESHOE	15210641	SSAA20	M	3A 20TC1	400C			
71 12	142417	OPHIR RD E	152125	SS N20			20TC	400		
71 12	141005	JENNIE PARKER NO15214041		SSAA20	M	2A 20TC	400B			
71 12	141000	JENNIE PARKER SO15214142		SSAA20	M	2A 20TL	1000B			
71 12	141010	PEACOCK	15214241							
71 12	142417	W LIME CK	152149	SS N10		1	5T	30		
71 12	142417	E LIME CK	152150	L N10			5TC	25		
71 12	142417	GOBBLERS KNOB	152151	L N20			10T	100		
71 12	142417	SWAMP	152154	L N10			5TL	50		
71 12	142417	HENRY BROWN	152155	L N10			5TL	50		
71 12	142417	COAL CK E	152157	L N10			5T	30		
71 12	142417	ENGINEER MTN B	152160	L N20			5T	100		
71 12	172405	GUADALUPE	152060	SS N20		2B	10ML1	200B		
71 12	172405	GALENA LION GLCH	152088	HS N30		6B	30TC1	400B		
71 12	17	EAGLE	152104	SS N20		2		1400		
71 12	172405	MULESHOE	152106	SS N20		2B	60TL1	400C		
71 12	172405	HULLION KING	152107	SS N20		2B	T	1700C		
71 12	172405	IMOGENE	152119	SS N30		4B	60TL1	400C		
71 12	182417	W 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	182417	ENGINEER MTN B	152160	WL N20		A	20TC	200		
71 12	192417	WATER GAUGE	152002	WL N20		A	10TC	200B		
71 12	192417	OLD SO MINERAL RD	152003	WL N20		A	10TC	450B		
71 12	192405	ENGINEER MTN A	152159	WL N20			5TC	200B		
71 12	222405	BROOKLYNS D	152018	L N10		A				
71 12	222405	SAM	152117	SS N20		A	10M	200B		
71 12	222405	BATTLESHIP	152128	L N20		A	5T	200A		
71 12	222405	ENGINEER MTN B	152160	L N10		A	5T	75B		
71 12	252300	BROOKLYNS D	152018	SS N3G		6B	40CM	400C	3	250
71 12	252405	SILVER GULCH	152073	HS N40		10B	70TL2	400C		
71 12	261600	CEMENT FILL	152010	HS N4G		15B	80TC2	400C15	400	
71 12	262200	BARTON	152012	SS N4		4B	90TC1	400C	4	100
71 12	261800	BLACKBURN	152013	SS N30		3B	25TR	300C	6	100
71 12	262200	BENNY LONG	152014	SS N20		2B	20TC	200C	6	75 3
71 12	261800	BROOKLYNS D	152018	SS N30		4B	90TC1	000C	5	300
71 12	261800	BROOKLYNS I	152024	SS N30		4B	60TC1	000C10	300	
71 12	261600	BROOKLYNS J	152025	SS N30		3B	60TR1	000C	3	150
71 12	261600	CEMETARY	152030	SS N30		3B	50TC	700B		
71 12	261600	1ST TWIN CROSSING	152031	SS N30		3B	70TC	700B		
71 12	261600	NO MINERAL BRDGE	152033	SS N30		3B	60TC	400B		
71 12	262000	NATIONAL BELL SO152042		HS N5G		8B100TC1	500C			
71 12	262000	NATIONAL BELL NO152043		HS N5G		15B100TC1	400C			
71 12	261842	RED MTN 3	152044	HS N5G		20B100TC2	200C			
71 12	262300	ROCKWALL	152101	SS N5G		5B100TC	400C10	1000		
71 12	262300	SILVE LEDGE MILL	152102	SS N5G		5B100TC	400C10	500		
71 12	262300	PORCUPINE	152103	SS N4G		8B	80TC1	300C	8	400
71 12	262300	EAGLE	152104	SS N4G		8B	80TC1	400C12	300	
71 12	262300	TELESCOPE	152105	HS N5G		20B100TC2	200C20	600		
71 12	262300	MULESHOE	152106	SS N36		8B	80TC2	100C	6	200
71 12	261600	SAM	152117	SS N20		3B	20MC	400L		
71 12	261600	CHAMPION	152144	SS N46		B	70TC1	400C15	350	
71 12	272405	OLD SO MINERAL RD	152003	SS N20						
71 12	272405	LOWER CEMENT FIL	152009	SS N30		3B	30TC1	000B		
71 12	272405	BROOKLYNS C	152017	SS N30		3B	70TL1	000C	4	400
71 12	272405	BROOKLYNS E	152019	SS N3G		4B	70TC1	000C	5	200
71 12	272405	BROOKLYNS I	152024	SS N4G		5B	80TC1	000C10	300	
71 12	272405	SALHANY GULCH	152055	HS N5G		15B	90TC3	100C		
71 12	270930	SLIPPERY JIM	152061	SS N3G		4B	50MC1	100C	9	300
71 12	270930	E RIVERSIDE	152064	HS N5GJ		30B100TC3	200C15	600		

71 12	272405SILVER GULCH	152073	SS N30	5	20TC2000B		
71 12	271245W RIVERSIDE	15207446	HSAA40	M 88	70TL2000C	2	70
71 12	272405W GUADALUPE	152075	HS N30	88	30TL2000B		
71 12	272405IRUNTON PARK	152082	SS N46	58	100TC1400C		
71 12	272405TIDY	152083	SS N30	38	100TC1000C		
71 12	272405FULL MOON GULCH	152084	SS N30	38	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	38	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 200C		
71 12	272405MILL CK B	152109	SS N20	2	30MC 200C		
71 12	272405MILL CK C	152110	SS N20	2	30MC 200C		
71 12	272405MILL CK E	152112	SS N20	2	30MC 200C		
71 12	272405MILL CK F	152113	SS N20	2	30MC 200C		
71 12	272405SAM	152117	SS N30	3	80TC 400C		
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	90TC1200C		
71 12	272405OPHIR RD W	152126	SS N30	5	90TC1200C		
71 12	272405BISMARCK	152127	SS N40	38	100TC2000C		
71 12	272405BATTLESHIP	152128	SS N40	48	100TC2400C		
71 12	272405DESTROYER	152129	SS N40	38	100TC1400C		
71 12	272405SNOWSLIDE GULCH	152132	HS N40	68	100TC2200C		
71 12	272405BEAR CK W	152134	SS N30		100TC1200C		
71 12	272405PUMPHOUSE	152136	SS N40	4	100TC2000C		
71 12	272405NORTH STAR	152137	SS N30		20TR1000B		
71 12	272405JENNIE PARKER	152141	SS N30	38	20TR1000B	2	50
71 12	272405KENO MINE	152146	SS N30	38	MC 700B		
71 12	272405HENRY BROWN	152155	SS N20	28	30TL 400B		
71 12	281150PEACOCK	15214242	SSAA46	M 58	90TC1500C18		200
71 12	281155HARLEY SHORT	15214342	SSAA20	S 2A	50TC 150B	2	100
71 12	291200BROOKLYNS E	15201941	SSAA36	38	30TR1000C12		200
71 12	290800BROOKLYNS F	152020	SS N36	38	70TC1000C12		300
72 01	031100LIME CK W	15215044					
72 01	031045COAL CK W	15215843					
72 01	031030ENGINEER MTN H	15216045	SSAA20	A 30	200		
72 01	042417CURA 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 200		
72 01	11 BROOKLYNS H	152016	SS N30	2	80TC 200		
72 01	11 ITALIAN	152051	SS N20	2	70TR 200		
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 200		
72 01	11 MILL CK E	152112	HS N20	1	20MC 200		
72 01	11 MILL CK F	152113	HS N20	1	20MC 200		
72 01	130900EAGLE	152104	HS N30	3	50TL1500C	4	350
72 01	13 MILL CK G	152114	HS N26	3	40MC 400		
72 01	142405IMOGENE	152119	HS N20	2	10TL 400		
72 01	14 SAN JUAN	152122	SS N10		54C 50		
72 01	14 TAVERN	152123	SS N20	1	40TC 400		
72 01	14 BATTLESHIP	152128	HS N30	3	TC1200		
72 01	181513E RIVERSIDE SO	152062	SS N20	1	HR 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		5HL 200		

72 02	212417	BROOKLYNS J	152025	WL N20	30TC	250		
72 02	22	NO MINERAL BRDGE	152033	WL N10	5	50		
72 02	222417	LONGFELLOW	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	F RIVERSIDE	152063	WL N20	5BR	300	3	15
72 02	222415	DUNSMORE	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	011620	BROOKLYNS B	152016	WLAS20 S	10T	400B		
72 03	011620	BROOKLYNS C	152017	WLAS10 S	5M	75B		
72 03	012417	E GUADALUPE	152060	WL N20	5M	250B		
72 03	012417	SLIPPERY JIM	152061	WL N20	5M	100B		
72 03	012417	E RIVERSIDE LEFT	152065	WL N20	5BC	200B		
72 03	021500	NO MINERAL BRDGE	152033	WL N20	10T	250B		
72 03	021500	RED MTN 3	152044	WS N20	2	5BC	150B	
72 03	022417	WATER GUAGE NO	152076	WL N20	15TC	250B		
72 03	021000	BATTLESHIP	152128	WL N20	5T	200B		
72 03	032417	E RIVERSIDE LEFT	152065	WL N20	5MC	150B		
72 03	032417	SILVER GULCH	152073	WL N10	5MC	75B		
72 03	03	SILVER GULCH	152073	SS N20	1	15MC	900B	
72 03	031200	MILLCK C	152110	SS N20	1	75	700C	
72 03	051300	GALENA LION GLCH	152088A	WL N2	20TC	300A		
72 03	05	WILLOW SWAMP	152095	SS N20	1	20TR	200B	
72 03	052417	EAGLE	152104	WL N20	15TC	300B		
72 03	052417	SAM	152117	SS N20	2	20TC	200B	
72 03	052417	SAN SUAN	152122	SS N20	1	50MC	200B	
72 03	051300	GI	152130	WL N2	20TC	200		
72 03	051300	G.I.	152130	WL N2	20TC	175B		
72 03	052417	PICKLE BARREL	152131	WL N20	20TC	175B		
72 03	102417	BROOKLYNS G	152022	WS N2G	1	30TC	700B	
72 03	102417	BATTLESHIP	152128	HS N30	3	40TC	600C	
72 03	132417	BROOKLYNS H	152023	WS N2G	40TC	600B		

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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		200		
71 12	04	BILLBOARD	157042	SS N20		200		
71 12	04	BILLBOARD	157042	SS N20		200		
71 12	04	BILLBOARD	157042	SS N20		200		
71 12	04	GRASSY GULCH	157043	SS N20	TR			
71 12	142405	ARCADE	157008	SS N20	30MR	1200		
71 12	161030	IRENE	15700541	HSAA30 M 5B	30TR	1300C		
71 12	161030	IRENE	15700541	HSAA30 M10B	40TL	1200C		
71 12	161130W	JUMP A	15702841	SSAA20 M 3B	TC	200B		
71 12	161130W	JUMP B	15702941					
71 12	161045	FAIRVIEW	15701641	HSAA20 M 5B	30TR	1000B		
71 12	161045	FAIRVIEW	15701641	HSAA40 M10B	70TC	900C	2	50
71 12	161045	FAIRVIEW	15701645					
71 12	161100	DRY GULCH W	15703941	SSAA40 M 3B	90TC	1400C	2	75
71 12	242405	DRY GULCH NO	157027	SS N30	3A	40TL	600C	
71 12	272405	DENVER	157001	SS N30	6R	40MC	1500	
71 12	272405	HENRIETTA GULCH	157004	SS N40	8B	100TC	2000C	
71 12	270530	IDAHO	157004	HS N5GJ	20B	100TC	3500	
71 12	270600	ARCADE	157009	HS N4GJ	12B	80TC	2200	
71 12	272405	ERIE	157014	SS N20	2A	90TC	700C	

71 12	272405MICHIGAN	157015	SS N4G	5R100TC	700C	3	100
71 12	272405FAIRVIEW	157016	HS N3G	5R 20TR1	000C		
71 12	272405BEATLES	157017	SS N30	3R 90TC	000C		
71 12	272405GEORGIA GULCH	157021	HS N3G	6R 20TL2	000C		
71 12	272405W JUMP B	157029	SS N4G	5R 90TC	000C	4	150
71 12	272405MOGUL	157030	SS N30	3R 80TC	700C	4	300
71 12	272405STANDARD MINE	157031	SS N30	3R 60TC	000C		
71 12	272405COLORADO SLIDE	157032	HS N40	6R100TC1	000C		
71 12	272405DRY BULCH SO	157040	SS N30		000		
71 12	272405TIGER GULCH	157041	HS N4G	6R 60TL2	000C		
71 12	272405GRASSY GULCH	157043	HS N4G	8R 80TC2	000C		
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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72 10	302417RED MTN 3	152044	SS N30		30TC	000B	
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	000M	
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 NC	152043	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	75R	2 30
72 11	082200ROCKWALL	152101	SS N20		70TC	200M	4 200
72 11	092405E RIVERSIDE	152064	SS N30	3	25TC3	000B	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	121000LUNGFELLOW	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 SOUT	152062	L N20		10MC	150B	
72 11	132417E RIVERSIDE LEFT	152065	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	000B	
72 11	132405MILL CK G	152114	SS N20	2	30TR	000B	
72 11	132405ENG MTN B	152160	SS N20	1	30TC	200M	

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	SMR	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 BRIDG	152033	SS N20	1A 5MC	250M		
72 11	210200E RIVERSIDE SOUT	152062	SS N20	1A 25TC	300B	2	25
72 11	211130E RIVERSIDE	15206444					
72 11	210200E RIVERSIDE LEFT	152065	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 10TL	1000M		
72 11	270700BROOKLYN F	152020	SS N20	2 50TC	800B	1	100
72 11	270700BROOKLYN G	152022	SS N20	2 50TC	850B		
72 11	2724051ST TWIN CROSSIN	152031	SS N20	1 10TL	1000B		
72 11	270830NCRTH MINERAL BD	152033	SS N20	2 25TR	800B		
72 11	272405E GUADALUPE	152060	SS N20	5ML	1000B		
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	1800B		
72 11	272405BULLION KING	152107	SS N30	75T	1800B		
72 11	272405IMOGENE	152119	SS N30	2 75TR	1200B		
72 11	272405OPHIR ROAD EAST	152125	SS N30	2 50TL	1500B		
72 11	272405BATTLESHIP	152128	HS N30	3 50TR	2100B		
72 11	272405SNOWSLIDE GULCH	152132	SS N20	1 10TL	1000B		
72 11	292405RED MTN 3	152044	HS N20	5TL	750M		
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 GULC	152088	L N20 S	5TC	1000B		
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 LEFT	152065	SS N20	50TC	200B	3	70
72 12	042417W RIVERSIDE	152074	SS N30	25TL	1900B		
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	50TC	1900B		
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	800B	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	100TC	1000	8	250
72 12	042200LOWER POND	152	L N20 M	100TC	1000	5	100
72 12	052405N MINERAL BRIDGE	152033	SS N20	2 5ML	150B		
72 12	052405N MINERAL BRIDGE	152033	SS N20	2 10ML	500B		
72 12	051400E RIVERSIDE	15206441	SSAA30 F	25TR	2500B	9	40

72 12	051400E RIVERSIDE	15206444							
72 12	051225WILLOW SWAMP	15209542	HSAA20	M 2A	25TL	300B			
72 12	051150SILVER LEDGE MIN	15210042							
72 12	051115EAGLE	15210444	SSAA30	M 4	75TC	2000B			
72 12	051115TELESCOPE	15210542	SSAA20	M 3	50TC	2000B			
72 12	070900BROOKLYN H	152023	SS N20	3	10MR	300B			
72 12	070900BROOKLYN J	152025	SS N20	2	25TR	400M			
72 12	070900N MINERAL BRIDGE	152033	SS N20	3	50TC	1000B			
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 N	15214041							
72 12	111500JEANNIE PARKER S	15214141							
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 RD	152003	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	25TC	1000M			
72 12	211000EAGLE	152104	SS N20	3	10TC	2000B			
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	50TC	2400B	7	100	
72 12	262405EAGLE	152104	SS N20	1A	10TR	1200M			
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	25TL	2000B			
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	600			
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	300B			
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		10TC	1100B			
73 01	102405GOBBLERS KNOB	152151	SS N20	2	10TL	250B			
73 01	112417BULLION KING	152107	SS N20		5TC	600B			

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 R	152003	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 LEFT	152065	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 500R		
73 02	062417E RIVERSIDE	152064	L N20	10TC1000B		
73 02	062417GALENA LION GULC	152088	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	L A S10	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 LEFT	152065	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 SC	152141	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 BRIDGE	15203341				
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		

73 02	131200MULESHOE	15210641							
73 02	150800JENNIE PARKER NC1	152140	SS N20	1A	5MC	200B			
73 02	231430BROOKLYN D	152018	L N20		5TC	250B			
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 RIGH	152063	DL N20		5TR	150B			
73 02	252417E RIVERSIDE LEFT	152065	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	10RR	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 MIN	152100	SS N10	1A	5BC	30C			
73 03	090800ROCKWALL	152101	SS N10	1A	5BL	50C			
73 03	090800SILVER LEDGE MIL	152102	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 LEFT	152065	LN 20		5TR	150C			
73 03	101000W RIVERSIDE	152074	SS N20	2	10TL	1400B			
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	800C	12	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	75TC	1200C			
73 03	131200E RIVERSIDE	15206441	SSAA20	1A	5TR	400A			
73 03	131200E RIVERSIDE	15206449							
73 03	130930E RIVERSIDE LEFT	152065	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	25TL	1600C			
73 03	131410MULESHOE	152106	SS N20						
73 03	131500MULESHOE	15210641							

73 03	130900MILL CK A	152108	HS N30	2	75TC1000C		
73 03	141800CEMETARY	152030	SS N30	38	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	28	100TC 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 58	30TC2600C12	60	
73 03	202400BROOKLYN I	152024	SS N30		75T 1000C	8	100
73 03	212417GOBBLEERS 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	48	10TC2400A		
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 SHOULD	152	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 RIGH	152063	L N20		10MC 150C		
73 04	072417E RIVERSIDE LEFT	152065	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 BRIDG	152033	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 LEFT	152065	WS N2G		5BC 200C	4	50
73 04	261600MOTHER CLINE	152069	WS N2G		10BC 100C12	75	
73 04	271750BROOKLYN B	152016	WS N4G	F 48	50TC 700C	8	100
73 04	271615BROOKLYN C	152017	WS N3G	F 28	50TC 600C	3	40
73 04	271745BROOKLYN F	152020	WS N3G	F 48	75TC 650C		
73 04	271605BROOKLYN F	152020	WS N3G	F 48	50TC 600C		
73 04	271550BROOKLYN G	152022	WS N4G	F 48	75TC 750C20	150	
73 04	271515BROOKLYN K	152026	WS N3G	F 48	75TC 700C		
73 04	271800BROOKLYN L	152027	WS N3G	F 48	50TC 600C		
73 04	271710TWIN CROSSING	152032	WL N2G	F B	50TC 300C		
73 04	271600ST GERMAIN	152059	WS N3G	4	25TR 300C		

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 68	25TR1400C12	250
73 04	281600LOWER CEMENT FIL	152009	WL N20	10TC 300B	
73 04	281500BROOKLYN E	15201941	WSAA3G F 48	25TC 700C 3	50
73 04	281553BROOKLYN E	152019	WS N4G F 48	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 LEFT	152065	WS N2G	25MC 200C 6	80
73 04	281630NC EMERGENCY PHO	152066	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 NC	152140	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 BRIDG	152033	WL N2G	10MC 500C	
73 04	291605NC MINERAL BRIDG	152033	WS N2G F 3B	25MC 500C	
73 04	291621NC MINERAL BRIDG	152033	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 FIL	152009	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	

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 NC	15214045	WLAA20 F	A 5TC 200A				
73 05	101245JENNIE PARKER SC	15214141	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 900C	7	75		
73 05	111600B LYN N	152029	WL N2G	25TR 600C				
73 05	111700NO MINERAL BRDGE	152033	WL N3G	50TR1000C				
73 05	112417ITALIAN	152051	WS N3G	6 25TL1900C				
73 05	112417E GUADALUPE	152060	WS N2G	6 5TC 900B				
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	25TL2100C	22	150		
73 05	111200MULESHOE	152106	WL N3G	10TC2100C				
73 05	111050MULESHOE	152106	WS N3G	6 25MC1600C	3	60		
73 05	111500IMOGENE	152119	WL N20	10TC1900C				
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				

73 05	131300BLUE WILLOW	152096	WL N1G		25TR	75C	2	25
73 05	151610NC MINERAL BRIDG	152033	WL N2G	F 8	5TC	450B		
73 05	152417TELESCOPE	152105	WL N2G		5TC	600B		
73 05	152417MILL CK G	152114	WS N3G	5	50TR	900C		
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	10TC1	200C		
73 05	182417COLONY	152053	WL N4G		75TC1	800C		
73 05	182417GALENA LION GULC	152088	WL N3G		25TC1	200B		
73 05	181100MILL CK F	152113	WS N2G	6	50TC1	000C		
73 05	202417MILL CK G	152114	WL N3G		50TL	900C		

AVALANCHE OCCURRENCES, STATION 153, 1972-73

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	10MC1	000B		
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		

AVALANCHE OCCURRENCES, STATION 157, 1972-73

72 11	272405FAIRVIEW	157016	HS N30		75TL1	900B		
72 11	272405BILLBOARD	157042	HS N20		5TR	500M		
72 11	272405BILLBOARD	157042	HS N20		5TL	700M		
73 03	132405BILLBOARD	157042	HS N30	2	50TC1	100C		
73 04	281600BAD NUMBER	157013	WL N2G		50TC	300C		
73 04	281600EIKE	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	900C		
73 05	102417GEORGIA GULCH	157021	WS N3G	6	10TL1	200B		
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	25TC3	150C		
73 05	102417CABIN	157	WL N2G					

73 05	111400FAIRVIEW	157016	WS N3G	7	25TR1800C			
73 05	192417COLORADO	157032	WL N3G		10ML 900C			
73 05	111400COLORADO	157032	WS N2G	4	10RR 400C			
73 05	192417BILLBOARD	157042	WS N3G		10TC2400C			
73 05	132405ARRASTRA GULCH	157	WS N3					

AVALANCHE OCCURRENCES, STATION 152, 1973-74

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	180830FRS LEFT	152065	SS N2G	2	25TC	150C	4	20
73 12	181530MOTHER CLINE	152069	SS N20	1	10TR	200C	6	25 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		25TC	1000C		
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	10ML	1000C	3	50
73 12	301245EAGLE	152104	SS N30 J		10TC2200C		1	100
73 12	300230TELESCOPE	152105	SS N30 J		25MC	1000C	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	10TC	2500C		
73 12	302405DESTROYER	152129	SS N30	4	75TC	2200C		
73 12	302405PICKLE BARREL	152131	SS N20	2	50TC	450C		
73 12	302405SNOWSLIDE GULCH	152132	SS N20		25TC	2000C		
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	25TC	1800C		
73 12	311020EAGLE	15210441	SSAA30JP	4	25TR	1800C	3	150
73 12	311020TELESCOPE	15210541	SSAA30 M	4	50TC	1800C	2	100
73 12	311030MULESHOE	15210641	SSAA30 M	2	25TC	2100C		
73 12	311035BULLION KING	15210741	SSAA30 M	6	50TC	2100C		
74 01	032405FULL MOON GULCH	152034	SS N40	4	75TC	1800C		
74 01	031135N CARBON	152	3SSRE30 F	4B	50TL	200C		
74 01	051404CEMENT FILL	152010	SS N30	4	25TR	2500C		
74 01	051300BROOKLYNS G	152022	SS N40		75TC	800C	15	250
74 01	051400BROOKLYNS I	152024	SS N30		50TC	1000C		
74 01	052415CEMETARY	152030	SS N20		10TC	300B		
74 01	0515002ND TWIN CROSSNG	152032	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		

74 01	0515000UTAH	152118	SS N30	4	50MC	300C				
74 01	051330IMOGENE	152119	SS N30		75TC	1900C				
74 01	052415BISMARK	152127	SS N30	4	25TR	1900C				
74 01	052415BATTLESHIP	152128	SS N30	4	10TR	2400C				
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	5MC	1000C	5	70		
74 01	061210E RIVERSIDE	15206443	SSAA2G	P B	5MR	1900C	15	80		
74 01	061210E RIVERSIDE	15206448								
74 01	061000EAGLE	15210444								
74 01	061000TELESCOPE	15210541								
74 01	060930BROOKLYNS-OTHERS	152 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 MINE	15210041	SSAA10	1A	5TL	50A				
74 01	071400SILVER LDGE MINE	15210041	SSAA2G	M 4B	10TL	150B				
74 01	071400SILVER LDGE MINE	15210041	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	200C	11	200		
74 01	092415SILVER GULCH	152073	SS N30	4	25TL	2000C				
74 01	092405W GUADALUPE	152075	SS N2G	4R	25MC	800C				
74 01	092415FULL MOON GULCH	152084	SS N3G	6	25TL	1500B				
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		
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	300C	15	250		
74 01	101445WILLOW SWAMP	15209542	SSAA3G	5	50TC	400C				
74 01	101345BATTLESHIP	152128	SS N4G	6	50TR	2500C				
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	80TL	1900C	14	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 BRIDGE	152033	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	300B				

74 02	112417WILLOW SWAMP	152095	L N20		10TL 180R		
74 02	190920NO CARBON	152	LAS20		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	152064	SS N20	1	75TC 250C10	300	
74 02	200230SILVER POINT	152070	L N20		50T 200C 6	20	
74 02	201100WILLOW SWAMP	15209541	SAA20		5TL 150R		
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	211500LUNGFELLOW	152039	SS N20	1	25TC 200C		
74 02	212405MILL CK A	152104	SS N20	1	5MC 200R		
74 02	212405MILL CK C	152110	SS N20	1	10MC 300R		
74 02	212405MILL CK D	152111	SS N20	1	25MC 200C		
74 02	212405IMOGENE	152119	SS N20	1	5TR 300R		
74 02	221245E RIVERSIDE	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 350R		
74 02	272405BROOKLYNS C	152017	L N20		10TC 400R		
74 02	271100NO MINERAL RDGE	152033	L N20		5MC 350R		
74 03	012417DUNSMORE	152068	WL N20		25TC 250C 1	30	
74 03	022405SLIPPERY JIM	152061	HS N30	4R	25TL1200R		
74 03	020800E RIVERSIDE	152064	HS N30	7R	25TR2600C12	70	
74 03	031300SNOWSLIDE GL	152132	SS N20		5TL1000R		
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 500R		
74 03	072417BROOKLYNS I	152024	SS N30	2	MC 700C		
74 03	072417BROOKLYNS M	152023	SS N20	1	25MC 450C		
74 03	071330BLUE POINT	152047	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 200C		
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 N26	2	10ML 150C 4	80	
74 03	102405EAGLE	152104	SS N20	2	5HL 400C		
74 03	102405MULTISHOT	152106	SS N20				
74 03	102417ERNEST	152115	SS N36	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		50 200		
74 03	110845BROOKLYNS J	15202541	LAA20		75TC 200		
74 03	112417BROOKLYNS K	152026	L N20		25 300		
74 03	110845BROOKLYNS L	15202741	SSAA20 M 2		75 200		
74 03	110845BROOKLYNS M	15202341	SSAA20 M 1		TC 300R		
74 03	110845BROOKLYNS N	15202941	SSAA26 7 2		75 600C		
74 03	112405NATIONAL BFLL NO1	152043	HS N20	5	25MR 250R		
74 03	111030E RIVERSIDE	15206441	SSAA2L	2	ML1100		
74 03	111120E RIVERSIDE	15206441	SSAA30	2U	M 2700C13	100	
74 03	111120E RIVERSIDE	15206441	SSAA30	2U	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 4 2A		75TC 200C 7	30	
74 03	110815PORCUPINE	15210344	LAA10				
74 03	110815EAGLE	15210441	LAA10		T 200A		

