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MINERALOGY AND CHEMISTRY OF THE
TUFF OF PRITCHARDS STATION, EAST-CENTRAL NEVADA.

BY

STANLEY CHRISTOPHER HATFIELD, 1959-

A THESIS

Presented to the Faculty of the Graduate School of the

UNIVERSITY OF MISSOURI-ROLLA

In Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE IN GEOLOGY/GEOPHYSICS

1983

Approved by

Advisor

ABSTRACT

The Tuff of Pritchards Station in east-central Nevada is a little known ash-flow tuff of limited areal extent. A detailed study of this tuff was conducted to determine if it is a distinctive unit which can be correlated from one locality to another.

Mineralogical and chemical data indicate that the Tuff of Pritchards Station displays significant lateral variability. Lateral variations in mineralogy include changes in total crystal content and the amount and grain size of individual minerals present over the area studied. Chemically, the tuff is a quartz latite to rhyodacite in composition. However, certain elements, most noteably titanium, show considerable lateral variation. No vertical variation or zonation was observed at the studied localities of the Tuff of Pritchards Station, which may not be complete vertical sections.

The reasons for the lateral variability in the Tuff of Pritchards Station are not known. Some possible explanations are: the lateral variations are actually due to vertical variations, multiple eruptions from a single magma chamber, lateral sorting during eruption and emplacement of the tuff, and miscorrelation.

The Windous Butte Formation, at the localities sampled, is another crystal-rich tuff that displays variations which

may be due to vertical or lateral changes. Like the Tuff of Pritchards Station, this unit needs detailed work to document the vertical and/or lateral variability. Until further detailed investigations are completed, these problems will persist in east-central Nevada.

ACKNOWLEDGEMENTS

I would like to express my deepest appreciation to Dr. Sheldon K. Grant who helped me select the thesis topic and guided me in both field and laboratory studies of ash-flow tuffs. His knowledge of ignimbrites and the many discussions with him were invaluable. Without his suggestions, ideas, and criticisms the completion of this study would not have been possible. Thanks also goes to Dr. Robert C. Laudon and Dr. David J. Barr, second readers for the thesis.

I thank Mr. Mike Roberson, department technician, who was very helpful in his sample preparation and knowledge of the laboratory equipment. Thanks to the secretaries and students of the Department of Geology and Geophysics who provided much needed encouragement and patience. A special thanks goes to Miss Vicki Laferty for her understanding and support during the thesis study.

I would like to express my gratitude to the School of Mines and Metallurgy at the University of Missouri-Rolla for financial support during the summer of 1982. I am indebted to Mr. Herbert D. Duey of Northwest Exploration Company who generously loaned me thin-sections from the Trap Spring oil field. Mr. Fred Meissner of Bird Oil Company was helpful in our discussions regarding the thesis area.

Lastly, I give a special thanks to my parents for their encouragement and support during all of my college career.

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I. INTRODUCTION

A. PURPOSE AND SCOPE

The purpose of this study originally was to gain detailed petrographic and chemical information about one particular ash-flow tuff, thought to be the reservoir rock in one or more of the Central Nevada oil fields. This knowledge was then to be used to decide whether the ash flow in question, the Tuff of Pritchards Station, was a distinctive and identifiable lithologic unit in east-central Nevada. As data accumulated, it became apparent that some of the tuffs in the area show extreme lateral variability. In fact, they are so variable that some previous mapping may be questioned. Until the problem is finally resolved, current names will be retained. If believed, extreme lateral variability of the surface tuffs allows some tentative correlations with the subsurface section. If several homogeneous, but different, tuffs are involved, then the correlations described herein may be in need of correction.

The area of study is located in a complex ignimbrite province which covers much of eastern and central Nevada. Except for a few isolated areas, very little detailed work has been done with the Tertiary volcanic rocks in this part of the Great Basin. To date, no detailed petrographic or chemical data have been published for the Tuff of

Pritchards Station. It has been mapped in the Park Range (Dixon et al., 1972) and the Pancake Range (Quinlivan et al., 1974) of northern Nye County, Nevada. The productive reservoir in the Trap Spring oil field in Railroad Valley was thought to be in the Tuff of Pritchards Station (Duey, 1979; French and Freeman, 1979). Aside from the above occurrences, no record of this unit was found.

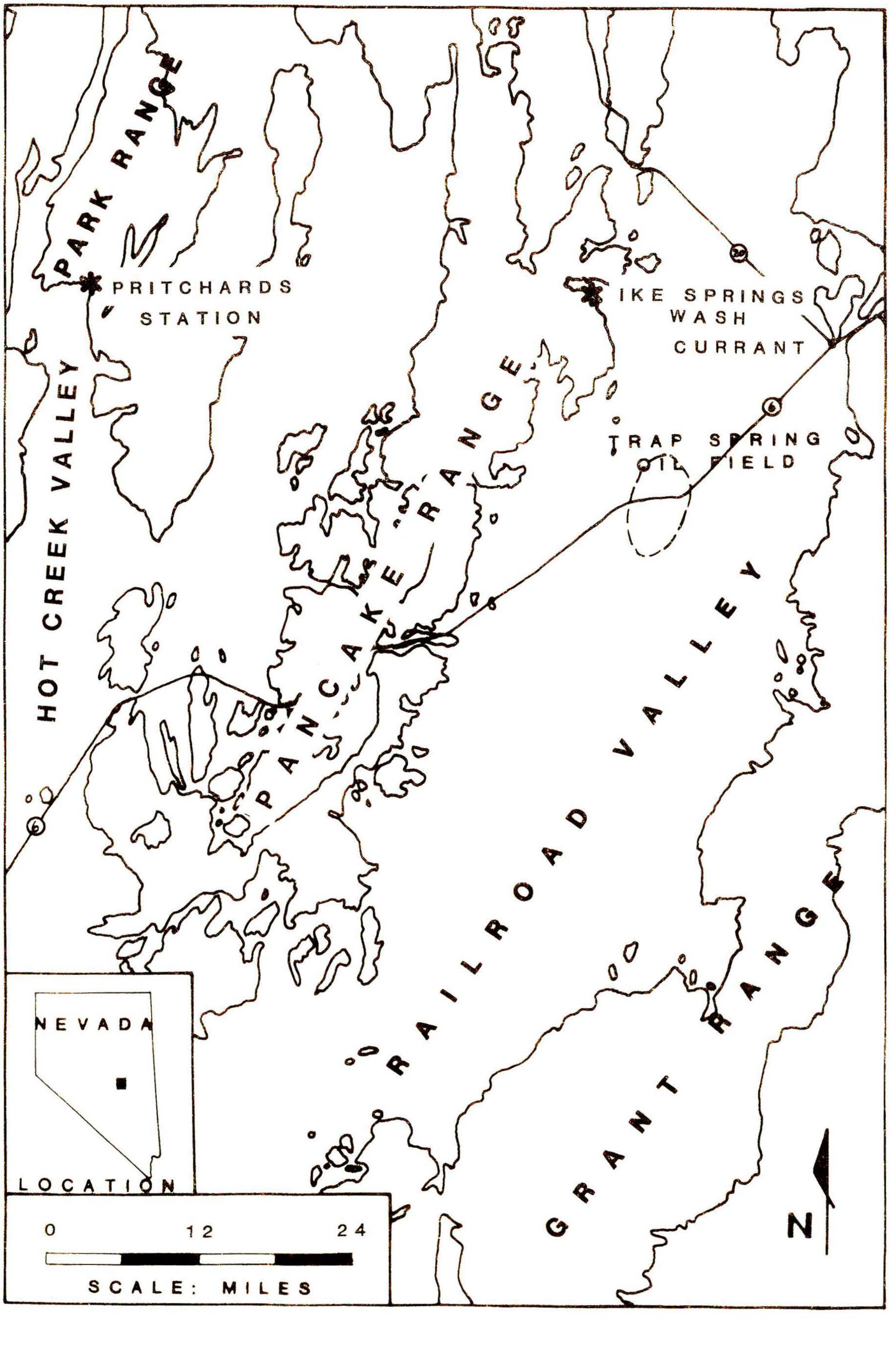
Approximately one hundred samples were collected for the purpose of studying the mineralogical, textural, and chemical characteristics of the ash flows. Methods of study included a detailed petrographic analysis of about 70 thin sections, careful examination of several hand samples under a binocular microscope, determination of plagioclase composition using the Michel-Levy method, and elemental chemical analyses on selected samples using x-ray fluorescence.

The ignimbrite terminology used in this report follows closely that of Smith (1960) and Ross and Smith (1961). While no type-section has been previously proposed, it is assumed that the Tuff of Pritchards Station was applied by Dixon et al. (1972) to the exposures located at the southern end of the Park Range near the old stage station of that name. For the purpose of this thesis, the name Tuff of Pritchards Station is retained.

B. LOCATION

The area of study is located in Nye County in east-central Nevada (Fig. 1). It is centered approximately on the intersection of latitude 38° 45' and longitude 116°. The western boundary of this area is at Pritchards Station in the southern Park Range while the easternmost edge is the Trap Spring oil field in Railroad Valley. About 25 samples were collected to the east of the study area for purposes of comparing them with the Pritchards Station ignimbrite. All of the localities sampled for this investigation are accessible by jeep roads only.

Figure 1. Map of the thesis area showing the three studied localities of the Tuff of Pritchards Station.


PARK RANGE
PRITCHARDS STATION
IKE SPRINGS WASH
CURRANT
HOT CREEK VALLEY
PANCAKE RANGE
TRAP SPRING OIL FIELD
RAILROAD VALLEY
GRANT RANGE
NEVADA
LOCATION
0
12
24
SCALE: MILES
N

II. PREVIOUS WORK

The Tuff of Pritchards Station is a relatively restricted unit; consequently very little has been written about it. Two similar ignimbrites of about the same age in east-central Nevada, the Stone Cabin and Windous Butte Formations, have received considerably more attention.

Winfrey (1960) assigned the name Garret Ranch volcanic group to the ignimbrite sequence in the Eagle Springs oil field on the east side of Railroad Valley. He did not, however attempt to differentiate between the individual ignimbrites.

Cook (1965), in his study of the Tertiary volcanic rocks in eastern Nevada, was the first to identify the Stone Cabin and Windous Butte Formations. He measured several stratigraphic sections in detail and correlated between them. Most of his work on the above formations was done in the Grant Range, but a few sections were measured in the Pancake Range.

Scott (1965) did both petrographic and chemical analyses on the Stone Cabin and Windous Butte Formations. His study was confined to the area of the Grant Range in east-central Nevada.

Gromme et al. (1972) conducted paleomagnetic correlations and potassium-argon dating of several ash flows in Nevada and Utah. They reported a mean age of

34.1 million years for the upper member of the Stone Cabin Formation. The mean age of the Windous Butte Formation was determined to be 30.7 million years. They also concluded from their study that the Windous Butte Formation does not extend as far north as previously thought by Cook (1965). This similar-looking ash-flow tuff was dated by them at 32.0 million years old and given the name Tuff of Pancake Summit.

The Tuff of Pritchards Station was first identified by Dixon et al. (1972) in their mapping of the Pritchards Station 15 minute quadrangle map. They show the Tuff of Pritchards Station directly underlying the Windous Butte Formation in the vicinity of Pritchards Station.

Quinlivan et al. (1974) mapped the Tuff of Pritchards Station in the area of Ike Springs Wash in the Pancake Range. There they found the Tuff of Pritchards Station to be stratigraphically between the Stone Cabin and Windous Butte Formation.

Duey (1979) reported that the Tuff of Pritchards Station is the productive reservoir of the Trap Spring oil field located on the west side of Railroad Valley. His cross-sections indicate that the Tuff of Pritchards Station is stratigraphically younger than the Stone Cabin Formation in the Trap Spring oil field. The Pritchards Station is in turn overlain by Miocene to Pliocene sediments.

