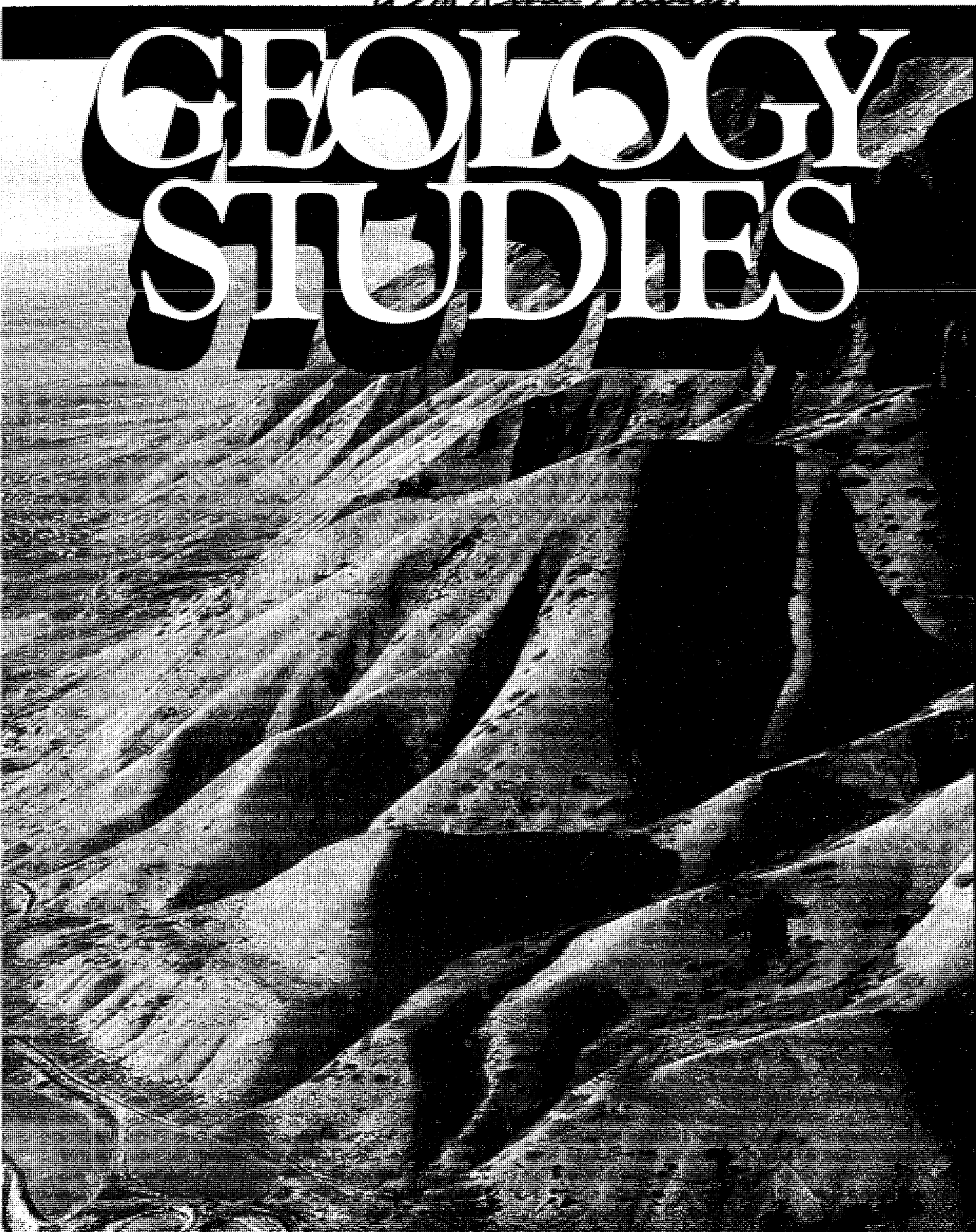
BRIGHAM YOUNG UNIVERSITY

GEOLOGY STUDIES



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CONTENTS

THE GLORY OF GOD IS INTELLIGENCE

Cover: Compound faceted spurs along the Wasatch Mountains indicate alternating periods of fault displacement and tectonic stability.

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CONTENTS

Stratigraphy of Pre-Needles Range Formation Ash-Flow Tuffs in the Northern Needle Range and Southern Wah Wah Mountains Beaver, County, Utah*

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ABSTRACT.—Pre-Needles Range Formation ash-flow tuffs are widespread throughout Beaver County, Utah, in the northern Needle Range and southern Wah Wah Mountains and preserve several paleovalleys and two major depositional basins. Conrad (1969) subdivided pre-Needles Range age volcanic rocks into three formations, the lowest of which he designated the Indian Peak Formation. Subsequent studies have shown that his stratigraphy requires revision. To document stratigraphic revisions, this investigation provides geologic maps, stratigraphic columns, and thin section and petrochemical data from three locations in the Needle Range and one in the Wah Wah Mountains. The new pre-Needles Range Formation stratigraphy proposed for these localities, from oldest to youngest is: Sawtooth Peak Formation, tuff of Sulphur Spring, Lamerdorf Member (new name) of the Escalante Desert Formation, and Beers Spring Member (new status) of the Escalante Desert Formation. It is recommended that Conrad's Indian Peak Formation be abandoned.

The distribution of rock types and stratigraphic thicknesses of pre-Needles Range units in Millard and Beaver counties, Utah, imply that a northwest-southeast barrier separated two major depositional basins prior to Needles Range Formation time.

INTRODUCTION

The eastern Great Basin consists of north-south trending valleys and intervening mountain ranges composed mostly of Paleozoic rocks that were folded and faulted during the Mesozoic Sevier orogeny. Middle to late Cenozoic extrusive rocks and minor sedimentary deposits overlie these deformed and eroded strata. Subsequent late-Cenozoic block faulting and tilting has exposed Paleozoic and Cenozoic rocks on the upturned edges of these ranges. Ash-flow tuffs are the most voluminous Tertiary rocks in the eastern Great Basin. The Oligocene Needles Range Formation, 29.7 ± 0.9 m.y. (Armstrong 1970), is one of the most widespread ash-flow sheets; it crops out over more than 33,600 km^2 in eastern Nevada and southwestern Utah (Best and others 1973, Cook 1965, Mackin 1963). Because of the wide lateral extent of the Needles Range flows, they have been used as key stratigraphic markers.

Numerous ash flows locally separate the Needles Range Formation from the erosional surface cut into Paleozoic sedimentary rocks. Paleogeographically, these units are significant because they fill and preserve these early canyons and Tertiary drainage channels.

Conrad (1969) mapped and described pre-Needles Range Formation units in the northern half of the Needle Range. Subsequent work by Best and others (1973), Rauch (1975), and unpublished mapping, on a scale of 1:24,000, in the northern Needle Range and Wah Wah Mountains by students of the Brigham Young University Summer Field Camps, has revealed several areas containing pre-Needles Range units (fig. 1). Northwest of Lund, Utah, at the south end of the Wah Wah Mountains, Grant (1978) named a sequence of ash-flow tuffs and intercalated volcanic sandstones the Escalante Desert Formation. Bushman (1973) identified several ash flows older than the Needles Range Formation in Millard County, Utah, north of Highway 21, about latitude 38°35' North. Rock types found by Bushman do not persist south of this highway even though the tuffs north and south of the highway are probably of similar age.

The purposes of this study are to (1) map the units that separate the Needles Range Formation from Paleozoic rocks in the northern Needle Range and southern Wah Wah Mountains, (2) correlate these units from area to area to establish their stratigraphic relations, and (3) make an interpretation of the paleotopography prior to Needles Range time.

METHODS OF STUDY

Fieldwork was performed during the spring and summer of 1975 and 1976. Mapping was done on air photos at a scale of 1:24,000 and later transferred to a topographic base at the same scale. Four areas were mapped (fig. 1).

Laboratory work included petrographic analysis of thin sections and stained rock slabs and determination of major element concentrations by X-ray fluorescence spectrometry. Modal compositions were determined by thin-section point counting of phenocrysts, lithic fragments, and groundmass. At least 700 points were counted per thin section. Counting precision and modal compositions are presented in tables 1 and 2. The staining procedure described by Bailey and Stevens (1960) was used to aid in the identification of phenocrysts. Petrochemical analysis followed the Norrish-Hutton (1969) method for ten major elements. Two glass buttons were prepared from each rock sample, and the average values are presented in tables 3 and 4.

NOMENCLATURE OF PRE-NEEDLES UNITS

Conrad (1969) described pre-Needles Range Formation tuffs in the northern half of the Needle Range, where they were divided into three formations, Indian Peak, Sawtooth Peak, and Beers Spring (table 5). Subsequent work has shown the ash-flow stratigraphy established by Conrad is in error. Conrad assigned the name Indian Peak Formation to rocks exposed for more than 2 km to the northwest, southeast, and northeast of Ryan Spring in section 30, T.28 S, R.19 W, northwest of Indian Peak. However, Rauch (1975) indicates that the nearest pre-Needles age tuffs to Ryan Spring are the "Escalante Valley Tuffs" (see below) 1.2 km to the southwest, near Paleozoic rock outcrops, where Conrad previously mapped alluvium. The Indian Peak units mapped by Conrad in this area are actually Needles Range age or younger.

Conrad's map also shows a large area in sections 24 and 25, T.28 S, R.19 W, which is occupied by the quartz-rich Sawtooth

*A thesis presented to the Department of Geology, Brigham Young University, in partial fulfillment of the requirements for the degree Master of Science, December 1976. Thesis committee chairman: Myron G. Best.

