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PRELIMINARY REPORT ON GEOTHERMAL RESOURCE INVESTIGATIONS AT MT. SPURR, ALASKA

By

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Alaska Division of
Geological and Geophysical Surveys

in cooperation with

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THIS REPORT HAS NOT BEEN REVIEWED FOR TECHNICAL CONTENT (EXCEPT AS NOTED IN TEXT) OR FOR CONFORMITY TO THE EDITORIAL STANDARDS OF DGGS.

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PREFACE

This report was submitted as an informal interagency quarterly progress report to the United States Department of Energy (DOE) on September 30, 1985. It is a preliminary description of work performed by the University of Alaska Geophysical Institute and the Alaska Division of Geological and Geophysical Surveys, under contract to DOE, during the summer of 1985. It does not contain the detailed interpretation of the data, or the final reductions of the additional CSAMT data, which will be presented in the final report on July 8, 1986. Any conclusions or statements regarding geothermal potential should be regarded as tentative. The release of this report is intended to provide basic data to individuals or companies who want to know what geothermal exploration work has been done as an aid in decision-making concerning the call for applications for a proposed geothermal lease sale which was issued by the Alaska Division of Oil and Gas on November 21, 1985.

After this report was submitted to DOE, DGGS completed the analysis of the warm spring water collected during the 1985 field season. The analysis of the water, an analysis of Crater Peak fumerole gas collected during the summer of 1982, and temperature estimates from several standard fluid geothermometers are appended to the back of this report. We urge that particular caution be used in interpreting these data. The warm spring water appears to be a mixture of water from diverse sources, and we consider interpretation of the results of the geothermometers to be problematic.

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Geothermal Energy Assessment of Mt. Spurr, Alaska

by

Eugene M. Wescott and Donald L. Turner

Geophysical Institute, University of Alaska-Fairbanks

Introduction

During this quarter a major field expedition was carried out in the Mt. Spurr, Alaska area. Starting on July 18, 1985, a camp was established at the 2400-foot level on a plateau on the south side of Mt. Spurr. An Otter fixed-wing aircraft ferried three planeloads of supplies, equipment and nine personnel to the site. A helicopter fuel supply had to be established about 8 miles to the west on the shore of Lake Chakachamna.

During the next three weeks we carried out geophysical, geological and geochemical surveys in the Mt. Spurr area. We also supplied the logistical support for the joint Alaska Division of Geological and Geophysical Surveys (ADGGS) petrochemistry and field mapping program conducted by Dr. Chris Nye. Dr. James Beget of the University of Alaska, a specialist in Quaternary geology and tephrochronology, was a guest investigator for the first week and worked with Dr. Nye on studies of Mt. Spurr's eruptive history.

The Mt. Spurr exploration had two main objectives:

1. To determine whether the volcanic history of Mt. Spurr is consistent with the formation of a caldera which might be underlain by a high-level silicic magma chamber.
2. To explore for accessible geothermal resource prospects with various geophysical and geochemical techniques.

The south side of Mt. Spurr was the site of a State of Alaska geothermal lease sale several years ago. Only one tract, Section 10, was leased. The lease holders employed a geothermal consultant, Bruce Gaugler, who was working in the area during part of our expedition. We cooperated in providing some helicopter transport to clear landing zones in Section 10, and conducted some geochemical and electrical survey work there.

The Surveys

A. Hot Springs: Until our expedition, no hot springs had been reported in the Mt. Spurr area. We found a hot spring and a series of seeps in a canyon on the southwest side of the most recent active vent, Crater Peak. The spring was located about 10 feet above the canyon floor flowing out of the contact between a lava flow and an overlying volcanic debris flow. The temperature measured 40°C with an estimated flow rate of 20 liters per minute. Water samples were taken for chemical analysis, which is being done by ADGGS.

B. Mercury Soil Concentration Sampling: Two hundred and two soil samples were taken at 189 stations on the south side of Mt. Spurr, primarily in the accessible areas above the extensive alder cover. The flanks of Crater Peak were intensively sampled. Preliminary analyses of soil and tephra samples for mercury were performed in the field using a Jerome Instruments model 301 gold foil mercury detector. The presence of anomalous Hg concentrations, particularly on the flanks of Crater Peak, was used to direct other survey activity in that area. The samples have now been re-analyzed in the lab. Plate 1 shows the mercury concentrations above a background value of 5 ppb.

C. Helium Soil Sampling: Fifty-five helium soil samples and one hot spring water sample were collected and sent to Chemical Projects Ltd., Toronto, for analysis of He and light hydrocarbon concentration. The He content of the hot spring water was low, suggesting mixing with ground water. Overall, the He soil gas values tended to be higher than atmospheric background. For 40 soil samples the mean background was 5.47 ppm with 10 samples of 8.0 ppm or greater and 16 samples of 6.0 ppm or greater. Sixteen mud (water saturated soil) samples had a mean background of 9.42×10^{-8} (cc gas at NTP/cc of mud). Five samples were greater than 18×10^{-8} and seven were greater than 15×10^{-8}. The high He values were clustered on the south flank of Crater Peak, generally in an area of high mercury concentrations, and also in an area of low swamps and small hills about 4 miles to the east. Plate 2 shows the He sample values.

