DRY TILT NETWORK AT MOUNT RAINIER, WASHINGTON

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ABSTRACT

In addition to its primary responsibility of monitoring active Mount St. Helens, the David A. Johnston Cascades Volcano Observatory (CVO) has been charged with obtaining baseline geodetic and geochemical information at each of the other potentially active Cascade volcanoes. Dry tilt and/or trilateration networks were established during 1975-82 at Mount Baker, Mount St. Helens, Mount Hood, Mount Shasta, Lassen Peak, Crater Lake, and Long Valley caldera; coverage was extended during September 1982 to include Mount Rainier.

INTRODUCTION

The dramatic reawakening of Mount St. Helens in March 1980 focused increased attention on the possibility of future eruptions elsewhere in the Cascade Range. Mount Baker had stirred briefly only 5 years earlier, prompting the installation of dry tilt (1975) and trilateration (1981) networks there to monitor possible ground deformation associated with increased thermal activity. A trilateration network was established on Mount Hood in 1980; tilt and trilateration networks were installed at Mount Shasta, Lassen Peak, and Crater Lake during 1981 (Dzurisin and others, 1982a; Chadwick, Iwatsubo, and Swanson, in preparation) and remeasured with null results in 1982. Dry tilt stations were likewise installed at Long Valley caldera during summer 1982, in response to increased seismicity and ground deformation there since 1978 (Dzurisin, Cashman, and Sylvester, 1982b). This program of geodetic surveillance was extended to Mount Rainier during September 1982, to supplement continuous seismic monitoring there by the U. S. Geological Survey and the University of Washington. This report presents station descriptions

and initial measurements of the Mount Rainier dry tilt network; trilateration results will be presented separately.

The last significant eruptive activity at Mount Rainier was between 120 and 160 years ago, and several minor eruptions were reported during the late 1800's. A careful stratigraphic study of the volcano's recent products led Crandell (1973) to conclude that "Mount Rainier will almost surely erupt again sometime within the next few hundred years," and that future eruptions might endanger the livelihood of thousands of people. Hence, the need for careful monitoring of this loftiest peak in the Cascade Range.

In earlier reports of this type (Dzurisin and others, 1982a; Dzurisin, Cashman, and Sylvester, 1982b), we have resisted using the term "dry tilt" owing to its obscure derivation (i.e., as an alternative to water-tube "wet tilt"). Although we still feel that a more accurate descriptive term would be preferable, we have none to offer, and "dry tilt" continues to receive widespread usage in the volcanological community. We have therefore relented in this report, and will henceforth embrace the term "dry tilt", albeit with some reluctance. A description of the dry tilt method has been given by Yamashita (1981).

MOUNT RAINIER DRY TILT NETWORK

Seven dry tilt stations were established on Mount Rainier during 13-17 September 1982 (Figure 1). Rugged glacial topography and extensive perennial snowcover made site selection difficult, but 4 linear and 3 triangular benchmark arrays were eventually installed with helicopter

support. Standard nippled benchmarks were cemented into bedrock according to the procedure outlined by Dzurisin and others (1982a); sub-freezing temperatures necessitated the use of a quick-setting additive at some stations. The southernmost benchmark in each array was labelled X; benchmarks Y and Z were assigned sequentially northward for linear arrays, or counterclockwise for triangular arrays. Station installation is covered in more detail by Yamashita (1981).

MOUNT RAINIER STATION DESCRIPTIONS

The following descriptions are keyed to the 1924 Mt. Rainier National Park 1:50,000 scale topographic map. Dimensions and orientation of each benchmark array are illustrated in Figure 9; equations for calculating tilt from measured elevation changes are given in Table 1.

GLACIER ISLAND (46° 49' 40"N, 121° 49' 00"W)

This triangular array is situated on a small rocky ledge above the Tahoma glacier north of Glacier Island, at roughly 7,200 feet elevation on the southwest flank of Mount Rainier (Figures 1 and 2). The station is likely to be snow covered except during the late summer or early fall. Benchmarks and the central instrument site are marked with small cairns.

SUNSET (46° 51' 32"N, 121° 50' 05"W)

Two benchmarks form a radial array along the prominent ridge which rises above Sunset Park on the west flank of Mount Rainier. The station is located at the south edge of a flat-topped ridge segment between the South Mowich and Puyallup glaciers, at roughly 7,400 feet elevation

(Figures 1 and 3). It should be measured early in the day to avoid looking directly into the afternoon sun. Benchmarks are marked with small cairns.

LOWER CURTIS (46° 54' 10"N, 121° 45' 36"W)

A radial array of three benchamarks is located on a flat-topped knob at roughly 7,000 feet elevation on the north flank of Mount Rainier, roughly 1 km SSW of Mineral Mountain (Figures 1 and 4). The central benchmark (Y) is tucked near the base of a large rock marked with a cairn.

UPPER CURTIS (46° 53' 20"N, 121° 45' 08"W)

This traingular station sits atop a flat segment of Curtis Ridge at roughly 8,700 feet elevation on the north flank of Mount Rainier (Figures 1 and 5). Benchmarks X and Z are located near the west edge of the ridge top; Y is nearer the center. Each benchmark is marked with a small cairn. Benchmark X is co-located with benchmark 7 of the trilateration network.