III. GEOLOGIC SETTING

A. INTRODUCTION

The area studied in this investigation lies within the Basin and Range physiographic province. Therefore, the topography is dominated by north-south trending mountain ranges and valleys. The ranges average 50-75 miles in length, rise anywhere from 3000 to 6000 feet above the valley floors, and are separated by valleys which average over 25 miles in width (Hunt, 1974).

Sedimentary rocks exposed in the area range in age from Cambrian to Recent and represent the dominant lithology exposed in the Basin and Range. Intrusive igneous rocks are very limited in areal extent and their ages are unknown. Extrusive igneous rocks are mainly ash-flow tuffs that range in age from Oligocene to Miocene. Several lava flows of varying composition occur in the area. Normal block faulting which began about 20 million years ago has created a very complex structural setting for much of the Basin and Range province.

B. SEDIMENTARY ROCKS

The sedimentary rocks in east-central Nevada are predominantly Paleozoic carbonates. The majority of these rocks accumulated in a miogeosynclinal setting from Cambrian to mid-Devonian time (Stokes, 1979). No Mesozoic sedimentary rocks are found in most areas of eastern and central Nevada. A large portion of the early Tertiary sediments exposed in the area are lacustrine in origin. A notable example of such deposits is the Sheep Pass Formation of Winfrey (1960). The late-Tertiary to Recent sediments which now fill the valleys have been formed largely from alluvial fans and playa lakes.

C. INTRUSIVE ROCKS

The only intrusive igneous rocks exposed in the thesis area are small rhyolitic to quartz latitic dikes which intrude only the Paleozoic rocks (Quinlivan, et al., 1974). Consequently, the age relation of these dikes with the Tertiary rocks is unknown. Similar intrusives located to the north in Eureka County are thought to be Jurassic in age. No other intrusive bodies have been reported in the Pancake or Park Ranges.

D. EXTRUSIVE ROCKS

1. General. Two main types of igneous extrusive rocks are exposed in east-central Nevada. From 34 to 17 million years ago, tremendous volumes of quartz latitic and rhyolitic ash-flow tuffs were deposited in central, south-central, and east-central Nevada (Stewart, 1980). The total thickness of this ash-flow sequence in several areas is 2000 to 3000 feet thick. Some rhyolitic and andesitic flows are interlayered with the ignimbrites, but they are generally far less voluminous than the ash flows (Stewart, 1980). The time period from 17 to 6

million years ago saw extensive volcanic activity in southern, western, and northern Nevada. Extrusives of this age are, however absent from the central and eastern portions of the state. Basalt flows constitute the other major volcanic rock exposed in the study area. These mafic extrusives are located in the vicinity of the Lunar Crater volcanic field, one of four major volcanic centers or calderas identified in northeastern Nye County. Scott and Trask (1971) have determined these basalts to be less than six million years old.

Three Oligocene ignimbrites, the Stone Cabin Formation, Windous Butte Formation, and the Tuff of Pritchards Station are discussed here in more detail.

2. Stone Cabin Formation. The Stone Cabin Formation is thought to be the oldest ash-flow tuff in the Tertiary volcanic province of the eastern Great Basin (Gromme *et al*., 1972). Overall, the formation is a crystal-rich tuff characterized by abundant quartz and sanidine phenocrysts with subordinate plagioclase and few mafic minerals. Quartz is easily the dominant mineral displaying crystals up to five millimeters in size. Chemically, the Stone Cabin is a rhyolite in composition (Scott, 1965). Its known thickness is up to 2500 feet, but its areal extent, though probably modest, is not agreed upon in the literature.

At most localities the Stone Cabin Formation has been described as consisting of more than one ignimbrite or cooling unit. As described by Cook (1965), the formation consists of two individual ignimbrites with a combined average thickness of 730 feet. He termed the lower ignimbrite a crystal-vitric tuff with phenocrysts of the following relative abundances: quartz 56%, alkali fledspar 30%, plagioclase 8%, mafics 6%. The total crystal content of the rock as determined in a binocular microscope is 11%.

Table 1 lists several average mineralogical compositions for the Stone Cabin Formation, Windous Butte Formation, and the Tuff of Pritchards Station. These compositional listings are in a form which gives the phenocryst percentages of the minerals present in the ignimbrite. The order of these percentages is always quartz, alkali feldspar, plagioclase, mafics. In studies since 1972, the mafics have been subdivided into biotite and hornblende in that order. The last number given in the sequence is the total crystal content of the rock. The lower Stone Cabin ignimbrite of Cook (1965) then becomes simply 56/30/8/6//11 under this system. Any future mineralogical compositions given in this report will be in this shorthand form.

Table 2 was constructed to show the phenocryst abundances of the three ignimbrites as absolute values. This conversion was done because it allows for much

TABLE I

Relative phenocryst compositions of three ash-flow tuffs in east-central Nevada. See text for explanation.

AUTHOR	UNIT	COMPOSITION
	Stone Cabin Formation	
Cook: (1965)	upper ignimbrite	53/35/9/3//18
	lower ignimbrite	56/30/8/6//11
Scott: (1965)	Stone Cabin Fm.	45/30/20/tr//43
	Calloway Well Fm.	20/20/50/10//30
Dixon: (1972)		35-50/30-40/13-25/1-4//30-45
Quinlivan: (1974)	upper unit	34-50/16-37/16-32/1-9//32-49
	middle unit	31-43/2-19/33-53/3-11/tr//26-43
	lower unit	31-38/7-8/45-48/4-11/tr//31
	Windous Butte Formation	
Cook: (1965)	upper ignimbrite	40/28/23/9//21
	lower ignimbrite	47/23/28/2//8
Scott: (1965)		25/30/35/10//33
Dixon: (1972)	upper part	20-30/8-20/40-55/7-12/3-10//35-40
	lower part	20-40/25-45/25-50/1-10/0-6//25-50
Quinlivan: (1974)		22-42/28-39/14-30/1-10/0-2//20-40
	Pritchards Station Tuff	
Dixon: (1972)		5-25/3-10/50-60/9-15/3-8//30-45
Quinlivan: (1974)		10-26/1-24/38-66/4-11/1-13//29-48
Duey: (1979)		10-20/15-30/---/2-4//35-50

clearer comparison of the individual formations. Variations within a single formation are also easier to spot using the absolute mineral percentages. The total crystal content values given by Cook (1965) have been adjusted upward in Table 2. His relative and total mineral percentages were calculated using a binocular microscope with stained rock slices. Cook's data would then be biased toward any mineral concentrated in the larger grain-size region. These type of total percentages are lower than those determined using thin sections with a petrographic microscope. S. K. Grant (oral communication, 1982) has found such binocular percentages to be only about one-half of the percentages obtained with a petrographic microscope. Therefore, the total crystal content values of Cook (1965) have been doubled in Table 2. It is assumed that the values reported by the other authors in Tables 1 and 2 are based on petrographic analyses using thin sections.

3. Windous Butte Formation. The Windous Butte Formation, like the Stone Cabin, is a crystal-rich ash-flow of rhyolitic composition. Quartz, sanidine, and plagioclase are all generally abundant in thin section in sub-equal proportions, but their exact amounts are variable as reported in the literature (see Tables 1 and 2). The formation consists of two ignimbrites at several localities which are thought by Cook (1965) to be

TABLE II

Absolute phenocryst compositions of three ash-flow tuffs in east-central Nevada.
See text for explanation.
*Binocular percentages, multiplied by two.

AUTHOR	UNIT	COMPOSITION
	Stone Cabin Formation	
Cook: (1965)	upper ignimbrite	19/13/3/1//36*
	lower ignimbrite	12/7/2/1//22*
Scott: (1965)	Stone Cabin Fm.	19/13/9/tr//43
	Calloway Well Fm.	6/6/15/3//30
Dixon: (1972)		11-23/9-18/4-11/0-2//30-45
Quinlivan: (1974)	upper unit	11-25/5-18/5-16/0-4//32-49
	middle unit	8-18/1-8/9-23/1-5/tr//26-43
	lower unit	10-12/2/14-15/1-3/tr//31
	Windous Butte Formation	
Cook: (1965)	upper ignimbrite	17/12/10/4//42*
	lower ignimbrite	8/4/4/tr//16*
Scott: (1965)		8/10/12/3//33
Dixon: (1972)	upper part	7-12/3-8/14-22/3-5/1-4//35-40
	lower part	5-20/6-23/6-25/0-5/0-3//25-50
Quinlivan: (1974)		4-17/6-16/3-12/0-4/0-1//20-40
	Pritchards Station Tuff	
Dixon: (1972)		2-11/1-5/15-27/3-7/1-4//30-45
Quinlivan: (1974)		3-12/0-12/11-32/1-5/0-6//29-48
Duey: (1979)		4-10/5-15/---/1-2//35-50

lithologically distinct, but petrographically similar. He states the upper unit is characterized by large phenocrysts of smoky quartz, but dark or smoky quartz crystals have been reported for the lower ignimbrite as well (Dixon _et al._, 1972). Other discrepancies concerning occurrences and details of the Windous Butte Formation have been found in the literature. Because of this variability and a lack of enough detailed studies, the author feels that the Windous Butte name may have been mis-applied in some areas. This topic is discussed briefly later in this report.

The Windous Butte Formation is thought by many to be one of the most extensive ash flows in east-central Nevada. Gromme _et al._ (1972) estimated an areal extent of 3166 mi^2 for the formation. The thickness of the Windous Butte ranges from 100 to 1800 feet. Stratigraphically, the Windous Butte Formation directly overlies the Stone Cabin Formation at some localities.

4. _Tuff of Pritchards Station_. The Tuff of Pritchards Station is mentioned very briefly here since it is the main topic of later discussion in this investigation. Dixon _et al._ (1972) described it as a quartz latitic to rhyolitic ash-flow tuff. In hand specimen the prominent phenocrysts are amethyst quartz, biotite, and hornblende (Quinlivan _et al._, 1974). Plagioclase, however is easily the most abundant mineral seen in thin section (Tables 1

and 2). The areal extent of this unit is unknown and aside from the mineralogical data in Tables 1 and 2, no detailed petrographic or chemical data are known.

E. STRUCTURE

The oldest structural features in the area of study are associated with the thrusting of the Antler orogeny which occurred in early to mid-Paleozoic time. These features are present in the form of autochthonous to para-autochthonous Paleozoic rocks which are thought to represent the lower plate of the Roberts Mountains thrust (Stewart, 1980). The folding associated with this large-scale thrusting is not evident in this portion of the Great Basin. Mesozoic structures, such as those associated with the sevier orogeny in eastern Nevada and western Utah, are absent in the thesis area. Some local Tertiary structures present in several areas of central and southern Nevada are the faulting, ring-fractures, and subsidence features associated with the calderas or volcanic source areas.

The most prominent structural feature of the Basin and Range are the north-south trending normal faults which were initiated roughly 20 million years ago. These faults, which bound major mountain or valley blocks, commonly dip about 60° (Stewart, 1980). In the area under investigation, such faulting has produced tilted fault blocks or mountain ranges which dip generally to the east.

At least three models have been proposed to explain the extensional tectonics of the Basin and Range province, but to date no single explanation has achieved unanimous agreement (Stewart, 1980).

IV. METHODS OF STUDY

A. SAMPLE COLLECTION AND PREPARATION

During the summer of 1982, the author collected samples of the Tuff of Pritchards Station and other ignimbrites in east-central Nevada. The two main areas sampled were at Ike Springs Wash in the Pancake Range and at Pritchards Station in the southern Park Range. Detailed staffing was conducted at each locality to determine the thickness of each unit and to record the position of each sample above the base of the ignimbrite. Field characteristics were noted, such as faulting, topographic expression as related to weathering, the presence of prominent phenocrysts of lithic fragments in each ash-flow tuff, and the stratigraphic relationships of the ignimbrites.