74 03	110835TELESCOPE	15210542	SSAA20		1100			
74 03	110835MULESHOE	15210641	SSAA20	1	500B			
74 03	122417HROOKLYN C	152017	L N20		450			
74 03	122417HROOKLYN 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	151600HROOKLYNS C	152017	WL N2G		25TC	300B		
74 03	151600HROOKLYNS C	152017	WL N2G		25TC	300B		
74 03	151600HROOKLYNS D	152018	WL N3G		75TC	450C		
74 03	151600HROOKLYNS G	152022	WL N2G		25TC	500B		
74 03	151600HROOKLYNS H	152023	WL N3G		75TR	300C		
74 03	151600HROOKLYNS K	152026	WL N2G		50TC	400B		
74 03	151600HROOKLYNS L	152027	WL N2G		75TC	400B		
74 03	151600N MINERAL BRIDGE	152033	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	161700HROOKLYNS F	152020	WL N2G		10TL	600B		
74 03	161530HROOKLYNS G	152022	WL N2G		10TC	500B		
74 03	161500HROOKLYNS H	152023	WL N2G		25TC	350B		
74 03	161530HROOKLYNS I	152024	WL N3G		75TC	300D	5	55
74 03	161300HROOKLYNS L	152027	WL N20		10TR	400B		
74 03	161700CEMETARY	152030	WS N20	1	5ML	300B		
74 03	1616002ND TWIN CROSSNG	152032	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		5TR	500B		
74 03	161200TAVERN	152123	WL M20		25TL	300C		
74 03	161400JENNIE PARKER N	152140	WL N20		5TC	350B		
74 03	161320CHAMPION	152144	WL N2G		25TR	300B	5	50
74 03	161215CHAMPION	152144	WL N2G		25TC	300B	4	25
74 03	172417WATER GUAGE N	152076	WL N3G		75TC	400C		
74 03	172417EARTH	152078	WL N2G		75MC	350C		
74 03	171500BLUE POINT	152097	WL N2G		25TR	150C	2	6
74 03	181450MOTHER CLINE	152069	WL N20		5TR	350C	3	20
74 03	191630MOTHER CLINE	152069	WL N20		10MR	300C	3	60
74 03	191600JACKPOT	152071	WL N30		50TC	350C	2	70
74 03	301500MILL CK A	152108	L N20		5HC	175C		
74 03	301500MILL CK C	152110	L N20		10MC	300B		
74 04	021000HROOKLYNS K	152026	SS N20	1	25TC	500M		
74 04	021000BLUE POINT	152097	SS N20	1	50TC	300B		
74 04	0324171ST TWIN CROSSNG	152031	SS N20		10TR	500M		
74 04	032145EAGLE	152104	SS N30		25TR	1200B		
74 04	042405HROOKLYN 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	350B		
74 04	042405MOTHER CLINE	152069	SS N20	1	10ML	350M		
74 04	040830MOTHER CLINE	152069	L N20					
74 04	041000BLUE POINT	152097	SS N20	1	50TC	300B		
74 04	0516001ST TWIN CROSSNG	152031	WL N2G		5ML	300M		
74 04	052417N MINERAL HDGE	152033	WL N2G		5M	300M		
74 04	051600HROOKLYNS	152	WL N2G		5T	350M		

74 04	161600BRUOKLYNS F	152020	WL N20	5TC 300M	
74 04	161600BRUOKLYNS G	152022	WL N20	10TC 400M	
74 04	161600BRUOKLYNS 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 200M	
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	8	
74 04	211145EAGLE	152104	WL N30	50T 1200B 6	30

AVALANCHE OCCURRENCES, STATION 153, 1973-74

74 03	161200DENVER	153001	WL N20	10TL1200	
74 04	062405SWANSEA GULCH	153	SS N30	5 25TR200M	

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 25TL1200C	
74 01	051600BEATLES	157017	SS N20	4 50TC 400C	
74 01	051600STONES	157018	SS N3G	4 75TC 550C	
74 01	051600WHJ	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 H	157029	SS N40	5 100TC 800C10	200
74 01	051600MOQUUL	157030	SS N30	50TC 200C	
74 01	091400IRENE	15700542	SSAA3G	4 50TR1200C	
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	157015	WS N3G	75TR 600C	
74 03	161330WHJ	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	25TL1200B	

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	204001STIWIN CROSSING	152031	L N2	5TC 200B	

74 11	204002ND TWIN CROSSING	152032	L N2		5TC	200B	
74 11	20400N MINERAL BRIDGE	152033	L N2		5TC	200B	
74 11	20400BLUE POINT	152097	L N2		5TR	200C	1 7
74 11	20400MILL CREEK H	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	21200GUBBLERS KNOR	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	250B	
74 11	81430BLUE POINT	152097	LA02	F 4	10TL	200C	1
74 11	111230MILL CREEK A	152108	SS N2	2	10TC	400B	
74 11	110800MILL CREEK H	152109	SS N2	2	10TC	400B	
74 11	112405MILL CREEK C	152110	SS N2	2	10TR	400B	
74 11	112417IMOGENE	152119	SS N2	2	5TR	200A	
74 11	112405BATTLESHIP	152128	SS N2	2	5TR	450B	
74 11	131645CEMENT FILL	152010	HS N2	4	5TL	450B	
74 11	141100BROOKLYNS H	152023	L N2		5MR	400B	
74 11	1524170PHIR ROAD F	152125	SS N2G	1	ML	200C	
74 11	191500BROOKLYN G	152022	SS N2	1	5T	100B	
74 11	192405GENNESSE F 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	400B	
74 11	230200BROOKLYN H	152023				300B	
74 11	230200BROOKLYN I	152024				400B	
74 11	2314002ND TWIN CROSSING	152032	L N1				
74 11	2314002ND TWIN CROSSING	152032	L N1				
74 11	2314002ND TWIN CROSSING	152032	SS N2	1	5MC	150B	
74 11	230700NATIONAL BELL N	152043	SS N3	3	25MC	200C	
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	400B	
74 11	230200FULL MOON GULCH	152084	L N2		5TL	400B	
74 11	230200GOVERNORS GULCH	152090	SS N2G		5TR	200A	
74 11	230200KING	152091	SS N2	2	10TC	200C	
74 11	230200WILLOW SWAMP	152095			TL	R	
74 11	230200BLUE POINT	152097	SS N2		25TC	250C	1 100
74 11	230500SNOWFLAKE	152098					
74 11	230845ROCKWALL	152101	SS N1	1	5M	40C	1
74 11	231200PORCUPINE	152103	SS N2	1	5TC	250A	1
74 11	230200EAGLE	152104	SS N2		5TC	200B	
74 11	231500EAGLE	152104	L N2		5TR	1000B	
74 11	231200MILL CREEK D	152111				R	
74 11	231200MILL CREEK F	152113				R	
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	200C	
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	

74 11	292417MILL CREEK R	152109	SS N2		T	>50R		
74 11	292417MILL CREEK C	152110	SS N2	1	10TC	300R		
74 11	292417IMOGENE	152119	SS N2	1	5TC	>50R		
74 12	22417MINERAL BASIN LT152		SS N2	1	25TR	100C		
74 12	52417EAGLE	152104	L N2		5TC	500R		
74 12	52417TELESCOPE	152105	L N2		5TC	500R		
74 12	52100BULLION KING	152107	N		TC	500A		
74 12	60800RRHOOKLYNS D	152018	L N1		10TC	75R		
74 12	60800RRHOOKLYNS F	152020	L N1		10TC	75R		
74 12	60800RRHOOKLYNS G	152022	L N1		10TC	75R		
74 12	60800RRHOOKLYNS H	152023	L N1		10TC	75R		
74 12	60800RRHOOKLYNS T	152024	L N1		10TC	75R		
74 12	60800RRHOOKLYNS J	152025	L N1		10TC	75R		
74 12	60800RRHOOKLYNS K	152026	L N1		10TC	75R		
74 12	60800RRHOOKLYNS L	152027	L N1		10TC	75R		
74 12	608002ND TWIN CROSS	152032	L N2		10MC	>00R		
74 12	60800N MINERAL BRIDGE	152033	L N2		10MC	>00R		
74 12	6 724N MINERAL BRIDGE	152033	L N2		5TC	300R		
74 12	60800WILLOW SWAMP	152095	L N2		5TL	100R		
74 12	60800BLUE WILLOW	152096	L N2		25TC	90C		1
74 12	62400BATTLESHIP	152128	SS N2	2	5TR	1000R		
74 12	61000GDBBLERS KNOR	152151	L N2		5TL	>00R		
74 12	91500RRHOOKLYNS F	152020	L N2		5T	B		
74 12	91500RRHOOKLYNS F	152020	L N2		5T	B		
74 12	91400N MINERAL BRIDGE	152033	L N2		5MR	700R		
74 12	112417WILLOW SWAMP	152095	L N2		5TL	150R		1
74 12	112417BLUE POINT	152097	L N1		5ML	75C		
74 12	112417BLUE POINT	152097	L N2		5TR	125R		
74 12	122405MILL CREEK CIRCU	152	SS N2			400		
74 12	122405PORPHYRY BASIN	152	SS N2			300		
74 12	131400RMP	152040	SS N2		25TL	100C		
74 12	132417GENESEEF S	152045	SS N3		10MR	350C		
74 12	132417MCINTYRE GULCH	152087	SS N3		10T	350R		
74 12	130800BLUE POINT	152097	L N1G		10TL	50R		
74 12	132417OPHIR POND W	152126	SS N2		5MR	300R		
74 12	132417BATTLESHIP	152128	SS N2		5TC	>00R		
74 12	132417BROWN MT AREA	152	SS N2					
74 12	141200RED MT J	152044	SS N2	2	5RC	100C		
74 12	142405RED MT I	152049	SS N3G	3	10M	350C		
74 12	142417SILVER GULCH	152073	SS N2G		5ML	400C		
74 12	150730RRHOOKLYNS D	152018	N		T	C		
74 12	152405RRHOOKLYNS I	152024	SS N2		25TC	700C		
74 12	150930RRHOOKLYNS J	152025	SS N3	2	50TC	>00C		
74 12	152405RRHOOKLYNS L	152027	SS N2		10TR	500R		
74 12	152405RRHOOKLYNS M	152028	SS N2	2	5TL	350C		
74 12	152405RRHOOKLYNS N	152029	SS N2	1	5TR	>50R		
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	300R		
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	400R		
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	>50R		
74 12	151200SAM	152117	SS N2	2	10TF	150A		
74 12	15120000TAH	152118	SS N1		MR	50R		
74 12	152405IMOGENE	152119	HS N3		25TC	300R		
74 12	151200BATTLESHIP	152128	SS N2	1	5TR	>00R		
74 12	152405CHAMPION	152144	N			R		
74 12	15 MILL CREEK AREA	152	SS N2					
74 12	152405PORPHYRY 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		

74 12	152405	PORPHYRY BASIN	152	HS N3G	3	400C		
74 12	152405	PORPHYRY BASIN	152	SS N3G	3	700		
74 12	152405	TRICO BASIN	152	SS N3	2	T 300R		
74 12	160600	CEMENT FILL	152010	SS N2		10TC1000H		
74 12	162405	BR00KLYNS F	152019	N		C		
74 12	160400	WILLOW SW. SHLDR.	152095	SS N2G	1	5TL 100C	1	20
74 12	160630	WILLOW SWAMP	15209521	SSAE2	2	10TL 200R		
74 12	161530	WILLOW SWAMP	152095R11					
74 12	161600	WILLOW SWAMP	152095R1					
74 12	162405	EAGLE	152104	SS N2		TR 200A		
74 12	160600	MULESHOE	152106	SS N2		1500C		
74 12	160600	MILL CREEK A	152108	N		C		
74 12	1R	WILLOW SWAMP	152095	L N1				
74 12	1R	BLUE WILLOW	152096	L N1				
74 12	1R2417	BLUE WILLOW	152096	L N2		TC 150C		
74 12	1R2417	BLUE WILLOW	152096	L N2		TC 150C		1
74 12	1R	BLUE POINT	152097	L N1				
74 12	202200	BR00KLYNS C	152017	SS N2G	2	50TC 500C		
74 12	202400	BR00KLYNS G	152022	SS N3G	4	75TC1000C		
74 12	202200	N MINERAL BRIDGE	152033	SS N2	2	10ML 250C		
74 12	202417	E GUADALUPE	152060	N				
74 12	202417	SLIPPERY 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	202300	ROCKWALL	152101	N				1
74 12	202200	TELESCOPF	152105	SS N3		TL2200C		1
74 12	202417	MILL CREEK A	152108	SS N2		25MR 400C		
74 12	20	MINERAL CK. AREA	152	SS N2G				
74 12	202300	PR0SPECT GULCH	152	HS N4	5	300		
74 12	211300	ANVIL SHINE	152001	SS N3G	2	TL 400C		
74 12	212405	ZUNI	152006	HS N3G		TL C		
74 12	212405	CEMENT FILL	152010	SS N2	3	MC 400R		
74 12	211000	HENNY LONG	152014	SS N2	2	5MC 100R		
74 12	210200	BR00KLYNS A	152015	SS N3G	2	75TF 400C		1
74 12	210200	BR00KLYNS B	152015	SS N3G	2	75TF 550C	2	100
74 12	210200	BR00KLYNS F	152020	SS N3G	4	50MC 650C	1	150
74 12	210630	BR00KLYNS H	152023	SS N3G	2	75TF 700C	1	60
74 12	210410	BR00KLYNS I	152024	SS N3G	3	50TC 850C		1
74 12	210300	BR00KLYNS K	152026	SS N3G	1	25TC 300C		1
74 12	210800	BR00KLYNS L	152027	SS N2G	2	25TC 400C		
74 12	210800	BR00KLYNS M	152028	SS N3	3	75TF 400C		
74 12	210200	CEMETERY	152030	SS N2	2	25MF 300C		
74 12	212405	SUS BASIN	152035	SS N2		TL 400		
74 12	210300	MARMOT TOWN	152038	SS N2	2	10TC 100C		
74 12	211450	GENESEE S	152045	SS N3	3	TL 500C		
74 12	212405	FIRE	152079	L N2		75TC 300C		
74 12	212405	IRONTON	152082	SS N2G	1	TL 500R		
74 12	212405	IRONTON	152082	SS N3G	3	50TR1000C		
74 12	212405	TIDY	152083	SS N2G	2	TF 300R		
74 12	211000	DAISY HILL	152085	SS N3	3	75TF 400C		
74 12	210700	RICHMOND	152086	HS N4G	4	75T		
74 12	210800	GALENA LION QUN.	152088	HS N3G	4	10TC1500C		
74 12	210800	GOVERNOR GULCH	152090	SS N2	3	10TF 400R		
74 12	211030	SNOWFLAKE	152094	SS N4	4	100TF 100C	6	250
74 12	210930	ROCKWALL	152101	SS N2G	3	10TL 350R	4	150
74 12	210930	ROCKWALL	152101	SS N2G	3	10TR 250R	5	350
74 12	212405	EAGLE	152104	SS N2		5MC1500C		
74 12	210740	EAGLE	152104	SS N3	5	25TL1500C		1
74 12	210730	JULLION KING	152107	SS N3	3	50TF2000C		
74 12	210100	ERNEST	152115	SS N3	2	75TF 300C		
74 12	210100	JULIO	152116	SS N3	2	50TC 500C		
74 12	210200	SAM	152117	SS N3G	3	50TF 300C		
74 12	210100	OTAH	152118	SS N2	2	TF 250C		
74 12	210200	IMOGENE	152119	HS N2G	4	10TR 600R		
74 12	210200	OUTLAW	152121	SS N2	2	50TC 300C		

74 12	210200TAVERN	152123	SS N3	3	75TF	800C		
74 12	210200HURRO BRIDGE	152124	SS N2	2	25TC	200B		
74 12	210300OPHIR POND F	152125	SS N2	2	5ML	300C		
74 12	210930HISMARK	152127	SS N3G	3	75TF1	800C		
74 12	212405RED MT PASS WEST	152	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		300		
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		
74 12	221020BROOKLYNS J	15202541	SSAA2	M 2	10TR	400C		
74 12	221015BROOKLYNS K	15202641	LAA2	F	5TR	200B		
74 12	222405RED MT 3	152044	HS N3G		25TR	800C		
74 12	222405RED MT 2	152047	SS N2	3	5MC	350C		
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 MIN	152100	SS N2		TL	225C 4 75		
74 12	221345SILVER LEDGE MIN	15210042	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	222405HATTLESHIP	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		5MB	500C		
74 12	231000BROOKLYN G	152022	N			C		
74 12	2324051ST TWIN CROSS.	152031	SS N3	2	75MF	400B		
74 12	2324052ND TWIN CROSS.	152032	SS N3	2	75MF	400B		
74 12	230900N MINERAL BRIDGE	152033	SS N2		25ML	400C		
74 12	230800LUNGFELLOW	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	800C		
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	800C		
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	400C		
74 12	242417E RIVERSIDE LEFT	152065	L N2		5TC	200C		
74 12	2405HPTAL	152120	SS N3	3	50TC	300C		
74 12	240830RED MT PASS W	152	SS N1	1		75		
74 12	271000N MINERAL RIDGE	152033	SS N3	3	25TR1200C			
74 12	271300BIG HORN	152036	L N1		5TC	400B		
74 12	271100WILLOW SWAMP RT.	152095	SS N3G	2	75TF	400C		
74 12	271100BLUE POINT	152097	SS N1		5TC	800B		
74 12	271100BLUE POINT	152097	SS N1		5TL	700B		
74 12	27 MCLAS 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	400R	
74 12	291000N MINERALH RIDGE	152033	SS N3	3	25TL	300C	
74 12	292405GOBBLERS KNOR	152151	SS N2				
74 12	29 ENGINEER MT R	152160	SS N2	3		100R	
74 12	29 LIME CREEK AREA	152	SS N2	2			
74 12	302417GOBBLERS KNOR	152151	L N2				
74 12	301500N CARBON	152 23	SSAE1G	2	I	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	300R	
75 01	22405MILL CREEK C	152110	L N2		5MC	200C	
75 01	22417MILL CREEK E	152112	SS N3G	3	100TF	300C	
75 01	22417BATTLESHIP	152128	SS N1	1	5TR	50A	
75 01	22417MINERAL BASIN	152	HS N3	3	25TL1	100C	
75 01	41222MOTHER CLINE	152069	L N1				1
75 01	62200LONGFELLOW	152039	SS N3	2	25MC	100C	
75 01	60900SLIPPERY JIM	152061	L N2		5R	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	62405TRONTON	152082	SS N2	1	10TL	150A	
75 01	60900KING	152091	SS N2	1	25TC	100R	
75 01	60600KING	152091	SS N3	1	75TR	350R	
75 01	60500WILLOW SWAMP	152095	SS N1				
75 01	60900WILLOW SWAMP	152095	SS N2	1	75MF	200R	
75 01	60300BLUE WILLOW	152096	SS N1	1	100TF	50R	
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	150R	
75 01	61205MINERAL BASIN	152	SS N2	1	75TF	150R	
75 01	60300PORPHYRY BASIN	152	SS N2	2	25TC	200R	
75 01	71520CEMENT FILL	152010	SS N3			C 2-300	
75 01	72417BROOKLYNS D	152018	HS N3	1	25TC	200R	
75 01	72417BROOKLYNS E	152019	SS N2	2	50TF	200R	
75 01	72417BROOKLYNS F	152020	SS N2	2	50TF	200R	
75 01	72417BROOKLYNS G	152022	SS N2	2	50TF	200R	
75 01	72417BROOKLYNS I	152024	SS N2	2	50TF	200R	
75 01	72417BROOKLYNS J	152025	SS N2	2	50TF	200R	
75 01	72417BROOKLYNS L	152027	SS N2	2	50TF	200R	
75 01	72417CEMETERY	152030	SS N3	2	100TF	400C	
75 01	71235E RIVERSIDE	152064	SSA3G			B	
75 01	71300E RIVERSIDE LEFT	152065	SS N1	1	5M	40C	1
75 01	71320MOTHER CLINE	152069	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	4	PH100TR	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	5BR	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	152150	N				1
75 01	72405RUNOFF-100A	152	SS N3	1	75TF	100	
75 01	81200CEMENT FILL	152010					

75 01	R1040RROOKLYN A	15201541	SSAA2	F 2	TL	400C		
75 01	R1040RROOKLYN C	15201741	SSAA2	M 2	100TR	400H		
75 01	R1040RROOKLYN C	15201741	SSAA2	M 3	100TL	400H		
75 01	R1100RROOKLYN F	15201941						
75 01	R1045RROOKLYN G	15202242	SSAA1	1	5TL	50A		
75 01	R1400RROOKLYN H	152023	SS N3			C10	70	
75 01	R1100RROOKLYN J	15202541						
75 01	R1100RROOKLYN L	15202741	SSAA2	F 2	TK	R		
75 01	R1115EAGLE	15210444	HSAA2	M	10TL	1500C		
75 01	R1115TELESCOPE	15210541						
75 01	R1115MULESHOE	15210641						
75 01	R2405MINERAL CK AREA	152	SS N1	1	100TF	40C		
75 01	90300WATER GAUGE	152002	SS N3	2	100TF	1400H		
75 01	90300S MINERAL ROAD	152003	SS N2	2	50MC	200H		
75 01	90300PIT	152004	SS N2	1	25TC	400H		
75 01	92000RROOKLYN C	152017	SS N2	2	50TL	400H		
75 01	92000RROOKLYN D	152018	SS N	2	50TF	400H		
75 01	92000RROOKLYN F	152020	SS N3	1	50MC	300C	3 30	
75 01	90300U S BASIN	152035	HS N3G	5	25MF	400C		
75 01	92405ITALIAN	152051	SS N3G	3	50TF	1500C		
75 01	91500E RIVERSIDE	152064	HS N2G	3	10MR	1000H		
75 01	90800E RIVERSIDE N	152065	SS N2	1	25TL	100H	3 90	
75 01	90815E RIVERSIDE N	152065	SS N2	M				
75 01	91400MOTHER CLINE	15206944	SSAA3	M 2	75TF	400H	3 300	
75 01	90815SILVER POINT	152079	SS N2G	1	10TF	200H	2 30	
75 01	91000W RIVERSIDE SMO	152074	SS N4GJ	3	100TF	1200C		1
75 01	92417W GUADALUPE	152075	HS N3G	7	5TL	200H		
75 01	92417IRONTON	152082	SS N3	2	75TF	1500C		
75 01	90300ROCKWALL	152101	SS N1	1	5TL	50H	2 15	
75 01	90300EAGLE	152104	SS N3	2	50TC	1200		
75 01	90300MULESHOE	152105	SS N2	1	50TC	400H		
75 01	90300MILL CREEK E	152112	SS N2	2	75TF	500H		
75 01	90300ERNEST	152115	SS N3	3	100 F	400C		
75 01	90300JULIO	152116	SS N4	3	100 F	400C		
75 01	90300SAM	152117	SS N4	3	100TF	1400C		
75 01	90300OUTAH	152119	SS N4	3	100TF	500C		
75 01	90300IMOGENE	152119	SS N3			1400C		
75 01	90300OUTLAW	152121	SS N4		TF	C		
75 01	91200RISMAFK	152127	SS N3	2	50TR	1400C		
75 01	90300HATTLESHIP	152128	SS N3	2	75TF	C		
75 01	91030JENNIF PARKER	15214043	SSAA3	P	85TF	R	3 150	
75 01	91030JENNIE PARKER	15214141	SSAA3	P	85TF	R10	25	
75 01	91035PEARCOCK	15214241	SSAA3	P	90TF	1200C	5 50	
75 01	91030CHAMPION	15214441						
75 01	92405SPRINGS	152148	SS N3	1	75TF	C	3 30	
75 01	92405E LIME CREEK	152149	SS N2G	1	50TC	150H	3 180	
75 01	92405W LIME CREEK	152150	SS N2G	1	50MC	150H	3 300	
75 01	92405W LIME CREEK	152150	SS N2G	1	50MC			
75 01	92417GOBBLEERS KITCH	152151	SS N2G	2	50TR	300C		
75 01	92405DEER CREEK S	152153	SS N3	3	100	200H	7 150	
75 01	92405DEER CREEK S	152153	SS N3	2	TK	150H	3 90	
75 01	92405SWAMP	152154	SS N2	2	100 F	R		
75 01	92405HENRY BROWN	152155	SS N4	2	100 F	R	3 140	
75 01	92405COAL CREEK E	152157	SS M1	1	10TL	25H		
75 01	92405COAL CREEK WEST	152158	L N1	1	100MF	30H		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 AREA	152	SS N4	2	100TF	1200C		
75 01	92405N OF SPRING AREA	152	SS N4G	3	75TF	200C		
75 01	09 RICHMOND	152085	HS N3			TL	1400H	
75 01	100125RENNY LONG	152014	SS N4	3	75TF	200C	7 600	
75 01	100300BLUE WILLOW	152026	SS N2	1	10TL	40H		
75 01	101515EAGLE	152104	SS N3			C	5 90	
75 01	102417ENGINEER MT	152	SS N3	2	100TF	C		