MEANY (46° 51' 30"N, 121° 39' 53"W)

This triangular station straddles a flat-topped knob at roughly 7,600 elevation, near Meany Crest on the east flank of Mount Rainier (Figures 1 and 6). Benchmarks and the central instrument site are marked with small cairns.

HAZARD (46° 50' 13"N, 121° 45' 41"W)

This radial array of 3 benchmarks is perched below an ice wall near Camp Hazard at 11,600 feet elevation on the south flank of Mount Rainier

(Figures 1 and 7). Each benchmark is marked with a small cairn. Benchmark Y is co-located with benchmark 5 of the trilateration network.

McCLURE (46° 48' 33"N, 121° 43' 28"W)

A radial array of 3 benchmarks hugs the east edge of McClure Rock, a flat-toppped prominence at 7,400 feet elevation along the trail from Paradise to Camp Muir (Figures 1 and 8). Benchmarks are buried beneath small cairns to minimize disturbance by hikers. Benchmark X is co-located with benchmark McClure in the trilateration network.

BASELINE MEASUREMENTS

Relative benchmark elevations at each station were measured with the 2-rod method described by Yamashita (1981), using Wild NA-2 level #436938, Wild GPM-3 optical micrometer #29932, and Wild GPL-3 level rods 5140A and 5140B. Results are given in Table 2.

SUMMARY

Seven dry tilt stations and a trilateration network were installed on Mount Rainier during September 1982 as part of a USGS program to monitor potentially active Cascade volcanoes. Similar networks had earlier been established on Mount St. Helens, Mount Hood, Mount Baker, Mount Shasta, Lassen Peak, and at Crater lake and Long Valley caldera. We estimate that future dry tilt surveys at Mount Rainier should be capable of detecting tilts greater than about 5 microradians. Ideally, the tilt network should be re-measured annually, at least until an adequate baseline is established against which to compare future changes.

ACKNOWLEDGMENTS

The support provided by National Park Service personnel, especially Superintendent William J. Briggle, Ranger William Larson, and Ranger Gary Olson made our work in Mount Rainier National Park safer and easier. We learned again that you're in good hands with helicopter pilot Gary Trailor, who took us where we needed to go.

REFERENCES

Chadwick, W. W., E. Iwatsubo, and D. A. Swanson (1983). Slope distance and vertical angle measurements at Mount Baker, Mount Shasta, Lassen Peak, and Crater Lake, 1981, U.S. Geological Survey Open File Report, in preparation.

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Dzurisin, D., D. J. Johnson, T. L. Murray, and B. Myers (1982a). Tilt networks at Mount Shasta and Lassen Peak, California, U. S. Geological Survey Open File Report 82-670, 42 p.

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Yamashita, K. M. (1981). Dry tilt: A ground deformation monitor as applied to the active volcanoes of Hawaii: U. S. Geological Survey Open File Report 81-523, 21p.

TABLE 1

MOUNT RAINIER STATION EQUATIONS

Glacier Island

$\tau(N) = 0.2030\ \Delta(Y-X) - 0.1775\ \Delta(X-Z)$

$\tau(E) = 0.4162\ \Delta(Y-X) + 0.7120\ \Delta(X-Z)$

Upper Curtis

$\tau(N) = -0.0449\ \Delta(Y-X) - 0.3016\ \Delta(X-Z)$

$\tau(E) = 0.4270\ \Delta(Y-X) + 0.0808\ \Delta(X-Z)$

Meany

$\tau(N) = -0.0589\ \Delta(Y-X) - 0.2568\ \Delta(X-Z)$

$\tau(E) = 0.4192\ \Delta(Y-X) + 0.1365\ \Delta(X-Z)$

Lower Curtis

$\tau(\text{radial}) = 0.3497\ \Delta(Y-X)$

(or)

$\tau(\text{radial}) = 0.3906\ \Delta(Z-Y)$

Hazard

$\tau(\text{radial}) = -0.7862\ \Delta(Y-X)$

(or)

$\tau(\text{radial}) = -0.4124\ \Delta(Z-Y)$

McClure

$\tau(\text{radial}) = -0.4292\ \Delta(Y-X)$

(or)

$\tau(\text{radial}) = -0.6969\ \Delta(Z-Y)$

Sunset

$\tau(\text{radial}) = 0.2350\ \Delta(Y-X)$

Tilts are expressed in microradians, elevation changes in thousanths of a centimeter. For linear arrays, positive tilts are outward from the summit (i.e., summit up).