B. PETROGRAPHY

A detailed petrographic study of the thin sections was done using a Nikon OPTIPHOT-POL microscope. The thin sections were studied carefully to determine the types and abundance of minerals present, the relative grain sizes for abundant minerals, the textures observed for individual minerals and the overall rock, and the types and degree of any alteration present. Characteristics relating directly to ash-flow tuffs such as the amount of pumice lenticules and glass shards present, their degree of devitrification, and the amount of welding in the ignimbrite were noted as well.

Plagioclase composition was determined using the Michel-Levy method. In each thin section, ten plagioclase grains with sharp, well-defined albite twins were selected and their extinction angles were measured. The largest extinction value from each thin section was then compared to the volcanic chart given by Troger (1971, p. 134) to determine the approximate anorthite content.

Mineral percentages were counted using a Zeiss binocular petrographic microscope with a grid ocular (8x) in combination with a medium-power objective (10x). Random fields were viewed and the grid areas occupied by each mineral were counted and complied. Thirty fields (3000 frid areas) were counted for plagioclase, which was generally the most abundant mineral present. Forty fields (4000 grid areas) were counted for quartz, sanidine, biotite, and hornblende to obtain a sufficient degree of precision in calculating their percentages. The amount of pumice fragments was counted in each field and subtracted from the total number of grid areas to give a more accurate figure for the percentage of each mineral present outside the pumice.

C. CHEMICAL ANALYSES

Powdered pressed pellet specimens, ground for 2 minutes to about 30 micron grain size, were analyzed in a

Phillips PW 1410 x-ray spectrometer to determine the elemental chemical compositions of the ash flows. The original x-ray intensities were adjusted by matrix factors and converted to concentrations through the use of 15 to 20 United States Geological Survey standards. The CIPW norms for these samples were determined by using a variable oxidation function which is dependent on the weight percent of the alkalis present. This oxidation function was modified after one given by Rittmann (1973).

V. DESCRIPTION OF THE TUFF OF PRITCHARDS STATION

A. INTRODUCTION

As the field and laboratory investigations of this study progressed, it became apparent that the Tuff of Pritchards Station displays extreme lateral variability. Because of this, the author feels it necessary to describe the specific characteristics of the ignimbrite at each locality sampled rather than try to present a picture of the unit as a whole. Therefore, the unit will henceforth be designated on the basis of its location within the area studied. These designations are as follows: Pritchards Station locality - Tuff of Pritchards Station (PS), Ike Springs Wash locality - Tuff of Pritchards Station (ISW), and the Trap Spring oil field locality - Tuff of Pritchards Station (TS).

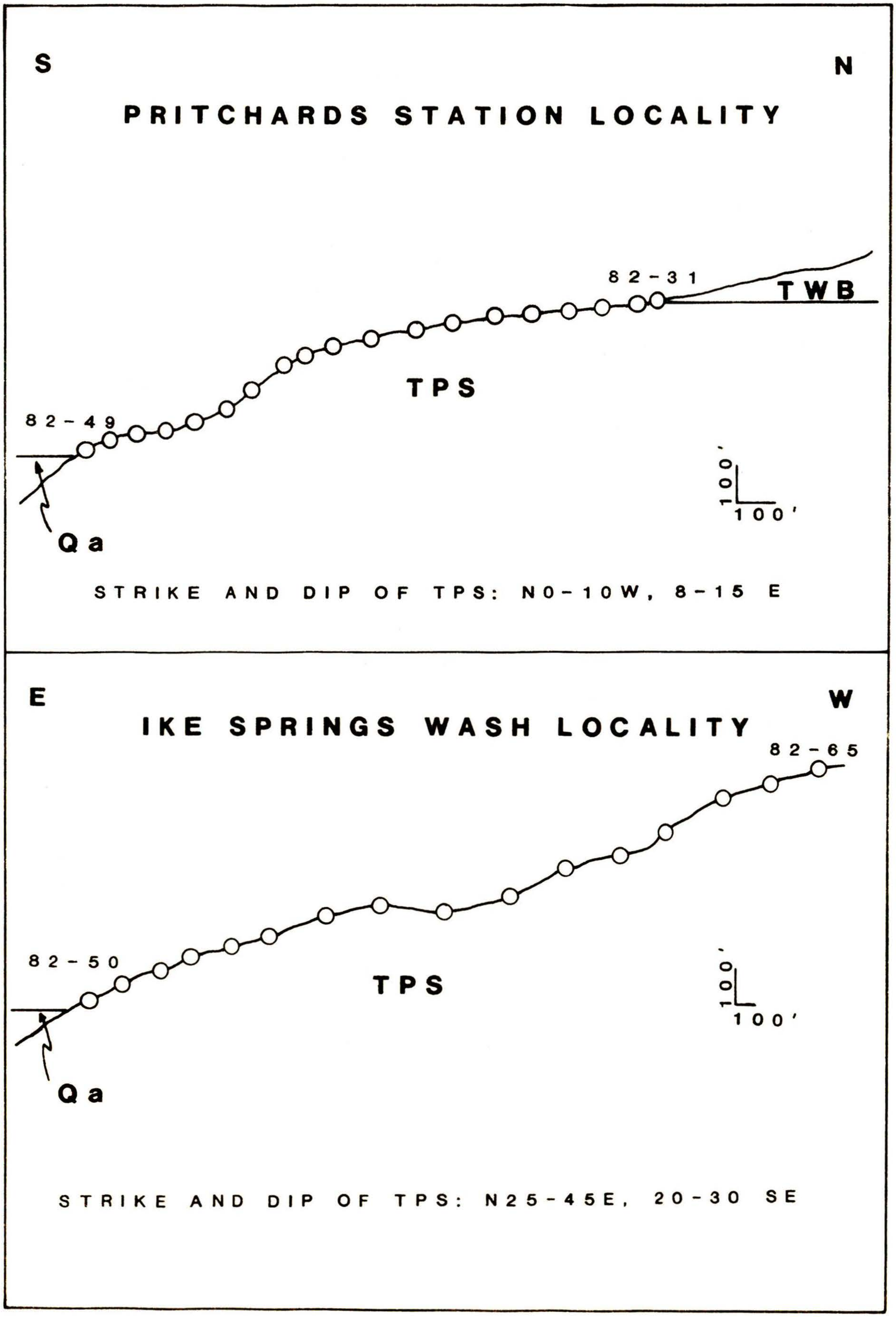
B. PRITCHARDS STATION LOCALITY

1. Field Characteristics. The Pritchards Station locality is located approximately 30 miles north of U.S. Route 6 at the northern end of Hot Creek Valley. This locality, named for the old stage station still standing there, is at 38°47' latitude and 116°11' longitude. The Tuff of Pritchards Station (PS) strikes N 0°-10° W and dips 8°-15°E. The Pritchards Station is underlain by alluvium and dacitic to andesitic lava flows. It is in turn overlain by the Windous Butte Formation. The

measured thickness of the Tuff of Pritchards Station at this location is 445 feet. The stratigraphic relationships and positions of samples collected are shown in Figure 2.

The Tuff of Pritchards Station (PS) appears to be a simple cooling unit. There is no vitrophyre visible and the lower 40 to 50 feet of the exposure does not show evidence of welding. This white to pale gray colored, basal nonwelded zone weathers to prominent teepee-shaped mounds, some of which are over eight feet high and five feet in diameter. This lower portion also contains abundant lithic fragments of various compositions. The upper 400 feet of the Tuff of Pritchards Station (PS) is moderatley to densely welded as evidenced by the flattened shapes of the pumice lenticules. The pumice lapilli are abundant throughout this portion above the nonwelded base. They contain considerably fewer phenocrysts than does the surrounding matrix and often have a gray to dark-gray perlitic appearance. Hand samples are generally light brown to dark reddish-brown in color, except for the nonwelded base. Quartz, biotite, and hornblende phenocrysts are easily seen in hand specimens, and quartz is sometimes dark to smoky colored in hand specimens. The contact between the Tuff of Pritchards Station (PS) and the overlying Windous Butte Formation is not exposed, and

Figure 2. Generalized cross-sections showing locations of samples collected. TPS-Tuff of Pritchards Station. TWB-Windous Butte Formation. Qa-Quaternary alluvium.


S
N
PRITCHARDS STATION LOCALITY
82-31
TWB
TPS
82-49
100'
100'
Qa
STRIKE AND DIP OF TPS: N0-10W, 8-15 E
E
W
IKE SPRINGS WASH LOCALITY
82-65
82-50
TPS
100'
100'
Qa
STRIKE AND DIP OF TPS: N25-45E, 20-30 SE

the uppermost exposures of the studied ignimbrite do display a considerable degree of welding. This fact may suggest that a portion of the Pritchards Station was eroded away before the deposition of the Windous Butte Formation.

2. Petrography. The Tuff of Pritchards Station (PS) is a crystal-rich ash-flow tuff which ranges from 35.3% to 44.6% total crystal content. The average modal composition of the ignimbrite is quartz 7.8% ± 0.77%, sanidine 2.2% ± 0.08%, plagioclase 20.5% ± 0.31%, biotite 5.5% ± 0.43%, hornblende 2.5% ± 0.29%. Apatite and zircon are also present in very minor amounts. The complete mineral composition of the Pritchards Station locality is given in Table 3.

Plagioclase normally occurs as large euhedral crystals which are up to 5 mm in diameter. The crystals are sometimes fractured or broken as a result of the eruption and emplacement of the ash flow. The average composition of the plagioclase is An_{37} (andesine). The most prominent feature of the plagioclase grains is extreme oscillatory zoning which is ubiquitous at the Pritchards Station locality. Zoning in plagioclase is present in many of the ignimbrites of east-central Nevada, but not nearly to the degree that it is developed in the Tuff of Pritchards Station (PS). As many as 100 compositional rings are found in some crystals. This

TABLE III

Absolute mineral concentrations for the Tuff of Pritchards Station at the Pritchards Station locality, given in volume percentages.

PRITCHARDS STATION SECTION

SAMPLE NO.	Ft./Above Base	Qtz	San	Pl	Bio	Hb	XLs
82-31	410	4.7	2.2	21.2	4.8	1.5	35.3
82-33	380	10.7	2.2	20.2	3.3	2.7	40.1
82-34	350	7.7	2.4	19.3	7.1	2.1	39.5
82-36	315	7.3	2.1	21.0	7.1	1.5	40.3
82-38	260	9.4	2.2	18.9	4.6	2.1	38.4
82-40	210	8.6	2.4	20.9	5.4	3.6	42.0
82-42	165	5.8	1.8	22.0	4.9	4.1	39.4
82-45	110	10.7	2.7	20.7	6.5	2.5	44.6
82-46	50	5.0	2.0	20.6	6.0	2.8	37.4
Mean		7.8	2.2	20.5	5.5	2.5	39.7
Std. Dev.		2.3	.26	.95	1.3	.88	2.7