75 01	10	KENDAL	152			1000			
75 01	112100	CEMENT FILL	152010	HS N3G	5	50TC	200R		
75 01	112030	BROOKLYNS A	152015	SS N2G	3	50TR	300C		
75 01	112030	BROOKLYNS C	152017	SS N3G	3	50TC	700C18	180	
75 01	112300	BROOKLYNS D	152018	SS N3G	3	25TC	400C		
75 01	112030	BROOKLYNS E	152019	SS N4G	5	75TF1	300C14	50	
75 01	110515	BROOKLYN K	152026	SS N3			300	5	90
75 01	112100	1ST TWIN CROSS.	152031	SS N4	5	75TF1	400C		
75 01	112100	2ND TWIN CROSS.	152032	HS N3G	3	75TF1	300C		
75 01	112100	MINERAL BRIDGE	152033	HS N4G	5	100TF1	400C		
75 01	110400	ARCHIE	152034	SS N3G	3	50TF	250C		
75 01	110830	STUDY PLOT	152037	SS N4G	3	100TF	400C		
75 01	110830	MARROT TOWN	152038	SS N4G	3	25TR	400C		
75 01	110830	LONGFELLOW	152039	SS N3	3	100TF	300C		
75 01	112417	E GUADALUPE	152060	HS N2G	3	5TL	400R		
75 01	112405	E GUADALUPE	152060	HS N3G	7	25MR	1400R		
75 01	112000	E RIVERSIDE L	152065						
75 01	111800	SILVER POINT L	152070	SS N2				5	30
75 01	111900	SILVER GULCH	152073	HS N4GJ	5	75TL	2400C	3	150
75 01	112000	W RIVERSIDE L	152074	HS N4G	3	75TR	2300C15	110	
75 01	112100	WILLOW SWAMP	152095	SS N2	3	MR	C		
75 01	112230	ROCKWALL N	152101	SS N2	2	100TR	150R	9	180
75 01	112230	ROCKWALL S	152101	SS N3	2	100TR	100R	9	450
75 01	112230	SILVER LEDGE MILL	152102	SS N4	2	100TF1	200C	9	450
75 01	112100	SAM	152117	HS N4G	3	100TF1	1400C		
75 01	112417	GLAUSTONE N	152138	SS N3		75TF	500C		
75 01	111100	DEER CREEK	152152	L N1		5MF	50R		
75 01	112417	HANK SLIPS	152	SS N1G					
75 01	112417	E LIME CK. AREA	152	SS N2G	3	T	250C		
75 01	112417	SNOWDEN AREA	152	SS N2	4	T	400C		
75 01	112100	S RMP GULL AREA	152	HS N2G	3	TF	75C		
75 01	112417	TURKS HEAD	152	HS N3	3		400		
75 01	112100	GREY COOPER GLCH	152	HS N4G		6	1100C		
75 01	122417	PIT	152094	SS N3G	4	25TC	400C		
75 01	122000	CAMP	152008	SS N3	3	75TF1	300R		
75 01	120900	LOWER CEMENT FILL	152009	SS N2		25T	400R		
75 01	120900	HARTON S	152011	SS N			C		
75 01	122405	HARTON W	152012	SS N3			R		
75 01	121000	BLACKBURN	152013	SS N3G	3	TC	C	3	60
75 01	121600	HENRY LENS	152014	SS N1	2		50		
75 01	120300	BROOKLYNS J	152025	SS N3G	3	50TC	1000C		
75 01	120300	BROOKLYNS K	152026	SS N4G	3	100TF1	1000C	3	90
75 01	120300	BROOKLYNS L	152027	SS N3G			TL	200C	
75 01	120300	BROOKLYNS M	152028	SS N5G	3	100TF1	1000C	9	90
75 01	120300	MINERAL BRIDGE	152033	SS N4	5	100TF1	1000C		
75 01	120900	RIG HORN	152035	SS N3G	3	50TC	150C		
75 01	121500	POTNEY PEAK N	152041	HS N4G	4	50TR	700C		
75 01	120900	GENEVESSE S	152045	HS N3G	5	75TF	700C		
75 01	120900	GENEVESSE W	152046	SS N3G	3	75TF	500C		
75 01	120300	CORA HILL	152048	HS N3G	3	25MR	400C		
75 01	120300	RIPPLE	152050	SS N3	3	75TF	400C		
75 01	122405	SLIPPERY JIM	152061	SS N3G	3	25TR	400C	5	75
75 01	122405	WHITE FIR	152072	SS N3G	5	75TL	2200C		
75 01	120300	W GUADALUPE	152075	HS N2	2	75HF	200C		
75 01	120300	FULL MOON UPPER	152084	HS N3G	5	25TR	300R		
75 01	120300	FULL MOON LOWER	152084	HS N3G	5	25MR	300C		
75 01	120300	PAISY HILL	152085	SS N3	3	100TF	400C		
75 01	120400	G RIDGE FACE	152089	SS N3	2	75TF	400C		
75 01	121500	DUARADO HANK SLID	152094	SS N1G			30	3	60
75 01	120300	SILVER LODGE. MINF	152100	SS N3	3	25TC	125R	9	60
75 01	120730	FAGLE	152104	HS N3G	2	10TF1	200C	6	120
75 01	120630	MULESHOF	152105	HS N4G	7	90T	2400C20	300	
75 01	120630	HULLION KING	152107	HS N4G	7	90T	2400C		
75 01	120300	MILL CREEK E	152112	HS N4G	5	75TC	1000C		
75 01	120300	MILL CREEK E	152112	HS N4G	5	75MF	1000C		
75 01	122405	ERVEST	152115	SS N3	3	50TC	300C		

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75 01	1203001MOGENE	152119	HS N4	3	75TL2000C	2	15
75 01	120300SAV JUAN	152122	SS N3	3	75TF	C	
75 01	120300TAVERN	152123	SS N4	2	100TF	C	
75 01	122405HURRO BRIDGE	152124	SS N3	3	100TF	C	
75 01	122000OPHIR POND E	152125	SS N2	3	10ML1200C		
75 01	120300HISMARR	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	75TF1200C		
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 HURRO HDGE	152	SS N3	3	100TF1000C		
75 01	122417US BASIN AREA	152	HS N3	5	T 500A		
75 01	120300MILL CREEK CTRD.	152	HS N4	5	T 1000C		
75 01	120300RALSTON CREEK	152	HS N4	2	75T	C	
75 01	131500ANVIL	152001	WL N2G		TR 200C		
75 01	131500WHITE FLY	152072	HS N3G	2	10MR 200B		
75 01	142417ANVIL	152001	WL N1G		5MC 50C		
75 01	142417THIRTY	152005	WL N2G		5TL 100B		
75 01	142417WATER GAUGE	152075	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	151353FORCUPONE	15210341	HSAA4G M	53	100TF1220C	8	150
75 01	151315EAGLE	15210446					
75 01	151350TELESCOPE	15210544	HSAA4G M	32	75 1220C	6	330
75 01	161320CEMENT FILL	15201044					
75 01	161255HROOKLYN A	15201541					
75 01	161255HROOKLYN 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 LFIDGE MIN	152190	SS N1	1	5ML 20B		1
75 01	231500OLD S MINERAL	152003	WL N2G	1	25TC 200B		
75 01	231500PIT	152004	SL N2G	1	25TC 400B		
75 01	231300WILLOW SWAMP	15209523	HSAE2G M	3	10TL 400B		
75 01	261620WILLOW SWAMP	15209521	HSAE3G F	23	10TL 200B		
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	280900HROOKLYN F	152020	SS N2			B	
75 01	280900HROOKLYN G	152022	SS N2	1	TL	B	
75 01	280900HROOKLYN H	152023	SS N3	1	MF	C	5 90
75 01	280900HROOKLYN J	152025	SS N3G	2	75TF	C	
75 01	280900HROOKLYN K	152026	SS N3G	2	75TF	C	
75 01	2809001ST TWIN CROSS.	152031	SS N3	3	M	C	1
75 01	2809002ND TWIN CROSS.	152032	SS N3	3	TF	C	
75 01	280900N MINERAL BRIDGE	152033	SS N4	3	100TF	C	
75 01	280300ARCHIE	152034	SS N2	2	M 100C		
75 01	280300US BASIN	152035	SS N3	3	TC 200C		
75 01	28 RIG HORN	152036				80	
75 01	281000LUNGFELLOW	152039	SS N2G	3	25TL 180C		
75 01	280900LUNGFELLOW	152039	SS N3G	5	TF	C	
75 01	280900RMP	152040	HS N5G	5	100TF 150C		
75 01	280900NATIONAL HELL S	152042	HS N3	5	TR 400C		
75 01	280900PEJ MT 3	152044	HS N3G	3	TC1400B		
75 01	280300GENESEE S	152045	SS N3G	3	TF 400C		
75 01	280300GENESEE N	152045	SS N3	3	TL 500C		
75 01	280300CURA BELL	152048	SS N3G	3	TF	B	
75 01	280300HROOKLYN GULCH	152054	SS N2	3	10ML 400B		
75 01	280300W GUADALUPE	152075	SS N3	5	TL		
75 01	281500WATER GAUGE	152075	SS N3	2	25TC1000C		

75 01	280300FULL MOON GULCH	152084	SS N2	3	10MR	200C		
75 01	280300FULL MOON GULCH	152084	SS N3	3	10TR	200B		
75 01	280300DAISY HILL	152085	SS N2	1	25T	200B		
75 01	280300DAISY HILL	152085	SS N2	1	25T	200B		
75 01	280300DAISY HILL	152085	SS N2	1	25T	200B		
75 01	280300DAISY HILL	152085	SS N2	1	25T	200C		
75 01	280900TWIN BRIDGES	152092	SS N2	3	TF	200C	3	60
75 01	280900WILLOW SWAMP	152095	HS N3	3	TL	C	3	60
75 01	280900BLUE POINT	152097	SS N46	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		90TF	2100C		
75 01	280900ERNEST	152115	SS N2	1	ML	200C		
75 01	280300OUTLAW	152121	SS N3		90TC	1400C		
75 01	280300OPHIR POND W	152126	SS N3	3	25TC			
75 01	280300RISMARR	152127	SS N3	5	75TL	1200C		
75 01	280900BATTLESHIP	152128	SS N26	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 GAUGE	152	SS N3		TL	400C		
75 01	280900CHAMPION GULCH	152	SS N46	3	MF	B		
75 01	290935BROOKLYN E	15201943						
75 01	290930BROOKLYN L	15202741						
75 01	290930CEMETERY	15203042						
75 01	291355E RIVERSIDE	15206446	HSA436	4	10MR	1500B		
75 01	291420MOTHER CLINE	15206942	SSA42	2	20TC	150C		1
75 01	291545W RIVERSIDE	15207444						
75 01	291525WILLOW SWAMP	15209541	SSAA4	M 5	75TC	600C	15	300
75 01	291525BLUE WILLOW	152096	SSAA46	F 5	100TF	100C	5	120
75 01	291010TELESCOPE	15210542						
75 01	291005MULESHOE	15210543						
75 01	302417SNOWSLIDE GULCH	152132	SS N2		25TR	1200C		
75 01	312405BROOKLYN I	152024	SS N36		75T	200C		
75 01	311045BLUE POINT	1520973	SSA02	M 2A	10TR	200C	4	30
75 01	312405BATTLESHIP	152128	SS N36	5	50MC	C		
75 01	310900STRING ALONG	152133	SS N3		100TF	1200C		
75 02	11600WILLOW SWAMP	15209521	HSAE56	F 5R	100TL	600C		
75 02	11030SILVER LEDGE MIN	152100	L N1		5	50B		
75 02	11030SILVER LEDGE MIN	152100	L N1		5	50B		
75 02	12405EAGLE	152104	SS N1	5	5M	100B		
75 02	12405MILL CREEK	152	SS N26	5	50	600C		
75 02	12405MILL CREEK	152	SS N46		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	152062	SS N2	2	5ML	200	7	50
75 02	51725EAST RIVERSIDE	152055	SS N2	1	50TC	400C	12	75
75 02	50700ROCKWALL	152101	SS N1	1	10MR	20B		
75 02	51300ROCKWALL	152101	SS N1	1	10TR	50B		1
75 02	51400EAGLE	152104	SS N2	2	MR	400B		
75 02	51400EAGLE	152104	SS N2	2	ML	400B		
75 02	50700RUDDUT	152	SS N1	1	10TL	50B		
75 02	61200CAMP	152024	L N2		5TR	1200C		
75 02	61145EAST RIVERSIDE	15205249						
75 02	61350EAST RIVERSIDE	15205242						
75 02	61200EAGLE + TELESCOPE	152104	DL N2		5TC	200C		
75 02	60900W LIME CREEK	152150	SS N2	1	25TC	200C		
75 02	60900GOBBLERS KNOP	152151	SS N2	1	35T	250B		
75 02	60900HENRY BROWN	152155	SS N2	1	10TC	350C		1
75 02	60900ENGINEER AT	152150	SS N2	1	10MC	200C		
75 02	72417BROOKLYNS D	152018	SS N2	1	TC	300B		
75 02	71500BROOKLYNS J	152025	L N2		5TC	300B		
75 02	72417BROOKLYNS K	152026	SS N2	1	5TL	250B		
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		

75 02	71000WILLOW SWAMP	152095	L N2		TL	250R		
75 02	71000BLUE POINT	152097	L N2		10TF	150C		
75 02	71500SILVER LEDGE MIN	152100	SS N2	1	10TR	150C		1
75 02	71500BUCKWALL	152101A	LA02		5MC	200C		
75 02	71100RMP AREA	152	L N1					
75 02	81200BRUOKLYNS K	152026	SS N2	1	5TC	200R		
75 02	81200EAGLE + TELESCOPE	152104	L N2		TL	200C		
75 02	81200EAGLE + TELESCOPE	152104	L N2		TR	150C		
75 02	91900COAL CREEK W	152158	SS N1	1	5TC	30R		1
75 02	91900SNOWFLAKE (MOLAS)	152	SS N1	1	10TL	20C		1
75 02	101500OLD S MINERAL RD	152003	L N1		TC	50R		
75 02	101100BENNY LONG	152014	SS N3	2	100TF	100C		
75 02	101100BRUOKLYN A	152015	SS N4	3	100TF	C		
75 02	101500BRUOKLYN C	152017	SS N2	1	50TF	200R		
75 02	101100BRUOKLYN C	152017	SS N3	3	75TF	C		
75 02	101500BRUOKLYN D	152018	L N1		10TC	50R		
75 02	101100BRUOKLYN D	152018	SS N4	3	TF	C		
75 02	101100BRUOKLYN E	152019	SS N3	3	100TF	C		
75 02	101500N OF BRUOKLYN G	152022	SS N1	2				
75 02	100700BRUOKLYNS 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	102100TIDY	152083	SS N2	1	25TR	200R		
75 02	102100FULL MOON BASIN	152084	SS N3	1	25TF	100R		
75 02	102100GALENA LION GLCH	152088	L N2					
75 02	102100GOVERNOR GULCH	152090	L N2					
75 02	101300BLUE POINT	152097	SS N1	1	5TL	75R		
75 02	101845EAGLE	152104	SS N3	2	75TF	200C	12 150	
75 02	101900TELESCOPE	152105	SS N2	2	100TF	200C	6 100	
75 02	101900MOLESHOE	152106	SS N2	2	100TF	200C		
75 02	101900HULLION KING	152107	SS N2	1	100TF	200C		
75 02	101500IMOGENE	152119	SS N3	2	50MC	140C		
75 02	102100OPHIR POND F	152125	SS N2		10MC	200R		
75 02	102100OPHIR POND W	152126	SS N2		10MC	200R		
75 02	102100BISMARCK	152127	SS N1	1	MC	50R		
75 02	102100BISMARCK	152127	SS N2	2	25TL	200R		
75 02	101900BATLESHIP	152128	SS N2	1	MR	500R		
75 02	102100PICKLE BARRFL	152131	SS N2	1	25MC	200R		
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	400C		
75 02	100900ENGINEER MT C	152161	SS N3	2	100TF	400C		
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	200C		
75 02	111120BRUOKLYN E	15201941	SSAA3	M 2	50TR	700C	12 90	
75 02	111118BRUOKLYN F	15202041	SSAA3	M 2	50TC	100C		
75 02	111116BRUOKLYN G	15202241	SSAA2	2	50TC	1100C	6 60	
75 02	111114BRUOKLYN H	15202341	SSAA3	M 3	50TC	1100C		
75 02	111112BRUOKLYN J	15202541	SSAA36	M 3	75TC	100C		1
75 02	111108BRUOKLYN L	15202741	SSAA36	M 3	75TC	100C		
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	SSA026	M 1	50TR	300C		
75 02	111050TELESCOPE	15210542	SSAA3	M 3	75ML	C	2 90	
75 02	111045MOLESHOE	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					

75 02	142417CHAMPION	152144	L N1						
75 02	142417GOSHLEERS KNOR	152151	L N1						
75 02	142417DEER CREEK W	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	1524172ND TWIN CROSS.	152032	SS N2	1		5M	300		
75 02	152000N MINERAL BRIDGE	152033	SS N2	1		TR	300B		
75 02	152000N MINERAL BRIDGE	152033	SS N2	1		ML	300B		
75 02	152000N MINERAL BRIDGE	152033	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 R	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		10MR1	200B		
75 02	170300MULESHOF	152106	SS N2	1		10ML	700B		
75 02	170300BULLION KING	152107	SS N2	1		25TC2	2000C		
75 02	172405WATERFALL	152147	SS N2	1		50TR	C 2	30	
75 02	172417E LIME CREEK	152149	L N1			25MR	50C		
75 02	172417GOSHLEERS KNOR	152151	L N2			TF	100B		
75 02	172405DEER CREEK S	152153	SS N1	1		10TF	50B		
75 02	172417DEEP 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 E	152157	SS N1	1		10TL	30C		
75 02	172417COAL CREEK F	152157	L N1			25TC	20B		
75 02	172417COAL CREEK G	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. CREEK	152	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 E	15201942							
75 02	181137BROOKLYNS 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	181500JUNCMPAGHRE GOR.	152	DL N1						
75 02	180300MILL CREEK CIRQ.	152	SS N3GJ	2		75TL1	300C		
75 02	211500RMP S	152040	SS N2				100		
75 02	210300RIVERSIDE LEFT	152065	SS N2	1		50TR	250C	2	30
75 02	210300W RIVERSIDE	152074	SS N3	3		25TL1	100C		1
75 02	210300E RIVERSIDE	152074	SS N3	3		25ML1	100C		1
75 02	210300W GUADALUPE	152075	HS N3	3		25TC2	500C		
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 W	152126	SS N3	1		25MF	C		
75 02	21 BATTLESHIP	152128	SS N2	2		5TC	900B		
75 02	212100LIME CREEK W	152150	SS N2			5HL	175C		
75 02	211500MINERAL BASIN	152	SS N2	2			600		
75 02	210600SNOWDEN AREA	152	HS N3	3			450		

75 02	220330	BENNY LONG	152014	SS N1	1	5TC	50C				1
75 02	221300	SLIPPERY JIM	15206141								
75 02	221200	E RIVERSIDE	15206447								
75 02	221130	SILVER LEDGE MIN	15210043								
75 02	220030	ROCKWALL	152101	SS N1	1	10TC	60B				1
75 02	221030	EAGLE	15210443	SSAA2	M 1	TL	C				
75 02	221030	TELESCOPE	15210541	SSAA2	M 1B	25TR	300B				
75 02	221030	MULESHOF	15210642	SSAA2	F 1	10TF	200A				
75 02	221500	COAL BANK W	152158	SS N1	3	5BC	40C	2	50		
75 02	231500	ZUNI	152006	HS N2	3	5TC	400B				
75 02	230430	LOWER CFMENT FIL	152009	SS N2		25TL					
75 02	230730	CEMENT FILL	152010	HS N4	5	75T	2600C	11	200		
75 02	230300	BROOKLYNS F	152020	HS N2	1	25TC	1000B				
75 02	230300	BROOKLYNS I	152024	SS N2	2	10TC	600B				
75 02	230300	BROOKLYNS I	152024	SS N2	3	10TC	600B				
75 02	230300	BROOKLYNS J	152025	HS N2	2	10TC	500B				
75 02	230300	BROOKLYNS K	152026	HS N2	2	10MC	500B				
75 02	230900	GUADALUPE	152060	HS N3	3	10ML	1500C				
75 02	230900	WATER GAUGE N	152076	SS N2	2	25	500				
75 02	230300	EARTH	152078	SS N2	1	25TC	400				
75 02	230300	IRONTON	152082	SS N2	2	5TC	400B				
75 02	230900	MACINTYRE GULCH	152087	HS N3	3	T					
75 02	230900	GALENA LION GLCH	152088	HS N2	3	5T	400B				
75 02	230300	GOVERNOR GULCH	152090	HS N3	3	5TC	1500C				
75 02	230300	KING	152091	SS N2	1	4C	125				
75 02	231345	PORCUPINE	152103	HS N3	3	50TC	1400C	8	100		
75 02	230300	EALGE	152104	HS N3	5	25TR	2200C				
75 02	230730	MULESHOF	152106	HS N3	5	50TC	2600C	8	200		
75 02	231000	BULLION KING	152107	HS N3	7	50					
75 02	230300	IMOGENE	152119	HS N3	3	TR	2200C				
75 02	230300	BATTLESHIP	152128	HS N3	3	TC	1500C				
75 02	230900	BASIN BATTLESHIP	152128	HS N3G	5	T	C				
75 02	231430	N STAK	152137	HS N3G	6						
75 02	230600	CHAMPION	152144	S N2	2	TC	600C	3	20		
75 02	230300	KINO MINE	152146	HS H	5						
75 02	230430	WATER FALL	152147	HS N4		T	1000C	12	120		
75 02	230430	SPRINGS	152148	HS N4		75T	1000C	9	70		
75 02	231500	F LIME CREEK	152149	WL N1		5HR	40				
75 02	230400	E LIME CREEK	152149	HS N2	2	25TL	200B	4	350		
75 02	230400	E LIME CREEK	152149	HS N2	1	25MR	150B	4	150		
75 02	231500	ENGINEFF MT A	152159	L N2		5T	250				
75 02	231300	RT. OF TRICO BAS.	152	HS N2							
75 02	230900	W LIME CK. AREA	152	HS N2	2	150					
75 02	230900	BEAK CREEK AREA	152	HS N3G	5						
75 02	232405	ENGIN. MT. E. FACE	152	HS N3	5	M	1500C				
75 02	230600	KENDALL AREA	152	HS N3	3						
75 02	231200	MILL CREEK AREA	152	HS N3							
75 02	230300	MINERAL BASIN	152	HS N3	3		600				
75 02	230300	RIMCO FACE WILL	152	HS N3G	3	50TC	500C				
75 02	231300	RT. OF TRICO BAS.	152	HS N3G							
75 02	231300	S MINERAL	152	HS N3	5						
75 02	230300	SULTAN MOLAS SHD	152	HS N3		M	500C				
75 02	231200	TRICO BASIN	152	HS N3							
75 02	232405	TWILIGHT PEAK	152	HS N4	5	1000					
75 02	241500	ANVIL	152001	DL N2		25TC	300B				
75 02	241500	WATER GAUGE	152002	DL N2		25TC	800B				
75 02	241400	WATER GAUGE	152002	SS N2	2	25TL	600C				
75 02	241500	OLD S. MINERAL RD	152003	DL N2		25TC	300B				
75 02	241400	OLD S. MIN. ROAD	152003	L N2	2	25T	500C				
75 02	241500	PIT	152004	DL N2		10TC	300B				
75 02	241400	PIT	152004	SS N2	2	25TL	500C				
75 02	241500	HUPI	152007	DL N2		25TC	600B				
75 02	241530	HUPI	152007	L N2		50TR	400C				
75 02	241400	1ST TWIN CROSS.	152031	L N1		5M	300B				
75 02	241500	1ST TWIN CROSS.	152031	DL N2		TC	200B				
75 02	241500	E RIVERSIDE LEFT	152055	SS N2	1		C				1

75 03	7	BRUNNEN K	152026	WL N1									
75 03		71115CEMENTARY	15203042										
75 03		71315E RIVERSIDE	15206449										
75 03	7	WATER GAUGE N	152076	L N2			25TC	750C					
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	152191	WL N2			5MR	100R	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	TOARAD0 BNSLIDE152		WL N1									
75 03		90600BRUOKLYN B	152016	L N2			25TR	100R					
75 03		90600BRUOKLYN B	152016	L N2			25TR	100R					
75 03		90600BRUOKLYN D	152019	L N2			25TC	125R					
75 03		91000BRUOKLYN D	152018	L N2									
75 03		91100BRUOKLYN J	152025	SS N2		1	50TC	200R					
75 03		90600BRUOKLYN L	152027	L N1			10TL	50R					
75 03		916001ST TWIN CROSS.	152031	SS N2		1	5M	400R					
75 03		916002ND TWIN CROSS.	152032	SS N2		1	5M	400R					
75 03		91600N MINERAL BRIDGE	152033	SS N2		1	5TC	400R					
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.SHL0	152095	L N1			25TC	50R					1
75 03		90900BLUE WILLOW	152096	L N1			50	90					1
75 03		91000BLUE POINT	152097	SS N2		1	TF	80R	3	90			
75 03		90800SILVER LEDGE MIN	152100	SS N1		1	10TL	50R					1
75 03		91000ROCKWALL	152101	SS N1		1	50TF	50R	2	15			1
75 03		91630ROCKWALL	152101	SS N2		1	5TR	150R	2	100			
75 03		91200EAGLE	152104	SS N2									
75 03		90800MULESHOE	152106	SS N2									
75 03		90900MINERAL BAS.AREA	152	SS N2				150					
75 03		91400RED MT S AREA	152	SS N2		1	T	100R					
75 03		92100TRICO BASIN AREA	152	SS N3			T	400C					
75 03		90800CUTBANK.B/W 104-152											1
75 03		101100SLIPPERY JIM	152061	DL N1				100					
75 03	10	E RIVERSIDE	15206449										
75 03		102100E RIVERSIDE L	152065	L N2			5TC	150C	3	45			
75 03		102100MOTHER CLINE	152069	L N2			25MR	200R	3	45			
75 03		111300BRUOKLYNS B	15201673										
75 03		110600ARCHIE	152034	SS N2		2	25TL	100C					
75 03		110600US BASIN	152035	SS N3			25MC	100C					
75 03		110600HIG HORN	152036	L N1			100	60C					
75 03		110600RMP	152040	L N1									
75 03	11	E RIVERSIDE	15206449										
75 03		110600WILLOW SWMP SHL0	152095	L N1			TR	60R					1
75 03		112417WILLOW SWAMP	152095	L N1									
75 03		110600WILLOW SWMP SHL0	152095	L N2			25TL	150R					
75 03		111100WILLOW SWMP SHL0	152095x										
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	90R	3	90			1
75 03		110600FENCE	152099	SS N1		1	25TR	30C					
75 03		110600SILVER LEDGE MIN	152100	SS N1		1	25TC	70R					1
75 03		111830SILVER LEDGE MIN	152100	L N2			25MR	200R	3	90			
75 03		111230SILVER LEDGE MIN	15210071	SS4L3		F 2	25TR	200R	6	75			
75 03		111300SILVER LEDGE MIN	15210071										
75 03		110600ROCKWALL	152101	SS N1		1	50TF	70R					1
75 03		110600ROCKWALL	152101	SS N1		1	50TF	70R	3	9			
75 03		111300ROCKWALL	15210171	SS4L1		1	10TL	150R					