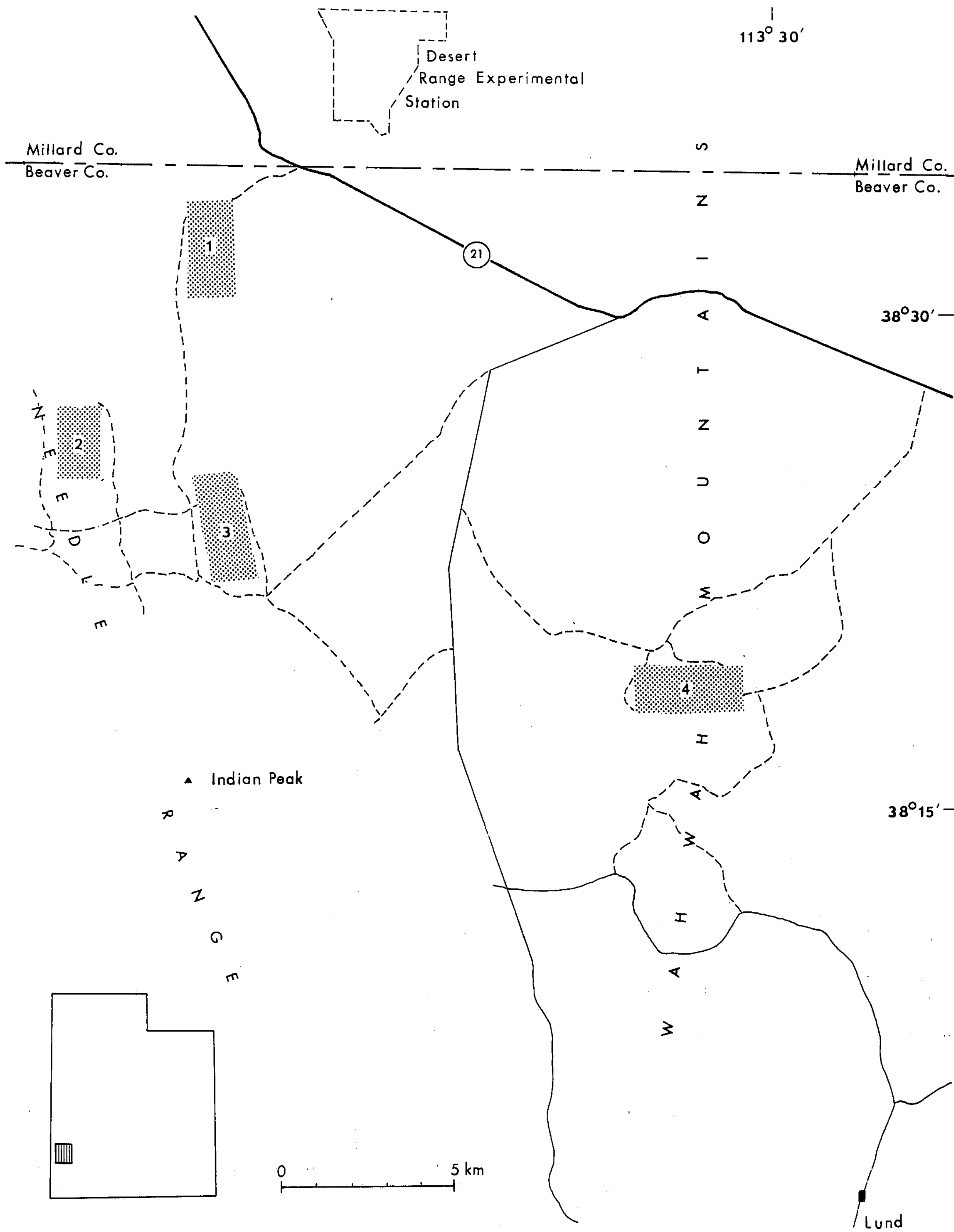


FIGURE 1.–Index map showing all areas of study. Shaded regions correspond to locations in the following 7½-minute topographic quadrangles: Area 1 (Halfway Summit), area 2 (Lopers Spring), area 3 (Sawtooth Peak), and area 4 (Lamerdorf Peak).

Peak Formation and is bounded below by Indian Peak units and above by the Beers Spring Unit 1, a weld tuff, and unit 2, a volcanic sandstone. From these stratigraphic relationships he proposed the Sawtooth Peak Formation to lie above the Indian Peak units (table 5), but mapping by Rauch and by students of the Brigham Young University Summer Camp in 1973 discovered this quartz-rich tuff to be the Lund Tuff Member of the Needles Range Formation and the ash flows bounding it below and above are the Ryan Spring Tuff (Rauch 1975) and the Isom Formation, respectively. The volcanic sandstone comprising the Beers Spring unit 2 actually underlies the Needles Range Formation.

Work by Best (1976) in the Lopers Spring Quadrangle shows several square kilometers of undifferentiated pre-Needles tuffs. New mapping in this area (fig. 2) has revealed at least four pre-Needles units that were previously mapped by Conrad as members of the Needles Range Formation. Three ash flows in this sequence are identical to Indian Peak units mapped by Conrad at Beers Pass (fig. 3) and south of The Toad (fig. 4). If these tuffs in the Lopers Spring Quadrangle are equivalent to members of the Indian Peak Formation, outcrops there clearly show that a quartz-rich tuff similar to the Sawtooth Peak Formation lies below them (fig. 2). This is contrary to Conrad's stratigraphy (table 1 and Conrad 1969, fig. 2).

It is proposed in this report that (1) the Indian Peak Formation and its members be abandoned because of uncertain stratigraphic relationships to other tuffs and doubtful outcrop occurrences and because Rauch (1975) has defined a new unit, the Ryan Spring Tuff, of Needles-Range age which is apparently equivalent to one of Conrad's pre-Needles Indian Peak members; (2) the newly named Escalante Desert Formation (Grant 1978) supersede the Indian Peak name for some of the units lying below the Needles Range Formation; (3) the Lamerdorf Member, a new name, be used as a designation for widespread tuffs within part of the Escalante Desert Formation; (4) Conrad's Beers Spring Formation be abandoned; and (5) Beers Spring unit 3 be redefined as a member of the Escalante Desert Formation overlying the Lamerdorf Member.

Lamerdorf Member

The Lamerdorf Member (new name) consists of a lower vitric-crystal tuff and an upper vitric-lithic tuff. At the type locality of the Escalante Desert Formation, Grant (1978) recognizes three ash-flows (D, E, F) which apparently correspond to

TABLE 1
MODAL COMPOSITIONS FOR THE LOWER LAMERDORF TUFF MEMBER

			MODAL COMPOSITION (Volume %)								
Area no.	Quadrangle	Sample no.	Quartz	Plagioclase	Sanidine	Biotite	Amphibole	Pyroxene	Fe-Ti oxides	Lithic fragments	Groundmass
1	Halfway Summit	Whc-Y	0.1	10.4	<0.1	1.8	<0.1	0	0.5	6.3	80.6
2	Lopers Spring	Ast-1	0.1	10.3	0	1.2	0	0	1.2	4.2	83.1
3	Sawtooth Peak	Swp-2	0.3	10.3	0	1.6	0	0	1.0	3.3	83.5
4	Lamerdorf Peak	Pal-2	0.6	8.6	<0.1	2.9	0	0	2.4	8.5	76.7
Precision, in relative percent[1]			96	7.5		23			25	10	1.5
Average composition			0.3	9.9	<0.1	1.9	<0.1	<0.1	1.3	5.6	81.0

[1]Determined by a method described by Dryden (1931).

TABLE 2
MODAL COMPOSITIONS FOR THE UPPER LAMERDORF TUFF MEMBER

			MODAL COMPOSITION (Volume %)								
Area no.	Quadrangle	Sample no.	Quartz	Plagioclase	Sanidine	Biotite	Amphibole	Pyroxene	Fe-Ti oxides	Lithic fragments	Groundmass
1	Halfway Summit	Whc-V	0.1	11.1	0.4	0.7	<0.1	0.1	0.7	24.5	57.4
2	Lopers Spring	M9-8	0	12.4	0.3	0.8	0.7	<0.1	0.9	27.5	62.4
3	Sawtooth Peak	Swp-1	0.2	12.0	0.2	1.0	0.2	<0.1	0.6	25.0	60.8
4	Lamerdorf Peak	Pal-1	0.5	16.5	0.4	3.1	0	0	1.9	22.7	55.3
5	Lund	Lnd-1	0.9	11.5	0.5	2.2	0.5	0	2.2	25.4	56.8
Precision, in relative percent[1]			96	7	96	24	96		25	4.5	2.0
Average composition			0.4	12.6	0.4	1.7	0.3	<0.1	1.4	25.0	58.0

[1]Determined by a method described by Dryden (1931).

TABLE 3
MAJOR ELEMENT CONCENTRATIONS FOR THE LOWER LAMERDORF MEMBER

AREA NO.	1	2	4	
QUADRANGLE	HALFWAY SUMMIT	LOPERS SPRING	LAMERDORF PEAK	PRECISION[1]
SAMPLE NO.	Whc-Y	Ast-1	Pal-2	
SiO_2	69.5	70.3	69.5	0.29
Al_2O_3	14.6	14.1	14.0	0.70
Fe_2O_3	3.14	2.63	2.86	0.5
MgO	0.78	0.84	0.77	1.5
CaO	1.90	1.85	1.37	0.66
Na_2O	2.4	2.6	2.1	3.
K_2O	5.25	4.27	5.02	0.30
TiO_2	0.51	0.47	0.46	0.97
P_2O_5	0.10	0.10	0.11	3.11
MnO	0.01	0.01	0.06	23.
Total	98.19	97.17	96.25	

[1]Percent relative standard deviation of the population.