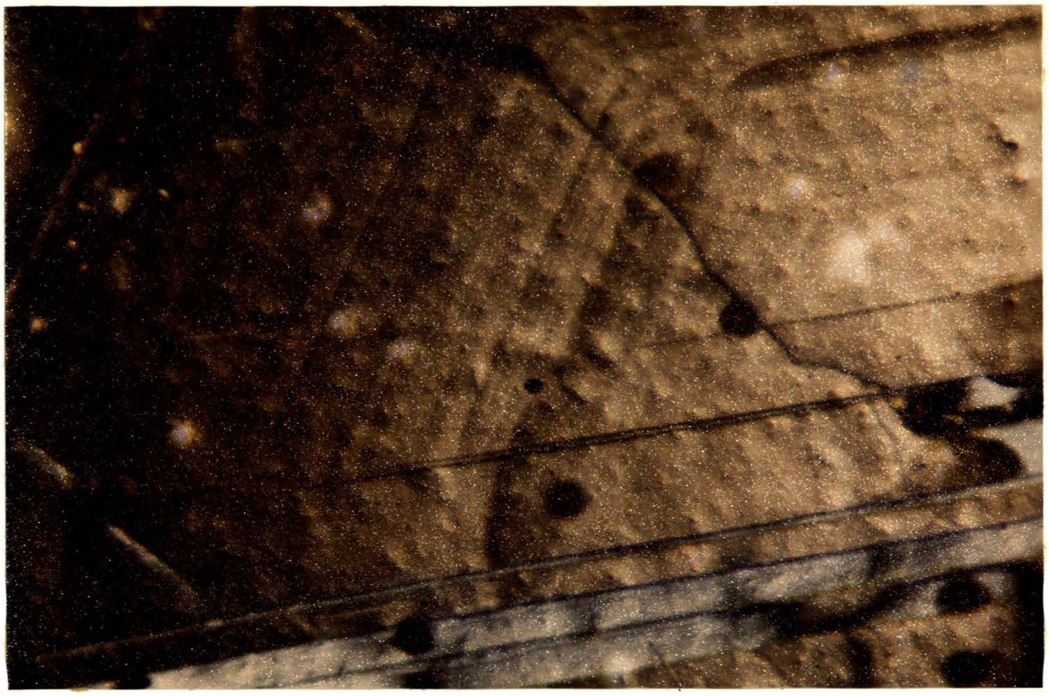
oscillatory zoning is shown in the photomicrographs of Figure 3. Zoning in plagioclase is thought by Sibley (1976) to be the result of changes in general environmental variables such as temperature and pressure and constitutional supercooling. He states (1976, p. 275) that, "Constitutional supercooling is supersaturation that results from concentration gradients in the melt at the crystal-melt interface". He also feels that the compositional range and the width of the zones in a crystal are a function of the diffusion rates in the interface liquid. No attempt was made in this study to determine the specific composition of individual zones. It was noted, however that the crystals are gradually more calcium rich from their centers outward in some cases and more sodium rich toward their outer edges in other instances. This was determined by examining the extinction characterisitics of individual grains. No alteration of plagioclase phenocrysts is present at the Pritchards Station locality.

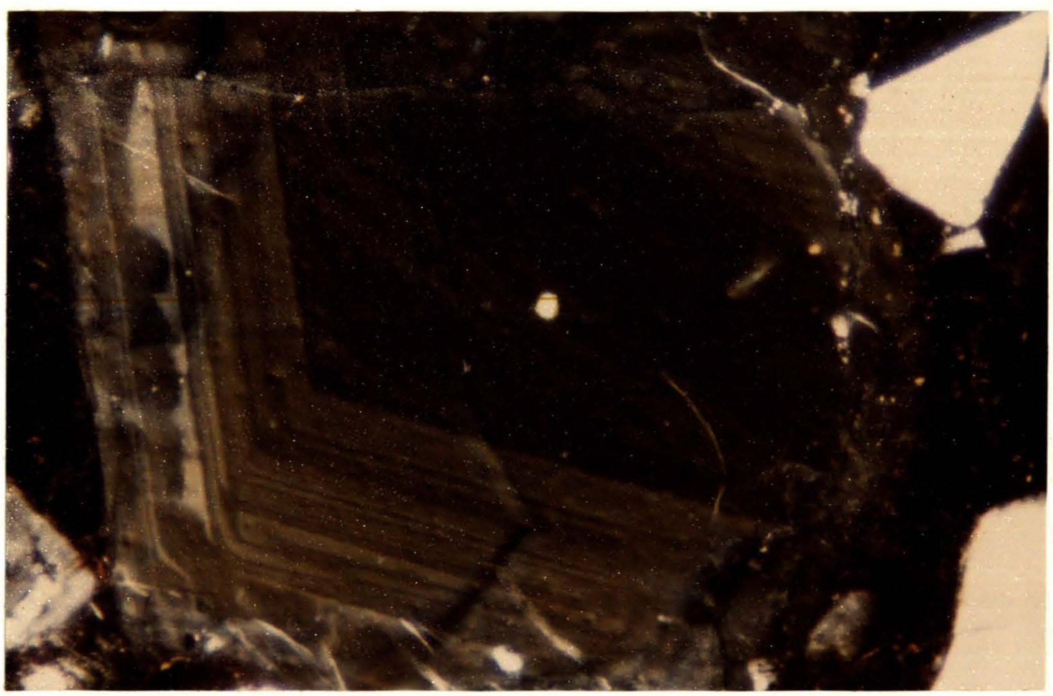
Quartz is present as subhedral to anhedral crystals which are commonly fractured or broken more than any other mineral. Individual grains are up to 3.3 mm in diameter and often display a resorbed or embayed texture. Quartz displays the greatest variability in abundance from one thin section to another as evidenced in Table 3. This is probably due to the fact that it almost always

Figure 3. Photomicrographs of the Tuff of Pritchards Station.

Upper photograph is a plagioclase crystal which exhibits extreme oscillatory zoning (closely spaced light to dark-gray banding) and polysynthetic twinning (white horizontal bands). Sample No. 82-33 (x132, crossed nicols).

Lower photograph illustrates oscillatory zoning in untwinned plagioclase (large olive brown crystal). Sample No. 82-42 (x132, crossed nicols).





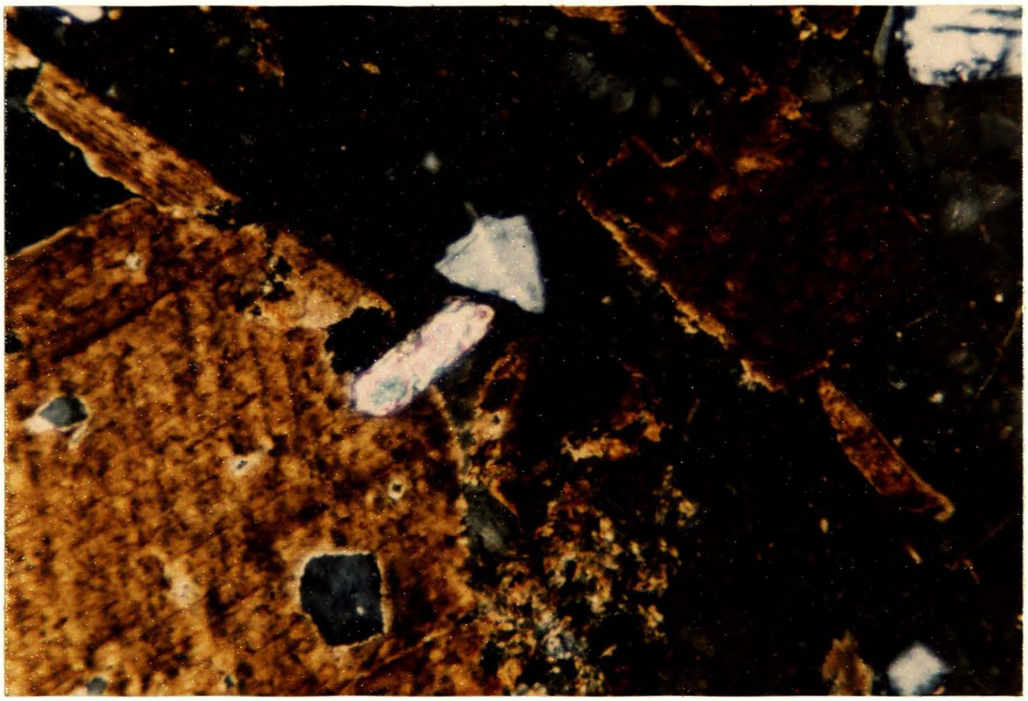
occurs as large crystals 2.0 mm to 3.0 mm in diameter. The presence or absence of just a few of these larger grains results in significantly different percentages. Sanidine is not very abundant in the Tuff of Pritchards Station (PS). When present, it is found as subhedral crystals which are less than 1.5 mm in size. Some of the sanidine grains display Carlsbad twins, but when these twins are absent the crystals are sometimes difficult to distinguish from quartz. Mild zoning is present in only a few of the sanidine phenocrysts. Biotite and hornblende generally exhibit crystals which have good euhedral form. Biotite is the more abundant of the two with individual flakes up to 5 mm across. Hornblende grains measure up to 2.5 mm in their long dimension and both of these mafic minerals show a preferred orientation in which they are aligned parallel to the layering of the entire ignimbrite. The two accessory minerals present, apatite and zircon, are distributed as euhedral crystals included in either biotite or hornblende phenocrysts (Figure 4, upper photograph). Small pyroxene grains are present only in trace quantities in a few of the samples.

The only alteration present in the Tuff of Pritchards Station (PS) is in the form of secondary iron-oxides. These iron-oxides occur as alteration products of biotite and hornblende. Biotite varies from fresh to completely

Figure 4. Photomicrographs of the Tuff of Pritchards Station.

Upper photograph displays zircon (white to pink grain near the center of the photo) and apatite (medium to dark gray) included in a larger biotite crystal (light tan to brown). Sample No. 82-31 (x132, crossed nicols).

Lower photograph: biotite (black) is completely altered to opaque iron-oxides while hornblende (brown, upper left) shows only slight oxidation around the margin of the grain. Also note the embayed or resorbed quartz (white) crystal near the center of the picture. Sample 82-36 (x70, plain light).



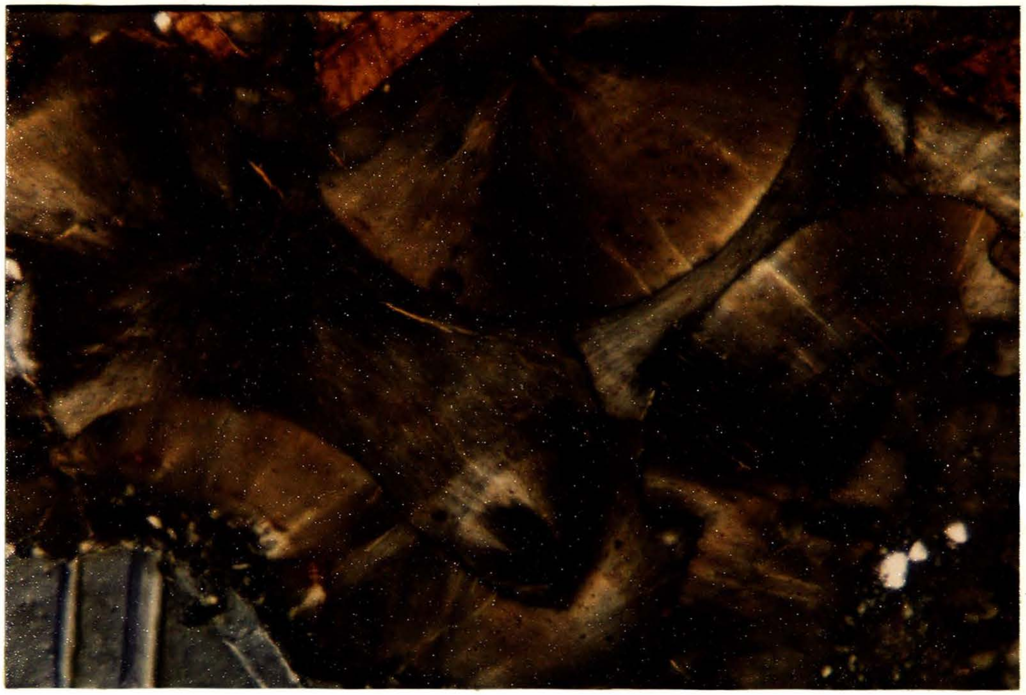
altered grains, the latter of which is often seen as pseudo-hexagonal opaque shapes. Hornblende is not nearly as altered displaying only opaque rings around some crystals (Figure 4, lower photograph). Weathering products from these secondary iron-oxides occasionally stain the phenocrysts and groundmass in the vicinity of the mafic minerals.