D. Self-Potential Surveys: Twenty-five km of electrical self-potential survey lines were surveyed on the flank of Crater Peak. All lines tied to less than 50 milli-volts. The data were taken using a fixed reference electrode, long lines of 32-gauge copper wire and high input impedance digital voltmeters. Telluric currents were recorded continuously at the base camp. The data show a strong correlation of negative potential versus elevation on the south flank of Mt. Spurr. This gradient of -78 mV/ft has been removed from the data, and the area of strong anomalies contoured on Plate 3. The anomalous helium and mercury values are shown as bold face H and M's respectively. There is a zone running roughly northeast containing S-P anomalies together with high helium and mercury values. The largest S-P anomaly is a dipolar pattern of total amplitude 1300 mV, which is surrounded by anomalous mercury and helium soil values. No soil samples were taken in the S-P anomaly area. There are two negative anomalies of -500 and -600 mV which seem to correspond with helium anomalies. The solid triangle on Plate 3 shows the location of the CSAMT #14 station which showed the lowest resistivity at a depth of about 600 m. Some additional S-P lines were run in the area of the camp plateau.

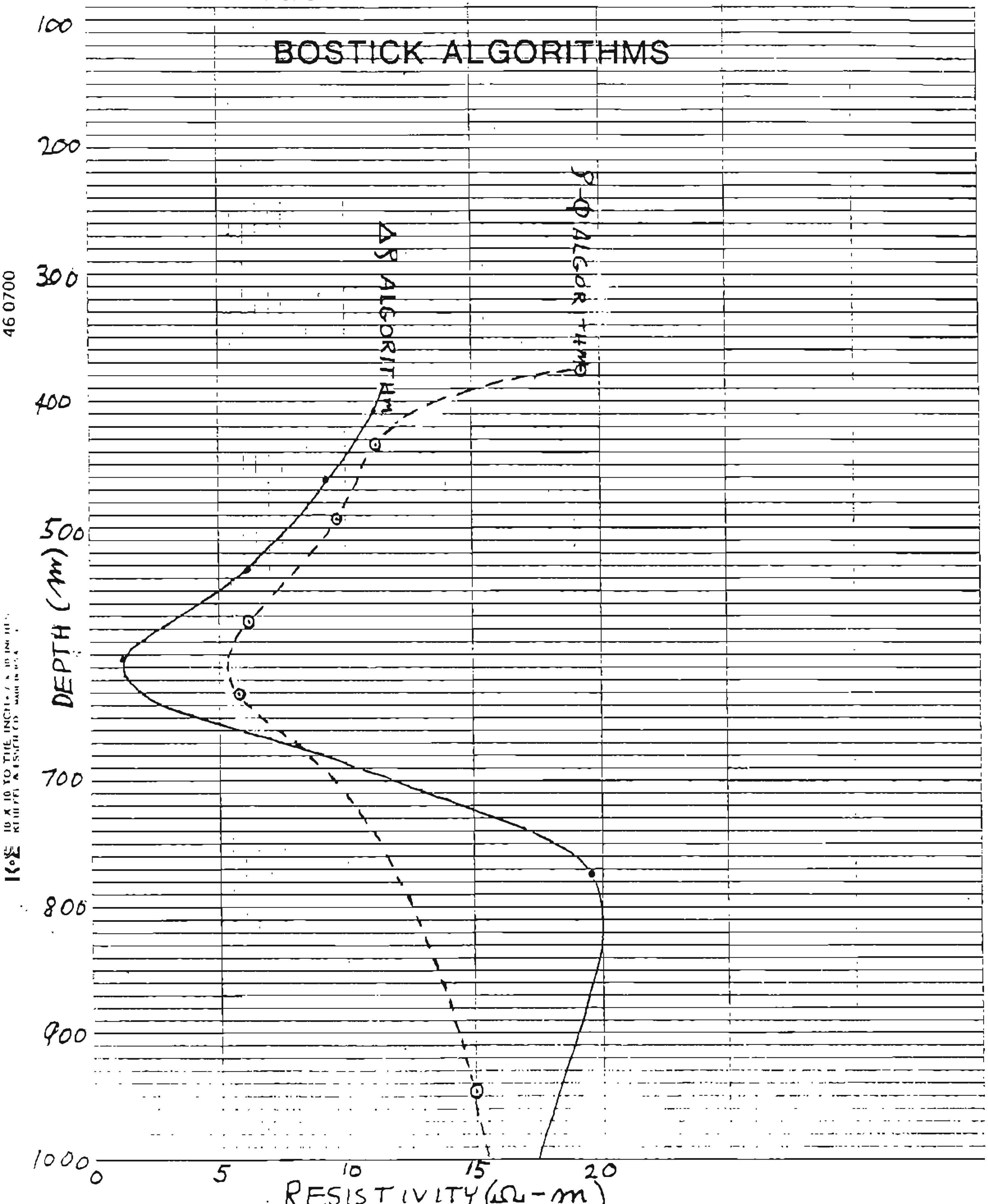
E. Controlled Source Audio-Magnetotelluric Resistivity: The CSAMT technique of resistivity sounding was a major part of our exploration program to locate zones of anomalous resistivity in the Mt. Spurr area. We used a 20-ampere transmitter into grounded dipoles as our signal source. Plate 1 shows the location of the two transmitter sites. Twenty-four CSAMT soundings were made, two of which were repeats using both transmitter sites. Natural telluric current activity proved to be a problem during most of the time we were operating. The last day, however, the activity became very low and we were able to obtain data at a site 17 km away from transmitter site 2. Afternoon sferics due to lightning strikes also caused problems with the low frequency readings.

However, we obtained some excellent data typically to a depth of about 1 km. Figure 1 shows the resistivity versus depth approximated by the Bostick inversion algorithm for CSAMT site 14 shown on Plate 3 in the He, Hg and S-P anomaly area near the 3500-foot level of Crater Peak. The resistivity is less than 10Ω-m at about 600 m depth. All other curves show a higher resistivity minimum. Over the area covered, all curves show a transition from the far field to near field around 1-2 hz. We are working on techniques to extend the data deeper through this region.