75 03	111300ROCKWALL	15210171	SSAL2	1	25TR	400R		
75 03	111830EAGLE	152104	L N3		50TF	2500C	3	45
75 03	110600TELESCOPE	152105	SS N2	1	25HF	200C		
75 03	110600HULLION KING	152107	L N1		25			
75 03	110600MILL CREEK R	152109	SS N2	1	90TC	200C		
75 03	11 CHAMPION	1521442	LAA1					
75 03	110600CLIFFS R/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	300C		
75 03	12 WILLOW SWAMP	152095	L N2	5	TL	200B		
75 03	121800WATERFALL	152147	SS N3	1	50TR	700B	4	70
75 03	121600F LIME CREEK	152149	SS N2		10	3		150
75 03	121500GURBLEYS KN03	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	200B		
75 03	121630HENRY HROWN	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	200C		
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	152095	WL N1		5M	50C		
75 03	131200BLUE POINT	152097	WL N1		5ML	50C		
75 03	131200ROCKWALL	152101	L N2		5ML	100B		
75 03	131200COMMODORE BASIN	152	SS N2	1	5	200B		
75 03	151500PIT	152004	L N2		10TC	450B		
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	151500BR00KLYNS C	152017	DL N2		10T	200B		
75 03	151500BR00KLYNS D	152018	DL N2		10T	200B		
75 03	151500BR00KLYNS E	152019	DL N1		10T	200B		
75 03	151500BR00KLYNS F	152020	DL N2		10T	100B		
75 03	151500BR00KLYNS G	152022	DL N1		10T	200B		
75 03	151500BR00KLYNS K	152025	DL N1		10T	200B		
75 03	151500BR00KLYNS K	152025	DL N1		10T	200B		
75 03	151500BR00KLYNS L	152027	DL N1		10T	200B		
75 03	151500BR00KLYNS M	152028	DL N1		10T	200B		
75 03	151500N MINERAL BRIDGE	152033	DL N2		5MC	100T		
75 03	151500N MINERAL BRIDGE	152033	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	200B		
75 03	162100CORA BELL	152048	SS N2	2	50TC	200B		
75 03	162000F RIVERSIDE	152054	HS N3 J	9	TR	2500C	9	90
75 03	162100BROWN MT AREA	152	HS N3	6	M	500B		
75 03	170100W RIVERSIDE	152074	SS N3	2	25TL	1200C		
75 03	181430ANVIL MT S FACE	152091	WL M3		10TL	200C		
75 03	18 F RIVERSIDE	15206449						
75 03	18 MOTHER CLINE	15206442						
75 03	181200PURDUPINE	15210341						
75 03	181200EAGLE	15210471	SSAL2	F 1	10TR	1200B		
75 03	181200EAGLE	15210473						
75 03	181200EAGLE	15210472						
75 03	181200TELESCOPE	15210541	SSAA3	1	25TC	1200B		
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	200B		
75 03	191400OLD S MINERAL R	152003	WL N2		25TC	250B		
75 03	191400LOVE R CEMENT FILL	152004	WL N2		10TC	400B		

75 03	191400HENNY LUNG	152014	WL N2	10TC	100B				
75 03	191400RR00KLYN H	152016	WL N2	25TC	400B				
75 03	191400RR00KLYN C	152017	WL N2	25TC	400B				
75 03	191400RR00KLYN D	152018	WL N2	25TC	400B				
75 03	191400RR00KLYN F	152020	WL N2	25TC	400B				
75 03	191400RR00KLYN G	152022	WL N2	25TC	400B				
75 03	191400RR00KLYN H	152023	WL N2	25TC	400B				
75 03	191400RR00KLYN I	152024	WL N2	25TC	400B				
75 03	191400RR00KLYN J	152025	WL N2	25TC	400B				
75 03	191400RR00KLYN K	152026	WL N2	25TC	400B				
75 03	191400RR00KLYN L	152027	WL N2	25TC	400B				
75 03	191400RR00KLYN M	152028	WL N2	25TC	400B				
75 03	191400N MINERAL BRIDGE	152033	WL N2	50TF	400B				
75 03	191200WHITE FIR	152072	L N2	10TC1	400B				
75 03	191400EAGLE	152104	WL N2	10	400B				
75 03	191000GOSHBLERS KNOP	152151	L N2	TF	250B				
75 03	191000ENGINEER MT C	152161	L N2	TF	250B				
75 03	191400TWIN SLIDES	152	WL N2	50TF	250				
75 03	201400DUNSMORE	152068	L N2		200C				1
75 03	202417G RIDGE	152089	SS N2	1	TC	500B			
75 03	210900ITALIAN	152051	SS N2		MR1	200B			
75 03	211300LAKE	152077	WL M3	50TC	450C				
75 03	211300BISMARCK	152127	SS N2		TL	200A			
75 03	211300BISMARCK	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	261100RR00KLYNS C	152017	SS M1	1	5TL	100A			
75 03	261100RR00KLYNS D	152018	SS N2		25TR	400B			
75 03	260800SLIPPERY JIM	152061	SS N2	1	10BL	200C			
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	2	100TF	200C	6	30	
75 03	260400BLUE POINT	152097	L N2		100TF	200C			
75 03	262417MILL CREEK D	152111	SS N4	3	75MF	400C			
75 03	260900MONUMENT	152	SS N2	1	50TC	200C			
75 03	260900RALSTON CREEK	152	SS N2	1	25TC	500B			
75 03	271300E RIVERSIDE S	15205445							
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	281050RR00KLYNS G	15202241	SSAA2	F 1	10TC	600B			
75 03	281050RR00KLYNS L	15202741							
75 03	280900SLIPPERY JIM	152061	L N2		5HC	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	25TR1	200C			
75 03	280900W GUADALUPE	152075	L N2		5HC	100C			
75 03	281100BLUE POINT	1520974	LA02	F	75TC	250C	3	30	
75 03	280940ROCKWALL	152101	L N2	F	5MR	150B			
75 03	280930EAGLE	152104	L N2		5HL	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	400B			

75 03	280900GORG AREA	152	L N1						
75 03	280900MONUMENT	152	L N1		TC	125C			
75 03	280830MILL CREEK AREA	152	SS N2		10T	400R			
75 03	301300PIT	152004	L N2		10TC	400R			
75 03	301300THIRTY	152005	L N2		10TL	400R			
75 03	301300OLD S MINERAL RD	152033	L N2		5TL	250R			
75 03	301300FARIN	152078	WL N2		25TC	500C			
75 03	301400POPCOCTINE	152103	L N2		5RL	150C			1
75 03	301400H/W 104 + 105	152	L N2		10TF	150R			
75 03	301400UPPER MILL CREEK AREA	152	L N3		T	500R			
75 04	11500WILLOW SWAMP	152095	SS N2	2	25TR	250R			
75 04	11130BLUE POINT	152097	L N2		10TL	150C	3	40	1
75 04	11000RUCKWALL	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	R			
75 04	11500CHAMPION	152144	N2						1
75 04	11600SWAMP	152154	SS N2		5TC	200R			
75 04	11630HENRY BROWN	152155	SS N3	2	100TF	350C	6	500	
75 04	41400ANVIL SHRINE	152001	WL N2		T	350R			
75 04	41500OLD S MINERAL RD	152003	WL N1		10T	350R			
75 04	41500PIT	152004	WL N2		5T	350R			
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	200R			
75 04	41200GURBLERS KNOB	152151	WL N2		5TC	200R			
75 04	61200GURBLERS KNOB	152151	WL N2		5TC	200R			
75 04	61200HENRY BROWN	152155	WL N2		5TR	150R			
75 04	110900HROOKLYNS D	152018	L N2		5TC	300R			
75 04	110900HROOKLYNS E	152019	L N2		5TR	300R			
75 04	110900HROOKLYNS G	152022	L N2		5TL	650R			
75 04	121300ANVIL	152001	L N2		T	500R			
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	200R			
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	152150	SS N2	1	25T	400R			
75 04	121200ENGINEER C	152161	SS N2	1	25T	400R			
75 04	131300ANVIL	152001	L N2		T	500R			
75 04	131700HOPI	152007	WL N2		10TC	600R			
75 04	13 CAMP	152008	L N3	2	50TR	1200R			
75 04	130500HROOKLYNS H	152016	SS N2	1	10TF	300R			
75 04	131200HROOKLYNS D	152018	L N2	1	10TC	600R			
75 04	130500HROOKLYNS E	152019	SS N2	2	10TR	600R			
75 04	13 HROOKLYNS E	152019	WL N2		5TR	600R			
75 04	130300HROOKLYNS F	152020	SS N3	2	90T	1000C			1
75 04	130300HROOKLYNS G	152022	SS N2	1	75T	700R			
75 04	13115HROOKLYNS H	152023	SS N2	1	10TC	600R			
75 04	131300HROOKLYNS J	152024	SS N2	1	10TC	600R			
75 04	131300HROOKLYNS K	152027	SS N2	1	10TC	600R			
75 04	131300HROOKLYNS L	152028	SS N2	1	10TC	600R			
75 04	130300TWIN CROSSINGS	152031	SS N3	1	10TR	400R			
75 04	130300N MINERAL BRIDGE	152033	L N2		25	600R			
75 04	130300N MINERAL BRIDGE	152033	SS N2	1	25	600R			
75 04	130800US BASTI	152035	SS N2		5TR	300R			
75 04	130500MARMOT TOWN	152038	L N1						
75 04	130500LONGFELLOW	152039	L N1						
75 04	130500RED MT 3	152044	SS N2		5TL	500R			
75 04	130500GENESSEE S	152045	SS N2		TL	400R			
75 04	130300RED MT 2	152047	SS N2		15	700R			
75 04	130300RED MT 2	152047	L N2		10	700R			
75 04	130300RED MT 2	152047	SS M2	2	10MR	400R			
75 04	130500E GUADALUPE	152060	L N1						
75 04	131200SLIPPERY JIM	152061	L N2						
75 04	130500E RIVERSTONE	152064	L N1						

74 11	292417ARCADE	153008	HS N2		5TC 200B
74 12	142405IDAHU GULCH	153004	HS N2	3	MR 200B
74 12	232405IDAHU GULCH	153004	SS N2		10TR B
74 12	272417DENVER	153001			600C
74 12	272417RIO GRANDE	153002			400B
74 12	292405WESTERN	153003	SS N2	3	STR 600B
74 12	292405WESTERN	153003	HS N3	5	10TC1200B
75 01	122405RIO GRANDE	153002	HS N2	5	M 200B
75 01	122405IDAHU GULCH	153004	HS N3		25TC 200B
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	153004	SS N3		
75 01	311100IDAHU GULCH	153004	SS N3	3	25TL3500C
75 02	230730DENVER	153001	SS N3	3	50T 1200C
75 02	230600RIO GRANDE	153002	SS N3		
75 02	230900IDAHU 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

AVALANCHE OCCURRENCES, STATION 157, 1974-75

74 11	241400BOULDER GULCH F	157	SS N2	2	25TF1200C
74 12	32417BOULDER GLCHAREA	157	SS N3G	2	M 1000C
74 12	142405IRENE AKFA	157	HS N2		TR 400B
75 01	92405RIO GRANDE	153002	SS N3	50	C
75 01	92405IDAHU GULCH	153004	SS N2		5R 200C
75 01	91155IRENE	15700543			
75 01	91155IRENE	15700541	SSAA2	P	TR
75 01	90200IRENE	157005	SS N2		M
75 01	90200IRENE	157005	SS N2		R
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	90300WHU	157019	SS N3G	3	75TC 200C
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 200C
75 01	90300W JUMP A	157028	HS N3		75TL1000C12 60
75 01	90300W JUMP R	157029	HS N4	3	TF1000C15 120
75 01	90300MOGUL	157030	HS N3	3	50ML 900C12 160
75 01	9 RIG COLORADO	157032	SS N3	3	75T 1400C
75 01	92000HALF TRACK	157038	SS N3		75T 200C
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 200C
75 01	112417MOGUL	157030	HS N2	3	10TL 200B
75 01	112417STRING	157034	SS N4	3	100T 200C

75 01	112417KOPF	157035	SS N4	100TF	200C			
75 01	112417RMYE	157040	SS N2	3	10M	200C		
75 01	112417GRASSY GULCH	157043	SS N3					
75 01	112417SARASFA BASIN	157	SS N3					
75 01	112000WOGGINS SLIDE	157	SS N4G	3	75T	C 6	200	
75 01	120300HENRIETTA GULCH	157004	SS N3	3	50TL	1200R		
75 01	120300RED POINT S	157008	SS N4		100TF	C 4	60	
75 01	120300RED POINT S	157009	SS N2		50			
75 01	120300ERIE	157014	SS N4G	3	75T	1100C	7	150
75 01	120300GILCHIGAN	157015	SS N4G	3	100T	1000C	3	20
75 01	120300FAIRVIEW	157016	HS N3G	3	25TL	1200C		
75 01	120300THREAD	157033	SS N2			200R		
75 01	121203ZZE JUMP	157036	SS N4	3	100T	200C	6	100
75 01	120300S E JUMP	157037	SS N4		100T	200C		
75 01	120300HILLBOARD	157042	HS N3G	5	25TF	1200C	3	75
75 01	120300FAIRVIEW N.SLIDE	157	SS N1G	3	TF	75C	3	200
75 01	121100HANCOCKGLCH.AREA	157	HS N4G	9	T			
75 01	122405S.SHOULDER HIO.PK	157	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 POKCUPINE	157	HS N3		75T	1200C		
75 02	172417FAIRVIEW	157016	SS N3		50TF	1200C		
75 02	172417HEATHS	157017	SS N2	2	75TF	C		
75 02	172417STONES	157018	SS N2	2	75TF	C		
75 02	172417WOOD	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	200		
75 02	191015IRENE	15700546	SSAA2	F 2A	TR	200A		
75 02	191030DRY GULCH N	15702741	SSAA4G	M 6H	90TF	1200C	12	90
75 02	200400CREME	157020	SS N2	1	TF	200R		
75 02	201245DRY GULCH N	15702743	SSAA2	F	TR	200R		
75 02	201250W JUMP A	15702741	SSAA3	3	TF	C		
75 02	201250W JUMP B	15702942						
75 02	201255WOGUL	15703044						
75 02	212405SHOULDER GULCH	157	HS N3	2	M	2000C		
75 02	230400IRENE	157005	HS N3		TL	1600R		
75 02	230900FAIRVIEW	157016	HS N3	3	10TR	1400C		
75 02	230300HILLBOARD	157042	HS N3	3	10TC	1500R		
75 02	230400BONITA BASIN	157	HS N3	2		1000		
75 02	230400BONITA BASIN	157	HS N3	5		450		
75 02	230300LITTLE GIANT BASIN	157	HS N3	5		200C		
75 02	230300POKUPINE	157	HS N3			1200		
75 03	60900MINNESOTA GULCH	157010	SS N2	3	SML	750R		
75 03	60900UPPER CEMENT CR	157	SS N3	3	T	200R		
75 04	60300WESTERN	153003	SS N2	2	5TC	700R		
75 04	131400MINNESOTA GULCH	157010	SS N3	1	5T	400R		
75 04	131400GEORGIA GULCH	157021	SS N2	1	5ML	100R		
75 04	131400HILLBOARD	157042	SS N2	1	5M	300R		
75 04	232417GALENA MT	157	WL N2			1200		
75 04	241400KING SOLOMON I	157	WL N2G		SMR	600R		
75 04	241600POKUPINEH-VILLE	157	WL N3G		T	400R		
75 05	152417ARASTRA GL	157	WS N3G	6	T	2000C		
75 05	152417GALENA MTN	157	WL N3G		T	1200R		
75 05	152000HEATHS	157	WS N3G	8	25TL	3000C		
75 05	152417KING SOLOMON I	157	WL N3G		ML	200C		
75 05	162417TUM MOORE	157	WS N5G	6	75TC	1000C		
75 05	171600ASPEN	157	WS N3G	4	TC	400C		
75 05	172417SHOULDER GL	157	WS N3G	6	TL	2000R		

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 snow-pack 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

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

TERRAIN AND VEGETATION COVER:

Starting Zone: Broad open slope, smooth cliffs

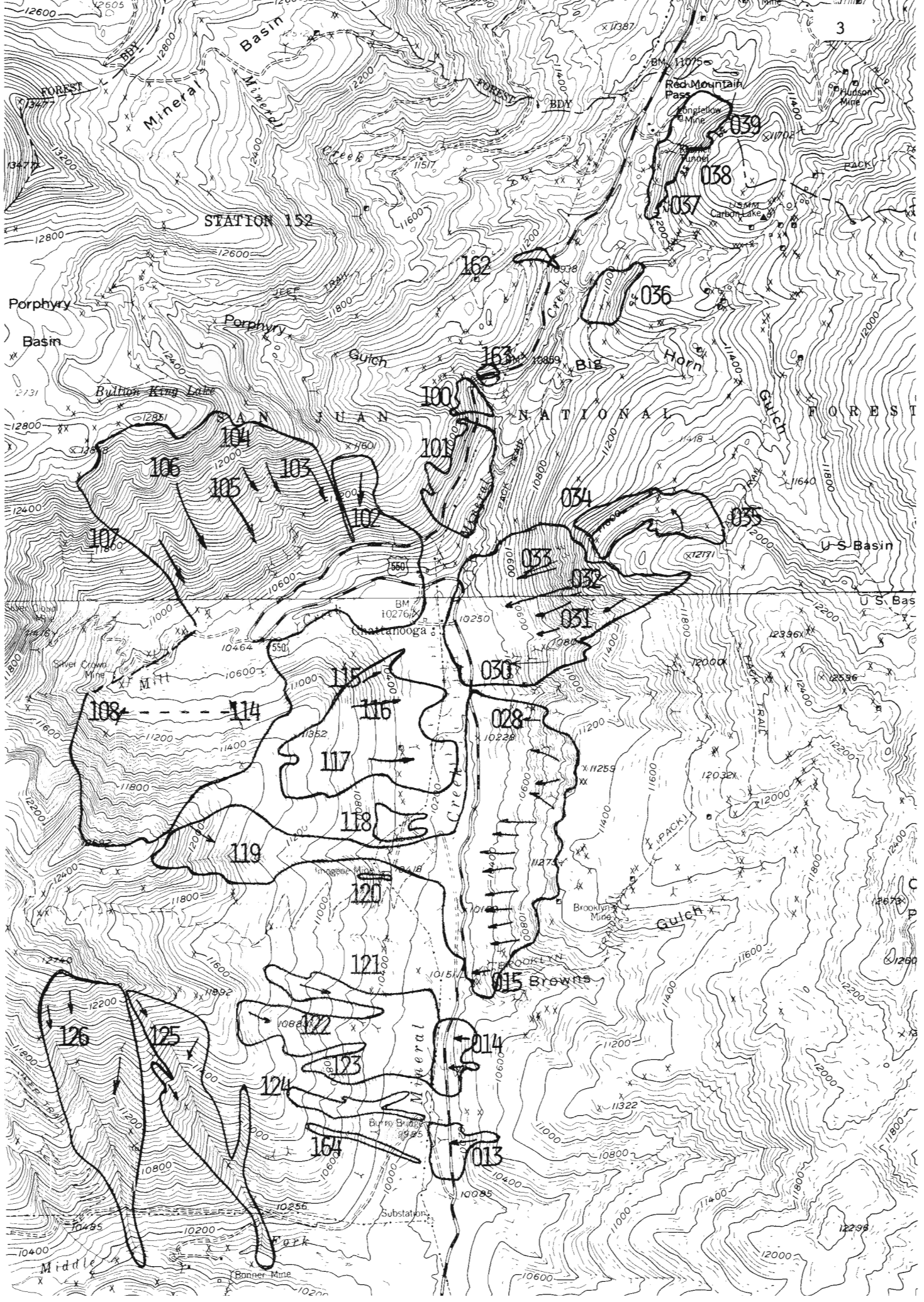
Track: Upper portion: broad open slope with broad v-shaped drainages;
Lower portion: drainages narrow to single v-shaped gully. Light coniferous,
grass and bare ground

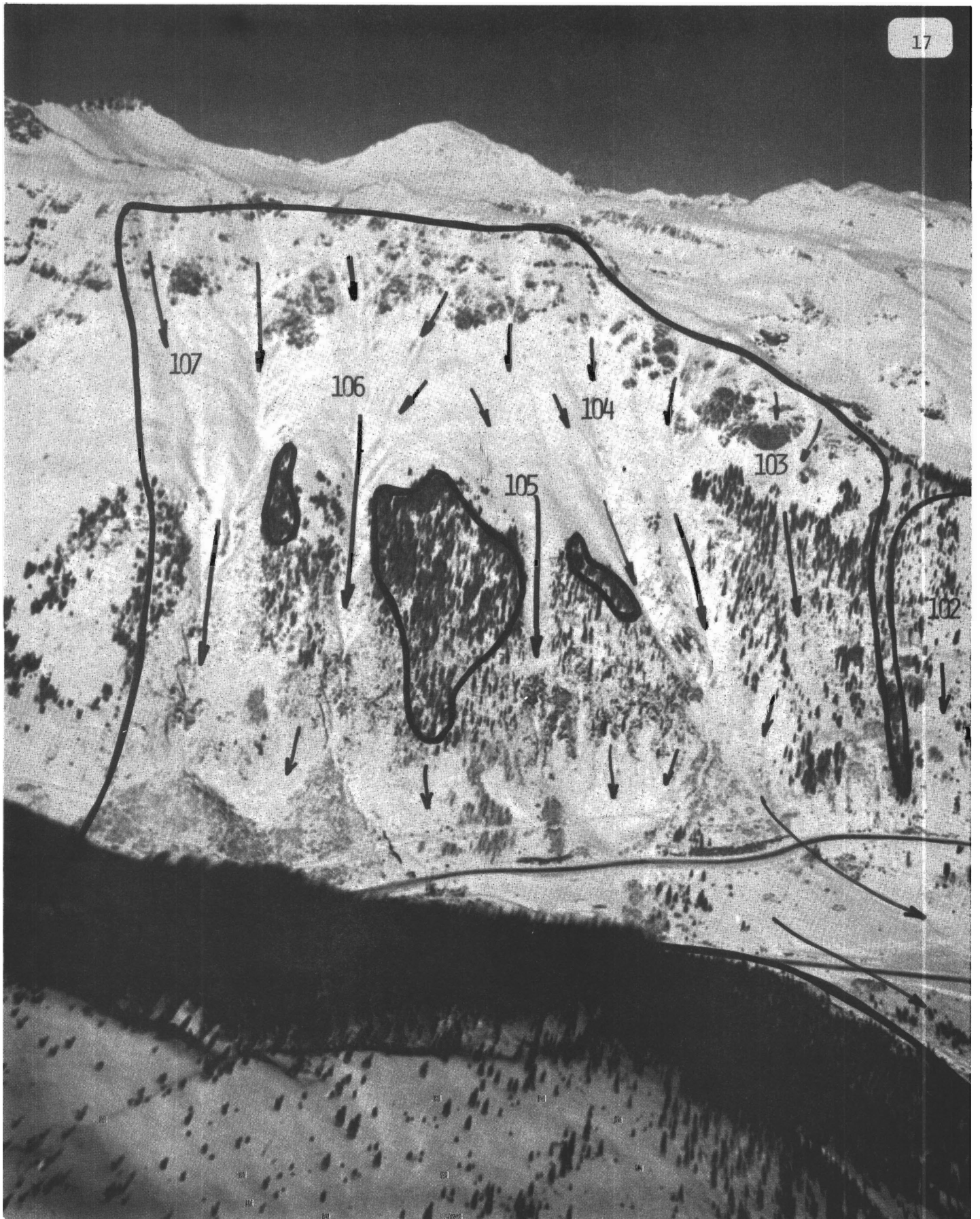
Runout Zone: Broadening fan, light coniferous, willows and grass

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

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

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





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

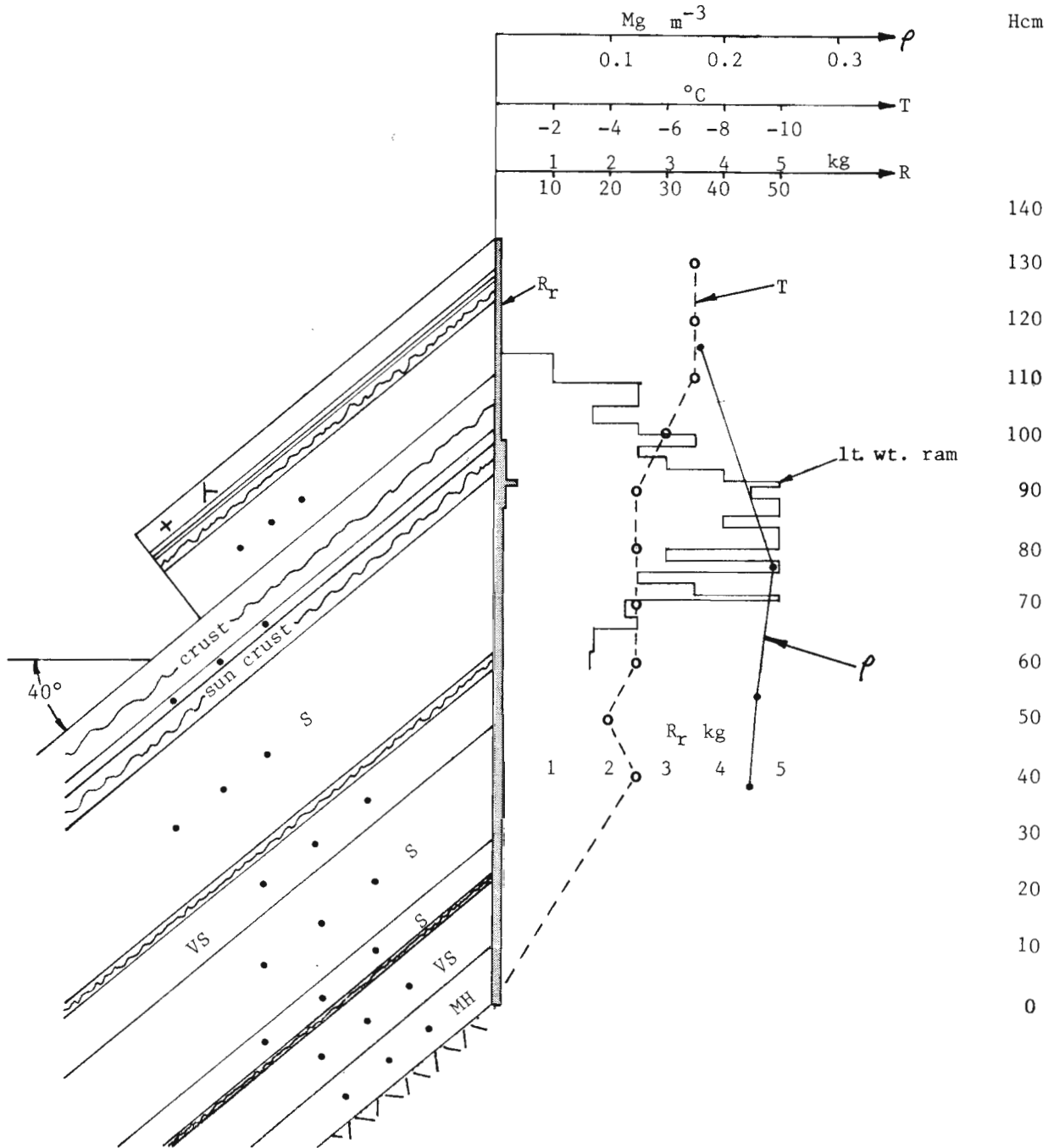
VS	Very Soft
S	Soft
MH	Medium Hard
H	<b>Hard</b>
VH	Very Hard

Crystal Size

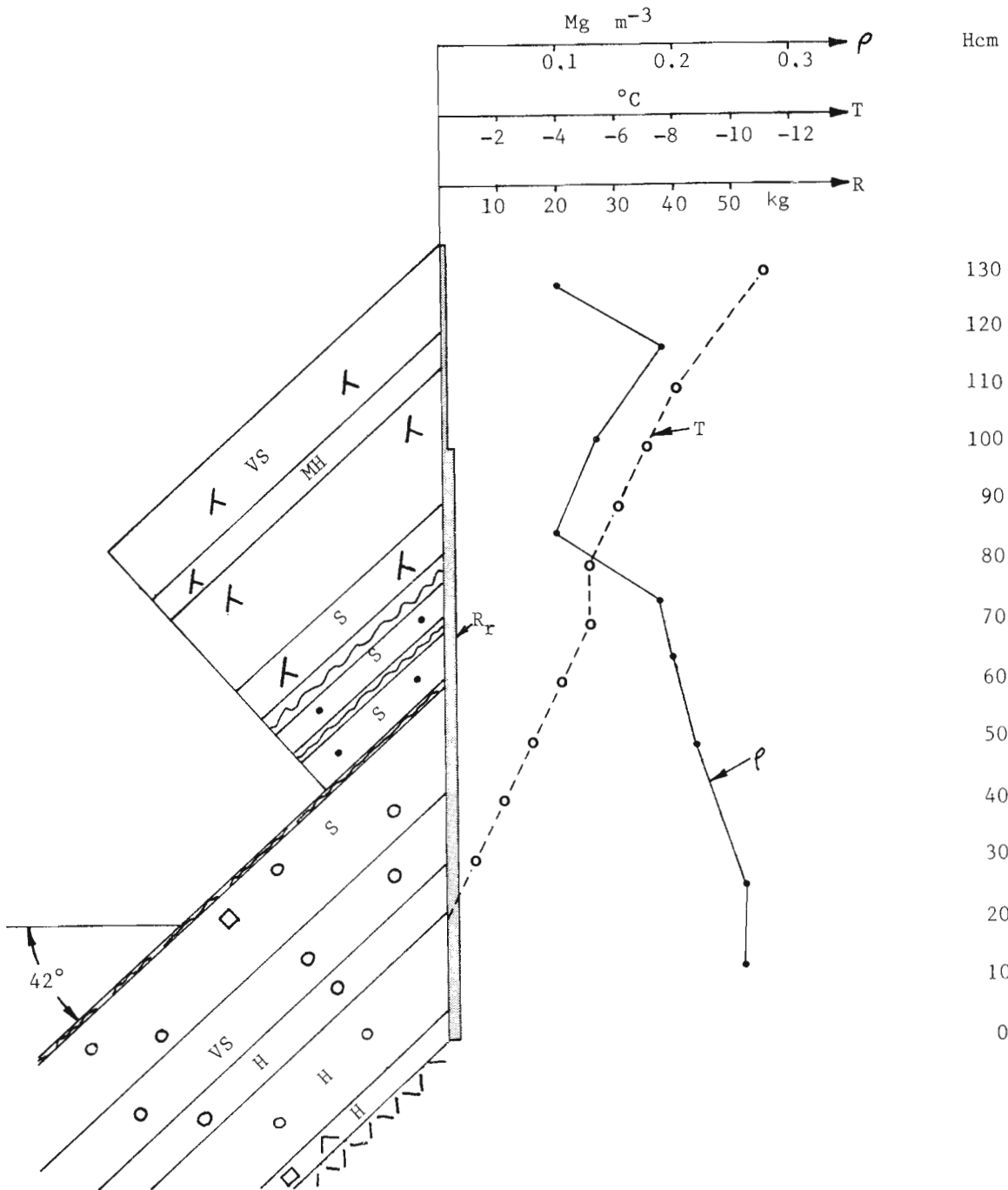
Provided as diameter in mm; e.g. 1.0-1.5 mm

→ Indicates transition between two crystal types.