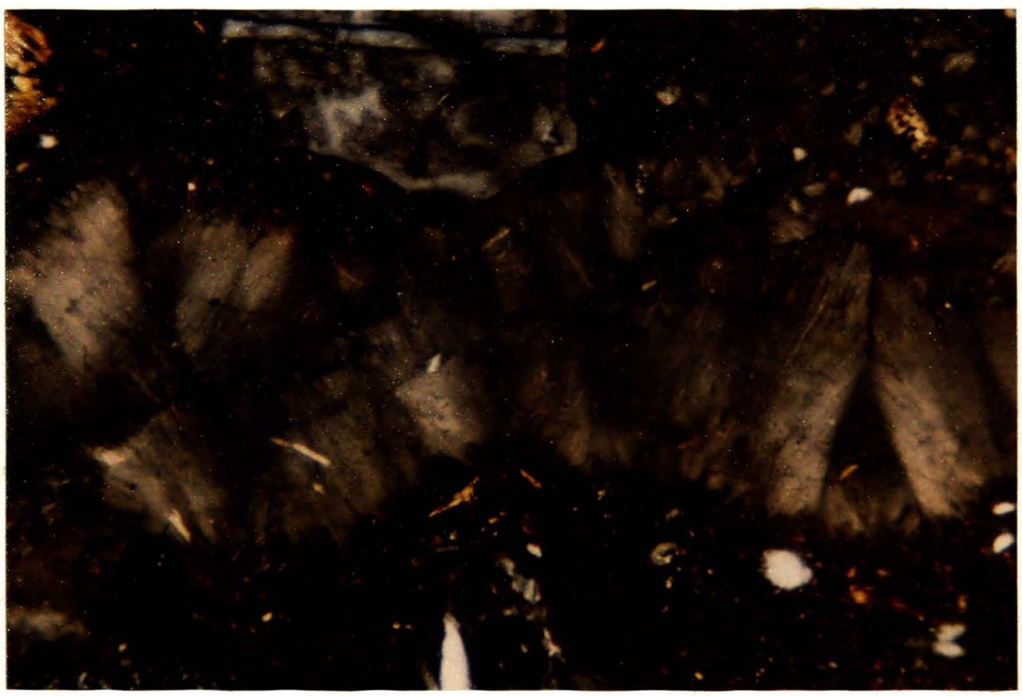
Pumice fragments and lenticules are abundant in every thin section of the Tuff of Pritchards Station (PS). They are usually flattened or partially collapsed due to compaction, but none of the lenticules are completely collapsed. The pumice contain fewer phenocrysts than does the groundmass of the tuff, but these crystals are normally larger and they are seldom fractured or broken. All of the pumice fragments observed at this locality show extreme devitrification. This solid state crystallization is in the form of spherulites which occupy every pumice lenticule or fragment in the welded portion of the exposure. The spherulites are gray to dark-brown in color and they occur as one of two types. The first type are the larger fan-shaped to rounded spherulites which are developed in the larger pumice (see Figure 5, upper photograph). These devitrification products exhibit definite boundaries and probably are the result of unconfined crystal growth. A second form of spherulites are those which occupy the smaller

Figure 5. Photomicrographs of the Tuff of Pritchards Station.

Upper photograph: large, well-formed spherulites (fan-shaped, light gray to tan) occupying a pumice lenticule. Sample No. 82-40 (x132, crossed nicols).

Lower photograph: poorly defined spherulites (light to dark gray) forming an axiolitic texture in a pumice lenticule extending across the center of the photo. Sample No. 82-31 (x132, crossed nicols).





and more collapsed pumice fragments (Figure 5, lower photograph). These irregular masses do not show well-defined margins and they represent the axiolitic texture of Ross and Smith (1961). The dark-gray perlitic appearance of pumice lenticules in hand samples of the Tuff of Pritchards Station is most likely due to these abundant spherulites.

Glass shards are well preserved in the basal nonwelded portion of the ignimbrite. These glassy fragments are typical Y and V shapes and they do not exhibit any evidence of welding. The shards and pumice in this lower portion of the Pritchards Station section are not devitrified either. The intense devitrification of the groundmass and pumice in the upper 400 feet of the tuff has nearly obliterated any visible evidence of original shard structure.

There is no obvious vertical variation or zonation present in the mineralogy of the Tuff of Pritchards Station (PS). All of the minerals discussed are found throughout the unit and the variation in content from one sample to another is rather small (Table 3). Quartz shows the greatest variation, but as mentioned before, this is probably due to the effect of grain size. Several ash-flow tuffs in the literature have been documented which exhibit vertical variations in the amount, size, and type of minerals present. Such variation or zonation is thought to represent such processes as stratification of the original magma chamber or vertical sorting of materials during eruption and emplacement. No definite explanation is given here as to why the mineralogy of the Pritchards Station locality displays such vertical continuity. One possibility is that a part of the original tuff was eroded away and the resulting exposure is only a portion of the total ignimbrite section. Another is that only a limited number of flows of a multiple flow eruption were emplaced here.

3. Chemistry. Chemically the Tuff of Pritchards Station (PS) varies even less than does its mineralogy. This chemical continuity of the ignimbrite is typified by the SiO_2 content which ranges from 69.2% to 70.5% with a mean of 69.7% ± 0.2%. Complete chemical analyses for several samples from Pritchards Station are given in Table 4. The mean value of 3.5% ± 0.28% for the K_2O content appears somewhat high considering the low amount of sanidine present in the rock. This high value probably results from potassium being concentrated in the glass shards and spherulites of the tuff.

On the basis of chemical analyses, the Tuff of Pritchards Station (PS) is classified here as quartz latite to rhyodacite in composition. These rock types were determined by plotting the normative proportions of

TABLE IV

Chemical analyses of the Tuff of Pritchards Station by x-ray fluorescence.
** Exact vertical position of sample is uncertain.

PRITCHARDS STATION SECTION

Sample No.	Ft./Above Base	SiO_2	Al_2O_3	Fe_2O_3*	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO
82-31	410	69.7	14.9	3.4	0.91	3.3	3.0	4.0	0.47	0.13	0.06
82-33	380	69.2	15.8	3.4	1.1	3.4	2.8	3.6	0.49	0.09	0.07
82-34	350	69.9	15.3	3.4	1.0	3.4	2.7	3.6	0.46	0.10	0.07
82-36	315	69.4	15.4	3.4	1.3	3.4	2.8	3.7	0.49	0.13	0.06
82-38	260	70.1	14.9	3.4	1.1	3.4	2.8	3.7	0.48	0.18	0.06
82-40	210	69.6	15.6	3.2	0.94	3.6	2.9	3.5	0.45	0.11	0.09
82-42	165	69.3	15.3	3.2	1.2	3.5	3.0	3.9	0.46	0.12	0.07
82-44	140	69.3	15.2	3.3	1.1	3.6	3.0	3.8	0.46	0.21	0.07
82-46	110	70.3	14.9	3.0	1.5	3.3	2.8	3.5	0.44	0.08	0.07
82-48	50	70.5	15.1	3.1	1.2	3.2	2.2	4.2	0.46	0.10	0.06
Mean		69.7	15.2	3.3	1.1	3.4	2.8	3.5	0.47	0.13	0.07
Std. Dev.		0.5	0.3	0.1	0.2	0.1	0.2	0.9	0.02	0.04	0.01

IKE SPRINGS WASH SECTION

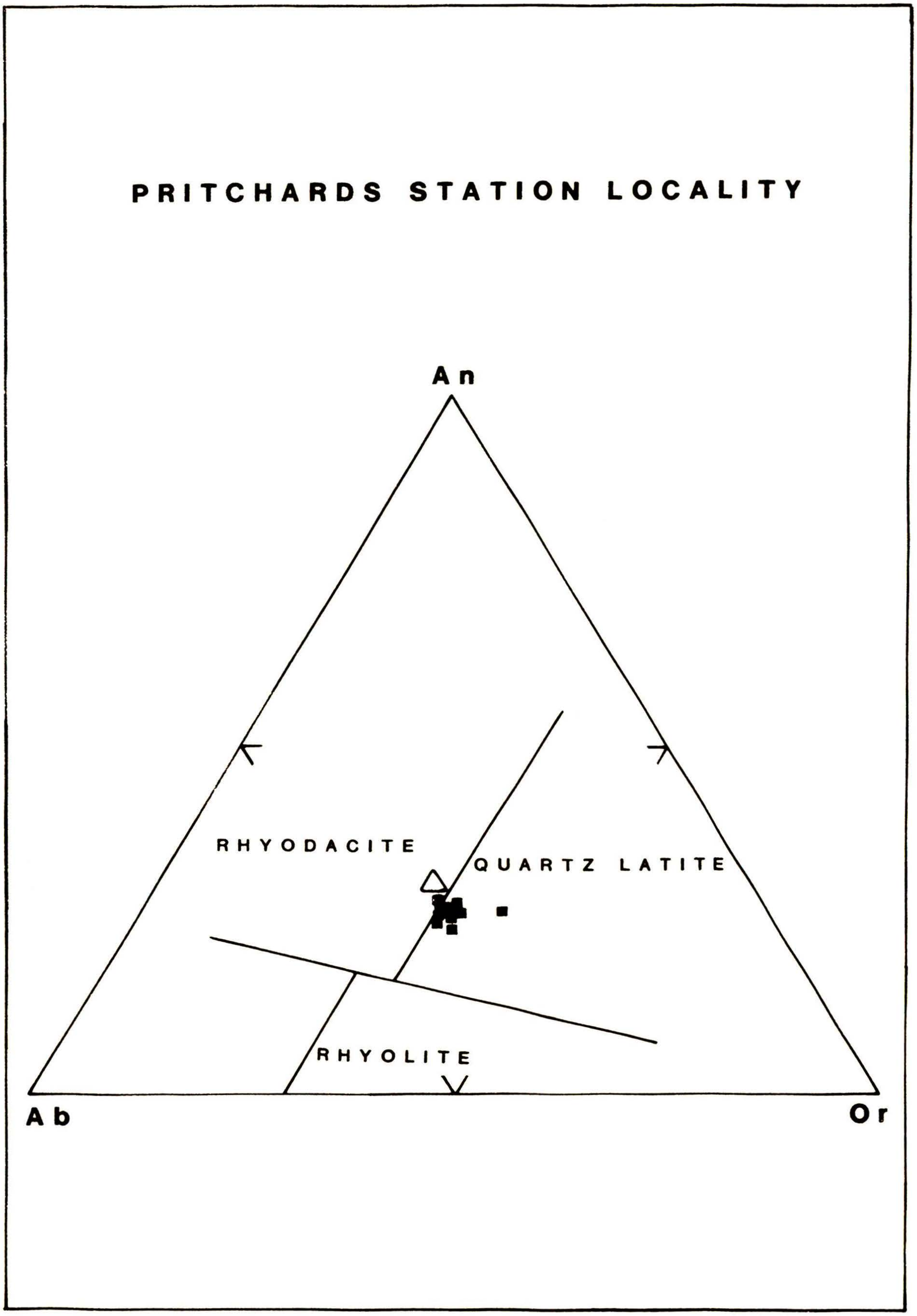
Sample No.	Ft./Above Base	SiO_2	Al_2O_3	Fe_2O_3*	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO
82-93	380**	67.0	16.1	3.9	1.1	4.5	2.8	3.7	0.63	0.18	0.11
82-90	360**	67.8	15.7	3.9	0.99	4.1	2.9	3.8	0.64	0.18	0.08
82-88	340**	67.7	15.8	3.8	1.1	4.1	2.8	3.6	0.64	0.21	0.08
82-84	320**	67.0	15.8	4.5	1.3	4.1	2.8	3.7	0.62	0.19	0.07
82-62	240	69.2	15.2	3.6	0.96	3.8	2.7	3.7	0.60	0.15	0.08
82-59	180	67.7	15.6	4.1	1.3	4.1	2.8	3.5	0.62	0.16	0.09
82-56	120	67.9	15.2	4.3	1.2	3.7	2.9	4.1	0.61	0.15	0.10
82-53	60	69.8	15.0	3.3	0.84	3.7	2.8	3.8	0.58	0.16	0.05
Mean		68.0	15.6	3.9	1.1	4.0	2.8	3.7	0.62	0.17	0.08
Std. Dev.		1.0	0.4	0.4	0.2	0.3	0.1	0.2	0.02	0.02	0.02

orthoclase, albite, and anorthite on a chart developed by O'Connor (1965). His chart relates the normative feldspar proportions to specific rock types for quartz-rich igneous rocks. The Pritchards Station samples from the chemical analyses are plotted on such a chart in Figure 6.

