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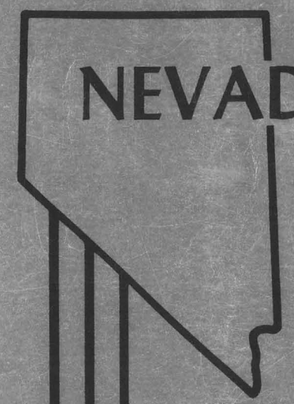
TERTIARY VOLCANIC ROCKS

NEVADA BUREAU OF MINES REPORT 11



NEVADA BUREAU OF MINES

VERNON E. SCHEID, DIRECTOR

REPORT 11

STRATIGRAPHY OF TERTIARY VOLCANIC ROCKS IN EASTERN NEVADA

By EARL F. COOK

MACKAY SCHOOL OF MINES
UNIVERSITY OF NEVADA

1965

NEVADA BUREAU OF MINES

Vernon E. Scheid, Director

REPORT II

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By Earl F. Cook

MACKAY SCHOOL OF MINES

UNIVERSITY OF NEVADA

RENO, NEVADA

1965

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At Iron Mountain, in the Iron Springs district of southwestern Utah, lateral movements of blocks and slices of Tertiary ignimbrites and the underlying Claron Formation are ascribed by Mackin (1960, p. 119-122) to gravity sliding from an intrusive dome. In the northern Schell Creek Range, northeast of Ely, Nevada, Young (1960, p. 168) interprets structural relations to indicate that Tertiary volcanics are in local thrust contact on older rocks, but cautions that "...more work is required on this relationship in order to prove or disprove it." Westgate (Westgate and Knopf, 1932, p. 42-43) described a post-volcanic thrust plate of greatly brecciated dolomite and quartzite which dips toward the valley between the West and Bristol Ranges, northwest of Pioche, and noted that "...the thorough brecciation of the overthrust block suggests that it was not under a heavy load at the time of faulting". Tschanz (1960), who maps this same block as part of an extensive "post-volcanic thrust plate" in northern Lincoln County, points out (p. 206) that "Westgate's explanation must be accepted unless the relations...can be explained by gravity sliding of portions of a Laramide thrust plate that became unstable during uplift of the Bristol Range." Portions of such a thrust plate that did slide from an unstable slope are found in the Welcome Spring area of extreme southwestern Utah (Cook, 1960b), where some of them overlie gravel containing Tertiary ignimbrite clasts. In the areas surrounding the Highland Range and the Pioche Hills (both west of Pioche), as well as on the east flank of the Schell Creek Range north of Patterson Pass (Tschanz, 1960, p. 206), brecciated Cambrian rocks overlie Tertiary volcanic rocks. Paul Gemmill (oral communication) explains the relations on the flanks of the Highland Range and the Pioche Hills by gravity sliding; Tschanz (1960, p. 206) thinks it likely that the Schell Creek relations can be explained by downslope gravity movement of brecciated masses.

Folds in the layered volcanic rocks of eastern Nevada are few. Some of them are of intrusive origin; others may be. Some are drag folds caused by faulting. Very few, if any, appear to be of compressive origin. The layered, block-faulted slabs have relatively low dips that can readily be ascribed to tilting. In the few places where the volcanic rocks have moved, or been overridden, along low-angle faults, the movement may have been caused by either gravity or compression.

The volcanic rocks of eastern Nevada lend little support to any hypothesis of post-ignimbrite low-angle faulting of a compressive origin.

STRATIGRAPHY OF TERTIARY VOLCANIC ROCKS IN EASTERN NEVADA

By Earl F. Cook[1]

ABSTRACT

Most of the volcanic rocks of eastern Nevada are ignimbrites: nonsorted sheet-like pyroclastic deposits of probable nuée ardente origin. Overlapping ignimbrites, studied in an area of about 20,000 square miles, include individual units traceable more than 100 miles linearly; some of these units had an original extent of 5,000 to 10,000 square miles or more. Several measured sections exceed 2,000 feet in thickness and include more than a dozen ignimbrites. At least one unit attains 1,000 feet in thickness, but the average thickness is about 200 feet.

Lateral lithologic variation in many of the Nevada ignimbrites is small, whereas the variety among units is great; hence individual ignimbrites may be recognized in widely separated sections. Correlation criteria used include: the ratio between lithic, crystal, and vitric components; identifiable minerals and their proportions; vertical variations in, and overall degree of welding within, units; and the presence and nature of planar and discoidal structures.