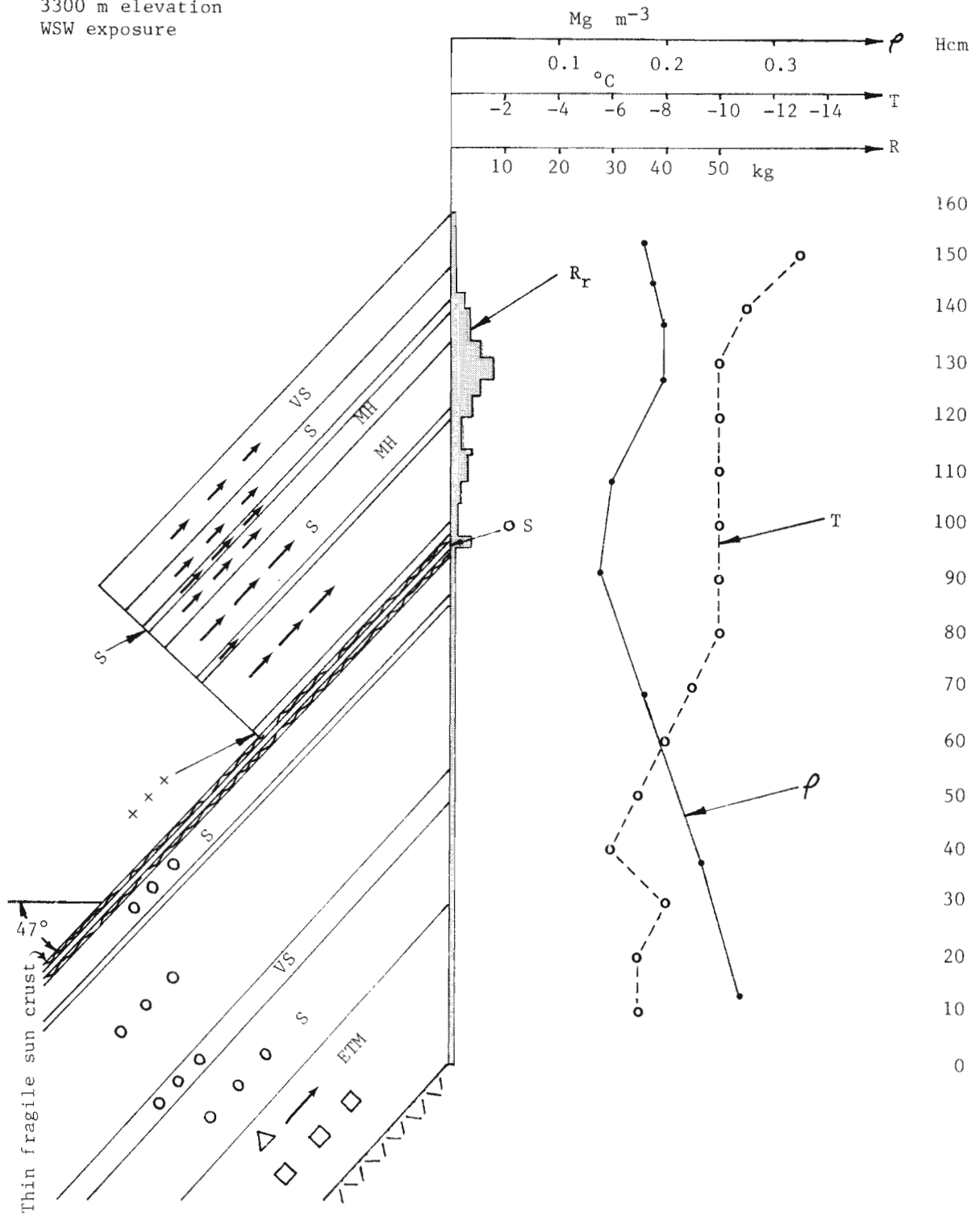
FRACTURE LINE PROFILE #1  
 1/2 mile SW of Red Mountain Pass  
 November 26, 1972  
 SS-N-1-0 (November 26, 1972)  
 3600 m elevation  
 ESE exposure



FRACTURE LINE PROFILE #2  
 Willow Swamp  
 December 6, 1972  
 SS-AA-3-0 (December 5, 1972)  
 3400 m elevation  
 E exposure



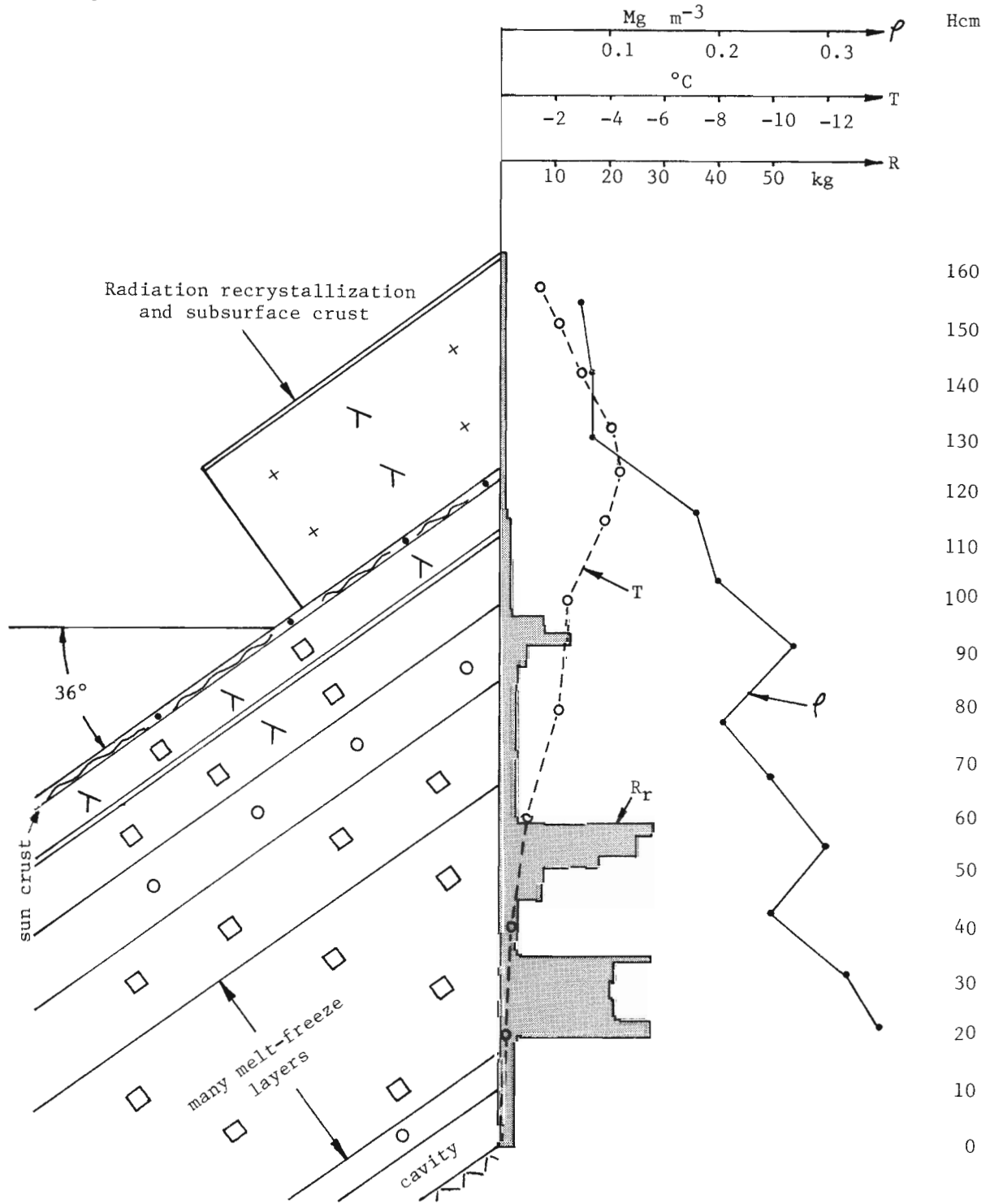
FRACTURE LINE PROFILE #3  
 No. Mineral Bridge  
 December 6, 1972  
 SS-N-2-0 (December 5, 1972)  
 3300 m elevation  
 WSW exposure



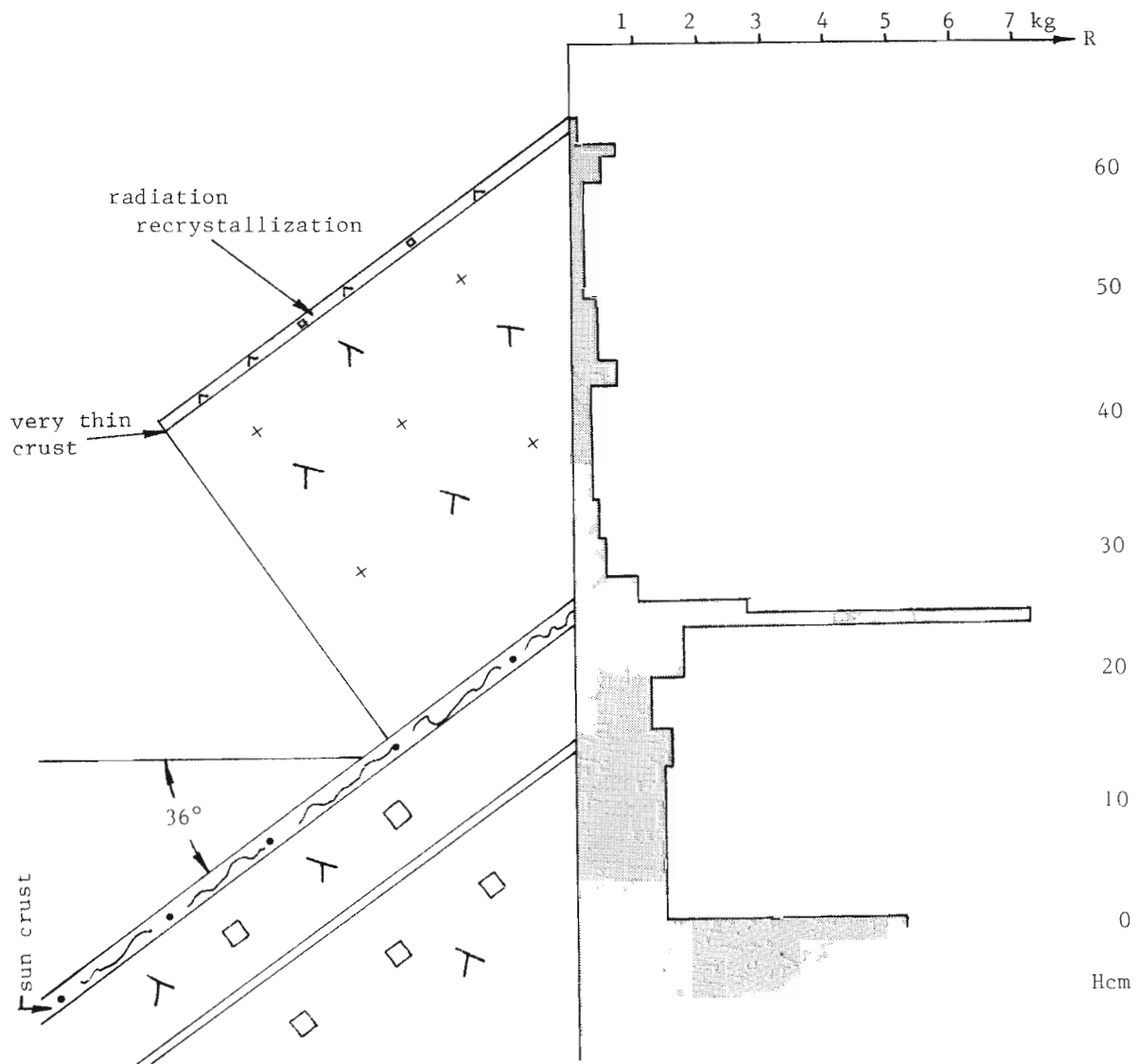
FRACTURE LINE PROFILE #4  
 Cement Fill  
 December 26, 1972  
 SS-N-4-0 (December 25, 1972)  
 3600 m elevation  
 SW exposure



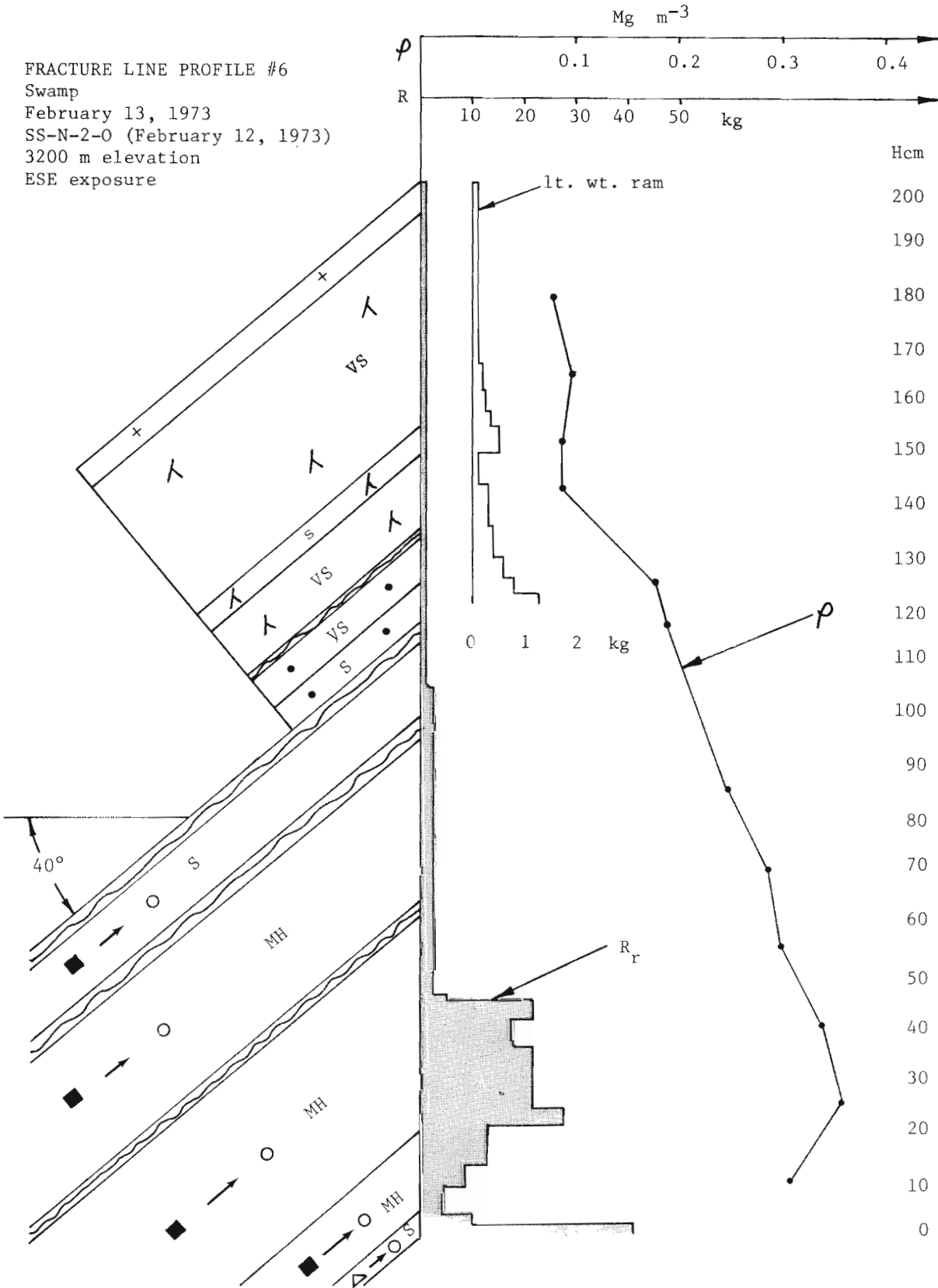
FRACTURE LINE PROFILE #5  
 Engineer A  
 January 6, 1973  
 SS-N-4-0 (January 5, 1973)  
 3400 m elevation  
 SE exposure



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

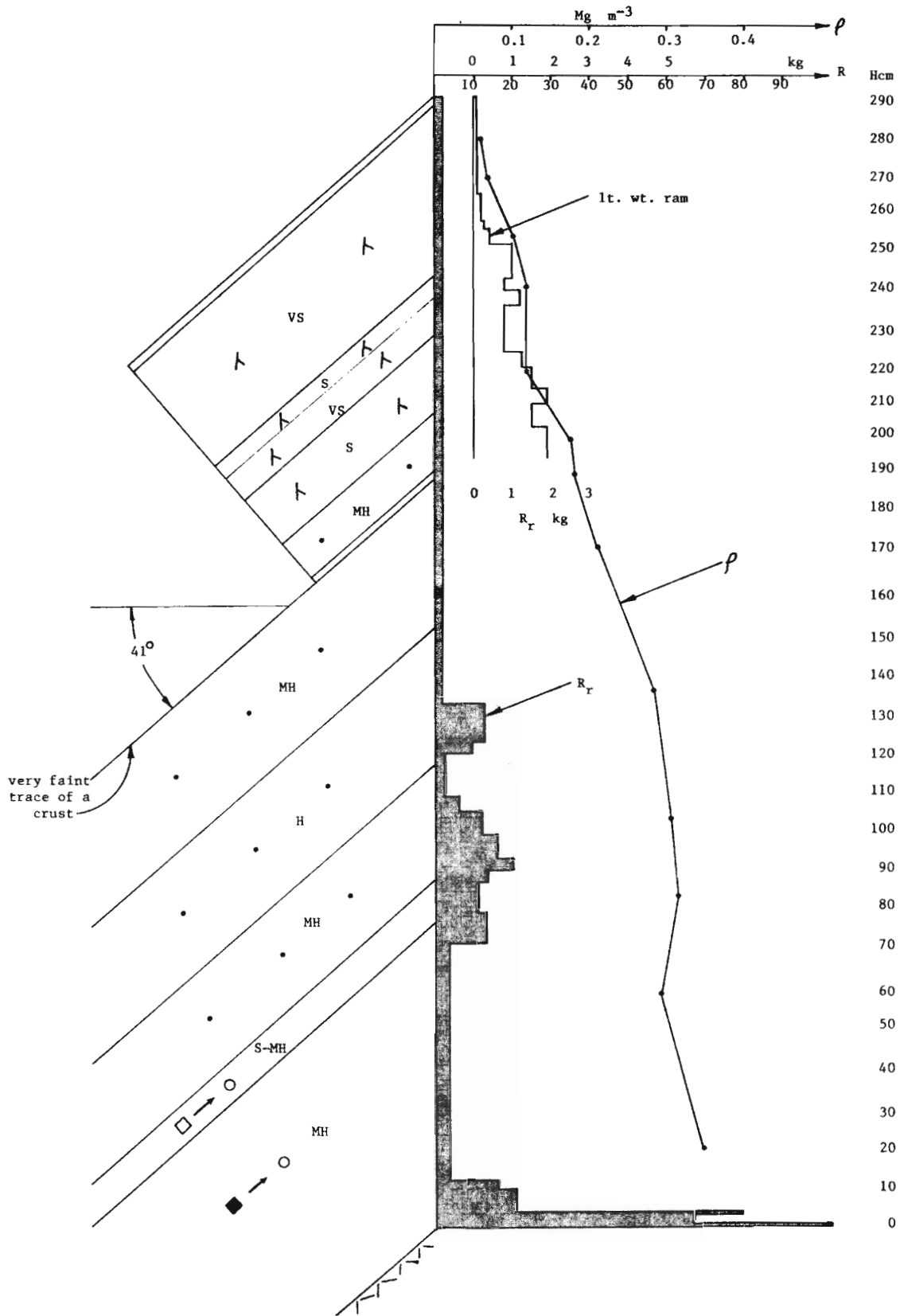


FRACTURE LINE PROFILE #6  
 Swamp  
 February 13, 1973  
 SS-N-2-0 (February 12, 1973)  
 3200 m elevation  
 ESE exposure

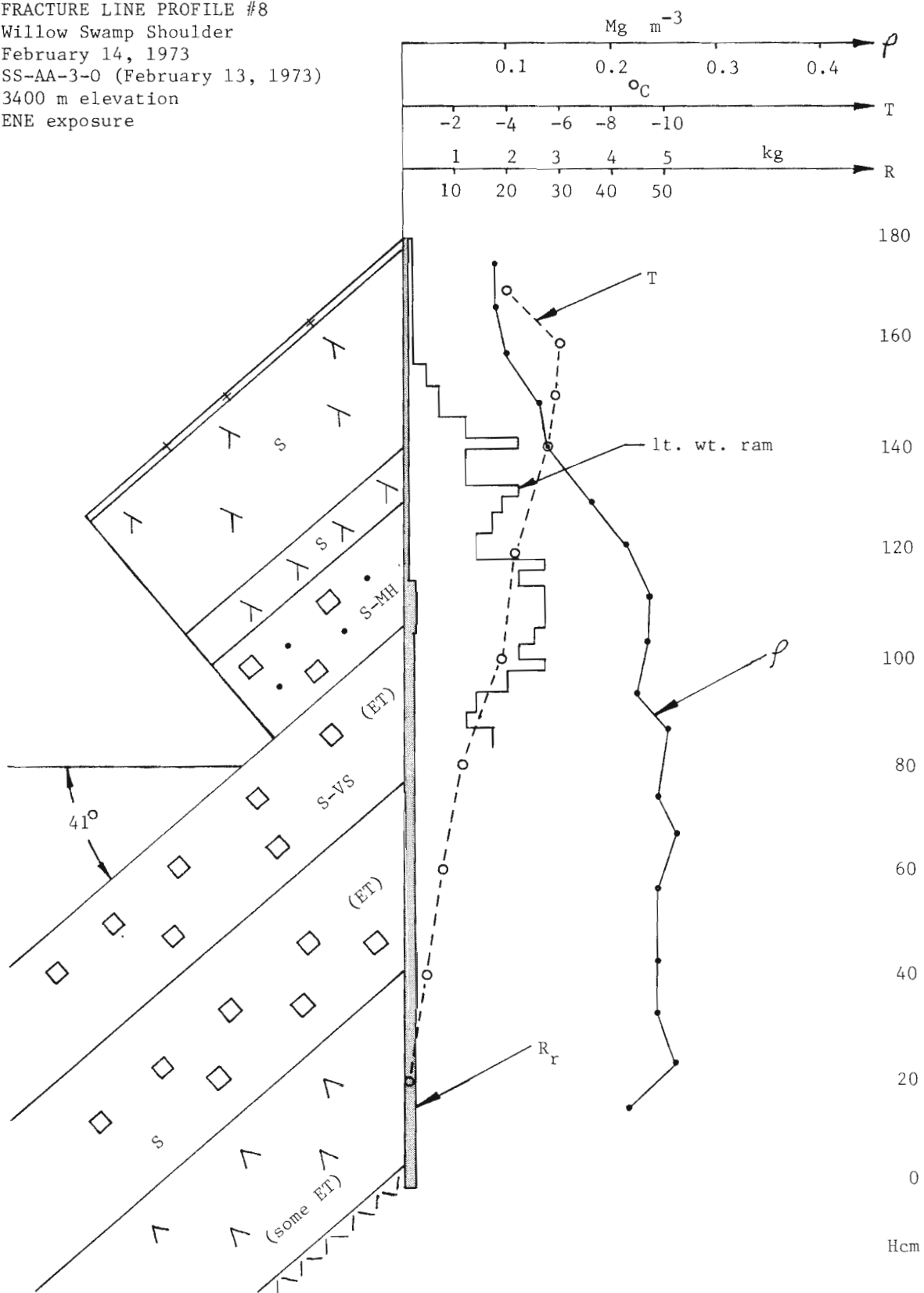




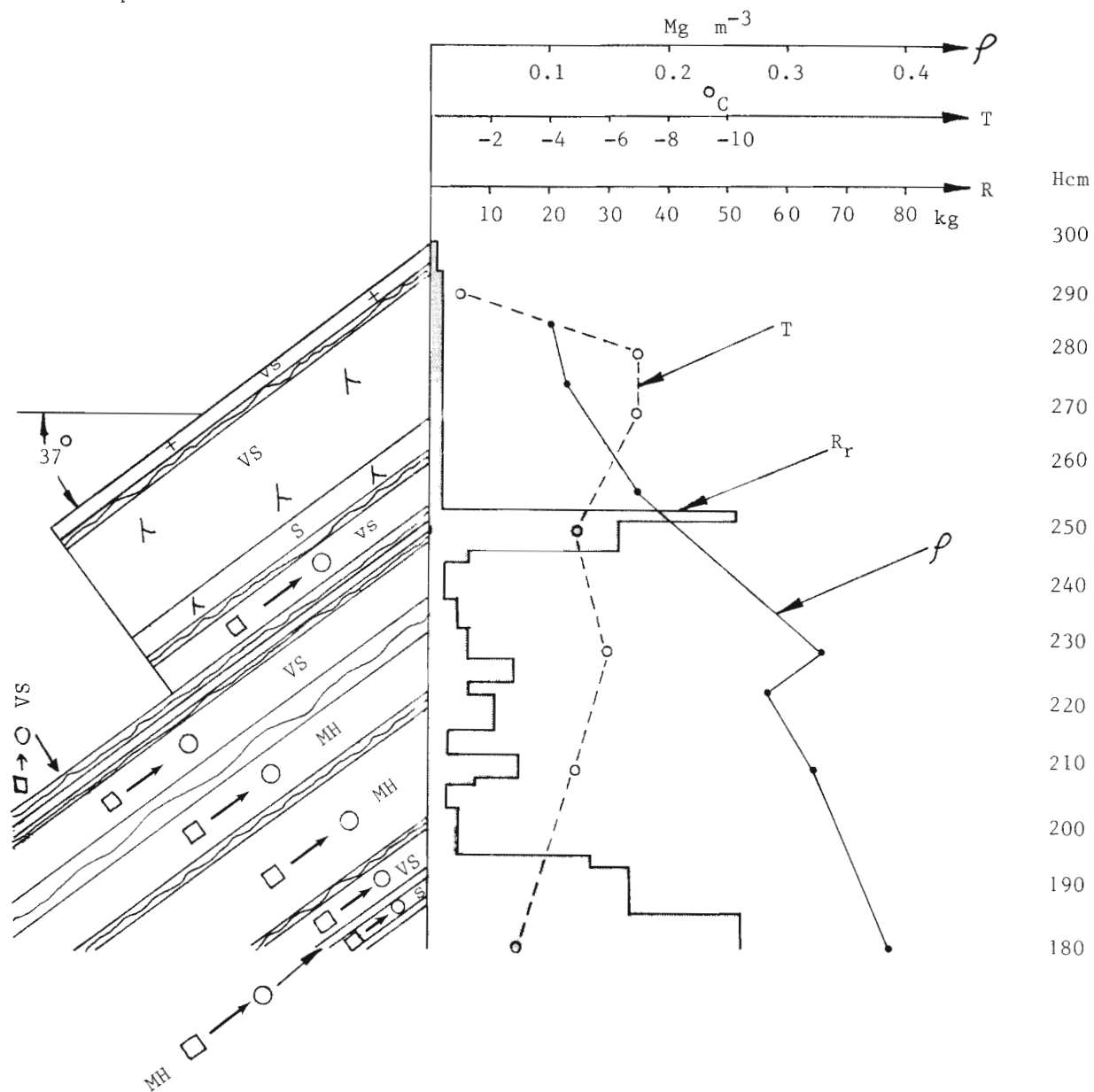
FRACTURE LINE PROFILE #7  
 North Shoulder of Potato Hill, Coal Bank Area  
 February 13, 1973  
 SS-N-2-0 (February 13, 1973)  
 3300 m elevation  
 N exposure