C. IKE SPRINGS WASH LOCALITY

1. Field Characteristics. The Ike Springs Wash locality is situated 15 miles north of U.S. Route 6 on the east side of the Pancake Range. The Tuff of Pritchards Station (ISW) section is located on the southwest side of Ike Springs Wash at 38°41' latitude and 115°44' longitude. The attitude of the Pritchards Station exposure at this locality is quite variable due to extensive faulting. The section measured by the author strikes N 25° - 45° E and dips 20° - 30° SE. The Pritchards Station is underlain by the upper unit of the Stone Cabin Formation, a bedded tuff, and a rhyolitic lava flow. The ignimbrite caps many of the ridges in the Ike Springs Wash area and it is generally faulted at its upper contact with other units. Therefore, the stratigraphic relationship of the Pritchards Station with the unit(s) above it was not determined. The measured thickness of the tuff at this locality is estimated to be 500 feet or more. This figure is questionable because of the complexity of faulting in the area. Three miles

Figure 6. Normative feldspar proportions related to rock type, after O'Connor (1965) for the Tuff of Pritchards Station. The solid squares are samples from Pritchards Station and the open triangle represents the average of the Ike Springs Wash samples, illustrated in Figure 7.


PRITCHARDS STATION LOCALITY
An
RHYODACITE
QUARTZ LATITE
RHYOLITE
Ab
Or

away on the northeast side of Ike Springs Wash, the Tuff of Pritchards Station has pinched out and the upper Stone Cabin Formation is directly overlain by the Windous Butte Formation. The positions of the samples collected at the Ike Springs Wash locality are illustrated in Figure 2.

Several exposures of the Pritchards Station at Ike Springs Wash exhibit conspicuous breaks in topography which may be interpreted as evidence of compound cooling. However, the attitude of the section often changes drastically from one side of these topographic benches or saddles to the other. This fact would seem to indicate the presence of faulting. Also, no real evidence of a compound cooling was observed in hand samples or thin section. The tuff is moderately to densely welded from the base to the uppermost portions of the exposed section. White pumice lapilli are abundant throughout the exposure and they are almost always partially flattened or collapsed. Hand specimens are variable in color ranging from a light yellow-green to dark red-brown. These color differences are most likely due to alteration rather than variations in the degree of welding of the tuff. Quartz, sanidine, biotite, and hornblende are visible in outcrop as rather large phenocrysts. Quartz and biotite grains are present up to 5 mm in diameter while sanidine crystals attain a maximum size of 3 mm. Quartz is often stained a red-brown color by secondary hematite. Small lithic fragments of unknown composition are scattered throughout the section at Ike Springs Wash.

2. Petrography. The Tuff of Pritchards Station (ISW) is an extremely crystal-rich ash-flow tuff. Total crystal content ranges from 40% to 50% with an average value of 46.8% ± 1.2%. Plagioclase, quartz, sanidine, biotite, and hornblende are all abundant in thin section. Pyroxene, apatite, zircon, secondary calcite, and iron-oxides are present ranging in concentration from trace amounts to approximately 3%-4%. Numerous pumice lenticules of various sizes are seen in every thin section, but lithic fragments are essentially absent under the microscope.

Plagioclase is the most abundant mineral present and it displays the most variation of the crystals in the tuff in terms of grain size. Euhedral crystals range from less than 0.5 mm to over 4.5 mm in diameter. Broken or fragmented phenocrysts are common especially in the smaller grains. Moderate zoning occurs in less than half of the plagioclase phenocrysts present in the rock. Plagioclase composition averages An_{39}. Large quartz crystals are found in every thin section of the Ike Springs Wash samples. Individual grains are subhedral to anhedral in shape and they attain a maximum diameter of 5.3 mm. Resorbed or embayed textures are common along with the shattering of fracturing of quartz grains. Sanidine is the third most abundant mineral in the tuff after plagioclase and quartz. Grains are euhderal and range from 1 mm to 2.5 mm in diameter. Much of the sanidine at the Ike Springs Wash locality has crystallized around a plagioclase core. Biotite and hornblende phenocrysts are present in near equal amounts. Biotite displays both pseudo-hexagonal and elongated, slender crystals which are often more than 4 mm in their longest dimension. Hornblende content averages 4.8% ± 0.26% and euhedral to subhedral grains are up to 3 mm across. Zircon and apatite occur as small grains in either plagioclase or the mafic minerals while pyroxene is restricted as inclusions in hornblende crystals.

Alteration in the Tuff of Pritchards Station (ISW) occurs in varying degrees with no recognizable pattern or zonation present. Calcite forms as an alteration product of plagioclase and hornblende. Both of these minerals vary from fresh to completely altered masses of calcite. The alteration is so intense that it is often difficult to determine the identity of the original mineral. Biotite and hornblende are commonly oxidized to secondary iron-oxides. Biotite exhibits all degrees of alteration, but hornblende shows only minor oxidation around the edges of grains.

Pumice lenticules are abundant throughout the ignimbrite at Ike Springs Wash. These fragments are well devitrified in the lower 160 feet of the ash flow in the form of large, well-developed spherulites. The remaining upper portion of the Ike Springs Wash section is only slightly to moderately devitrified. Here, the pumice lenticules are crystallized to a very fine-grained texture and original shard structures are easily recognized in the groundmass of the ignimbrite. The pumice lenticules are greatly flattened in all parts of the Tuff of Pritchards Station (ISW), but nowhere are they completely collapsed. Pheoncrysts are not nearly as abundant in the pumice as the fragmented rock, but they are on the average larger and seldom broken or fractured.

3. Chemistry. At Ike Springs Wash, like the Pritchards Station locality, the tuff displays little or no vertical variation in chemistry. SiO_2 and Al_2O_3 are the most abundant chemical constituents averaging 68.0% ± 0.35% and 15.6% ± 0.14% respectively. Fe_2O_3, CaO, Na_2O, and K_2O all average between 3% and 4% while MgO, TiO_2, P_2O_5, and MnO are present in amounts of approximately 1% or less. No vertical variation or zonation is present for any of these chemical elements in the Pritchards Station at Ike Springs Wash. Chemical analyses for eight samples from this locality are listed in Table 4.

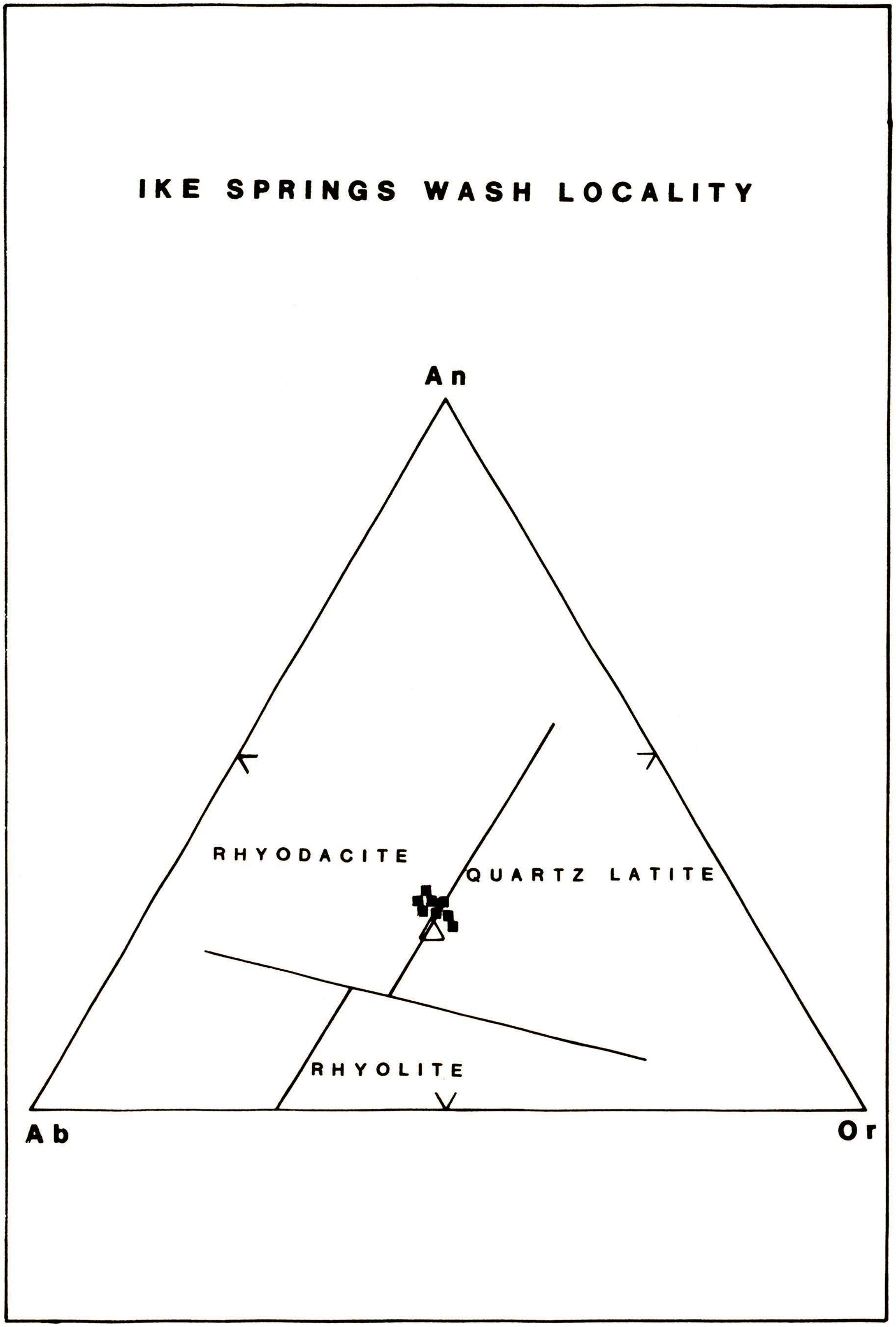
The normative feldspar proportions of the Tuff of

Pritchards Station (ISW) were obtained from the chemical analyses and plotted on the chart shown in Figure 7. Using this chart the ignimbrite at the Ike Springs Wash locality is found to be a rhyodacite to quartz latite with slightly greater An content than at Pritchards Station.

D. TRAP SPRING OIL FIELD LOCALITY

1. Introduction. The third reported occurrence of the Tuff of Pritchards Station is at the Trap Spring oil field on the western side of Railroad Valley. No outcrops are present here, but the Tuff of Pritchards Station has been identified in the subsurface (Duey, 1979). Thin sections from the No. 1 and No. 3 Trap Spring oil wells were generously loaned to the author by Northwest Exploration Company in Denver, Colorado. No samples were available for chemical analyses, but the thin sections do allow a petrographic analysis of the Tuff of Pritchards Station at this locality. The Pritchards Station overlies the upper Stone Cabin Formation in the Trap Spring oil field (Duey, 1979). It is in turn overlain by the Horse Camp Formation which consists largely of late-Tertiary valley fill. The contact between the Tuff of Pritchards Station and the Stone Cabin Formation occurs at a depth of approximately 5000 feet in the NWE T.S.1 well and at about 4080 feet in the NWE T.S.3 well. The thickness of the Tuff of

Figure 7. Normative feldspar proportions related to rock type, after O'Connor (1965) for the Tuff of Pritchards Station. The solid squares are samples from Ike Springs Wash and the open triangle represents the average of the Pritchards Station samples, illustrated in Figure 6.