TABLE 2

MOUNT RAINIER BASELINE DRY TILT MEASUREMENTS
15-16 September 1982

STATION NAME	Y-X	X-Z	Z-Y
Glacier Island	-59.524 cm	+222.297 cm	-162.773 cm
Upper Curtis	-6.786	-206.435	+213.221
Meany	-99.531	-34.454	+133.985
Hazard	-232.586	-	-238.558
McClure	-45.770	-	-178.352
Lower Curtis	+101.783	-	not measured
Sunset	+148.752	-	-

MOUNT RAINIER TILT STATIONS

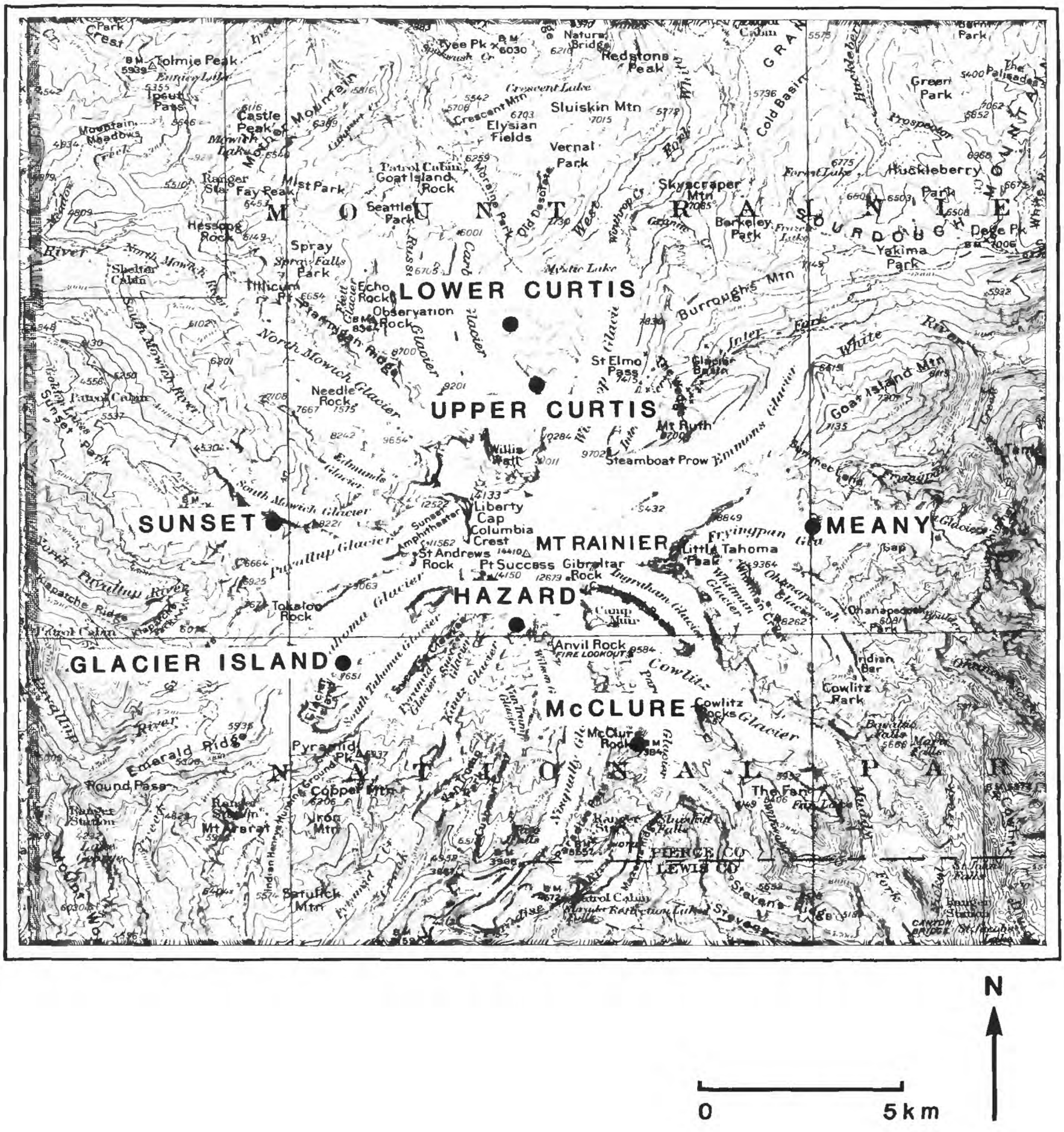


Figure 1. Mount Rainier dry tilt network, shown on 1924 Mount Rainier National Park 1:50,000 scale topographic map.