TABLE 4
MAJOR ELEMENT CONCENTRATIONS FOR THE UPPER LAMERDORF TUFF MEMBER

AREA NO.	1	2	4	5	
QUADRANGLE	HALFWAY SUMMIT	LOPERS SPRING	LAMERDORF PEAK	LUND	PRECISION[1]
SAMPLE NO.	Whc-V	M9-8	Pal-1	Lnd-1	
SiO_2	66.3	67.3	65.4	63.5	0.38
Al_2O_3	15.1	15.5	15.3	14.8	0.98
Fe_2O_3	2.90	3.15	4.22	3.76	0.4
MgO	0.89	1.07	0.99	1.46	1.5
CaO	2.56	2.60	2.48	4.89	0.26
Na_2O	3.1	3.3	3.6	2.8	1.
K_2O	4.96	4.25	4.24	4.37	0.20
TiO_2	0.54	0.58	0.63	0.59	0.52
P_2O_5	0.09	0.13	0.16	0.15	4.24
MnO	0.03	0.05	0.07	0.06	12.
Total	96.47	97.93	97.09	96.38[2]	

[1]Percent relative standard deviation of the population.
[2]Approximately 2 percent calcite contamination.

TABLE 5
COMPARISON OF STRATIGRAPHIC NOMENCLATURE PROPOSED BY VARIOUS WORKERS FOR PRE-NEEDLES RANGE FORMATION ASH-FLOW TUFFS IN SOUTHWESTERN UTAH

NORTHERN HALF OF NEEDLE RANGE CONRAD (1969)	SOUTHWEST MILLARD COUNTY BUSHMAN (1973)	SOUTHERN END OF WAH WAH MTNS. GRANT (1973)	CENTRAL NEEDLE RANGE RAUCH (1975)	SOUTHERN END OF WAH WAH MTNS. GRANT (1978)	NORTHERN HALF OF NEEDLE RANGE AND SOUTHERN WAH WAH MTNS. CAMPBELL (1978)
Needles Range Fm.	Needles Range Fm.	Needles Range Fm.	Needles Range Fm.	Needles Range Fm.	Needles Range Fm.
				F	
Beers Spring Fm.	Tuff of Cedar Pass	Tuffs of Escalante Valley	Ryan Spring Tuff	Escalante Desert Fm. E	Escalante Desert Fm. Beers Springs Member
Sawtooth Peak Fm.			Needles Range Fm.	D	
	congl. of Skull Rock Pass			C	Lamerdorf Member
Indian Peak Fm.			Escalante Valley Tuffs	B	
	Tunnel Spring Tuff			A	Tuff of Sulphur Spring
					Sawtooth Peak Fm.

the upper tuff of the Lamerdorf found to the north in the Wah Wah Mountains and the Needle Range.

The Lamerdorf Member is widespread in the Lamerdorf Peak Quadrangle (fig. 5). The type locality lies east of Willow Creek Spring and west and south of Bucket Ranch Spring. This tuff is named for Lamerdorf Peak, in section 18, T. 29 S, R. 15 W. In the type locality the lower tuff consists of 15 percent crystals, 7–9 percent lithic fragments, and about 80 percent groundmass and varies in color from pale red to lavender (see lithologic description of the lower tuff and table 1). The upper tuff is composed of 23 percent lithic fragments in a pale yellowish brown to lavender groundmass. Crystals and groundmass represent 23 and 55 percent of the rock, respectively. The upper tuff is the most commonly exposed tuff in the type area and can usually be distinguished from the lower by the darker colored groundmass and the more abundant lithic fragments. However, certain portions of the lower tuff, in the type locality, have a high percentage of lithic inclusions resembling the less consolidated top of the upper. For this reason reference sections are recommended for each tuff outside the type area.

The most complete reference section of the lower tuff is found southeast of the Toad (fig. 4) in the northeast corner of section 33, T. 26 S, R. 18 W, in the northern Needle Range. At this reference section a good basal vitrophyre grades upward into a moderately welded, pale red tuff which weathers into massive clinkery outcrops. The uppermost part of this unit is

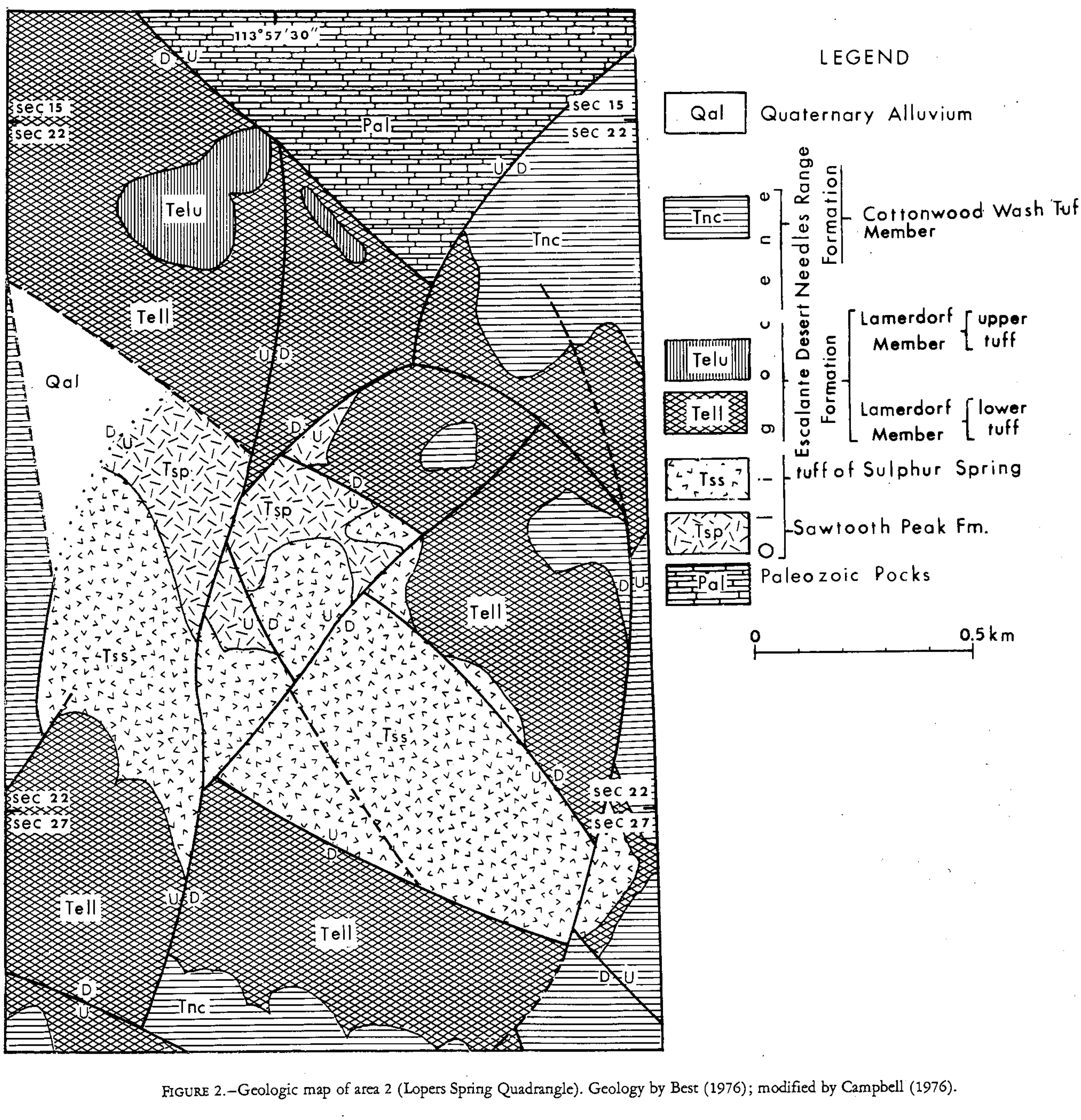


FIGURE 2.–Geologic map of area 2 (Lopers Spring Quadrangle). Geology by Best (1976); modified by Campbell (1976).