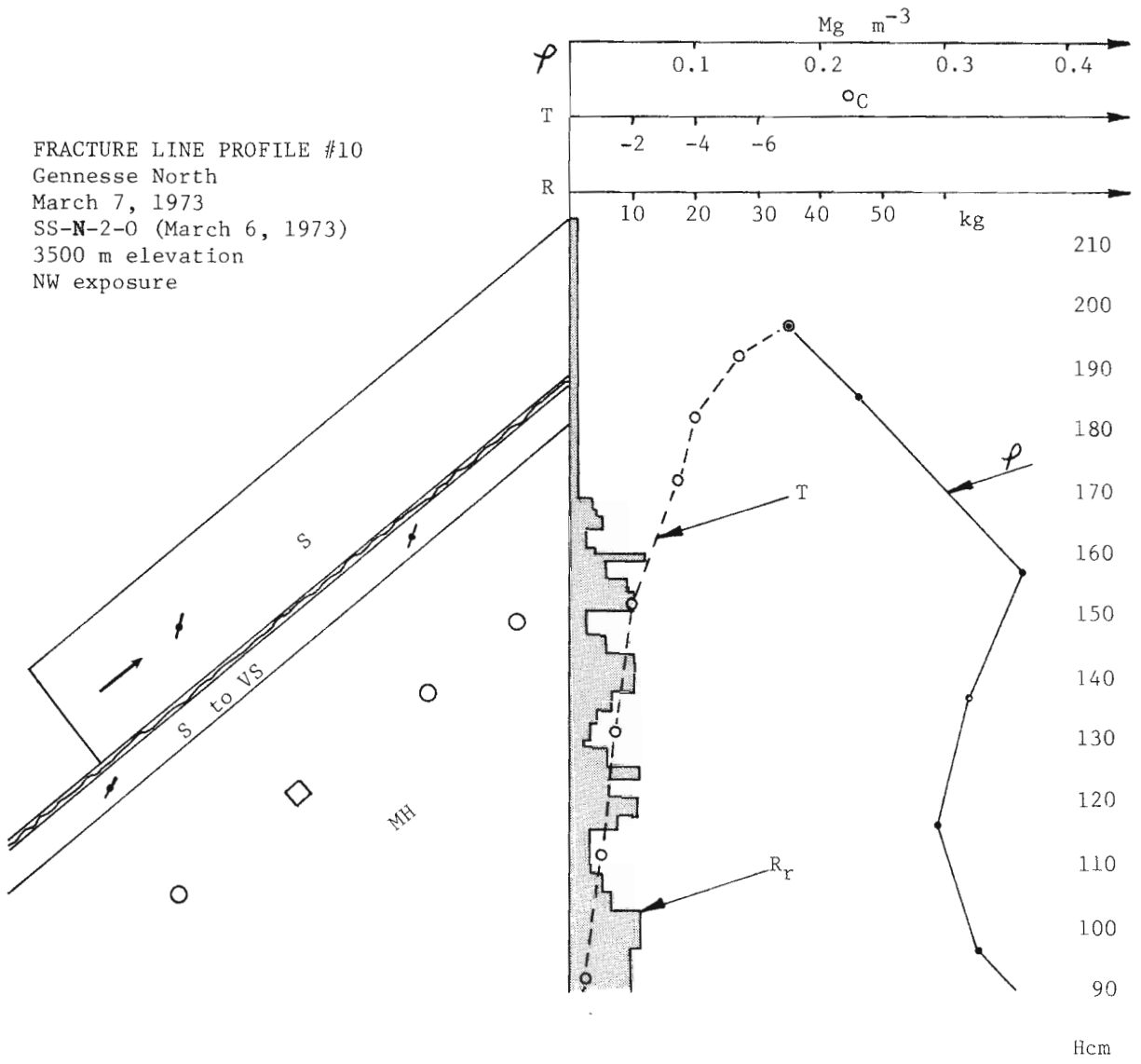


FRACTURE LINE PROFILE #8  
 Willow Swamp Shoulder  
 February 14, 1973  
 SS-AA-3-0 (February 13, 1973)  
 3400 m elevation  
 ENE exposure

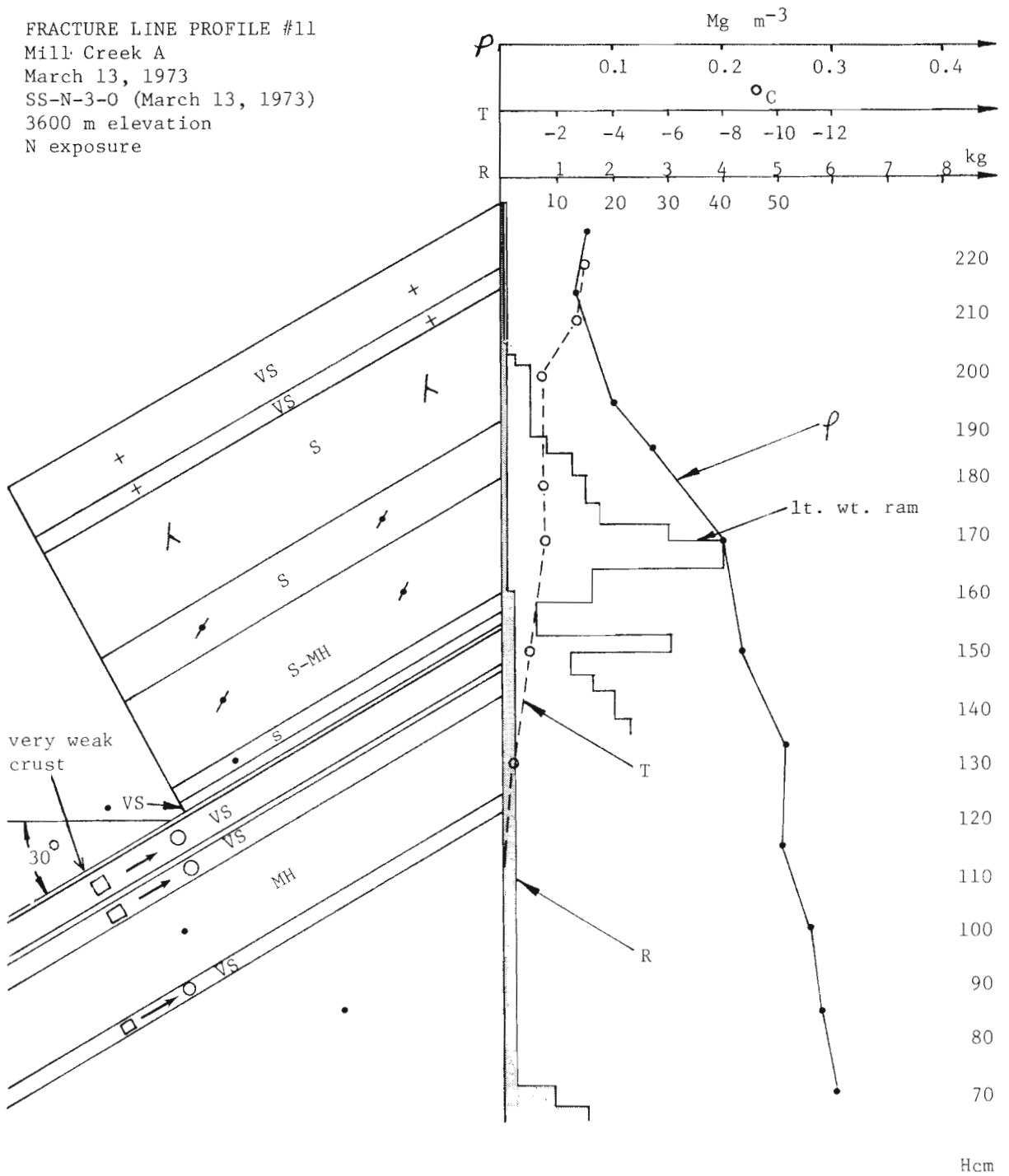


**FRACTURE LINE PROFILE #9**  
 Eagle  
 February 14, 1973  
 SS-AA-2-0 (February 13, 1973)  
 3800 m elevation  
 ESE exposure

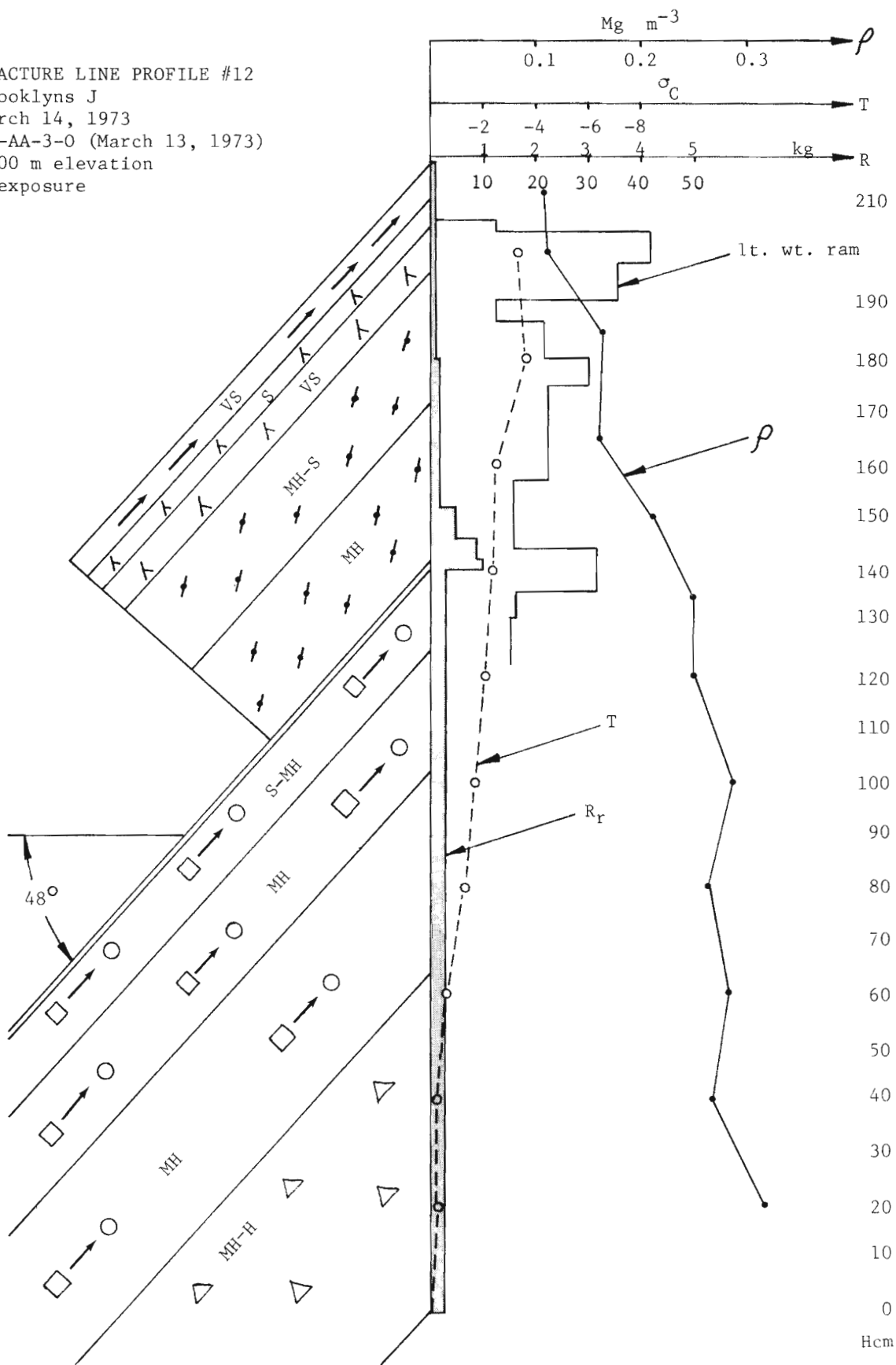




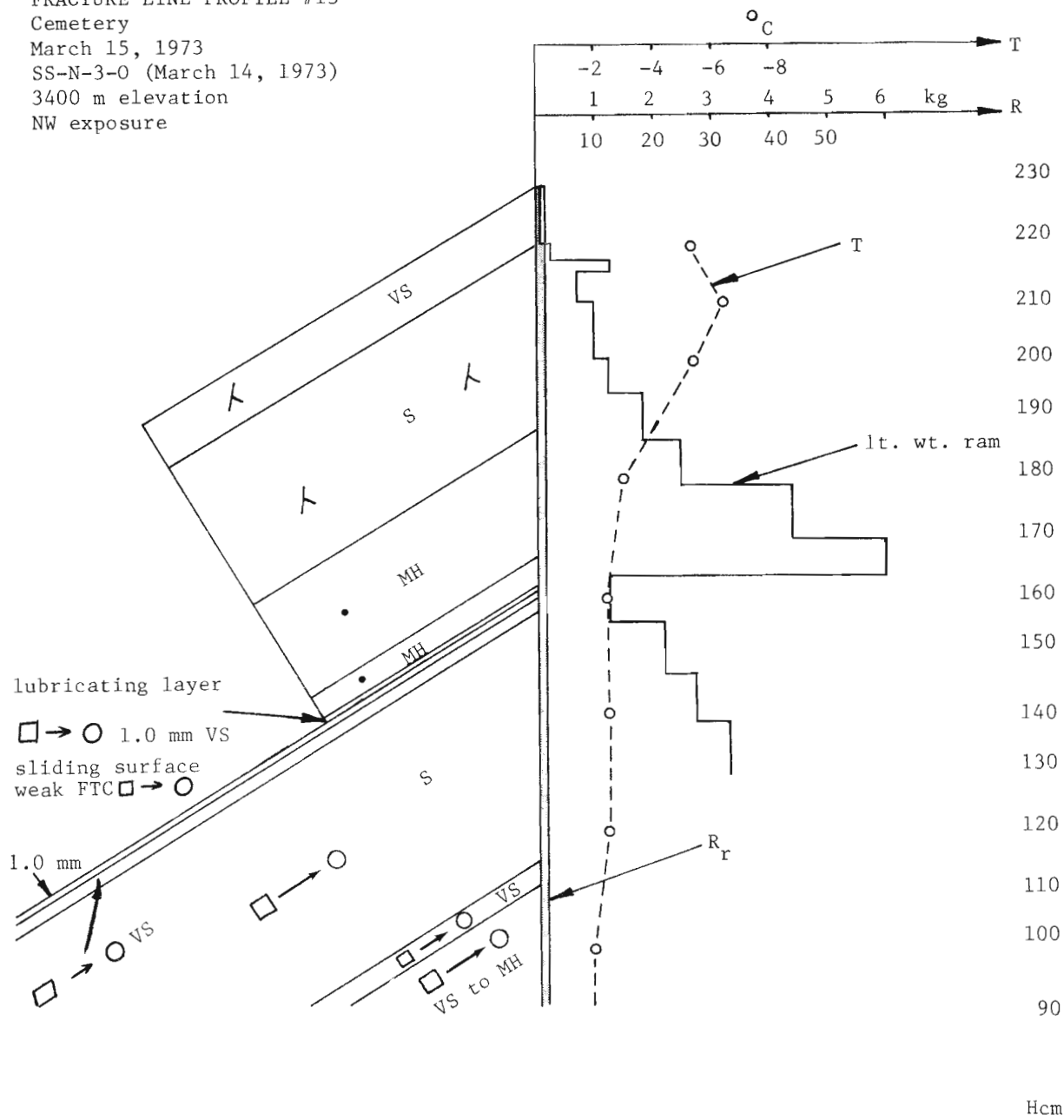
FRACTURE LINE PROFILE #11  
 Mill Creek A  
 March 13, 1973  
 SS-N-3-0 (March 13, 1973)  
 3600 m elevation  
 N exposure



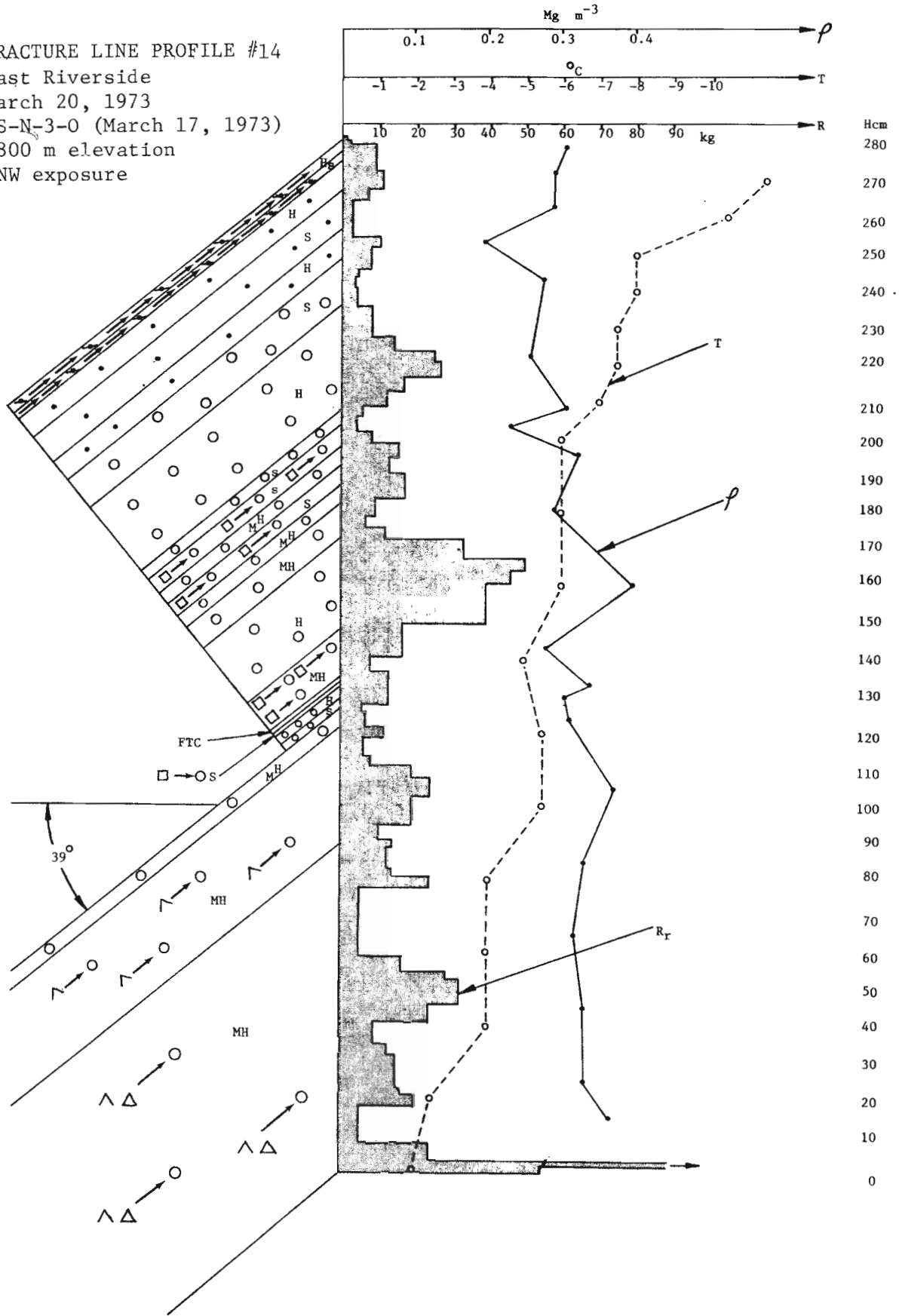
FRACTURE LINE PROFILE #12  
 Brooklyns J  
 March 14, 1973  
 SS-AA-3-0 (March 13, 1973)  
 3400 m elevation  
 W exposure



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

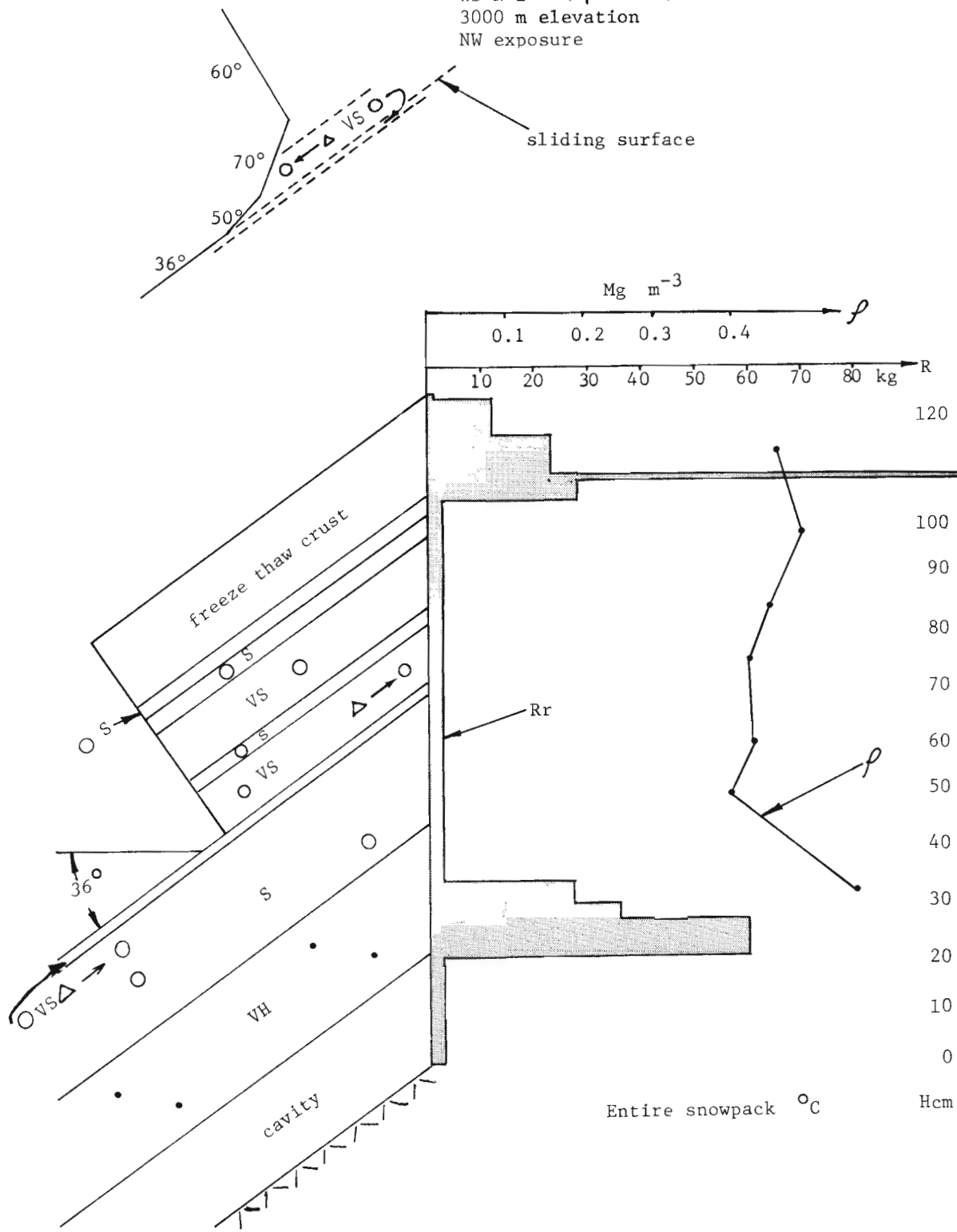


FRACTURE LINE PROFILE #14  
 East Riverside  
 March 20, 1973  
 HS-N₃-0 (March 17, 1973)  
 3800 m elevation  
 WNW exposure