F. Radar Ice Depth Soundings on Mt. Spurr: One of our project goals was to determine whether the Mt. Spurr area is a collapsed caldera. To this end we used a radar system to measure ice depths on the glaciers surrounding the central Mt. Spurr peak. The USGS had previously measured one ice depth

FIGURE 1. CSAMT SITE 14

BOSTICK ALGORITHMS



northwest of the peak at 385 m. None of our measurements agreed with the USGS depth. Most were near 100 m. These data are yet to be analyzed.

G. <u>VLF EM-16R Ice Depth Measurements</u>: We also made measurements of the Mt. Spurr ice field depths using the Hawaii VLF radio signal ratio of E/H and phase. For a two-layer case we have three parameters and two equations. If we specify the ice resistivity, then we can calculate the ice depth and the resistivity of the underlying rocks. Assuming a nominal 100,000Ω-m resistivity, ice depths somewhat deeper than the radar depths were calculated. However, reasonable assumptions for resistivity of glacier ice are difficult to make here due to unknown amounts of water and volcanic particulates in the ice which could radically alter actual resistivity values.

Interim Report on Geological Work at Mt. Spurr, Alaska

by

Christopher Nye

Alaska Division of Geological and Geophysical Surveys

As part of a collaborative University of Alaska Geophysical Institute (UAGI) - Alaska Division of Geological and Geophysical Surveys (ADGGS) investigation of the geothermal potential of the Mt. Spurr area, ADGGS undertook a geological investigation of the volcanic rocks in the Mt. Spurr area. The principal aims of this investigation were to describe the geology of the volcano, to look for surface manifestations of a geothermal system and to determine whether or not there is an extensive shallow level magma chamber. Such a chamber, if it existed, would provide large quantities of heat to the upper crust, and would probably drive a large geothermal system.

We recognize five major volcano-stratigraphic units within the Mt. Spurr area. The first, and oldest, is a set of volcanic remnants which dip radially outward (quaquaversally) from near the present position of the Mt. Spurr summit. These remnants are composed of interbedded lava flows of diverse composition, thick pyroclastic flows, and dikes and sills. Based on the degree of glacial dissection we suspect that they are mid-Pleistocene, and will confirm or correct this age by measuring K-Ar ages. K-Ar dating is now in progress at UAGI on eight rock samples from several of the major volcano-stratigraphic units discussed here.

The second unit is one of thin interbedded basalt flows. These flows are exposed in erosional remnants immediately east and west of, and dip away from, Crater Peak. We believe that these flows are from an ancestral Crater Peak, and that they were erupted during the early Holocene.

The third unit comprises the basalt flows of Crater Peak itself, which is a small Holocene volcano with a well defined summit crater and crater lake. Both Crater Peak and the ancestral Crater Peak (the second unit) contain many flows which are petrologically distinct from flows of the first unit because they contain abundant polycrystalline, monomineralic, clinopyroxene clots.

The fourth unit comprises Mt. Spurr itself. Mt. Spurr is also a Holocene vent which has a breached, snow-filled crater. It is usually snow covered, but we were able to collect a few andesite or dacite samples from areas which were snow free because the snow had been melted off by diffuse fumaroles.

The fifth unit is a thick series of pyroclastic flows and minor lava flows which fills the Chakachatna River valley. This unit was of interest because we believed that it could be related to a postulated caldera-forming eruption. An area of hummocky terrane immediately to the east may be a debris avalanche deposit. This deposit is discussed by Beget in a separate section of this report (see Figure 3).

Has There Been Recent Caldera Collapse?

We initially hypothesized that a large shallow magma chamber existed because it seemed that Mt. Spurr might have undergone relatively recent caldera collapse. Caldera collapse requires a large shallow magma chamber to drive the eruption, and these chambers are usually not completely emptied during the eruption. Evidence of a caldera collapse was sparse because there had not yet been detailed geological studies of the volcano, but included 1) possible presense of remnants of a volcanic edifice which appeared to dip radially outward from the present location of Mt. Spurr, 2) reports by USGS of anomalously thick ice in the summit ice field, which could have been caldera fill, and 3) an extensive pyroclastic and/or volcaniclastic blanket in the Chakachatna River valley which could have been produced by the hypothesized caldera-forming eruption.

We are still uncertain if the quaquaversally dipping flows require relatively recent sector or caldera collapse of an ancestral Mt. Spurr. We have collected rocks from the uppermost part of this hypothesized edifice for K/Ar dating. If the K/Ar ages are unmeasurably young, then some violent evisceration of an ancestral volcano must have taken place. However, we do not anticipate that these rocks will be that young. The degree of glacial dissection of the hypothesized caldera rim (particularly by the Capps and Straight Creek glaciers) suggests that the quaquaversally dipping flows are mid-Pleistocene, and hence too old to be associated with a modern, caldera-related hydrothermal system.

UAGI geophysical efforts were unable to confirm the USGS reports of anomalous ice thickness in the summit ice field. This, along with the latest detailed USGS computer modeling (Gail March, personal communication) of the local subglacial topography, makes it seem unlikely that there is a large ice-filled caldera in the summit region.

There is a 1000-foot thick unit composed of volcaniclastic flows with a few interbedded lava flows and avalanche deposits which fills the Chakachatna River valley south of Crater Peak. Because these flows fill what is otherwise a major, deeply glacially scoured valley, we suspect that they are post-Pleistocene. However, these deposits are not characteristic of those produced during caldera collapse. Rather than being a single, homogeneous deposit, this unit is composed of many discrete flows which differ from each other in mode of emplacement as well as composition. The dominant lithology is block and ash flows which are usually only a few meters, or a few tens of meters thick, although the valley south of Crater Peak exposes a flow several tens of meters thick. Blocks in these flows often have the large polycrystalline clinopyroxene clots which are characteristic of Crater Peak lavas, but are not characteristic of lavas from the old quaquaversally dipping remnants. Some of the flows are subglacial hyaloclastites, which suggests that the whole unit was deposited over a significant time span, as the glaciers must have been at different stages of advance during different times of deposition.