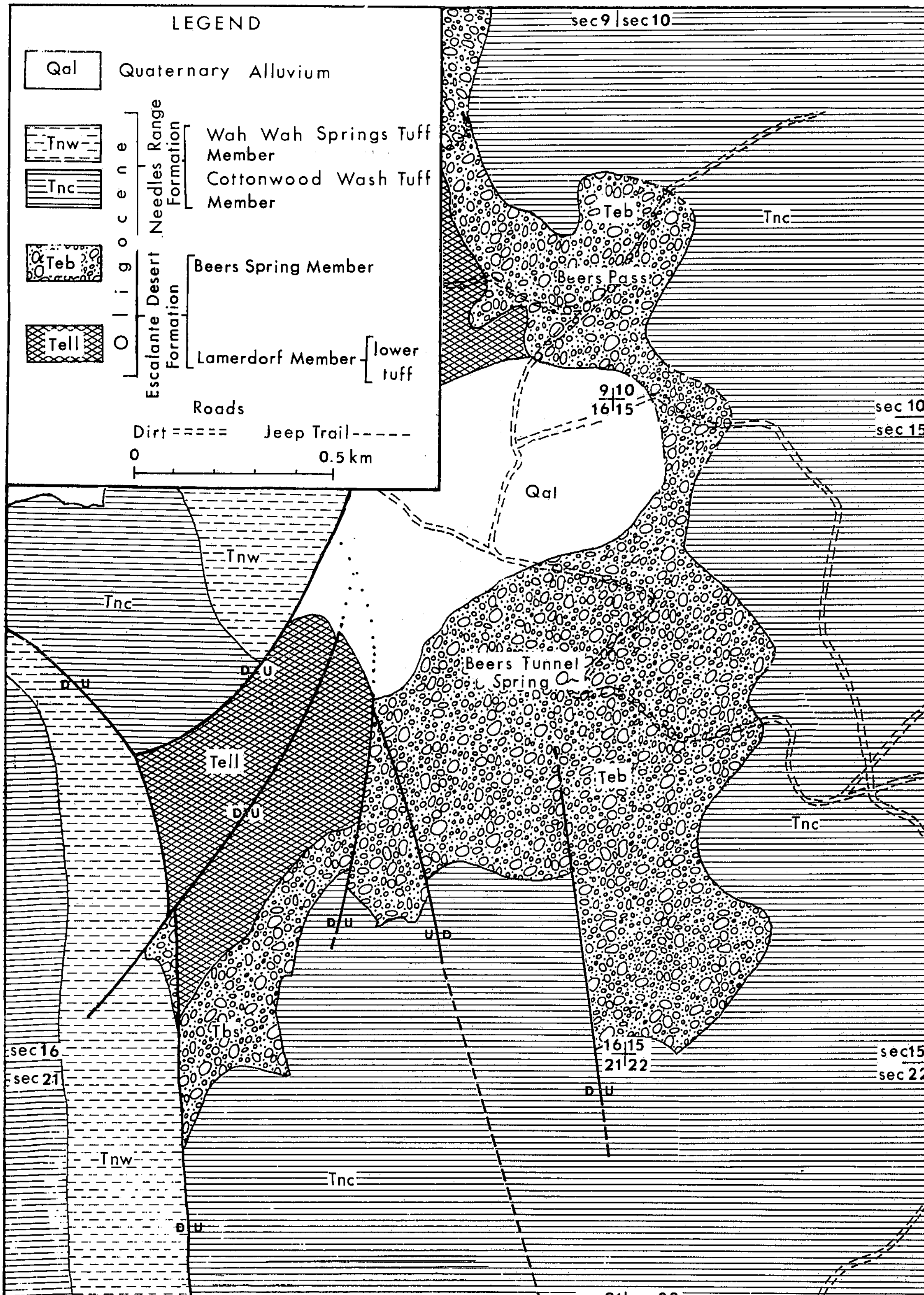


FIGURE 3.—Geologic map of the northern half of area 1 (Halfway Summit Quadrangle) in the vicinity of Beers Pass.

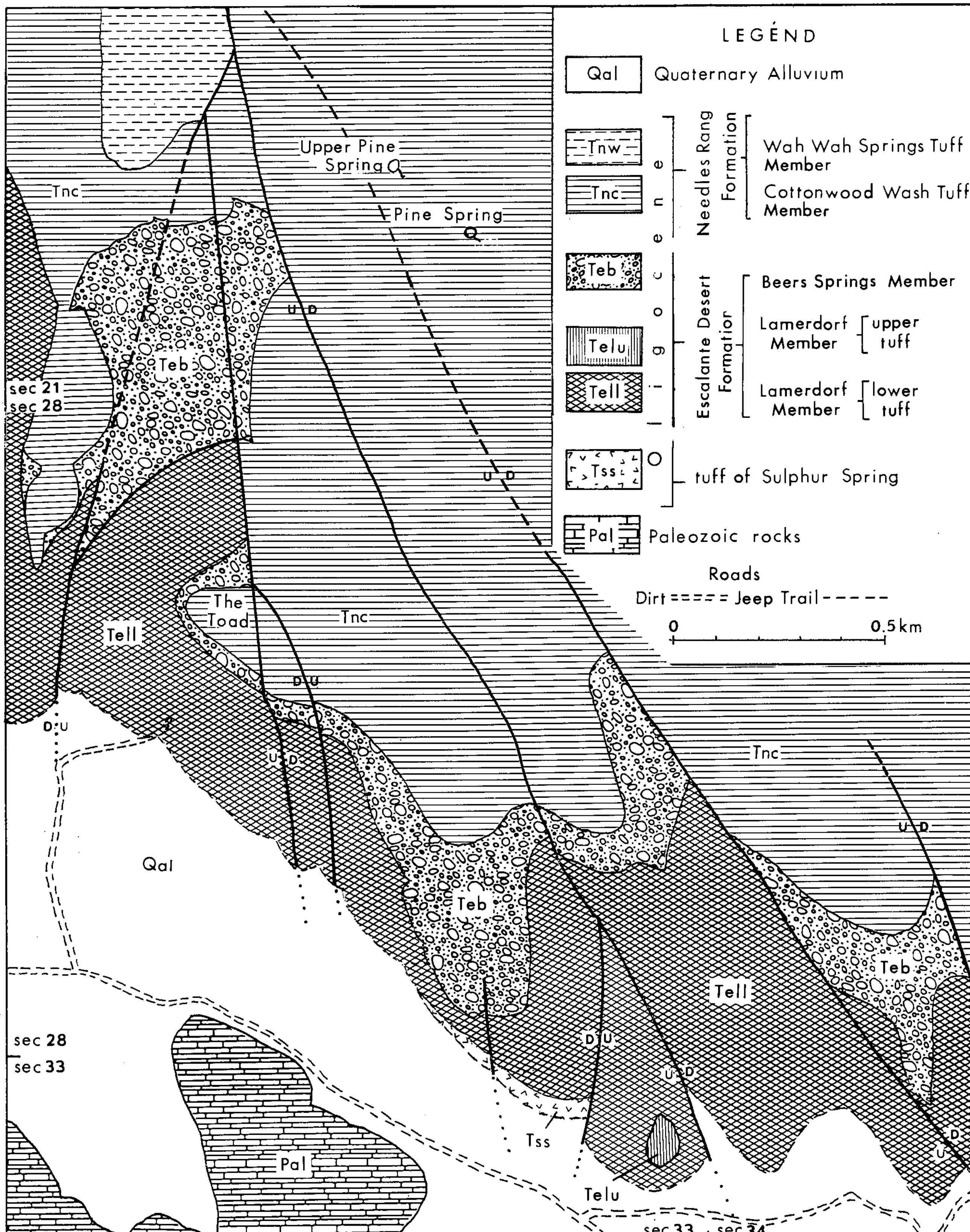


FIGURE 4.–Geologic map of the southern half of area 1 (Halfway Summit Quadrangle) in the vicinity of The Toad.

lavender colored with conspicuous bronze-colored biotite phenocrysts. Atop this flow is the upper tuff of the Lamerdorf Member. Immediately west of these outcrops the buff-colored cliffs of the tuff of Sulphur Spring are exposed beneath the lower Lamerdorf Tuff member.

The reference section for the upper tuff lies immediately below the Wah Wah Springs Tuff Member of the Needles Range Formation northwest of Lund, Utah (Best and others 1973, fig. 6), where it actually comprises three ash-flow sheets: D, E, and F of Grant (1978).

DESCRIPTION OF PRE-NEEDLES RANGE FORMATION UNITS

Mappable units lying below the Needles Range Formation are ash-flows, andesitic lava flows, and minor volcanic conglomerate and sandstone bodies (fig. 6). These units filled topographic lows in the mid-Tertiary landscape and reduced the topography to small hills and canyons. The wide lateral extent of the Needles Range Formation can be attributed in part to prior filling and flattening of topographic barriers by these rocks.

The pre-Needles age tuffs mapped and described in this investigation can be divided into two categories, the younger consists of the two lithic-rich, crystal-poor ash-flow tuffs making up the Lamerdorf Member of the Escalante Desert Formation. The older category includes more crystal-rich ash flows—such as the tuff of Sulphur Spring and the Sawtooth Peak Formation (Conrad 1969).

The lithologic descriptions that follow include the four flows mentioned above plus the epiclastic Beers Spring Member of the Escalante Desert Formation. The Cottonwood Wash Tuff and the Wah Wah Springs Tuff, members of the Needles Range Formation, are also included in the descriptions because they are extensively exposed throughout the study areas and define the upper boundary of the pre-Needles Range section.

Sawtooth Peak Formation

The Sawtooth Peak Formation (Conrad 1969) is a crystal to crystal-vitric ash-flow tuff exposed in the Lopers Spring Quadrangle (fig. 2) and the Sawtooth Peak Quadrangle (fig. 7) and is the oldest flow in the volcanic section. Most outcrops are gray, gray-green, or grayish pink in color. It is a ledge-forming unit in the Lopers Spring area, but near Sawtooth Peak it forms cliffs and monolithic hilly exposures surrounded by alluvium. The flow is moderately to strongly welded with a well-developed basal vitrophyre locally exposed. The vitrophyre is gray to black, ranging in thickness from 6–13 m, containing phenocrysts of quartz, plagioclase, and biotite.

Near Sawtooth Peak portions of the bottom of the formation locally appear water laid with conspicuous horizontal bedding. In the Lopers Spring Quadrangle the upper part of the unit locally exhibits cross-bedding and graded bedding. Three cooling units with gradational contacts apparently make up this ash-flow deposit at Sawtooth Peak where the middle unit is highly foliated and comprised of abundant collapsed pumice fragments. Conrad (1969) indicates this formation is composed of three members at the type locality with undulating contacts probably due to flow after deposition.

Throughout the flow, conspicuous crystals of quartz, plagioclase, and biotite and minor amounts of inconspicuous sanidine and pyroxene comprise 35–50 percent of the unit. Abundant, embayed, and broken quartz phenocrysts, 2–3 mm in diameter, occupy up to 16 percent of the tuff. At Sawtooth Peak, quartz phenocrysts are colorless or amber colored, but in the Lopers Spring Quadrangle they may be smoky gray. Biotite crystals, 1–2 mm across, may form books 1–1.5 mm thick.

Pale yellow to pale pink pumice is the only conspicuous clast, measuring 10–30 mm across and representing 2–10 percent of the flow near Sawtooth Peak to nearly 20 percent in the Lopers Spring area.