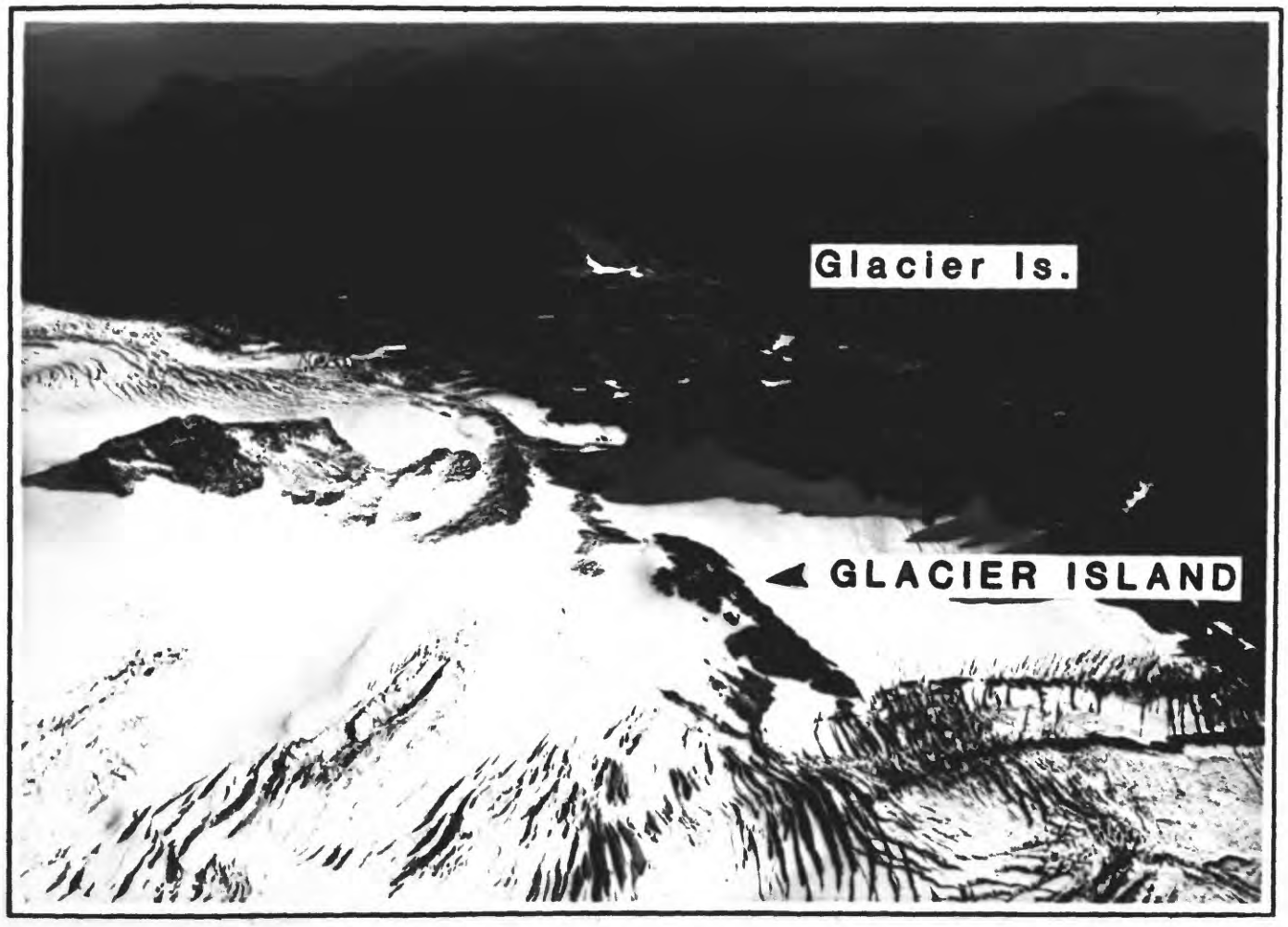


Figure 2. View southward of GLACIER ISLAND dry tilt station. Southeast margin of the Tahoma glacier is visible in the foreground. Photograph taken 17 September 1982.