This unit does not have the homogeneous nature of a caldera-forming deposit. It is also mostly composed of juvenile magma; it is not composed of the re-transported avalanche debris that would be expected if it was produced during sector collapse. We expect that this unit is a distal pyroclastic apron that was produced during the formation of Crater Peak or the ancestral Crater Peak.

Surface Geothermal Manifestations

Surface geothermal manifestations were more abundant than we had anticipated. There is a kilometer-long zone of warm springs in the bottom of the valley immediately south of Crater Peak. We sampled 40°C water from a seep in the eastern wall of the canyon, but have not yet analyzed the sample. Most of the springs are in the valley bottom and are extensively diluted with stream water. Total warm water flow for the entire valley bottom is probably on the order of a thousand liters per minute.

We were aware that Crater Peak crater contained fumaroles, but were surprised to find that there is also fumarolic activity on Mt. Spurr. At the 10,000-foot level on Mt. Spurr there are extensive areas of steaming ground that are probably at the pressure boiling point.

Three miles northeast of Mt. Spurr, at about the 9,500-foot level, we saw an ice cave with icicles hanging from the mouth. Snow does not melt at that altitude so the icicles indicate geothermal activity beneath the ice. We were unable to land the helicopter at the cave.

With the exception of the Crater Peak fumaroles, all surface geothermal manifestations were unexpected. Geothermal activity indicates a north-south zone of hot ground from south of Crater Peak to north of Mt. Spurr. There is thus excellent potential for a substantial geothermal resource in the area, but most of it may be covered with ice.

Postglacial Tephrochronology and Volcanic History of Mount Spurr, Alaska: A Preliminary Report

by

James E. Beget

Department of Geology and Geophysics

University of Alaska-Fairbanks

Abstract

Preliminary fieldwork suggests that tephra deposits from eruptions of three volcanoes are present on the flanks of Mt. Spurr. The oldest tephras appear to have originated at the Mt. Hayes volcano to the northeast. Younger deposits consisting of fine pumice lapilli and ash may have been produced at large eruptions of Mt. Redoubt to the southwest. Still younger tephra deposits record eruprions of Mt. Spurr. Cross-bedded surge deposits preserved on the south side of the volcano, together with a voluminous rockfall-avalanche and pyroclastic flow deposits preserved along the Chakachatna River may record a recent eruption similar to the 1980 Mt. St. Helens event.

Introduction

All large high-temperature geothermal systems known in the world are associated with active volcanic systems. During late July, 1985, I made a reconnaissance survey of tephra deposits (volcanic ash and pyroclastic flows) preserved on the flanks of Mt. Spurr, to estimate the number and size of Holocene eruptive events at the volcano. Other than the 1953 eruption of

Crater Peak, a small parasitic crater on the south shoulder of Mt. Spurr, virtually nothing is known about the volcanic history of this volcano.

Reconnaissance was accomplished in four days of helicopter-supported field work.

Tephra Stratigraphy

Approximately 20 soil sections were described, measured, and sampled for tephra and ^{14}C dating. All sections were on the south and east flanks of the volcano. Composite proximal and distal tephra sections are shown in Figure 2. Two fine-grained tephras were present in both proximal and distal sections. They did not coarsen or thicken in sections closest to Mt. Spurr, indicating they originated at other volcanoes. Based on separate surveys by this author, the lower tephra is tentatively correlated with Hayes River tephra, erupted ca. 3600 yr B.P. (J. Riehle, personal communication). The upper regional tephra is thought to originate at Mt. Redoubt (Beget, unpublished mapping). Laboratory work is currently proceeding to establish this correlation.

Thick ash and pyroclastic deposits from Mt. Spurr occurred above the regional tephras in sections on the south side of Mt. Spurr. These deposits locally consisted of coarse pyroclastic deposits which contained abundant exotic blocks, overlain by fine-grained surge deposits, in turn overlain by pyroclastic flows. In many sections only one or two parts of the tephra pile were present. The cross-bedding in the surge deposits was only clearly exposed in two localities, however correlative(?) fine ash deposits mantled ridges and slopes on all slopes south of the volcano to a distance of 10-15 km from the modern cone.