Tuff of Sulphur Spring

The informal name Tuff of Sulphur Spring, used for the first time in this report, is taken from a small spring in the Lopers Spring Quadrangle, section 3, T. 28 S, R. 19 W. The crystal-vitric tuff overlies the Sawtooth Peak Formation near Lopers Spring (fig. 2) and underlies the lower Lamerdorf Tuff member southeast of The Toad (fig. 4) in the Halfway Summit Quadrangle. The tuff is moderately to poorly welded and light brown to pale pink in color and weathers as cliffs or rocky slopes.

FIGURE 5.–Geologic map of area 4 (Lamerdorf Peak Quadrangle) between Willow Creek Spring and Bucket Ranch Spring.

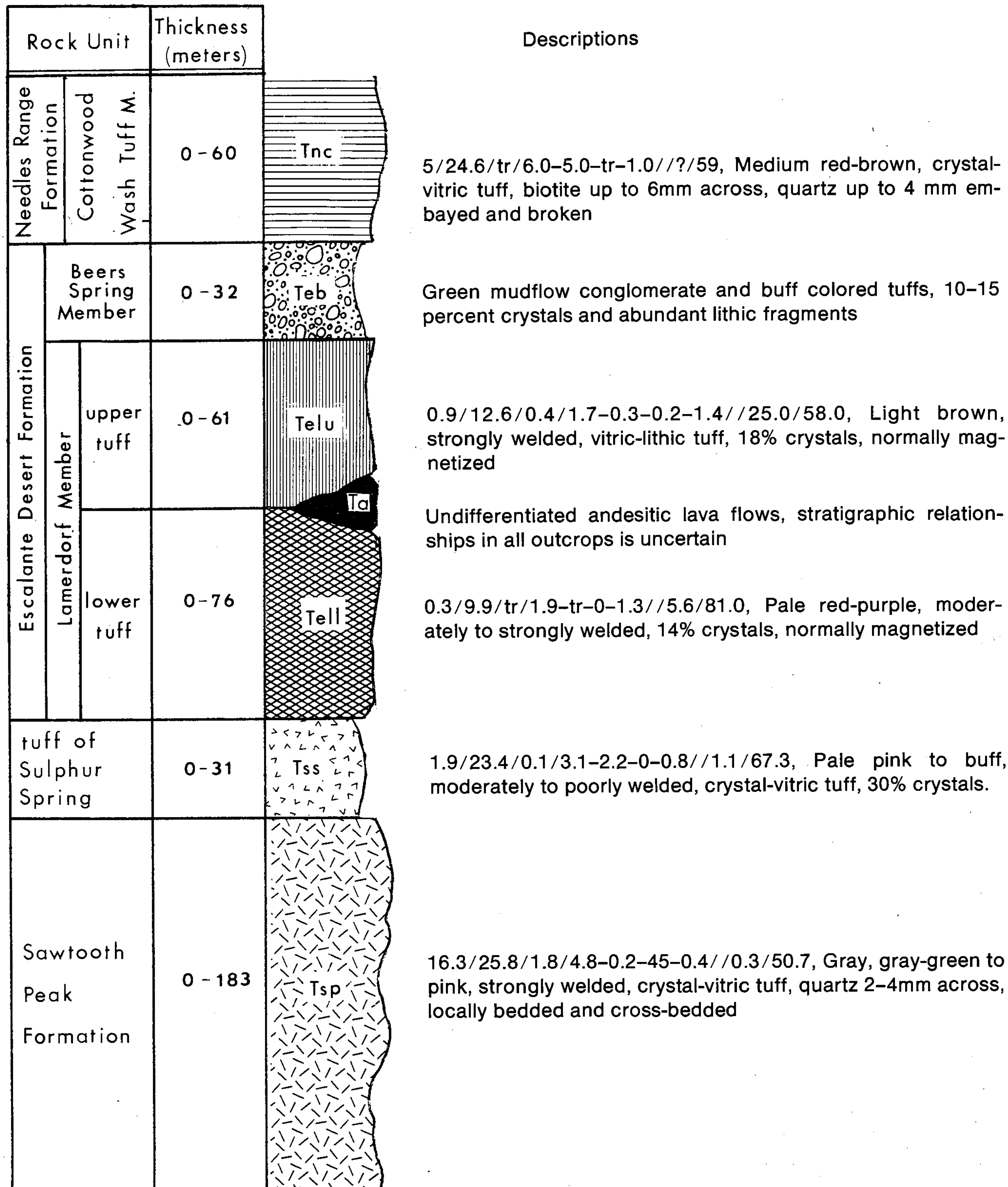


FIGURE 6.—A composite stratigraphic column for pre-Needles Range Formation units in the northern Needle Range and Wah Wah Mountains, Beaver County, Utah. The modal percentages of constituents in thin section are: quartz/plagioclase/sanidine/biotite-amphibole-pyroxene-Fe-Ti oxides/lithic fragments/groundmass.

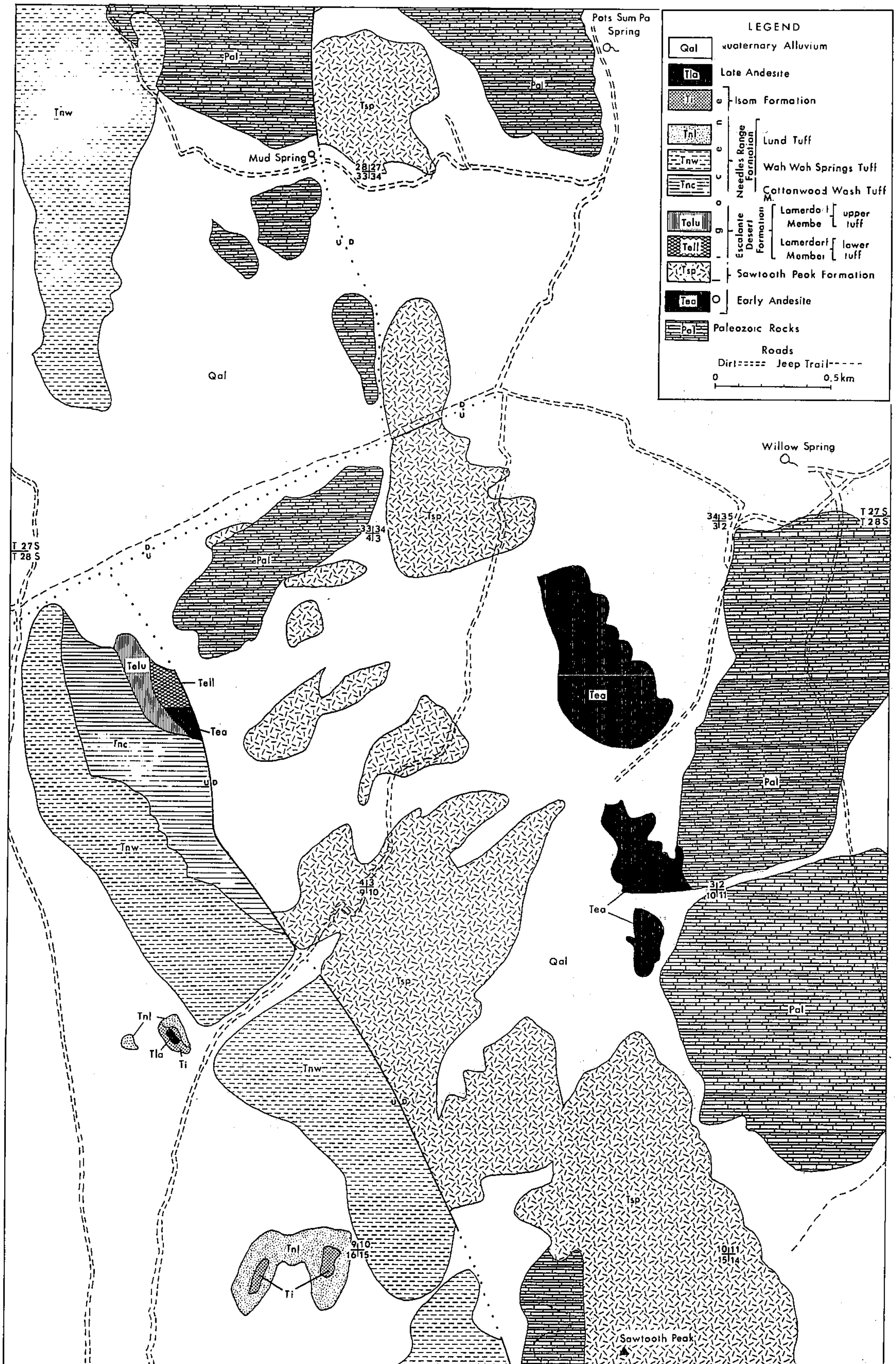


FIGURE 7.–Geologic map of area 3 (Sawtooth Peak Quadrangle).

Phenocrysts of plagioclase and biotite are easily recognized with the unaided eye, and quartz and amphibole are identifiable in thin section. Crystals make up 30–35 percent of the flow and range in size up to 2 mm. Only 2 percent or less of the flow consists of volcanic rock fragments.

Escalante Desert Formation

Lamerdorf Member, lower tuff

The lower tuff of the Lamerdorf Member is a vitric-crystal unit exposed beneath the Cottonwood Wash Tuff (Lopers Spring Quadrangle), Beers Spring Member (Halfway Summit Quadrangle), or the Lamerdorf Member Upper tuff (Lopers Spring and Lamerdorf Peak quadrangles). The groundmass is pale red-purple near the base where it weathers into massive, clinkery exposures, grading upward into a poorly consolidated, light purple or lavender-colored groundmass, containing bronze-colored biotite phenocrysts. A gray-to-black vitrophyre, 3–4 m thick, is locally exposed in the Lopers Spring area (fig. 2) and southeast of The Toad, in the Halfway Summit Quadrangle (fig. 4). But near Sawtooth Peak (fig. 7) and in the Lamerdorf Peak locality (fig. 5) no vitrophyre occurs.