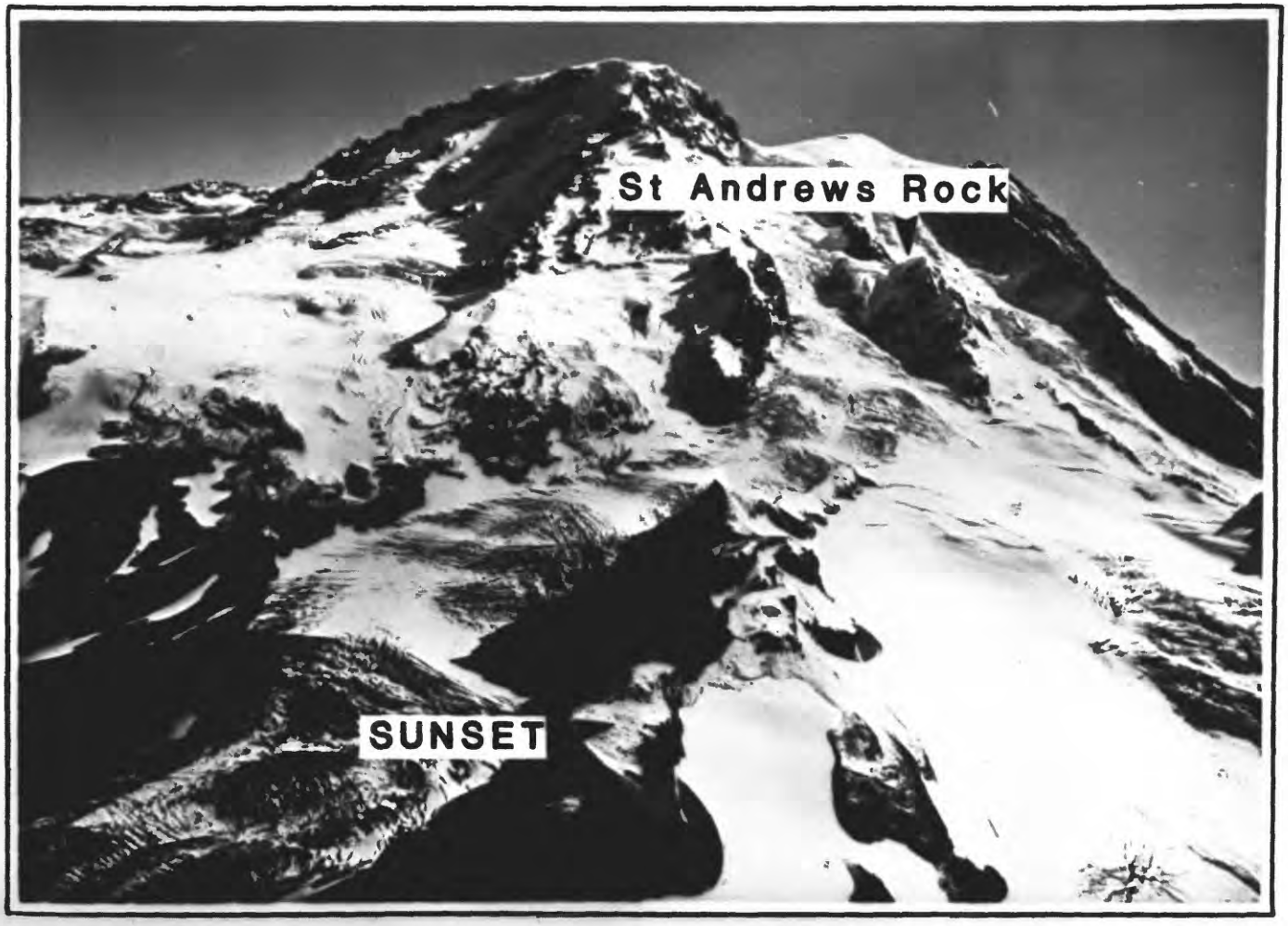


Figure 3. Aerial view looking east of the SUNSET dry tilt station, along the cleaver between the South Mowich and Puyallup glaciers. Photograph taken 17 September 1982.

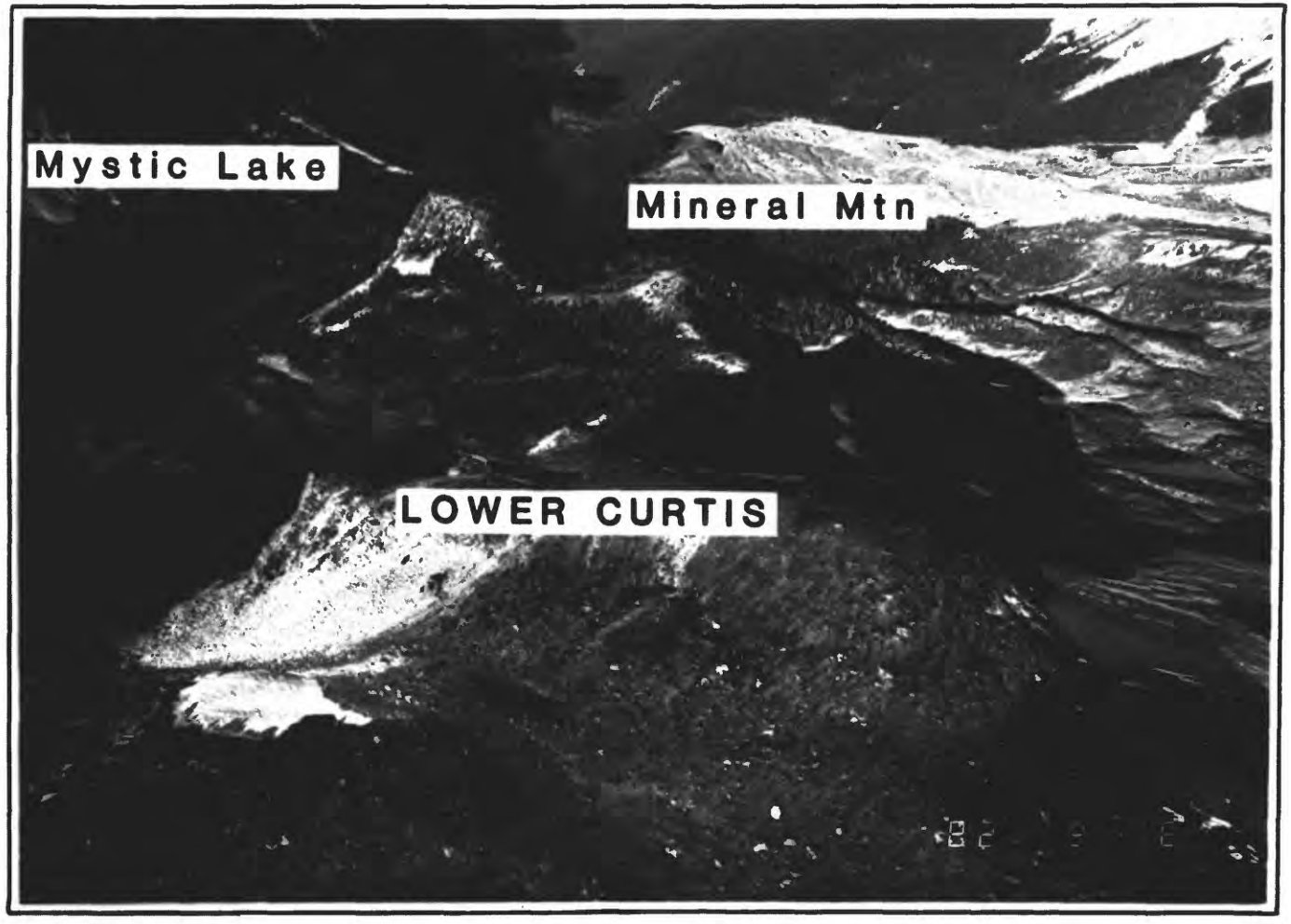


Figure 4. View northwestward from LOWER CURTIS dry tilt station along the northward extension of Curtis Ridge. Photograph taken 17 September 1982.