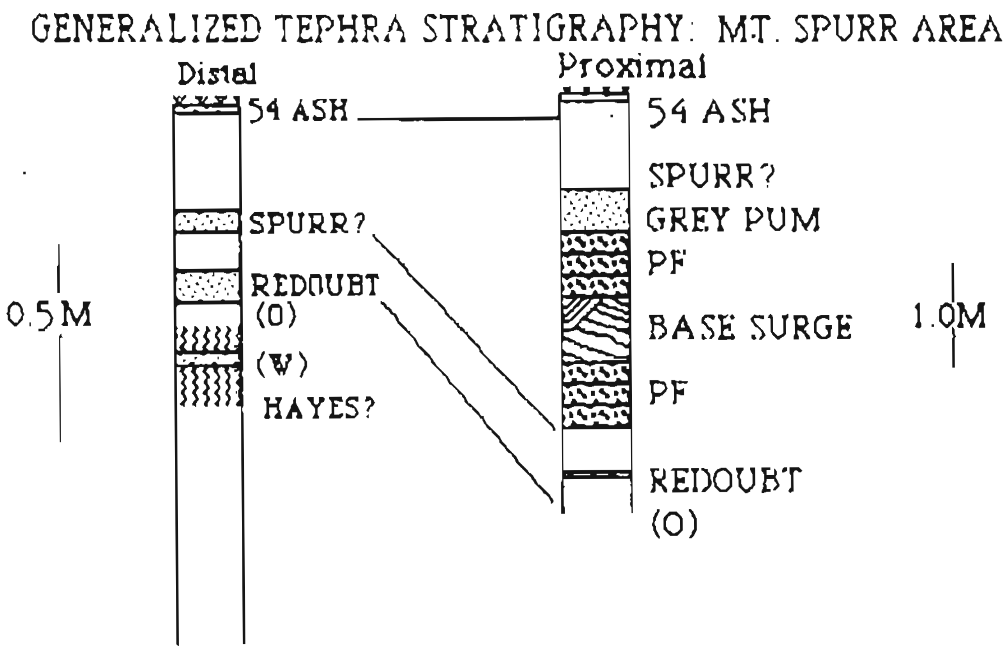


Figure 2. Distal soil sections found from 10-30 km from Mt. Spurr. Proximal soil sections occur on south flank between Mt. Spurr and Chakachatna River, some 4-10 km from Mt. Spurr.

A possibly correlative rockfall-avalanche deposit extends approximately 11 km down the Chakachatna River valley. The debris avalanche contains many coherent blocks of lava, visible on topographic maps as local knolls (Figure 3). In exposures along the Chakachatna River, these blocks are seen to be rotated and fractured. The blocks lie in less coherent heterolithic volcanic debris, including much hydrothermally-altered material. Pyroclastic flows are locally preserved on the avalanche surface. The base of the rockfall-avalanche was not exposed anywhere along the Chakachatna River, which has cut down over 100 m into the deposit. The deposit covers about 30 km^2. Its minimum volume is 3 km^3.

Conclusions

The reconnaissance tephra survey suggests Mt. Spurr erupted dacite tephra and pyroclastic flows within the last few thousand years. It is possible the debris avalanche deposit, surge, and pyroclastic flow deposits at Mt. Spurr record a volcanic eruption similar to the 1980 eruption of Mt. St. Helens. Geological evidence of large recent eruptions suggest Mt. Spurr is still active, and may be a viable geothermal target.

Future Work

Additional study is needed to determine the age of the last major eruption of Mt. Spurr. Further reconnaissance on the east and north sides of the volcano would be useful in identifying tephra falls from eruptions which occurred on those sides of the volcano, or which were directed away from the south flank by prevailing winds.

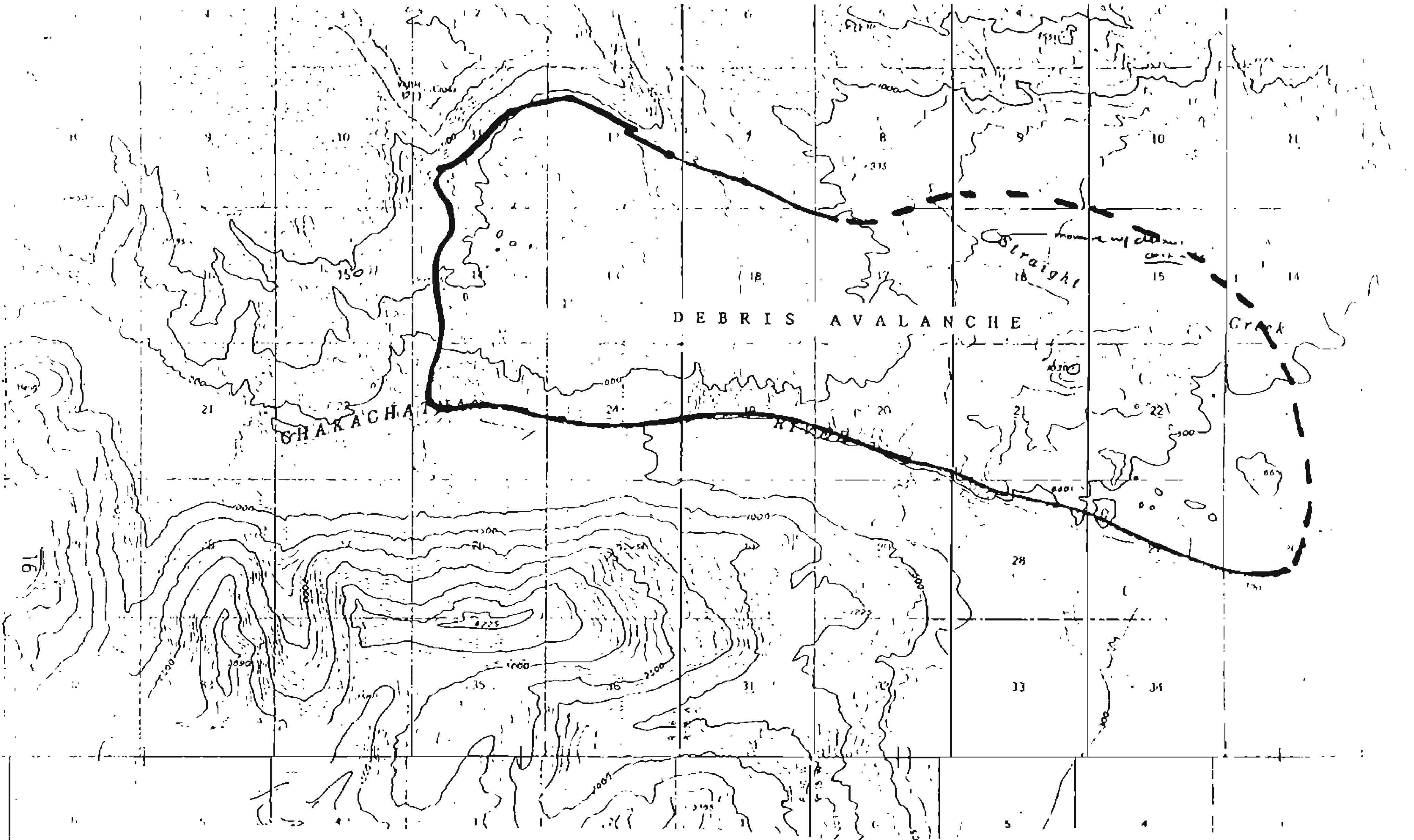
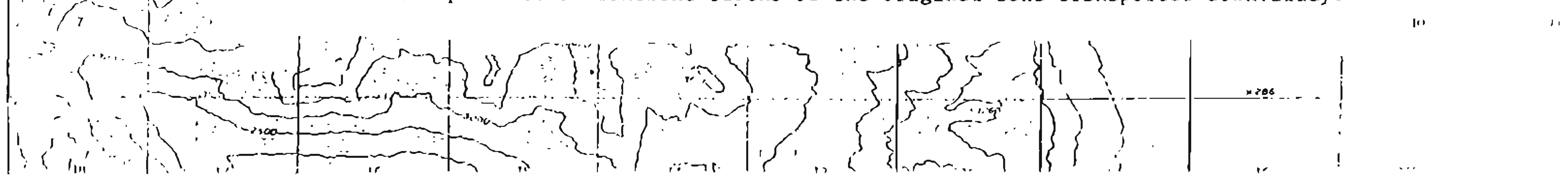