Lamerdorf Member, upper tuff

The upper tuff of the Lamerdorf Member is a vitric-lithic tuff found locally beneath a thin, red, unnamed unit in the Sawtooth Peak Quadrangle (fig. 8) or the Cottonwood Wash Tuff (fig. 5) or the Wah Wah Springs Tuff (fig. 8; and Best and others 1973, fig. 6), members of the Needles Range Formation. Where the tuff is strongly welded, the groundmass is pale brown to pale yellowish brown. At the base, a black, lithic-rich vitrophyre, 2–3 m thick, is exposed, except in the Lamerdorf Peak locality where the vitrophyre is lacking.

Plagioclase and biotite crystals up to 3 mm in size are obvious in hand sample; and quartz, sanidine, amphibole, and Fe-Ti oxides can be seen in thin section. Plagioclase is typically chalky white and euhedral, 1–2 mm in length. Amphibole phenocrysts 1–1.5 mm long are identifiable in hand specimen at the Lopers Spring and Lund localities.

The abundance of lithic fragments is the most characteristic feature of this unit and distinguishes it from most other pre-Needles age flows. Pumice, red, and dark purple aphanitic volcanic rocks and minor amounts of sedimentary inclusions constitute 20–25 percent of the flow and measure 15–20 mm in diameter, but 30–40 mm fragments are not uncommon. The pumice may weather out of the outcrops leaving lenticular voids. In the Lopers Spring Quadrangle, collapsed pumice forms black lenses up to 5 cm in length in a yellowish brown groundmass, and similar fragments form red or purple lenses at other locations.

Beers Spring Member

Conrad (1969) describes this unit as a series of volcanic mudflow conglomerates and tuffs. At Beers Pass (fig. 3) three members of this unit are locally exposed immediately beneath the Cottonwood Wash Tuff. A green conglomerate, with amphibole-rich andesitic clasts held together by a green or brown sand matrix, overlies two lithic-rich tuffs. The upper tuff is white with dark-colored aphanitic volcanic inclusions up to 30 mm in diameter. The lower unit is very similar and may be part of the same flow, but the lithic fragments are generally larger, up to 30 cm. Both ash flows are poorly welded and contain up to 10 percent quartz, plagioclase, and biotite. South of Beers Pass, in the vicinity of The Toad (fig. 4), this unit is well exposed, but the conglomerate portion interfingers with a quartz sandstone composed of equant quartz grains 0.5–1 mm in diameter and rock fragments about the same size. Mafic minerals (biotite and magnetite) make up less than 1 percent of the sand and are cemented together by calcium carbonate.

It is an impersistent, generally thin unit which nonetheless is widespread throughout the Needle Range and southern Wah Wah Mountains. At the Lund locality, Grant (1978) has included a Beers-type conglomerate within his Escalante Desert Formation. Accordingly Conrad's Beer Springs Unit 3 is redefined as a member of this formation.

Cottonwood Wash Tuff Member

The Cottonwood Wash Tuff Member of the Needles Range Formation is a crystal-rich tuff with conspicuous, large biotite phenocrysts throughout the flow. The groundmass is medium-red grading upward to pink, where the flow is poorly consolidated and pumaceous (Best and others 1973). A well-developed gray-to-black vitrophyre, 3–4 m thick, directly overlies the Lamerdorf Member, in the Lopers Spring and Sawtooth Peak Quadrangles (figs. 2 and 7) and the Bears Spring Member in the Halfway Summit area (figs. 3 and 4).

Crystals comprise 35–40 percent of the tuff consisting of quartz, plagioclase, and biotite in hand sample and amphibole and Fe-Tio oxides in thin section. Biotite phenocrysts, 4–6 mm across, are characteristic of this flow, and occasional embayed and broken quartz crystals, 3–4 mm in diameter, are present in most samples.

Wah Wah Springs Tuff Member

Also crystal rich is the Wah Wah Springs Tuff Member, which overlies the upper tuff of the Lamerdorf Member at the Lund locality (fig. 8; Best and others 1973, fig. 6). This flow has a red-brown groundmass, where highly welded, and grades upward into pink and pink-brown, where poorly consolidated.

Unlike the Cottonwood Wash Tuff, this unit has conspicuous amphibole phenocrysts identifiable with the unaided eye. Other phenocrysts recognizable in hand specimen include plagioclase and biotite. Crystals represent about 40 percent of the unit and measure less than 3 mm in length.

DESCRIPTION OF LOCALITIES

Four occurrences of the Lamerdorf Tuff and other pre-Needles age flows have been mapped in the northern Needle Range and southern Wah Wah Mountains. They will be discussed for areas in the following quadrangles: (1) Halfway Summit, (2) Lopers Spring, (3) Sawtooth Peak, and (4) Lamerdorf Peak.

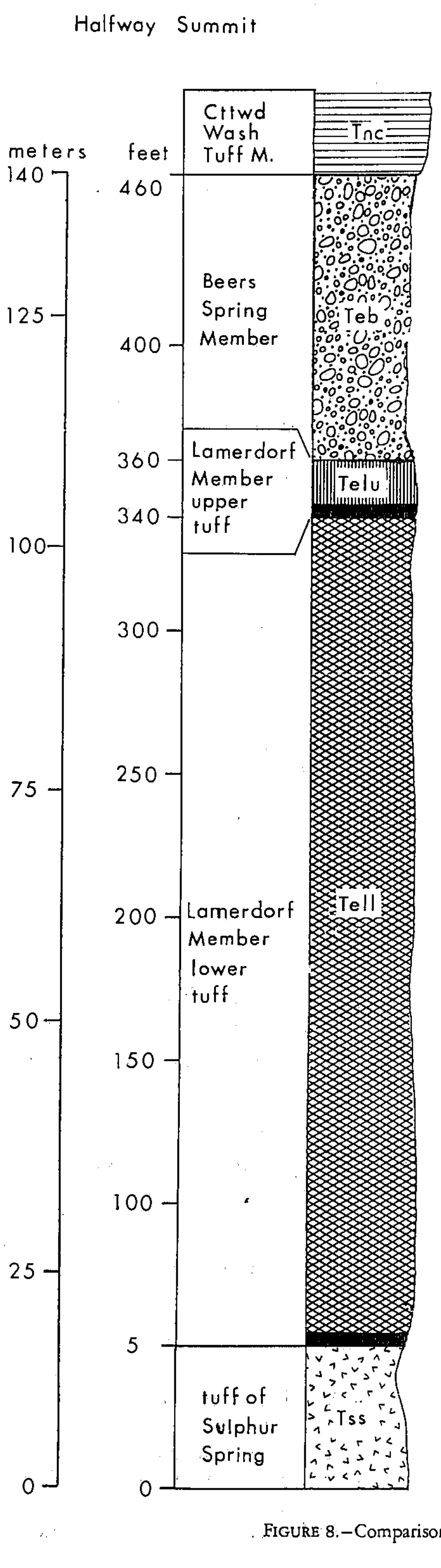
Halfway Summit

At Beers Pass (fig. 3) the Cottonwood Wash Tuff forms prominent cliffs, underlain by the slope-forming Beers Spring Member and the thick ledges of the lower tuff of the Lamerdorf Member. South of Beers Pass the tuffs of the Beers Spring Member appear thicker and more noticeable below the Cottonwood Wash Tuff.

South of Beers Pass, in the vicinity of The Toad (fig. 4), two additional pre-Needles age units occur, the upper tuff of the Lamerdorf Member and the tuff of Sulphur Spring (fig. 8). The Beers Spring Member is still exposed beneath the Cottonwood Wash Tuff, but the conglomerate portion interfingers with a quartz sandstone. Below the buff-colored tuffs of the Beers Spring unit are thick cliffs of the lower Lamerdorf, overlying smaller ledges of the tuff of Sulphur Spring. The only exposure of the upper Lamerdorf occurs in the northeast corner of section 33, where it caps a small hill. The base of the hill is the reference section for the lower tuff of the Lamerdorf Member.

Lopers Spring

Excellent exposures of pre-Needles Range age tuffs occur at the southern end of the Mountain Home Range in the Lopers Spring Quadrangle (fig. 2). The upper and lower tuffs of the Lamerdorf Member form hills near the Paleozoic rocks in sections 15 and 22. In the southerh half of section 22 the Sawtooth Peak Formation is clearly exposed beneath the tuff of Sulphur Spring. Farther south, in sections 22 and 27, the lower Lamerdorf tuff overlies the tuff of Sulphur Spring, and the Cot-



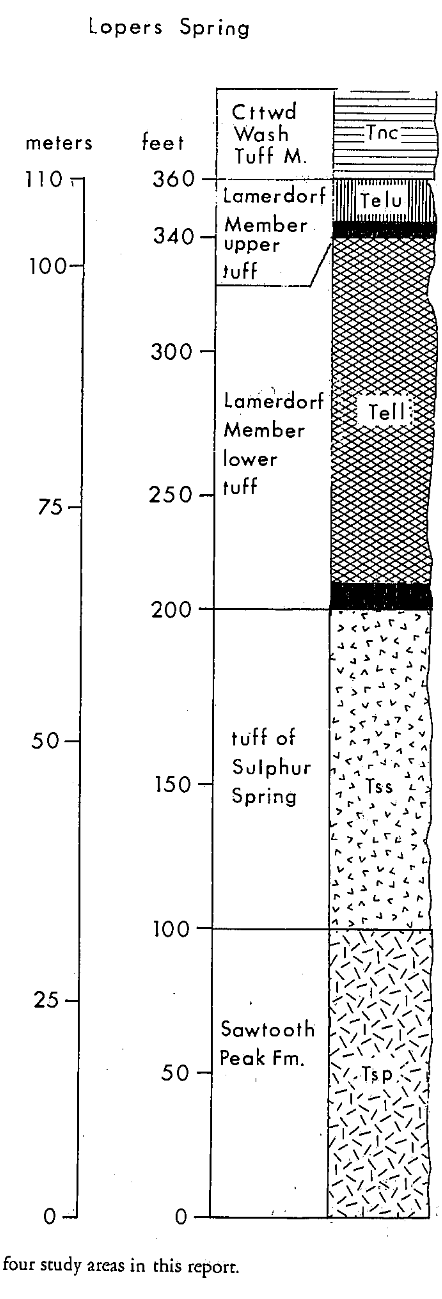


FIGURE 8.—Comparison of stratigraphy for the four study areas in this report.

tonwood Wash Tuff caps the pre-Needles Range Formation sequence (fig. 8).