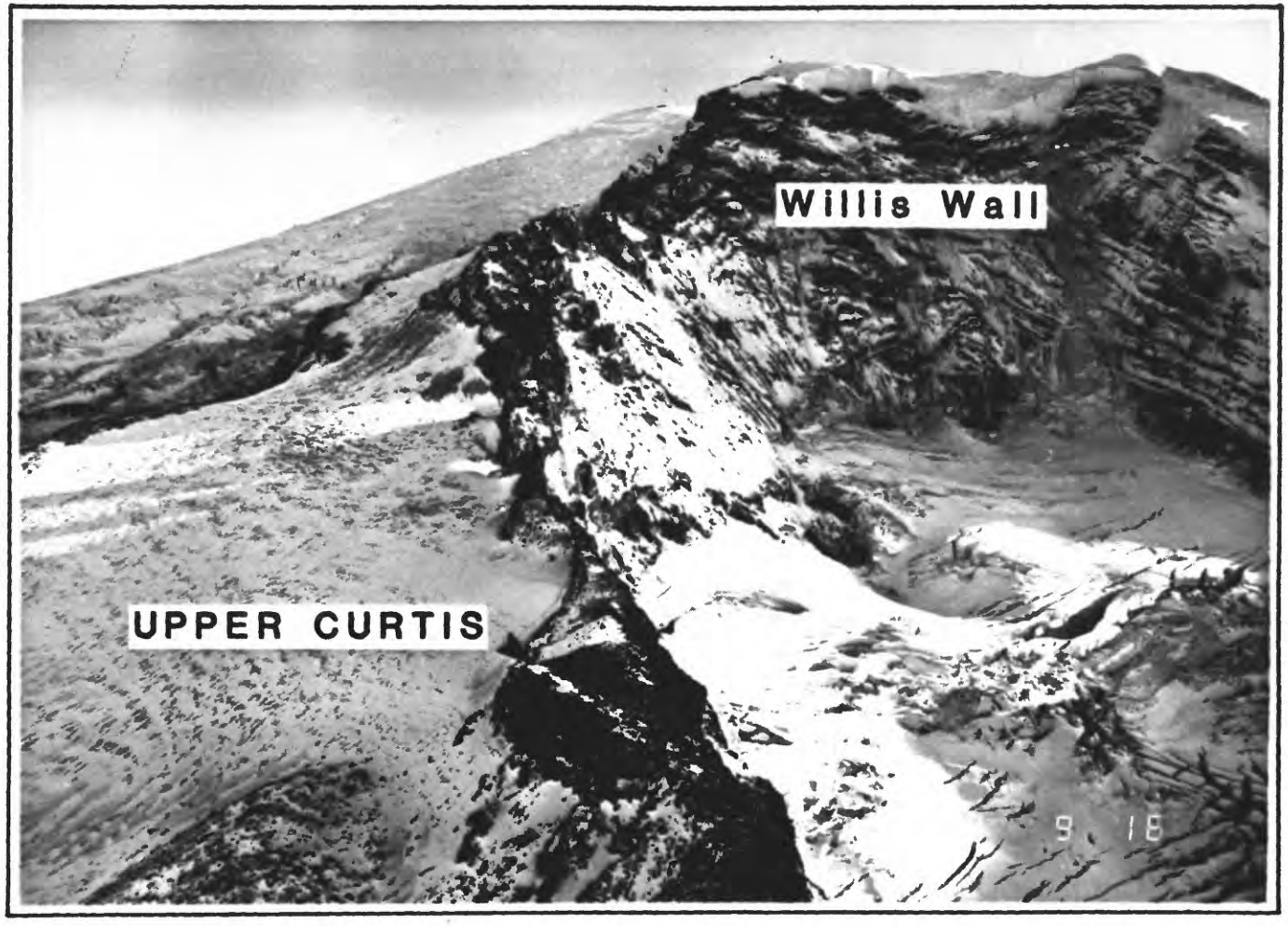


Figure 5. View southward of UPPER CURTIS dry tilt station and Willis Wall. Photograph taken 17 September 1982.