Figure 3. Debris avalanche deposit on south flank of Mt. Spurr. Exposures along Chakachatna River are locally more than 100 m thick. Note large mounds and blocks visible as topographic knobs on the surface of the flow, indicating the presence of coherent blocks of the original cone transported downvalley.



Acknowledgements

I'm grateful to DOE for providing an opportunity for me to do a tephra survey of the Mt. Spurr area. I'm also pleased and grateful that I had the opportunity to work with Dr. Don Turner, Dr. Gene Wescott, and Dr. Chris Nye on an interdisciplinary study of the volcanological and geophysical problems at Mt. Spurr.

Base map from U.S.G.S. Tyonek Quads Alaska

A6, A7, B6, B7

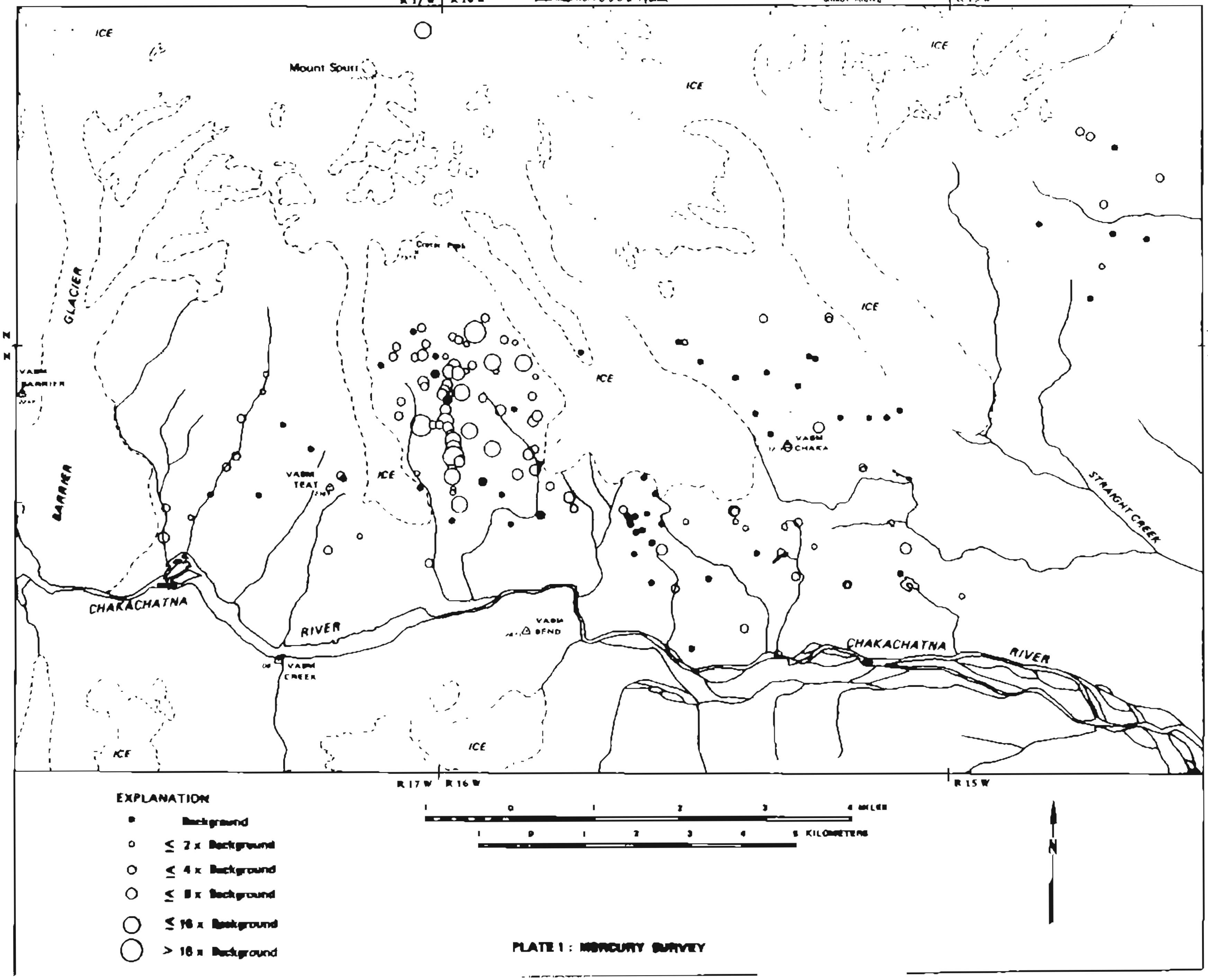
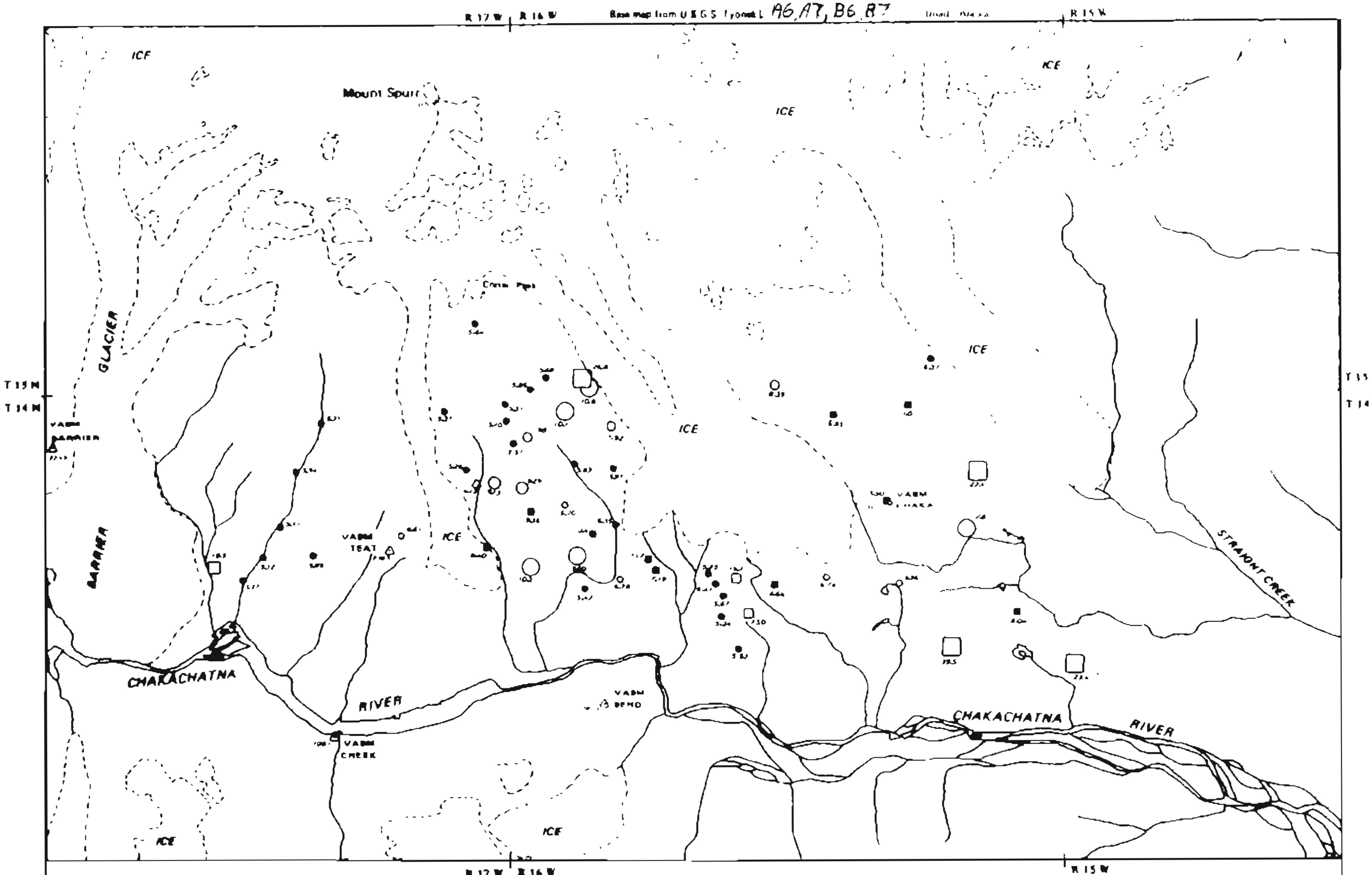


PLATE 1: MERCURY SURVEY



CHEMICAL PROJECTS LTD.