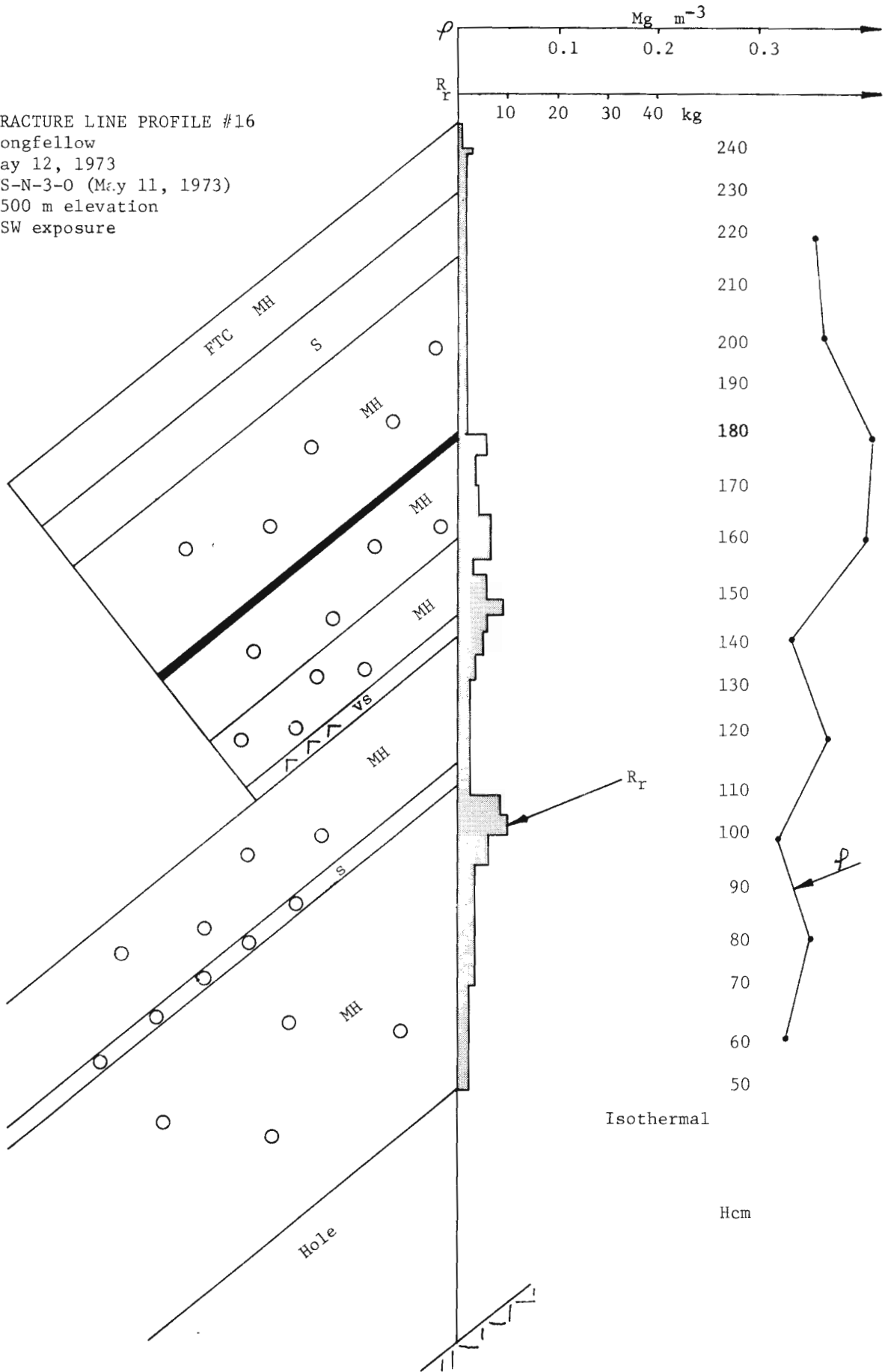




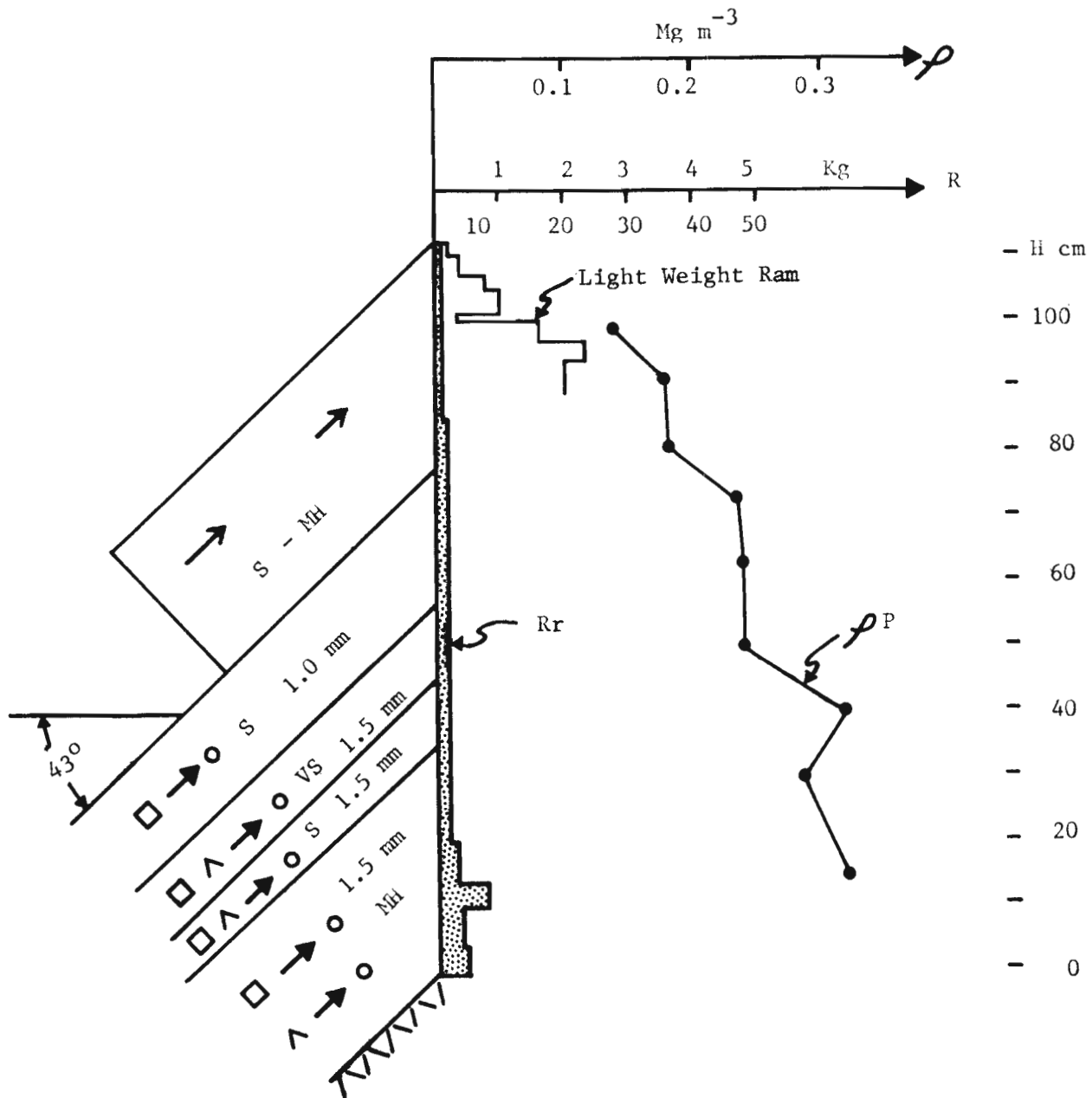
FRACTURE LINE PROFILE #15  
 Kendall Mountain North of Idaho Gulch  
 April 14, 1973  
 WS-N-1-0 (April 13, 1973)  
 3000 m elevation  
 NW exposure



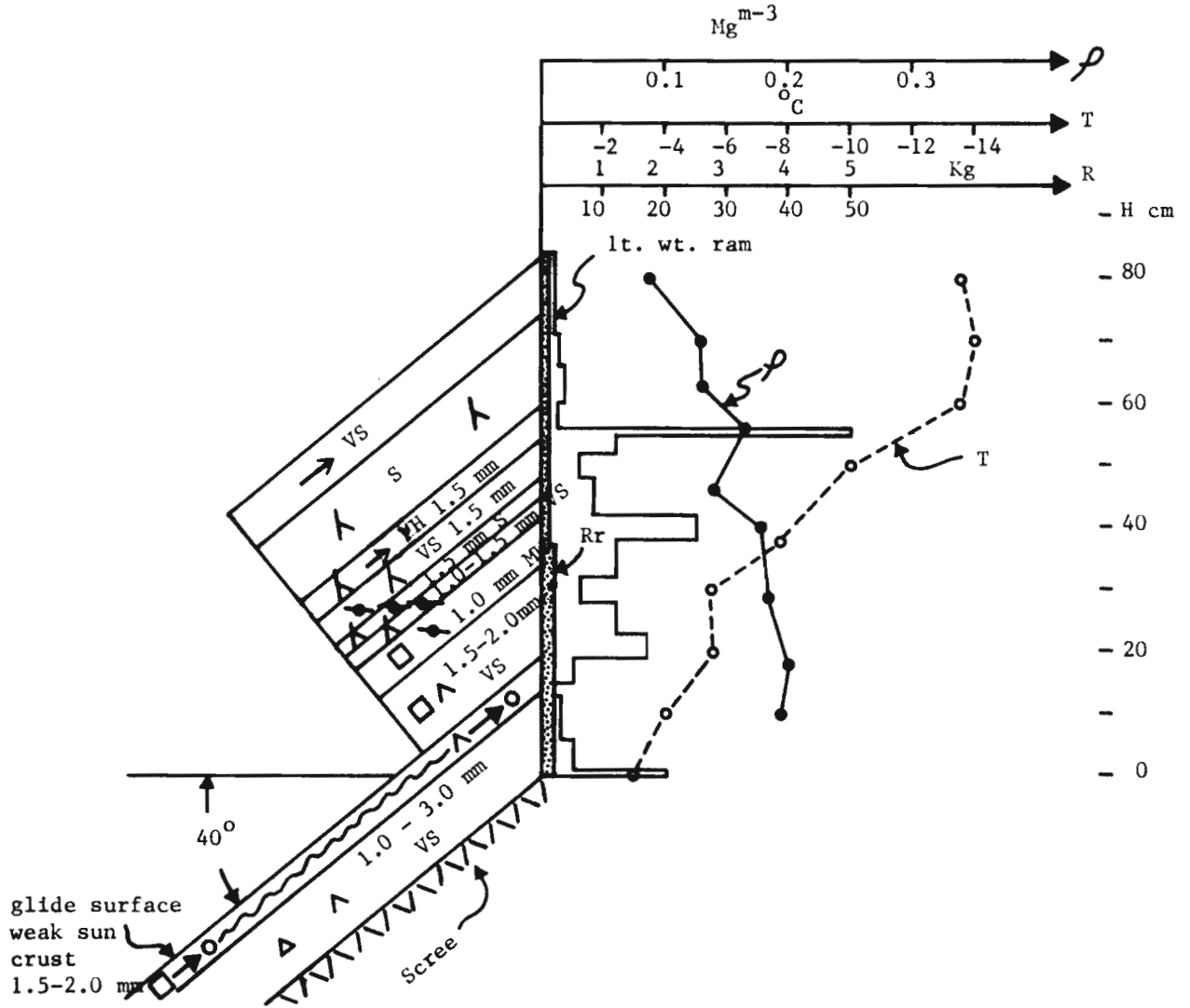
FRACTURE LINE PROFILE #16  
 Longfellow  
 May 12, 1973  
 WS-N-3-0 (May 11, 1973)  
 3500 m elevation  
 WSW exposure



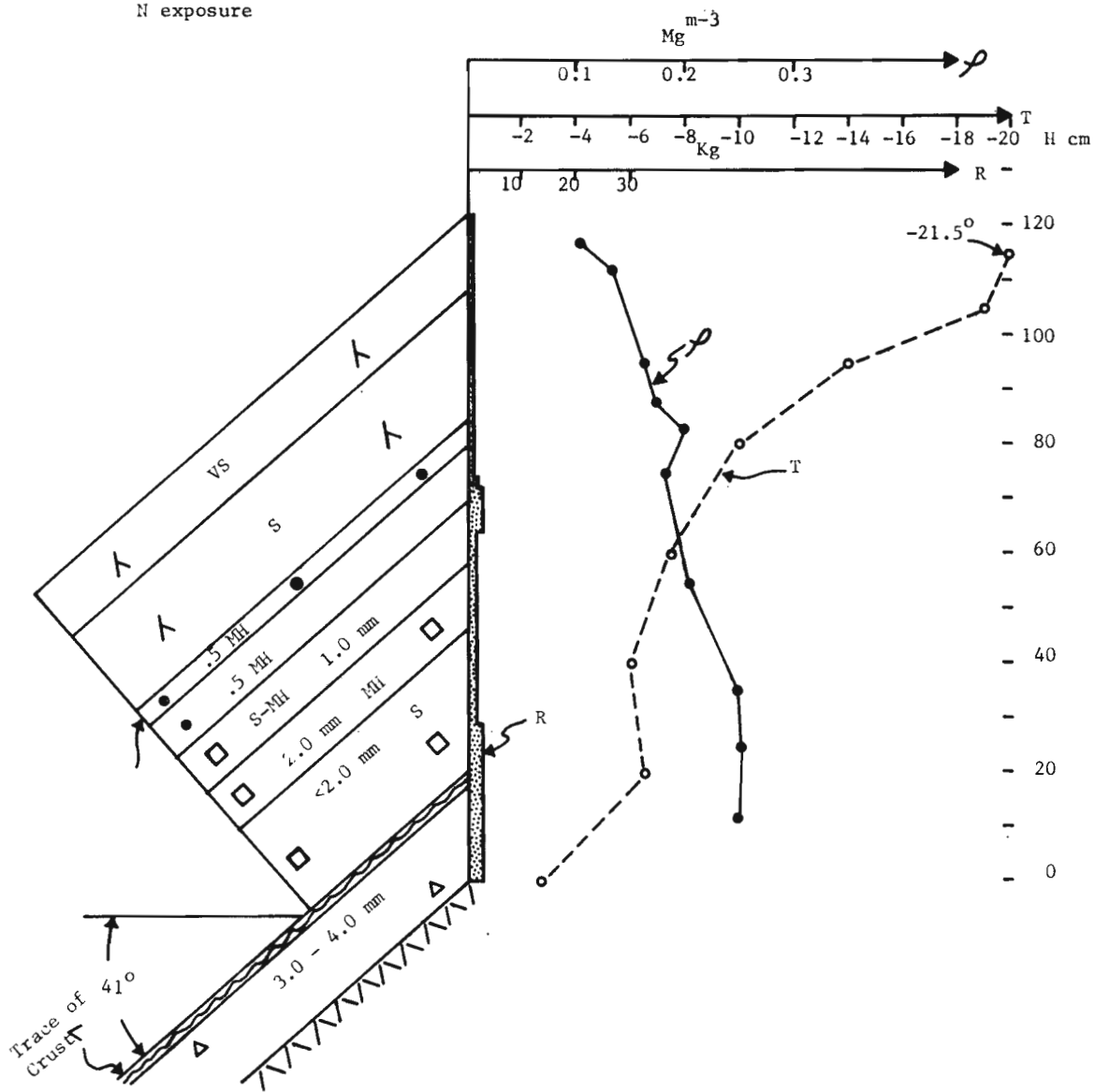
FRACTURE LINE PROFILE #17  
 Willow Swamp Shoulder  
 December 28, 1973  
 SS-N-2-0 (Dec. 28, 1973)  
 3400 m elevation  
 E N E exposure



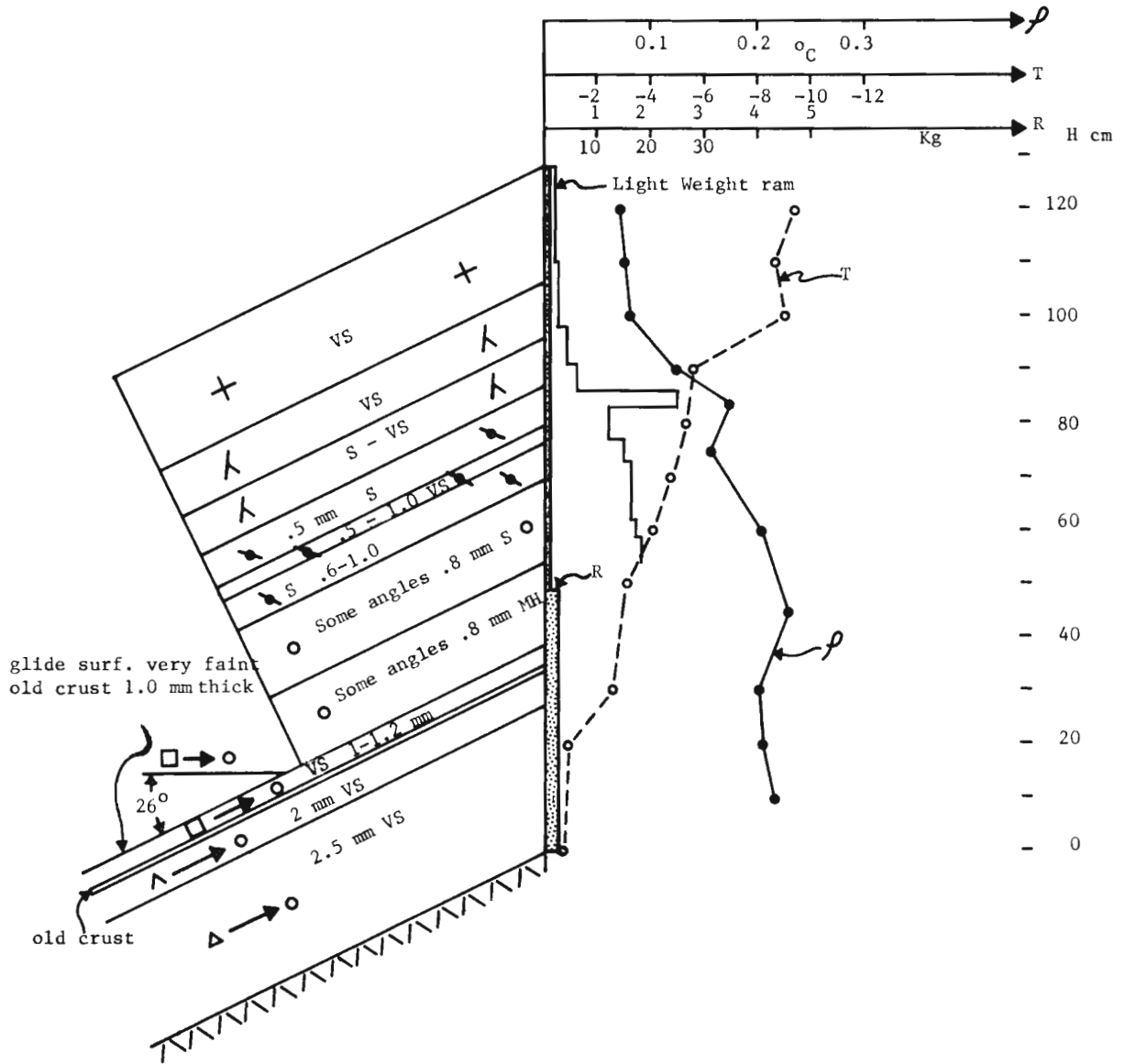
FRACTURE LINE PROFILE #18  
 Brooklyns E  
 December 31, 1973  
 SS-AA-2-OG (Dec. 31, 1973)  
 3400 m elevation  
 W exposure



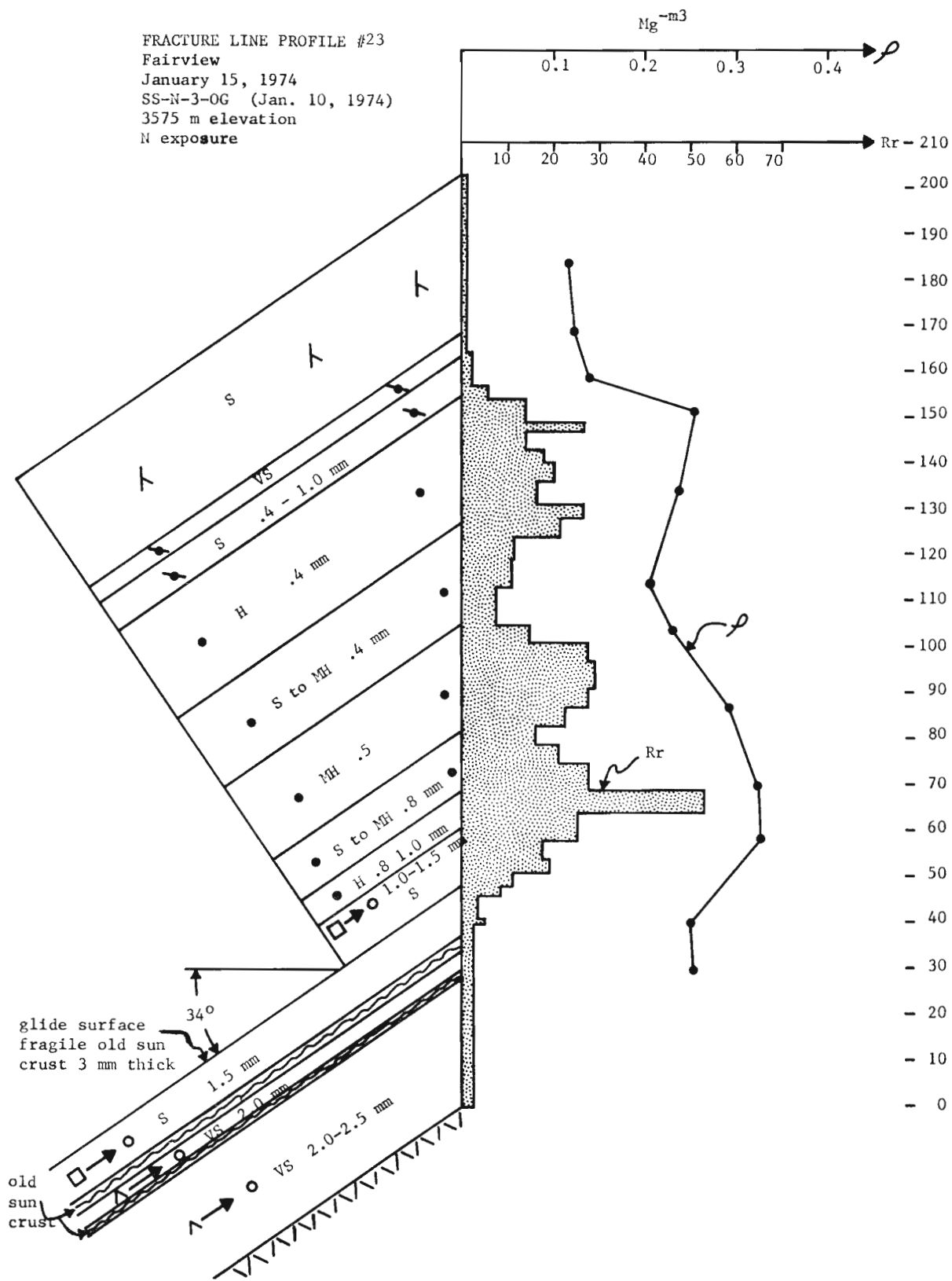
FRACTURE LINE PROFILE # 19  
 North Carbon Test Slope  
 January 3, 1974  
 SS-AE-3-0G (Jan. 3, 1974)  
 3500 m elevation  
 N exposure



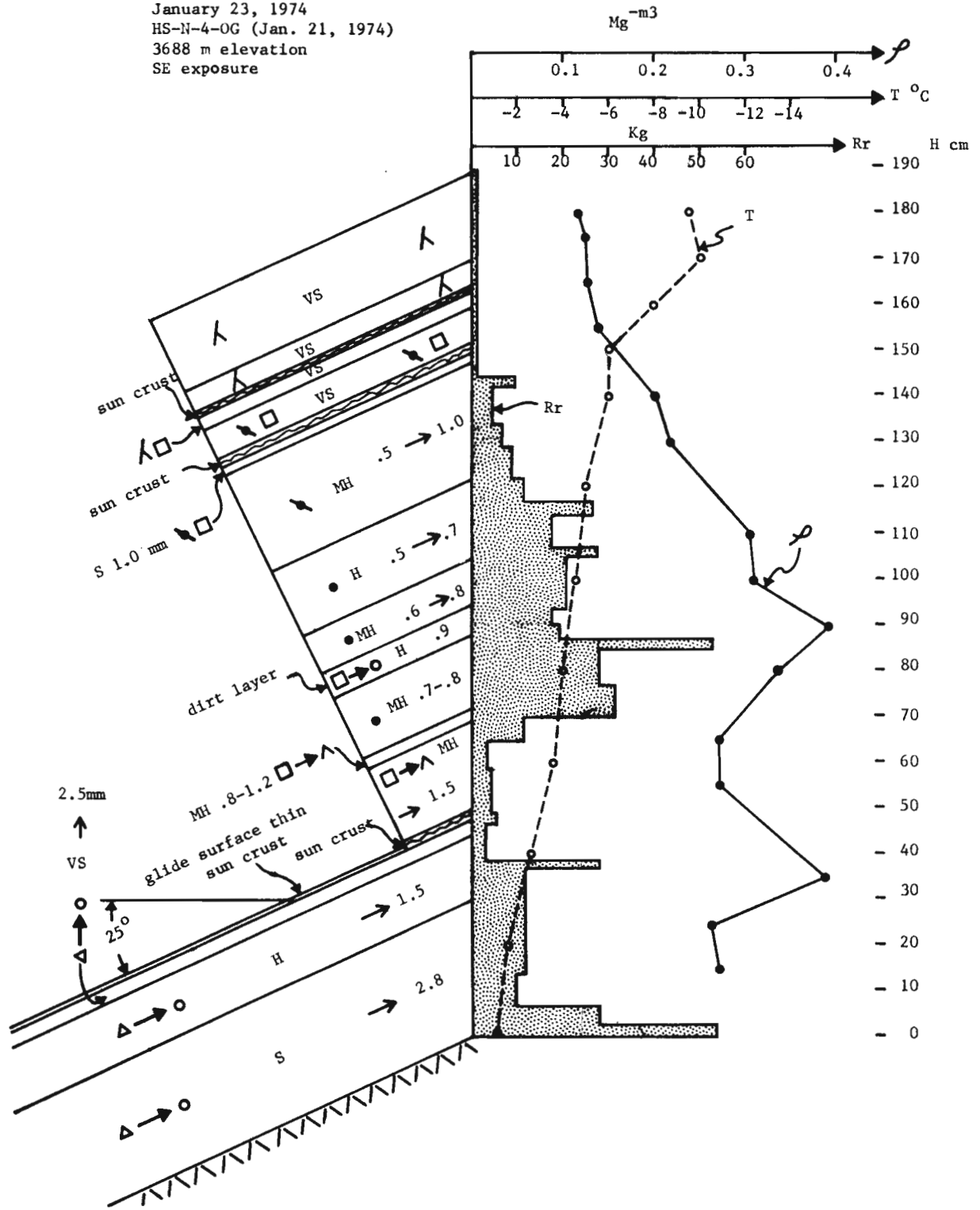
FRACTURE LINE PROFILE #22  
 Cement Creek - Bunker Hill  
 January 9, 1974  
 SS-N-2-OG (Jan. 9, 1974)  
 3000 m elevation  
 ESE exposure