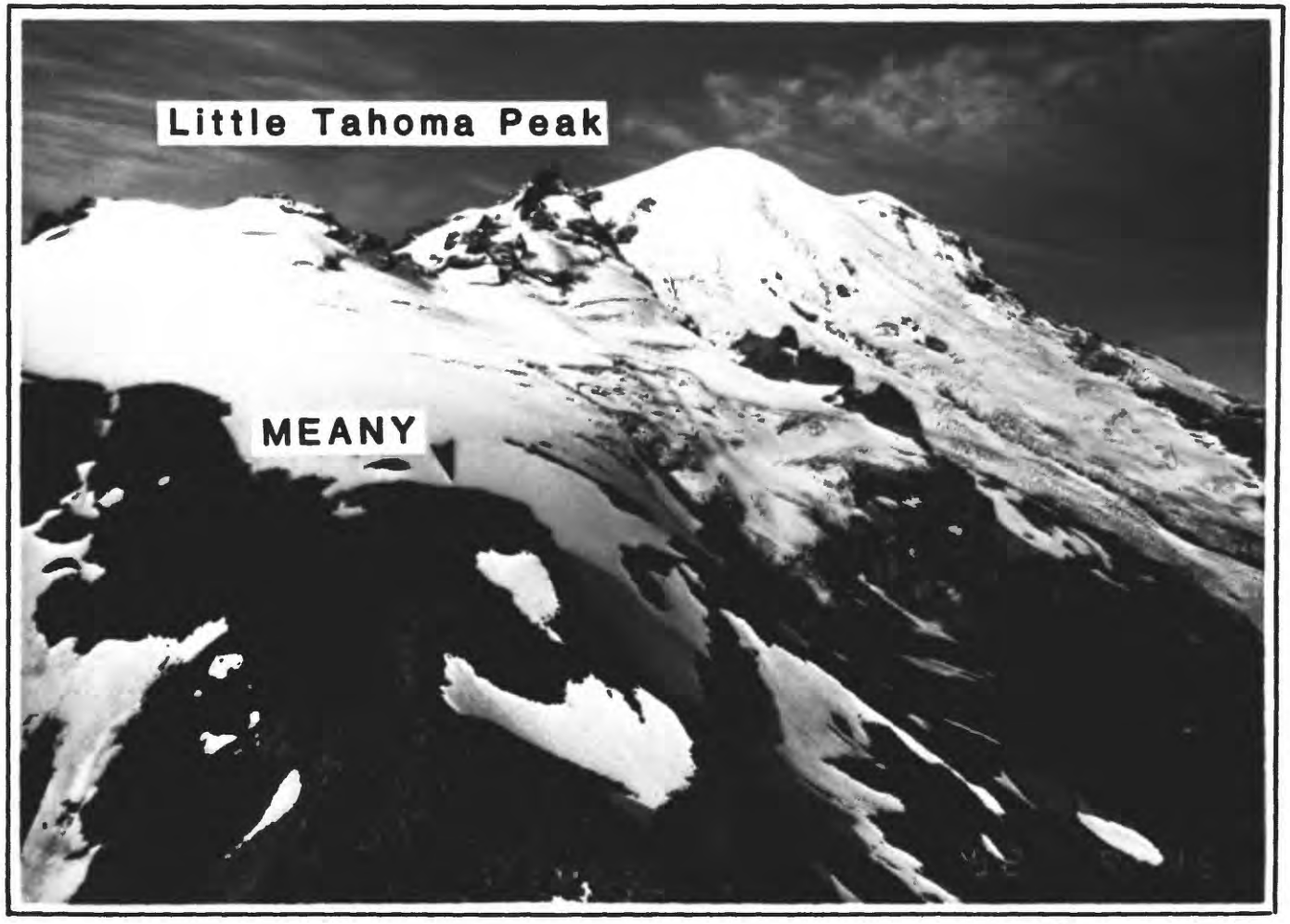


Figure 6. Aerial view looking westward toward MEANY dry tilt station, at the base of the Fryingpan glacier. Photograph taken 17 September 1982.

Figure 7. Northward view of HAZARD dry tilt site, at the base of an ice wall near Camp Hazard. Photograph taken 17 September 1982.