MOUNT SPURR HELIUM SURVEY PROJECT D.O.E. GEOTHERMAL

PLATE 2: HELIUM SURVEY

LEGEND

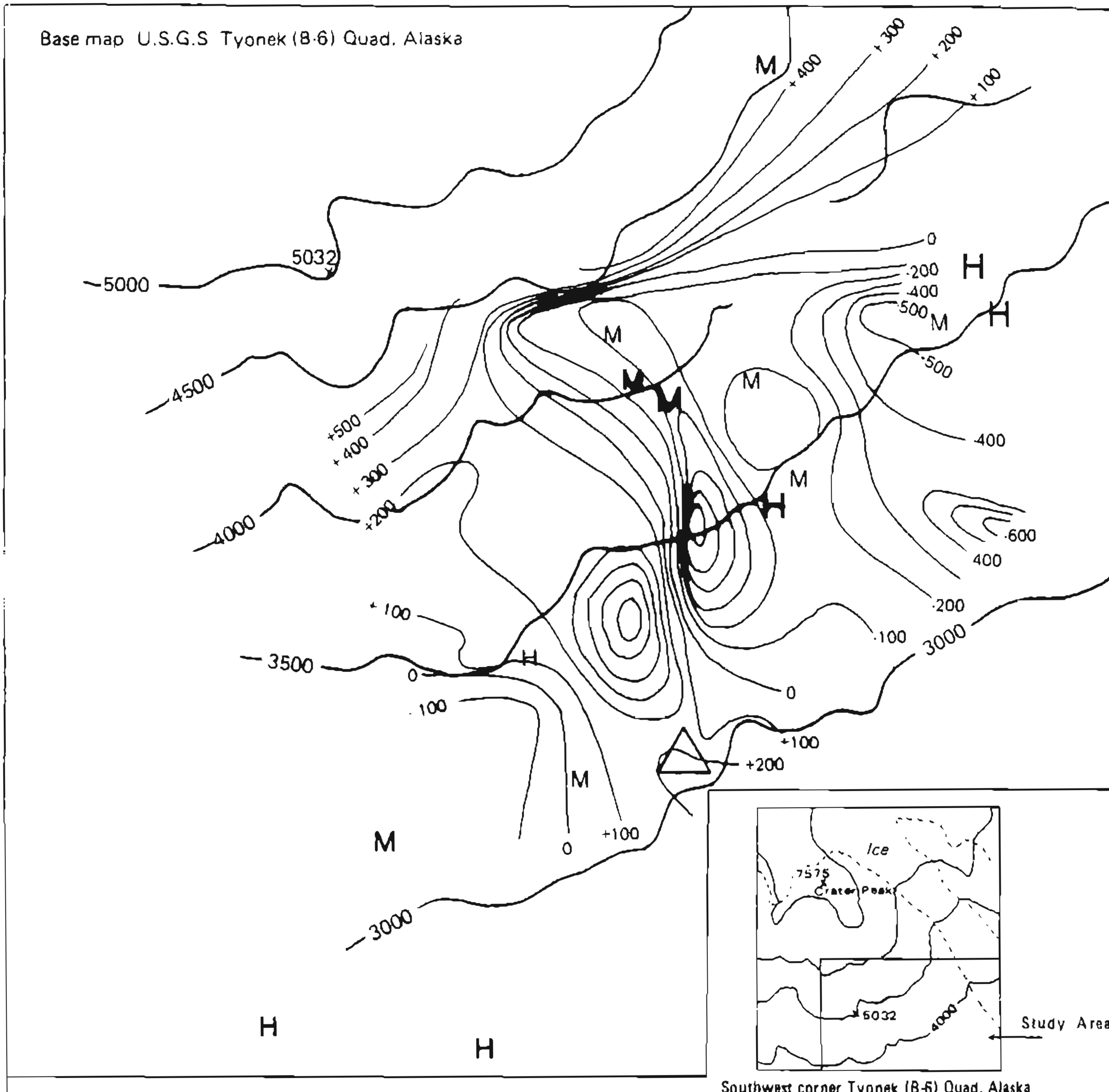
- ○ Soil sample
- □ Mud Sample
- △ Water Sample
- Helium Concentration

Scale: 1 0 1 2 3 4 MILES; 1 0 1 2 3 4 5 KILOMETERS

N

ANOMALY RANGE

- □ ○ > 4th
- □ ○ > 3rd 4th
- □ ○ > 2nd 3rd
- □ ○ > 1st 2nd
- ■ ● < 1st



EXPLANATION

H	> 4 X Standard Deviation	M	> 20 X Background
H	> 3-4 X Standard Deviation	M	≥ 16 X Background
H	> 2-3 X Standard Deviation	M	≥ 8 X Background

△ CSAMT STATION 14

N

0 .1 .2 .3 .4

MILES

PLATE 3:

SELF - POTENTIAL SURVEY

Table . Chemical analyses of waters collected from Mt Spurr hot springs, 1985[a]. (Concentrations in mg/l unless otherwise specified).

Sample	Spurr-85
Cations	
Na	266
K	75
Ca	95
Mg	99
Li	0.42
Sr	
Cs	0.04
NH_4	nd
Anions	
HCO_3[b]	622
SO_4	477
F	1.0
Cl	254
Br	0.5
I	0.1
Balance %[c]	-3.4
SiO_2	125
H_2S[b]	0.1
B	7.7
Al	nd
As	0.021
Fe	nd
TDS[d]	1707
T, °C	40.2
pH[b]	6.4
$\delta^{18}O$[e]	
δD[e]	
Date	8-03-85

a) Alaska Division of Geological and Geophysical Surveys, Fairbanks, M.A. Moorman, S.A. Liss and R.J. Motyka, analysts.
b) Determined in the field.
c) Computed from ½(C - A)/(C + A) where C and A are the total cations and anions in milliequivalents/liter, respectively.
d) Calculated.
e) Values with respect to standard mean ocean water (SMOW).

Table Analysis of gases from fumarole located on rim of active crater Mt. Spurr, Alaska. Analysis in mole per cent.

Date sampled	Xg'	CO_2	H_2S	H_2	CH_4	N_2	Ar	N_2/Ar	C/S
8-04-83	2.129	95.624	0.781	0.248	2.81E-02	1.276	0.044	75.0	122.5

Gas geothermometer of D'Amore and Panichi.

P, CO_2	1.0 bar	0.5 bars
T, C	215	195

Table Geothermometry of Mt. Spurr hot springs

<------------------Silica				Geothermometers---------->					
<-----------Quartz----------->				<-----Chalcedony---->					
<-Conductive->		<--Adiabatic->			Conduct	Adiab		Cristobalite	
Fourn	Arnor	Fourn	Arnor	Fourn	<--Arnorsson->		Amorph	Alpha	Beta
150	142	143	143	125	122	120	29	100	51

<-------------------- Cation				Geothermometers -------------->					
<-----Sodium-Potassium----->				Fournier's			Fouillac-Michard		
		<-Arnorsson-->		Na-K-Ca		Mg corr	Sodium-Lithium		Giggenbach
Fourn	Trues	Nbr 1	Nbr 2	4/3	1/3	Na-K-Ca	Lo Salt	Hi Salt	K-Mg
325	334	331	313	155	237	17	103	222	88