IKE SPRINGS WASH LOCALITY
An
RHYODACITE
QUARTZ LATITE
RHYOLITE
Ab
Or

Pritchards Station in the oil field varies from 300 to 1000 feet.

2. Petrography. The Tuff of Pritchards Station (TS) appears to be a crystal-rich ash-flow tuff. The unit at this locality is extremely altered in every thin section so consequently the original mineral suite of the ignimbrite is difficult to determine. The altered masses were included when calculating the total crystal content, but since the alteration may increase or decrease the original size of minerals present, this value is only an approximation. The amount of crystals present in the Tuff of Pritchards Station (TS) ranges from 35% to 42% with an average value of 37.6% ± 1.9%. Quartz and sanidine are the only minerals present in abundance with biotite and plagioclase content averaging 2% or less. Hornblende is scarce at the Trap Spring locality; it is completely absent from several of the thin sections. Calcite, quartz, chlorite, and iron-oxides are present in varying amounts as alteration products. Pumice lenticules are somewhat abundant, but few if any lithic fragments are present in the Pritchards Station at the Trap Spring locality.

Quartz is the most prominent mineral in the Tuff of Pritchards Station (TS) exhibiting numerous, large crystals. Many of the samples contain three or more quartz grains which have a diameter of 3 mm or greater.

Phenocrysts are subhedral to anhedral and there appears to be two stages of fracturing present. The first and earlier stage is the common breaking or shattering thought to be associated with the eruption of ash-flow tuffs. A second stage of fracturing is the veining of quartz and other minerals by calcite and secondary quartz veins during alteration of the tuff. Sanidine is approximately equal in abundance to quartz in the Trap Spring samples. Crystals are frequently euhderal and reach a maximum diameter of 3.5 mm. Plagioclase was undoubtedly much more abundant originally, but only a few small grains have escaped complete alteration to calcite. Hornblende, like plagioclase, is very scarce under the microscope due to alteration. Biotite occurs as subhedral flakes 1 mm to 2 mm in length with occasional included grains of apatite or zircon.

The most distinctive feature of the Pritchards Station at Trap Spring is the intense alteration present everywhere in the tuff. Calcite is easily the most abundant alteration product present ranging in amount from 20% to 40% of the entire rock. It occurs as irregular masses after plagioclase and hornblende and also as veins which cut across the thin sections with no observed pattern. The altered masses are typically entirely calcite leaving no clues as to the identity of the original mineral. It is probable that the majority of these were plagioclase at one time. A small percentage of the masses, however contain secondary iron-oxides and chlorite along with calcite. This fact suggests that hornblende rather than plagioclase was the primary mineral in a few instances. The calcite veins in the ignimbrite at Trap Spring vary in width from hair-like fractures to continuous bodies 1.5 mm across. The veins are sometimes connected to the calcite masses while other times they do not exhibit any preferred orientation.

A second type of alteration is represented by quartz veins which are continuous and appear to fracture or brecciate the ignimbrite. These veins vary in width up to 1 mm across and contain tiny fragments of various crystals, pumice, and groundmass which were incorporated as the veins spread through the tuff. The quartz veins are not as prevalent as the calcite veins as evidenced by their presence only in selected samples at the Trap Spring locality.

The last kind of alteration observed in the ignimbrite is the oxidation of biotite to iron-oxides. The amount of secondary iron-oxides after biotite at Trap Spring varies considerably as it does at Prithcards Station and Ike Springs Wash. Fresh to completely altered phenocrysts are found throughout the ash flow.

The entire Pritchards Station section at the Trap Spring oil field appears to be moderately to densely welded. Pumice lenticules are commonly quite flattened. Glass shards, though devitrified, are readily identified in thin section. They are often bent and warped around phenocrysts due to compaction and welding. The ignimbrite is devitrified in all portions studied to a moderate degree. Spherulites are seen in some pumice fragments, but both the pumice and groundmass of the tuff are generally crystallized only to a fine-grained appearance.

VI. RESULTS AND DISCUSSION

A. INTRODUCTION

The Tuff of Pritchards Station in east-central Nevada displays considerable lateral variation despite the limited, known areal distribution of the unit. This variability is difficult to explain, since no vertical differences in the mineralogy or chemistry of the ignimbrite are present at the localities studied. Some mineralogical and chemical parameters are consistent over relatively short distances. These lateral changes in the Tuff of Pritchards Station are examined here in more detail.

B. VARIATIONS IN MINERALOGY

The suite of primary minerals present in the Tuff of Pritchards Station is essentially the same at each locality studied. Plagioclase, quartz, sanidine, biotite, and hornblende are commonly seen in thin section along with trace amounts of pyroxene, apatite, and zircon. The amount and size of certain minerals, however does change considerably from one area to another. In general, secondary minerals resulting from alteration are not necessarily consistent laterally over distances of miles. Therefore, they are not considered here as reliable indicators of lateral variability.

Large, euhedral plagioclase crystals are found at both

Pritchards Station and Ike Springs Wash. Plagioclase is also the most abundant mineral at these occurrences of the Tuff of Pritchards Station. It was undoubtedly more common at the Trap Spring locality prior to alteration, but whether plagioclase was the most abundant mineral there originally is uncertain. The extreme oscillatory zoning present in plagioclase at Pritchards Station is absent from the other two localities. There, only mild zoning of plagioclase is present. This feature, which is thought to be related to conditions of the original magma chamber, should theoretically be present laterally throughout the Tuff of Pritchards Station.

Quartz phenocrysts are abundant and easily seen in both hand samples and thin sections at all localities. However, the average content of 7.8% ± 0.77% at Pritchards Station increases to approximately 11%-12% at Ike Springs Wash and Trap Spring oil field. More obvious is the large increase in the size of quartz phenocrysts from Pritchards Station to the locations further east. The diameter of the largest quartz grain present in each thin section was measured for several samples from each locality. The results of this are given in Table 5. The largest crystal in each sample at Pritchards Station averaged 2.3 mm ± 0.21 mm in diameter. Those at Ike Springs Wash and Trap Spring were significantly larger averaging 3.7 mm ± 0.21 mm and 3.6 mm ± 0.19 mm respectively.

TABLE V

Tuff of Pritchards Station.
Maximum size of quartz grains viewed in thin section.
*Exact vertical position of sample is uncertain.

PRITCHARDS STATION LOCALITY		IKE SPRINGS WASH LOCALITY		TRAP SPRING FIELD LOCALITY	
Sample No.	Diameter (mm)	Sample No.	Diameter (mm)	Sample No.	Diameter (mm)
82-31	1.1	82-50	5.3	TP#1 NWE*	3.2
82-33	2.8	82-52	2.9	TP#1 Par. *	3.6
82-34	1.4	82-54	2.7	TP#1 Per. *	3.1
82-36	1.7	82-56	3.2	TP#1 4376	4.7
82-38	2.6	82-58	3.1	TP#1 4385	3.4
82-40	2.4	82-60	3.3	TP#1 4395	3.6
82-42	2.2	82-62	3.4	TP#1 4399	4.9
82-45(a)	2.9	82-64	4.9	TP#1 4405	3.2
82-45(b)	3.2	82-83	2.8	TP#1 4409	2.9
82-46	3.3	82-85	3.6	TP#3 3214	3.6
82-48	1.8	82-87	4.3	TP#3 3220	4.8
		82-89	3.4	TP#3 3229	3.5
		82-91	4.7	TP#3 3319	3.0
		82-93	4.1	TP#3 3324	3.2
		82-95	3		
Mean	2.3		.7		3.6
Std. Dev.	0.7		0.8		0.7

Also, several quartz grains over 4 mm in size were observed at Trap Spring and Ike Springs Wash while the largest diameter found at Pritchards Station was only 3.3 mm. It is problematical whether the normal eruptive and emplacement processes of ignimbrites could sort grains laterally by size as is observed in the Tuff of Pritchards Station. Decreasing grain size westward would be inconsistent with a source in that direction.

Sanidine crystals from the three localitites studied vary both in size and abundance. At Pritchards Station sanidine content averages 2.2% ± 0.08% and no grains above 1.5 mm were found. The average content increases at Ike Springs Wash to approximately 6%-8% with phenocrysts up to 3 mm across present. Both crystal content and the size of sanidine achieve a maximum at Trap Spring averaging 10.7% ± 0.47% in abundance and attaining diameters up to 3.7 mm.

Hornblende content in the Tuff of Pritchards Station is approximately 5% or less in all samples studied. It does exhibit some variation in content from an average of 2.5% ± 0.29% at Pritchards Station to 4.8% ± 0.26% at Ike Springs Wash. The near absence of hornblende in the Trap Spring thin sections is likely due to the intense alteration present there.

It is not surprising that the total crystal content of the Tuff of Pritchards Station should display some lateral variation since many of the individual minerals do. The amount of total crystals in the tuff ranges from an average of 46.8% ± 1.2% at Ike Springs Wash down to 39.7% ± 2.7% at Pritchards Station. The Trap Spring average of 37.6% ± 1.9% is really only an estimate since alteration has effected the total mineral content. The total crystal content of ash-flow tuffs has been documented to vary both vertically and laterally. Therefore, this parameter may not be as reliable as other factors in considering variability in the Tuff of Pritchards Station.

Lateral variations in the mineralogy of ash-flow tuffs have been documented by some workers. Fisher (1966) found that the total crystal content of an ignimbrite in Oregon decreased away from the source area. This decrease was attributed to a loss in energy by the ash flow as it moved away from the source. However, he measured the size of individual plagioclase grains, and their median diameters were consistent laterally in the tuff. In studying the Aso III tuff in Japan, Lipman (1967) also discovered a decrease in the amount of phenocrysts away from the Aso caldera. Kreider (1970) studied both the vertical and lateral variations in the mineralogy of the Lund Tuff, an extensive, crystal-rich ignimbrite in western Utah and eastern Nevada that could serve as a model for other crystal-rich tuffs in that area. He determined that the crystal content of the Lund Tuff decreased laterally away from the source area. At a locality approximately 60 miles from the source area, he also noted a decrease in the average grain size of the ignimbrite. The size reduction of the phenocrysts was not given quantitatively. Judging from the above examples, lateral variations in mineralogy may not be detectable except over long (>30 miles) distances. Also, as noted in the summary, the above ignimbrites display significant vertical variations, that theoretically could contribute to the observed lateral variations.

C. CHEMICAL VARIATIONS

The chemical data from this study were analyzed using a statistical test which compares the means of two or more groups. This test, commonly referred to as a t - test, attempts to prove whether or not significant differences exist between the means of the groups. The two groups considered here are the Pritchards Station and Ike Springs Wash localities. The means are the average content of selected chemical elements in samples from the two localities (See Table 4).

The equation for the t - test is:

$$t = \frac{\bar{Y} - u}{s/\sqrt{n}}$$

in which Y is the mean of the group being tested, u is the mean of the total population, s is the standard deviation of the population and n is the number of samples in the group. The applicable t value for the .005 significance level of a population of 18 (18 total samples from the two localities) is 2.921. If the t - test gives a value greater than this value, then the hypothesis is rejected that there is no difference between the means of the chemical parameters from the two localities, i.e., lateral variations in chemistry are present. The t - test was only used for the chemical parameters which displayed at least a slight variation. Therefore, it was not used to compare the means of MgO, Na_2O, and MnO (See Table 4). The following results are obtained by using the t - test to compare the chemistry of the samples from the Pritchards Station and Ike Springs Wash localities.