FRACTURE LINE PROFILE #23  
 Fairview  
 January 15, 1974  
 SS-N-3-OG (Jan. 10, 1974)  
 3575 m elevation  
 N exposure

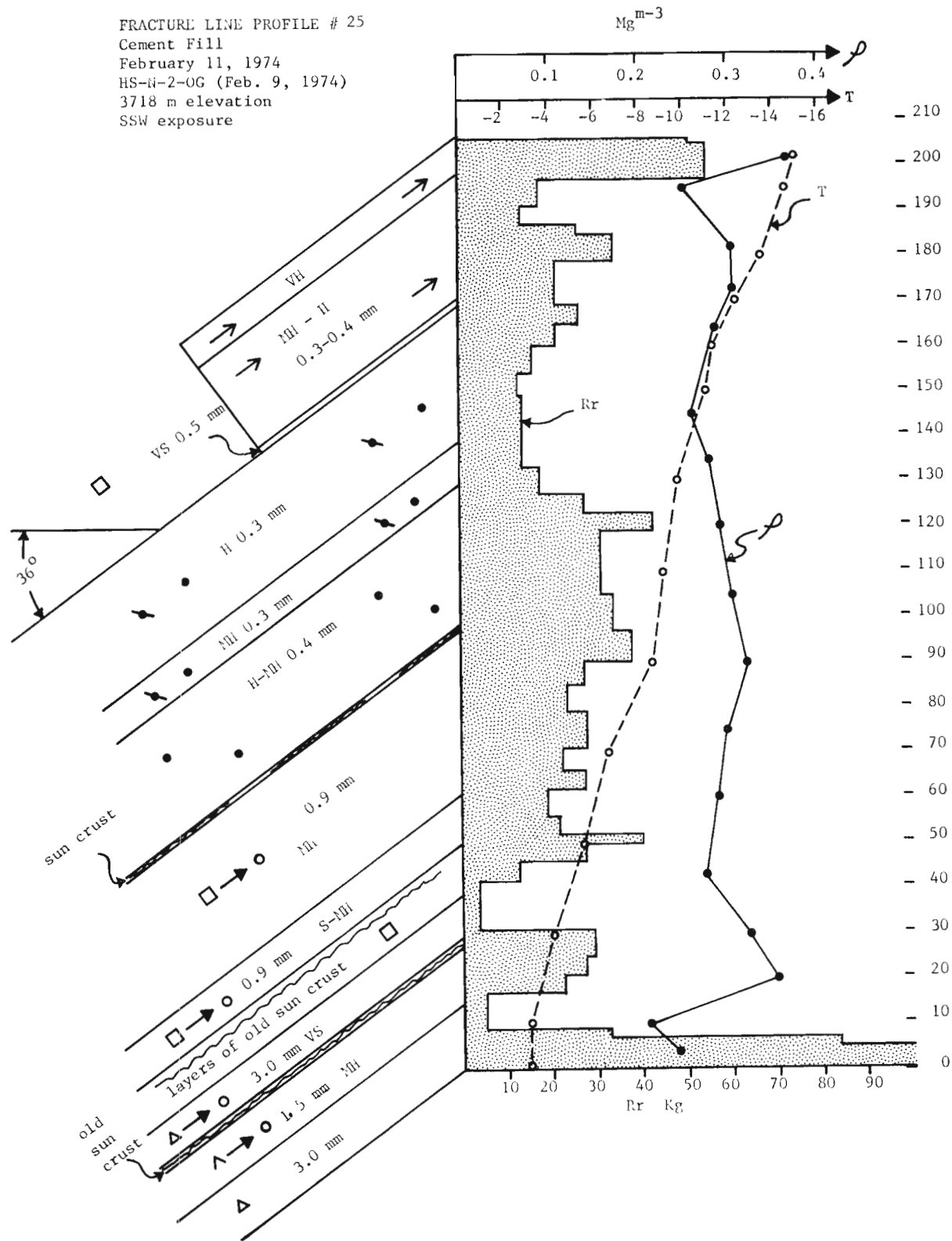


FRACTURE LINE PROFILE #24  
 NE Shoulder Pt. 12,325  
 January 23, 1974  
 HS-N-4-OG (Jan. 21, 1974)  
 3688 m elevation  
 SE exposure

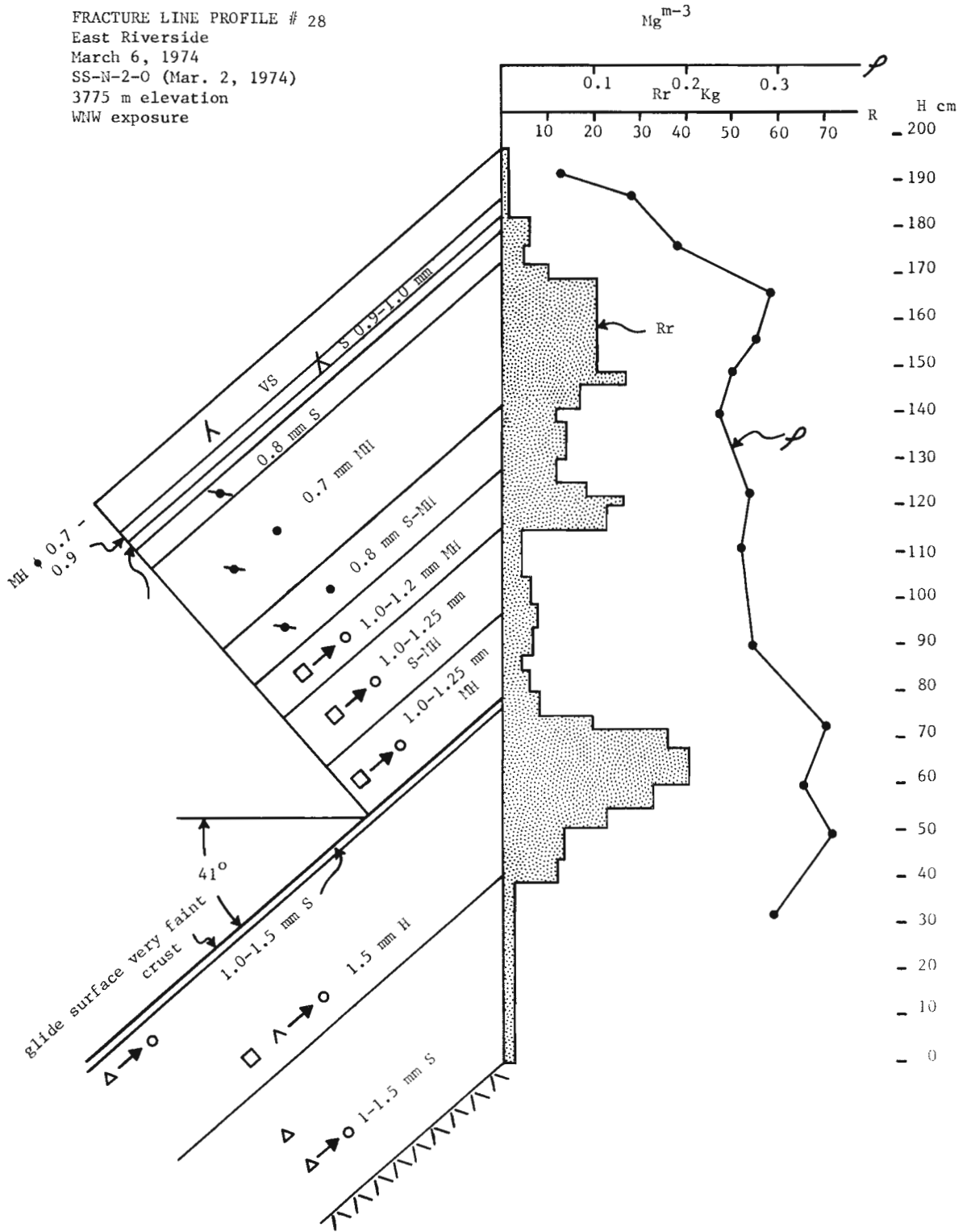


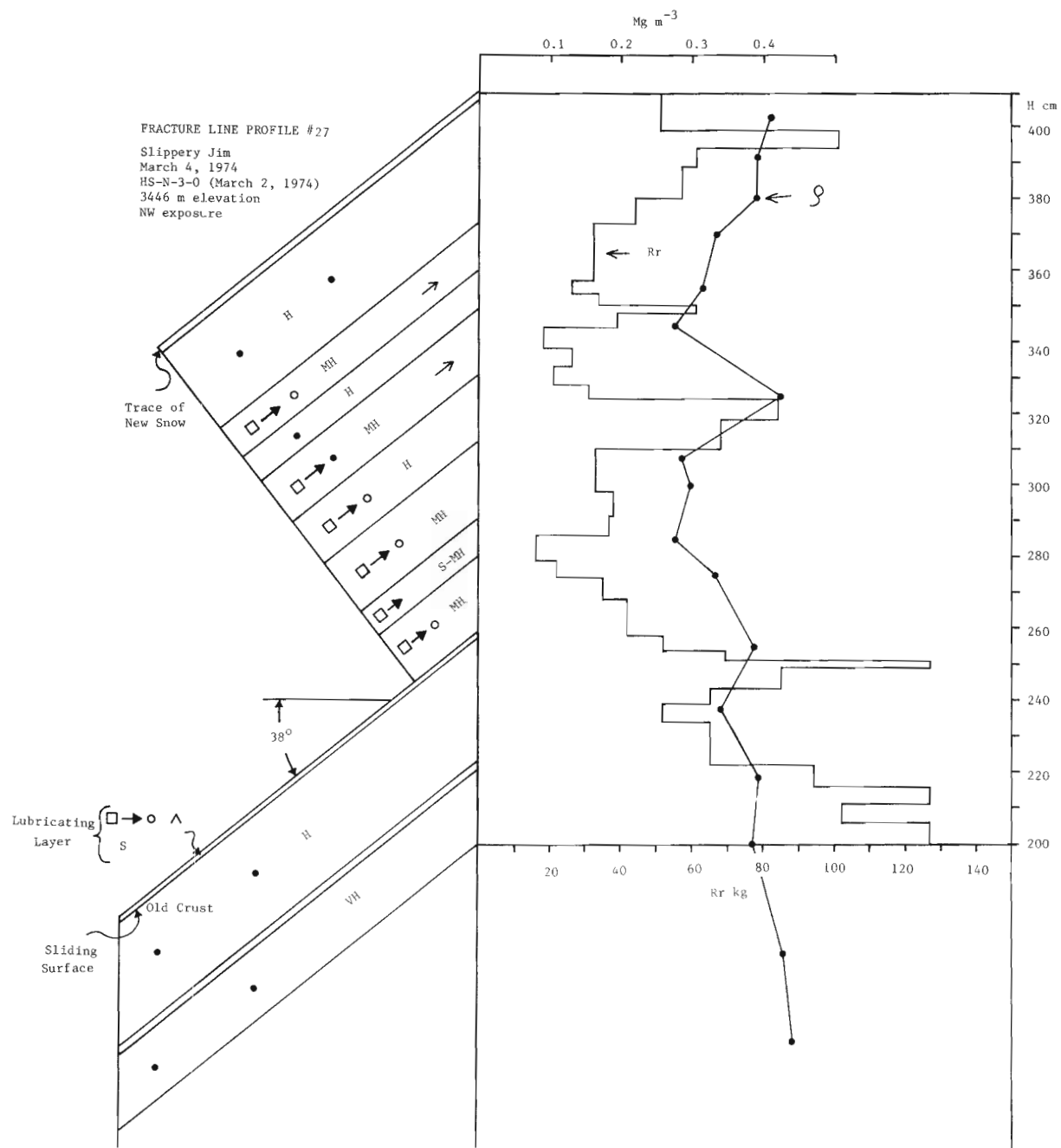


FRACTURE LINE PROFILE # 25  
 Cement Fill  
 February 11, 1974  
 HS-N-2-OG (Feb. 9, 1974)  
 3718 m elevation  
 SSW exposure

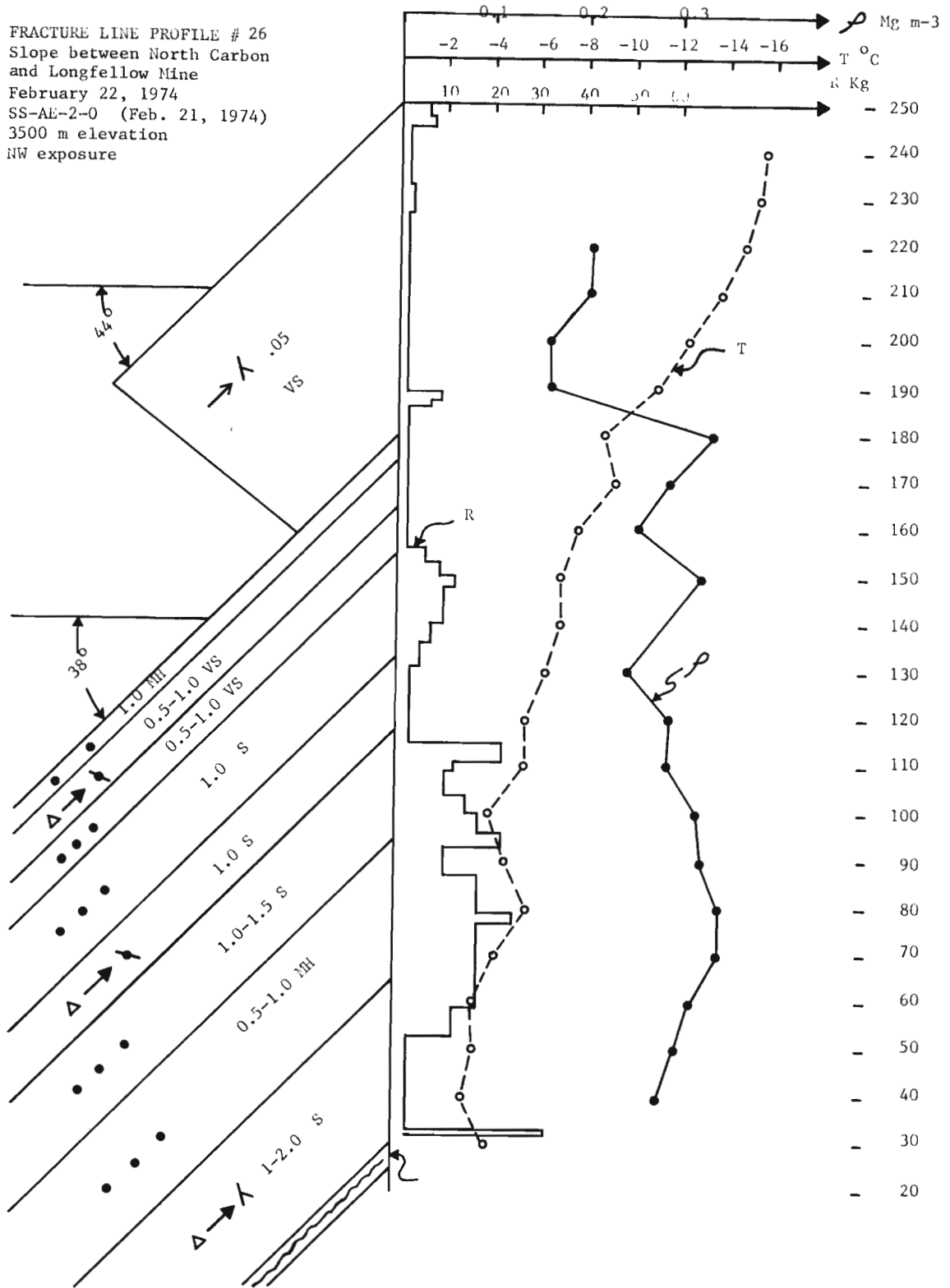


FRACTURE LINE PROFILE # 28  
 East Riverside  
 March 6, 1974  
 SS-N-2-0 (Mar. 2, 1974)  
 3775 m elevation  
 WNW exposure

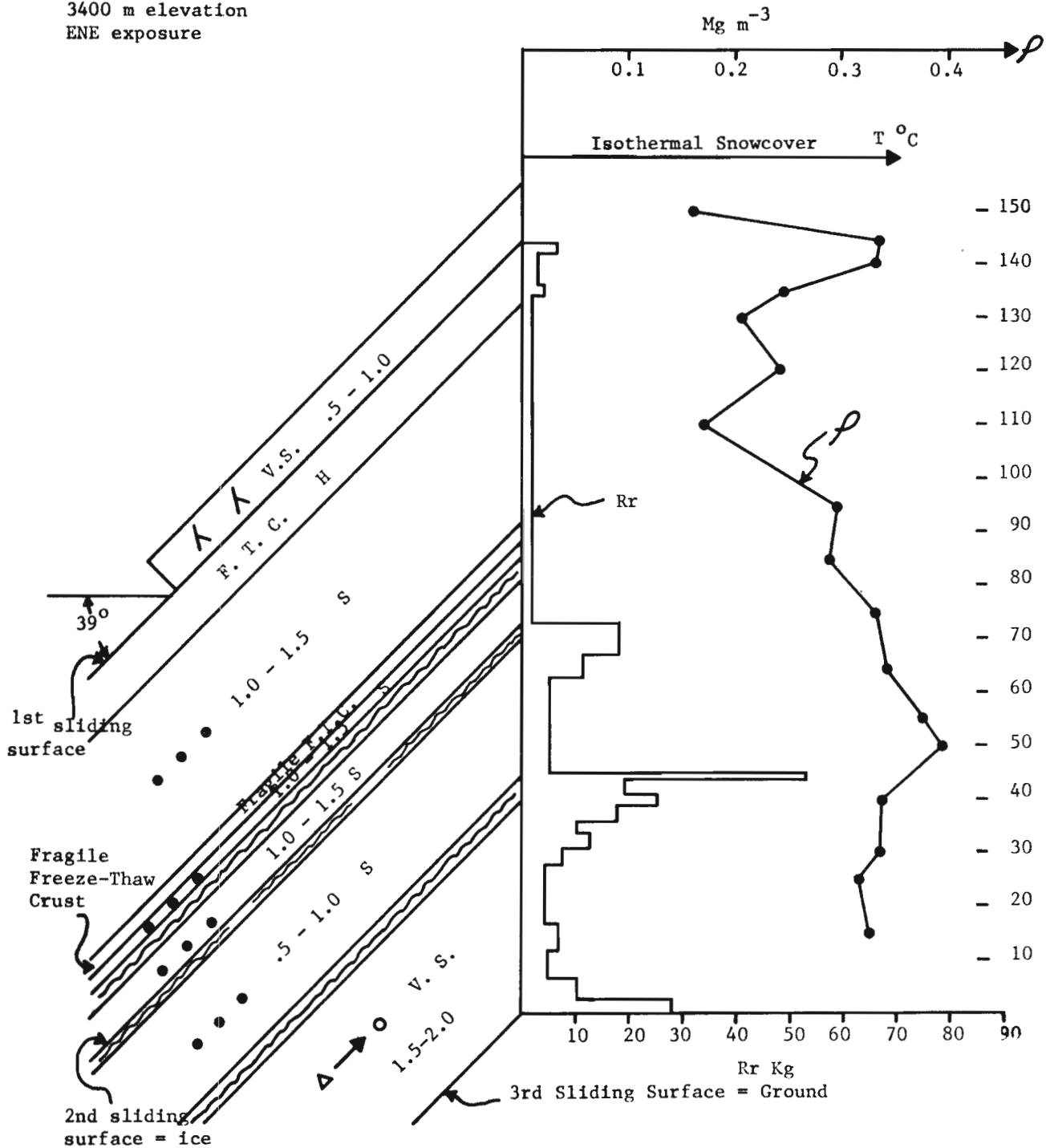




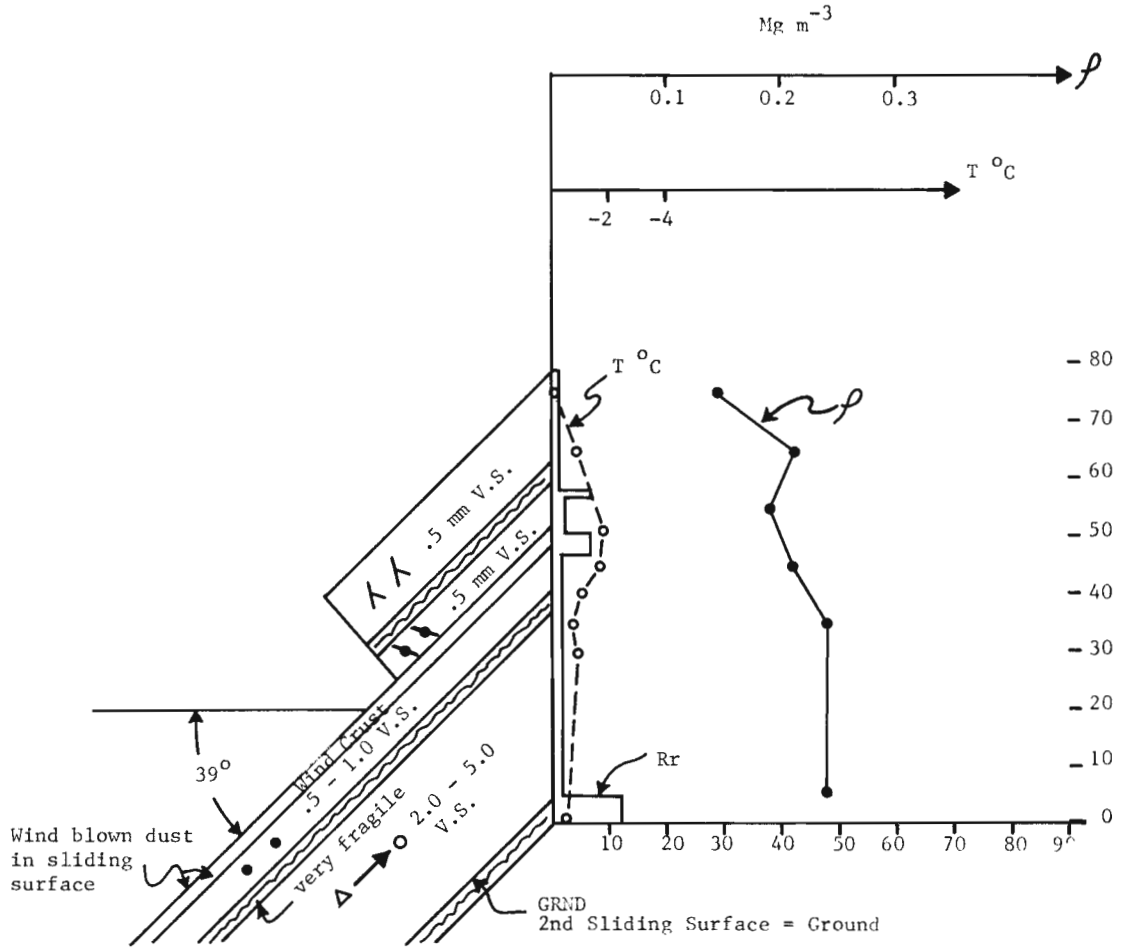
FRACTURE LINE PROFILE # 26  
 Slope between North Carbon  
 and Longfellow Mine  
 February 22, 1974  
 SS-AE-2-0 (Feb. 21, 1974)  
 3500 m elevation  
 NW exposure



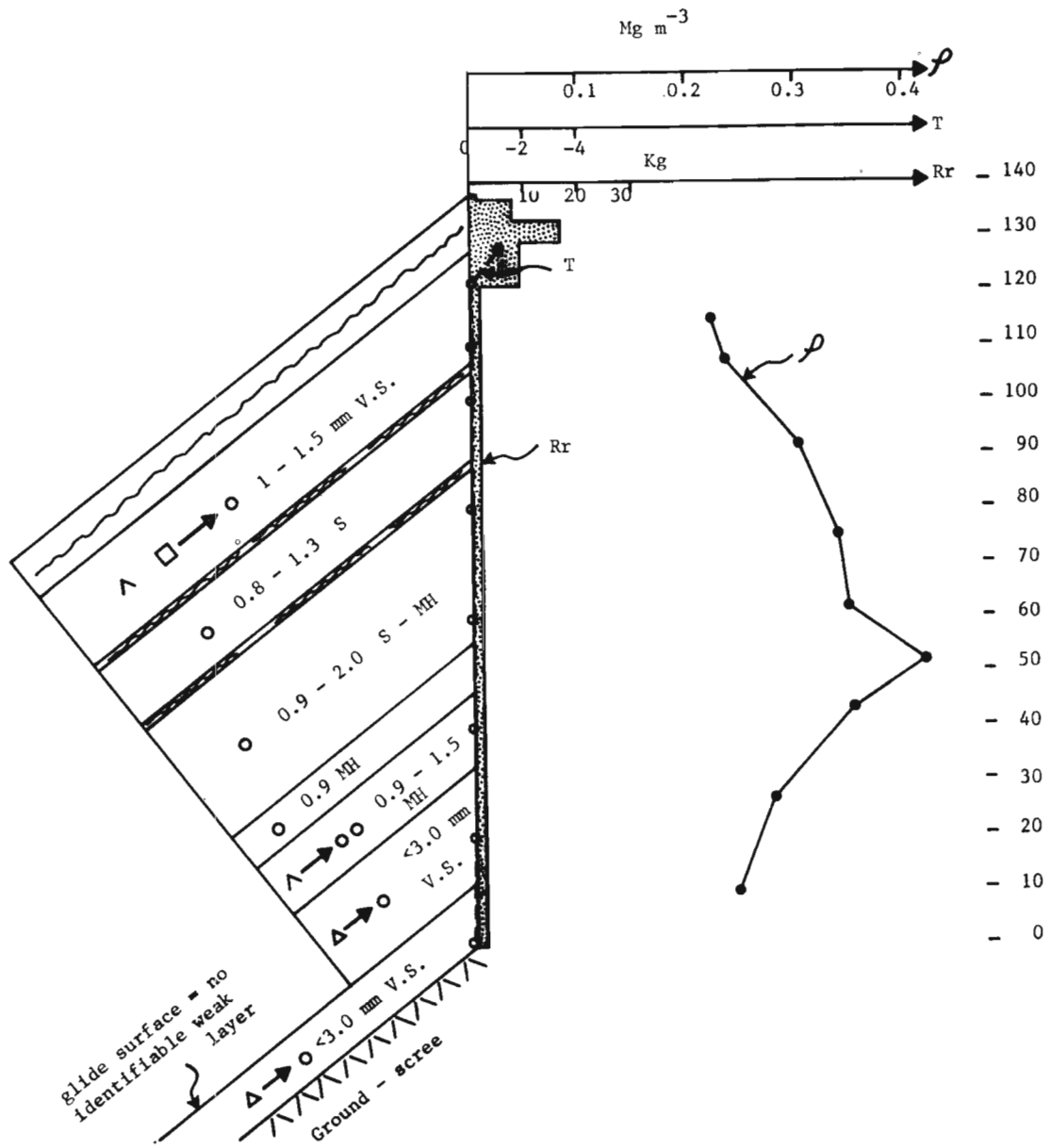
FRACTURE LINE PROFILE #29  
 Willow Swamp Shoulder  
 March 11, 1974  
 SS-N-2-G (Mar. 10, 1974)  
 3400 m elevation  
 ENE exposure



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-3-0 (Mar. 16, 1974)  
 3416 m elevation  
 WSW exposure







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