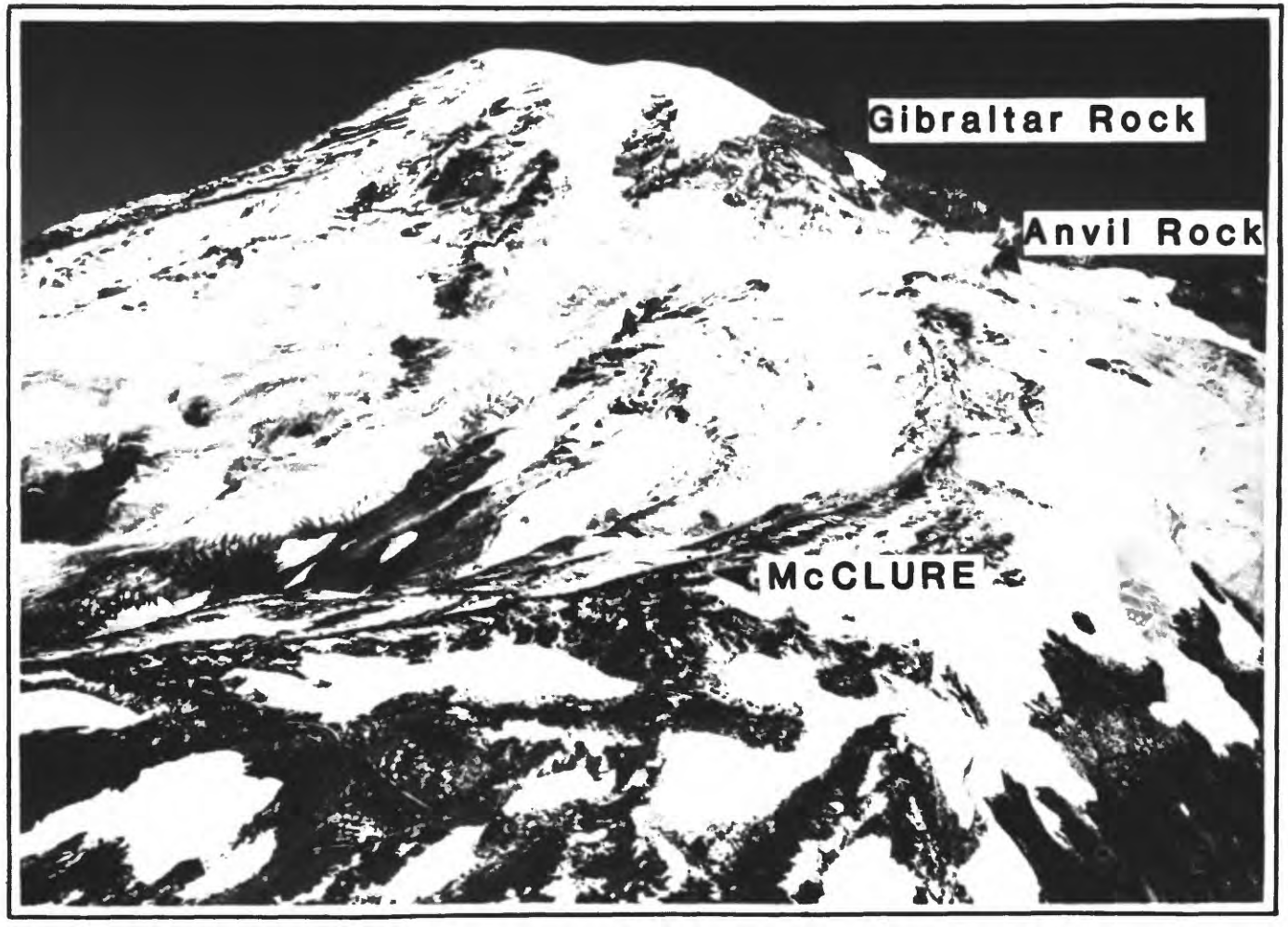
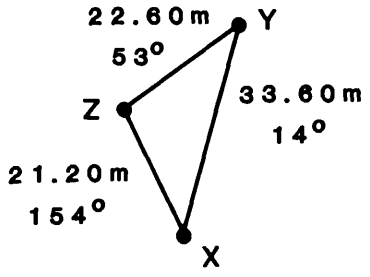


Figure 8. View of Mount Rainier from the south, showing McCLURE dry tilt station along the trail from Paradise to Camp Muir. Photograph taken 17 September 1982.

STATION LAYOUTS

GLACIER ISLAND



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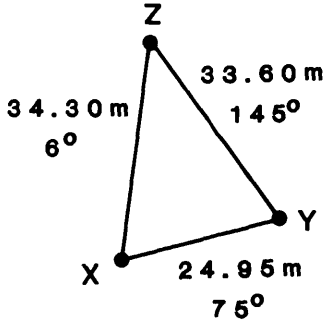

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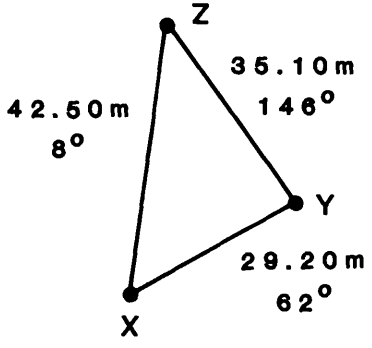
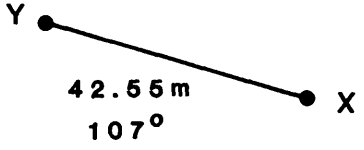
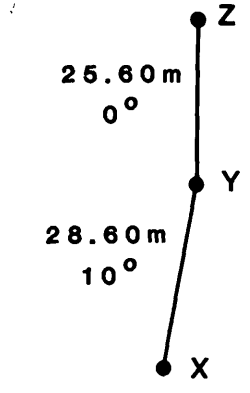


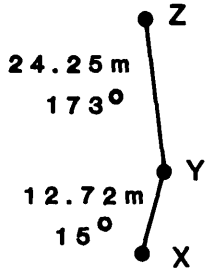
SUNSET



LOWER CURTIS



HAZARD



McCLURE

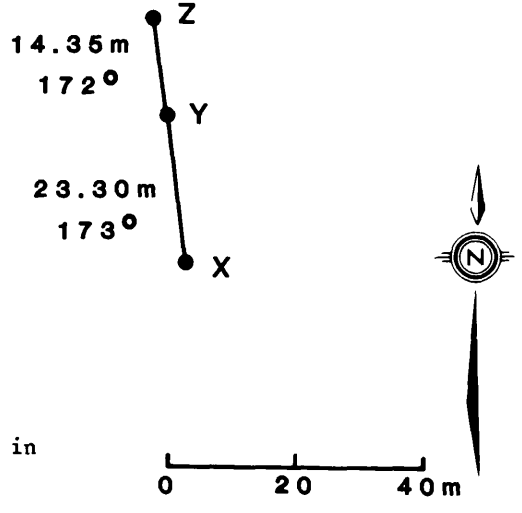


Figure 9. Layouts of 7 dry tilt stations established on Mount Rainier in September 1982.