Chemical Parameter	t - Value	Hypothesis
SiO_2	4.71	rejected
Al_2O_3	2.43	accepted
Fe_2O_3*	4.60	rejected
CaO	5.96	rejected
K_2O	0.61	accepted
TiO_2	15.81	rejected
P_2O_5	2.57	accepted

From the above results it is evident that titanium shows the most variation laterally in the Tuff of Pritchards Station. This is significant since the TiO_2 content of a specific igneous unit is thought to remain fairly constant over long distances. Mueller *et al.* (1983)

considered TiO_2 to be an immobile element during metamorphism which would include various types of alteration. S.K. Grant (oral communication, 1983) has found that the titanium content is a reliable indicator of original chemistry for several of the ignimbrites in western Utah and eastern Nevada. Along with titanium the amount of silicon, iron, and calcium all varied significantly in the Tuff of Pritchards Station between the two localities. These chemical variations are difficult to explain especially since both the Pritchards Station and Ike Springs Wash localities display no evidence of vertical variations in chemistry. As noted before, vertical variations may lead to apparent lateral variations.

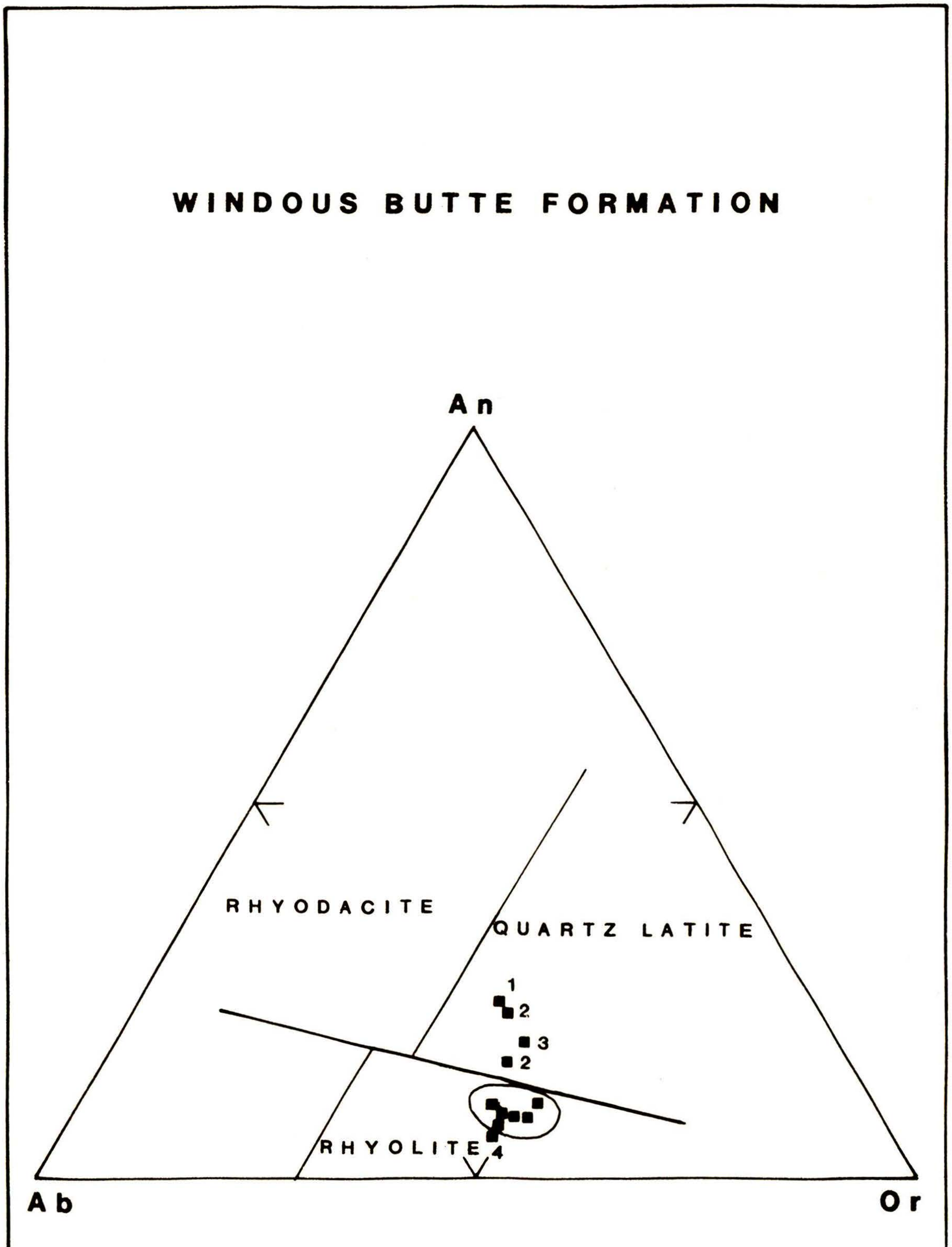
No example of lateral variation in the chemistry of ignimbrites was found in the literature. S.K. Grant (oral communication, 1983) has done x-ray fluorescence analyses for titanium in the Lund Tuff from nine widespread localities. Despite significant vertical variations at each locality, the site averages for TiO_2 show no significant differences within a 25-mile radius of the center of the ash-flow field. The unwelded, distal margins of the tuff are considerably lower in titanium than the main welded portion. These facts suggest that chemical variations, like the mineralogy, in ash-flow tuffs are recognizable only over distances of several tens of miles.

D. WINDOUS BUTTE FORMATION

The Windous Butte Formation is mentioned briefly here in association with the problem of lateral variability. The Windous Butte is thought by many to be one of the most extensive and most easily recognizable ignimbrites in east-central Nevada. However, to date, no detailed chemical or petrographic data have been published for the entire Windous Butte Formation. Therefore, the author feels that the specific characteristics and extent of this Formation are not well documented. Eight localities where the Windous Butte has been reported were visited and samples were collected. The samples were studied only briefly for petrography and chemistry, but some obvious variations are present.

The appearance of the Windous Butte Formation in hand specimen varied considerably from one area to another. The unit is light brown to tan in color with abundant, very dark quartz crystals in the Pancake and Park Range. This distinctive looking unit was not observed at any other locations in east-central Nevada. The minerals in thin section such as sanidine were very abundant at some localities and nearly absent at others. Chemically, the Windous Butte Formation ranges from a silica-rich rhyolite to a quartz latite (Figure 8) with a widespread array of points. Chemical analyses of the Windous Butte from six

Figure 8. Normative feldspar proportions related to rock type, after O'Connor (1965) for the Windous Butte Formation from several localities in east-central Nevada. 1= Southern end of Egan Range; 2= One mile north of Windous Butte type locality, on U.S. Route 6; 3= Shingle Pass locality in the Egan Range; 4= Stone Cabin type locality in the Grant Range; Circled area= combined samples from the Park Range (Pritchards Station) and the Pancake Range (Ike Springs Wash).


WINDOUS BUTTE FORMATION
An
RHYODACITE
QUARTZ LATITE
1
2
3
2
RHYOLITE
4
Ab
Or

localities are given in Table 6.

The Windous Butte Formation was not studied in enough detail by the author to draw specific conclusions concerning it. However, variations do exist in the ignimbrite as described, and they are not easily explained. These variations create confusion when working with the Windous Butte Formation and this problem will remain until further studies are done.

E. SUMMARY

The chemical and petrographic evidence indicates that the Tuff of Pritchards Station varies considerably from one locality to another in east-central Nevada. The unit as described at Pritchards Station is a distinctive and identifiable ash-flow tuff. Lateral changes over distances of only 25 to 30 miles create correlation problems. To date, the Tuff of Pritchards Station has been correlated and identified essentially by identification in outcrop and on the basis of stratigraphic position. Ignimbrites can not necessarily be treated as sedimentary rocks for stratigraphic purposes since their distribution is often erratic as a result of the topography prior to eruption and emplacement. The lateral variability of the Tuff of Pritchards Station has not been detected before now, simply because no detailed studies of the unit had been completed. The exact cause of these differences between localities of the Pritchards Station

TABLE VI

Chemical analyses of the Windous Butte Formation by x-ray fluorescence from several localities in east-central Nevada

WINDOUS BUTTE FORMATION

Sample No.	Lat.-Long.	SiO_2	Al_2O_3	Fe_2O_3*	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO
82-24	38.80-116.18	76.9	12.4	1.2	0.16	1.1	3.2	4.9	0.11	0.02	0.06
82-28	" "	76.5	12.4	1.1	0.17	1.2	3.4	5.0	0.10	0.08	0.06
82-30	" "	75.8	13.3	1.1	0.31	1.1	3.2	4.9	0.10	0.05	0.07
82-70	38.73-115.73	75.2	13.2	1.3	0.27	1.2	3.4	5.3	0.12	0.02	0.10
82-71	" "	75.8	12.7	1.2	0.48	1.1	3.1	5.3	0.11	0.02	0.06
82-72	" "	76.6	12.4	1.2	0.50	1.2	2.8	5.2	0.12	0.02	0.05
Mean		76.1	12.7	1.2	0.32	1.2	3.2	5.1	0.11	0.04	0.07
Std. Dev.		0.6	0.4	0.1	0.15	0.1	0.2	0.2	0.01	0.03	0.02
82-96	38.94-115.22	70.3	14.7	3.5	0.91	3.0	2.7	4.3	0.43	0.13	0.07
82-97	" "	71.4	14.9	2.2	0.50	2.2	3.2	5.2	0.27	0.05	0.07
76-23	38.32-114.98	70.5	14.2	3.5	1.3	3.1	2.6	4.2	0.41	0.10	0.06
76-24	38.57-114.94	71.9	14.4	2.8	0.60	2.3	2.6	4.9	0.35	0.08	0.07
82-21	38.65-115.37	75.9	13.2	1.2	0.24	1.0	3.2	4.9	0.10	0.08	0.07

was not determined in this thesis, but a few possibilities are postulated.

The degree of welding and the vertical continuity of the Tuff of Pritchards Station at the various localities suggests a homogeneous unit for the portions exposed. Since the position of each locality relative to one another in a vertical sense is not known, the sections from each location may have originally occupied different stratigraphic positions in the entire ash flow. Hence, the variations now seen in the Tuff of Pritchards Station would be due to vertical rather than lateral changes in the ignimbrite. A second possibility is that the three main exposures of the Pritchards Station represent eruptions from the same magma chamber at slightly different times. This hypothesis could explain the overall similarities of the various localities and yet, allow for the chemical and mineralogical variations. A third and viable explanation is simply that the observed lateral variability of the Tuff of Pritchards Station is a result of the normal eruptive and depositional processes of ash-flow tuffs. Lastly, the possibility exists that the three localities studied have been mis-identified and they are not the same unit. If this direction is taken, then it is suggested that the Ike Springs Wash and Trap Spring localities are probably the same unit and the Pritchards Station section is a separate ash flow. This division is based on petrographic and chemical considerations and the proximity of the Ike Springs Wash locality to the Trap Spring oil field. This final explanation warrants serious consideration since the Tuff of Pritchards Station has not previously been examined in detail.

VII. CONCLUSIONS

The Tuff of Pritchards Station, as currently known, is not a distinctive and easily identifiable ash-flow tuff in east-central Nevada. Only a few occurrences of this informal mapping unit have been documented. Correlations are difficult despite the short distances between localities.

The ignimbrite is a homogeneous unit at each locality studied. Variation is present only in the degree to which the tuff is welded and this change is only minor in some cases.

Certain chemical and mineralogical characterisitcs of the Tuff of Pritchards Station differ significantly from one locality to another. The mineralogy of the tuff is consistent over the area studied, but the amount and size of phenocrysts vary considerably. Also, some chemical constituents are distributed unequally over the areal extent of the unit. Intense alteration in one area has further complicated correlation.

The origin of the lateral variability in the Tuff of Pritchards Station is not known. Several explanations are possible, but enough details are not available to attain a definite conclusion. Misidentification of the tuff in some areas is suggested here as a distinct possibility.

Future work should be directed toward verifying the published work and/or toward finding any incorrect correlations. This will require careful and thorough sampling, of the type done in the thesis, over the entire area.

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VITA

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