Sawtooth Peak

Ash flows older than the Needles Range Formation occupy several areas in the Sawtooth Peak Quadrangle (fig. 7). The dominant flow is the Sawtooth Peak Formation, covering large areas north and south of Sawtooth Peak where it is over 200 m thick. Other pre-Needles age tuffs occur on the east facing slope of a small hill in section 33, T. 27 S, R. 18 W, 3.5 km northwest of Sawtooth Peak. At this locality three ash flows are exposed beneath the Cottonwood Wash Tuff (fig. 8). The youngest is a thin, red, unnamed unit containing plagioclase, biotite, and small euhedral magnetite crystals. The other two flows are Lamerdorf.

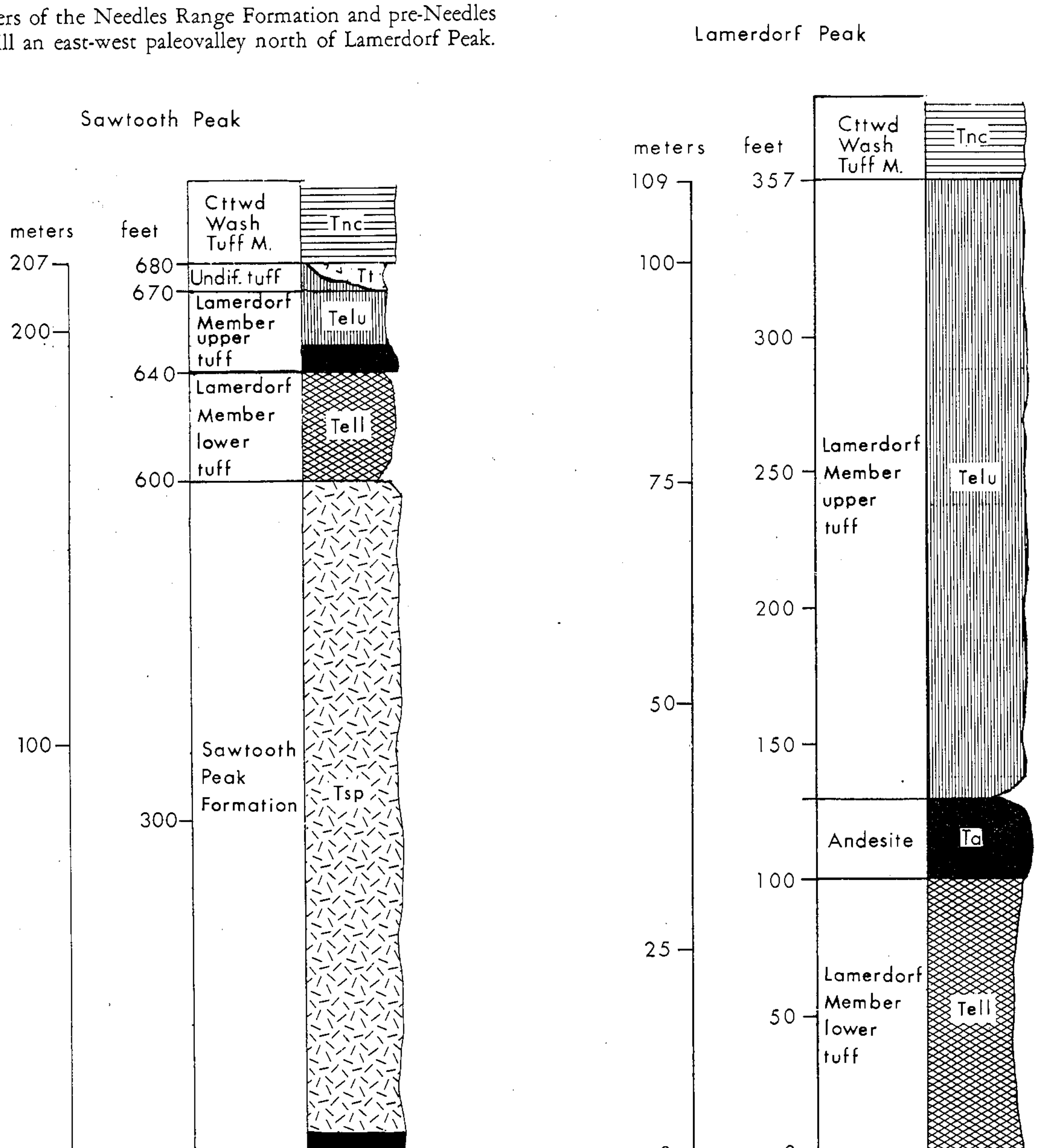
Lamerdorf Peak

Members of the Needles Range Formation and pre-Needles age tuffs fill an east-west paleovalley north of Lamerdorf Peak. Between Willow Creek Spring and Bucket Ranch Spring in sections 2 and 4 of T. 29 S, R. 16 W, numerous outcrops of the Lamerdorf tuffs occur (fig. 5). These two tuffs are locally separated by a plagioclase and pyroxene-rich andesite (fig. 8). A white-to-pale-green tuff resembling the lower part of the Escalante Desert Formation (Grant 1978) is exposed 1.5 km west of Bucket Ranch Spring.

EARLY CENOZOIC PALEOTOPOGRAPHY

The distribution and thickness of pre-Needles Tertiary volcanic rocks reflect the paleotopography carved into the Paleozoic section prior to about 30 m.y. B.P. Several local paleovalleys and hills are evident, and at least two major depositional basins existed prior to Needles Range Formation time.

One paleovalley occurs near Sawtooth Peak where tuffs filled a northwest-southeast trending topographic low cut into



Ordovocian sediments. The preserved topographic relief is at least 66 m, and the Sawtooth Peak Formation is highly foliated where it compacted around local hills.

In the Wah Wah Mountains other paleovalleys have been found where volcanic rocks fill two well-preserved topographic features. East-west valleys south of Wah Wah Springs in section 11, T. 27 S, R. 15 W, and north of Lamerdorf Peak are filled with tuffs and andesite flows. South of Wah Wah Springs, the Needles Range Formation and other flows preserve an east-west paleocanyon (Best and others 1973, fig. 4). Alternatively, this apparent inverted-valley feature may be due to headward erosion of ash-flow sheets that were deposited on Paleozoic rocks, and subsequent erosion has reduced the sheets to isolated east-west outcrops with the depositional contacts preserved.

A similar feature exists farther south in the Lamerdorf Peak Quadrangle, where members of the Lamerdorf Tuff and one andesite flow filled an east-west canyon with at least 100 m of relief. The volcanic landscape also underwent significant erosion and later channel filling. The most obvious erosional episode occurred after the deposition of the lower Lamerdorf tuff and the overlying andesite (fig. 9). South of Bucket Ranch Spring outcrops of the upper Lamerdorf tuff frequently lie topographically below the lower tuff with no sign of faulting to create this relationship. Deep channels were probably cut into the lower tuff and the andesite, creating a highly dissected topography with ridges and islandlike features. The upper Lamerdorf tuff later filled and flattened this topography (fig. 9), and subsequent erosion has exposed the upper tuff along the flanks of these channels, topographically below the lower tuff and the overlying andesite.

Two major depositional basins that contain significantly different pre-Needles Range Formation rock units are separated by a paleotopographic barrier that is approximately coincident with Utah Highway 21 (fig. 10). Bushman (1973) mapped and described the Tunnel Spring Tuff and other pre-Needles Range flows north of this barrier in Millard County. One of these flows, a quartz-rich ash-flow tuff, has been found as far south as Wah Wah Summit (fig. 10). Although the Sawtooth Peak Formation is a quartz-rich tuff, on the basis of petrochemical and petrographic data, it does not correlate with the quartz-rich units described by Bushman. None of the pre-Needles units in this report have been observed between Wah Wah Summit and the Lamerdorf Peak Quadrangle in the Wah Wah Mountains.

At the north end of the Needle Range, near Highway 21, and at the southern end of the Tunnel Spring Mountains (fig. 11) conglomerates separate older flows from the Needles Range

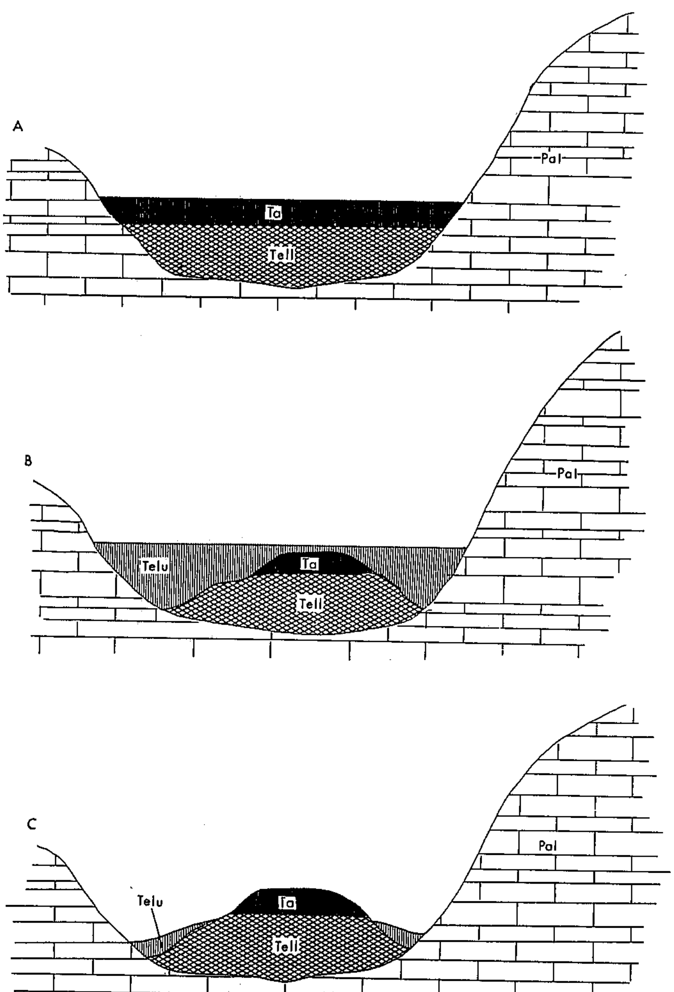


FIGURE 9.—A highly schematic diagram representing events that influenced the local stratigraphic relationships of the upper and lower Lamerdorf tuffs in area 4 (Lamerdorf Peak Quadrangle): (a) deposition of the lower Lamerdorf member and andesite into a paleocanyon; (b) erosion of the tuff and andesite into ridges and islandlike exposures, followed by deposition of the upper member of the Lamerdorf Tuff; (c) subsequent erosion reveals the upper Lamerdorf Tuff member topographically below the lower member and the andesite.

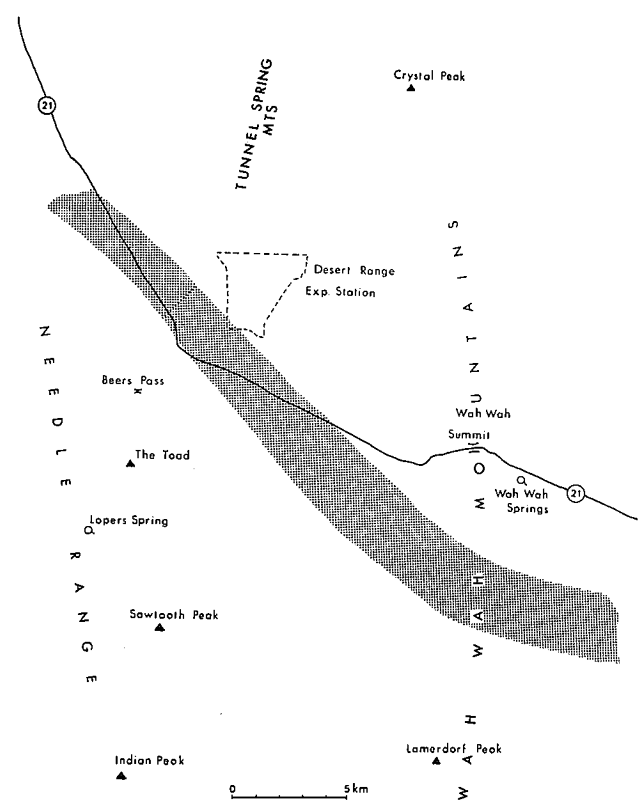


FIGURE 10.—Approximate position of a topographic barrier separating two major depositional basins prior to Needles Range Formation time.

Formation, indicating significant uplift or collapse and erosion occurred prior to deposition of the Needles Range Formation.

These stratigraphic relationships suggest two distinct basins were separated by a topographic barrier, trending northwest-southeast, prior to and during deposition of the Tunnel Spring Tuff and the units described in this study (fig. 10). The presence of the Needles Range Formation in both basins implies that older flows filled and flattened the topography allowing the Needles Range Formation to flow almost unobstructed.

It is suggested that future K-Ar dating be done on the flows in this report for comparison with the 32.7 ± 1.3 m.y. to 33.7 ± 0.7 m.y. dates for the Tunnel Spring Tuff (Bushman 1973) to indicate whether simultaneous filling of the basin occurred from different source areas.

SUMMARY AND CONCLUSIONS

Locally thick sections of volcanic rocks lying below the Needles Range Formation in the northern Needle Range and southern Wah Wah Mountains consist of at least seven mappable units. In the Needle Range the stratigraphy from bottom to top is: (1) The Sawtooth Peak Formation, a quartz-rich tuff, with conspicuous phenocrysts of plagioclase and biotite; (2) the tuff of Sulphur Spring, a crystal-vitric tuff with buff-to-pink-colored groundmass and plagioclase and biotite obvious in hand specimen; (3) the lower tuff of the Lamerdorf Member (new name) of the Escalante Desert Formation, a vitric-crystal unit containing plagioclase and biotite in hand sample and quartz, sanidine, and Fe-Ti oxides in thin section; (4) the upper tuff of the Lamerdorf, a vitric-lithic tuff with inclusions of sedimentary, but primarily volcanic, rocks and crystals of plagioclase, biotite, and amphibole in hand specimen; (5) the Beers Springs Member of the Escalante Desert Formation, composed of mudflow conglomerates and thin tuff units which locally separate the lower members of the Needles Range Formation from older ash-flow tuffs.

From work by Best (1976), Rauch (1975), and observations in this study and by students of the Brigham Young University Summer Camps, Conrad's Indian Peak Formation should be abandoned because of erroneous stratigraphic relationships with other tuffs, doubtful outcrop occurrences, and recognition of the Needles-Range age Ryan Spring Tuff (Rauch 1975), which is apparently one of Conrad's (1969) pre-Needles, Indian Peak units. It is recommended that the Lamerdorf Member, with upper and lower tuffs, should replace the Indian Peak Formation below the Needles Range Formation.

The thick volcanic section and its distribution in the Needle Range and Wah Wah Mountains preserves paleovalleys and local hills and implies the existence of two major depositional basins prior to Needles Range time. Paleovalleys and canyons are preserved at Sawtooth Peak in the Needle Range and south of Wah Wah Springs and north of Lamerdorf Peak in the Wah Wah Mountains. The relief preserved by the volcanic section is at least 100 m.

The distribution between Bushman's (1973) pre-Needles Range tuffs and those in this investigation suggest two major depositional basins were separated by a northwest-southeast topographic barrier prior to Needles Range Formation time.

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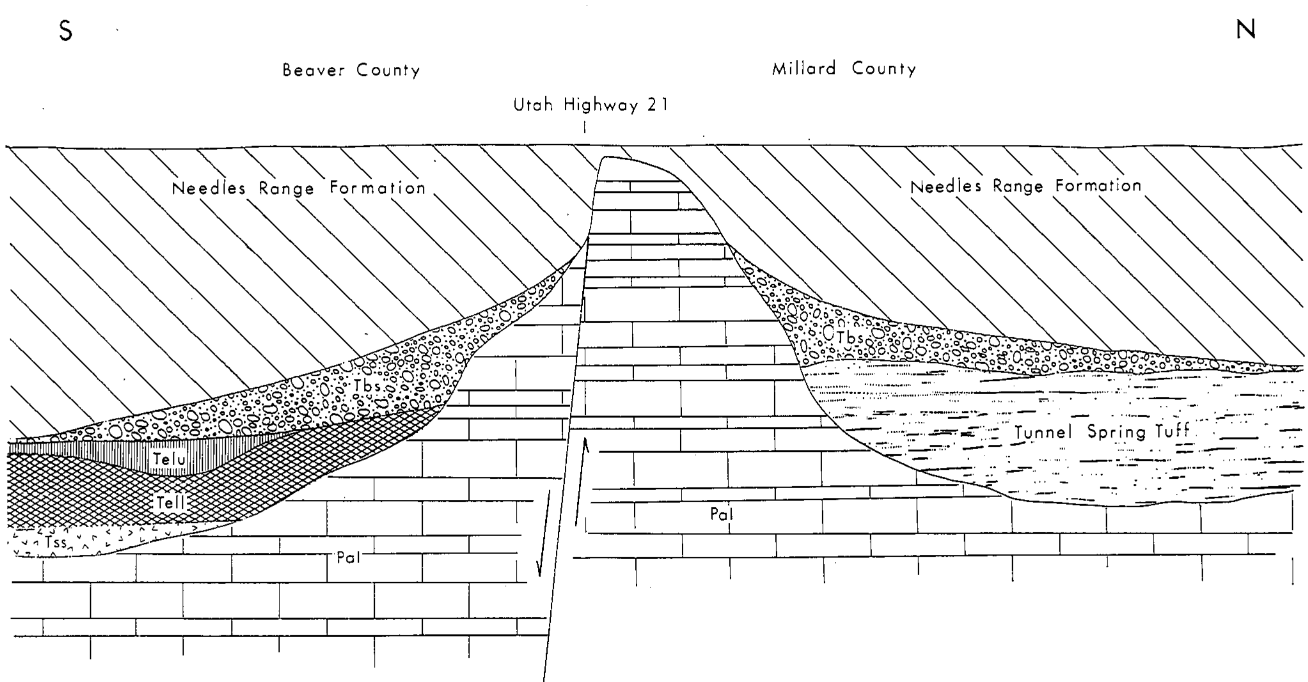

FIGURE 11.–Hypothetical cross-section from the northern end of the Needle Range, in the vicinity of Beers Pass, to the southern end of the Tunnel Spring Mountains.

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