Field relations indicate that the upper surface of each ignimbrite was horizontal when deposited, and that the evenness of such surfaces has been modified only by differential compaction over irregular terrain, by subsequent erosion, or by deformation. The extent of each ignimbrite depended largely if not entirely on the basin or depression in which it formed.

The more extensive, consequently the more stratigraphically useful, of the eastern Nevada ignimbrites, are named and described herein. They probably appeared within the middle third of the Tertiary period; thus they represent a relatively brief segment of geologic time. But they document, by their stratigraphic and structural relations, some of the major events in the tectonic history of the region.

The Tertiary volcanic sequence rests on sedimentary rocks ranging in age from Cambrian to Eocene. In many of the eastern Nevada sections the volcanic units are essentially parallel to the underlying sedimentary rocks, although the hiatus represented by the contact in some cases spans most of the Paleozoic and all of the Mesozoic.

The Tertiary volcanic rocks generally decrease in age toward the south and southeast; the stratigraphic relations suggest progressive subsidence from central toward southern Nevada. Although isopach maps of these rock units seem to reflect some contemporaneous linear fracturing, the trends do not parallel present basins and ranges: modern basin-range topography originated after the extrusion of the widespread ignimbrites.

INTRODUCTION

In mapping the Iron Springs district of southwest Utah, J. H. Mackin (Mackin and Nelson, 1950; Mackin, 1952) discovered that the volcanic rocks of the district are mainly ignimbrites, and that these extensive and distinctive rock units lend themselves to stratigraphic interpretation in the manner of sedimentary strata.

[1] Executive Secretary, Division of Earth Sciences, National Academy of Sciences -- National Research Council, Washington, D. C.

The Iron Springs district thus became the logical area from which to try to extend the known volcanic stratigraphy westward into Nevada where similar rocks were known, or northward toward the Marysvale district, Utah, where the volcanic sequence had been worked out by Callaghan (1939). However, except for relatively minor projections of the volcanic stratigraphy of the Iron Springs district, northward by Threet and southward by me (Mackin, Cook, and Threet, 1954; Cook, 1957a, 1957b), the regional possibilities of such work went untested until the Gulf Refining Company in 1955 decided to sponsor a study of the volcanic rocks of the eastern Great Basin. Following an initial reconnaissance of the region by Mackin, during which he demonstrated the regional extent of several ignimbrites by field correlation criteria, I began to work out the stratigraphy of the Tertiary volcanic rocks in eastern Nevada.

Since the start of the project, I have examined 84 volcanic sections (see pl. 1) and measured 68 of them, and have collected approximately 1,300 specimens, from which about 800 ground slabs for binocular study and 100 thin sections have been made. The measured sections represent an area of about 25,000 square miles in eastern Nevada and southwest Utah. This area is only the central portion of an arcuate ignimbrite province (see fig. 1) of 60,000 square miles which reaches from the west margin of the Colorado Plateau to western Nevada (Cook, 1960a).

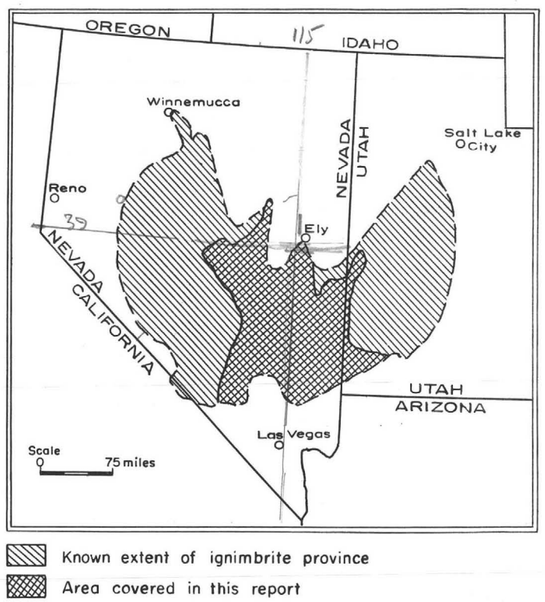


FIGURE 1. Sketch map showing relation of area covered in this report to other known areas of Tertiary ignimbrites.

In eastern Nevada outside the area studied, the Tertiary volcanic rocks are either flow rocks unsuitable for stratigraphic study, or ignimbrites (in extreme northeastern Nevada and in extreme southern Nevada) that seem to belong to different provinces. The same ignimbrites, or some of them, extend westward from the area considered in this

are essentially parallel to the underlying sedimentary rocks - although the hiatus represented by the contact in some cases spans most of the Paleozoic and all of the Mesozoic era. In other words, the attitude of the volcanics in many places reflects the attitude of the subjacent sedimentary rocks; locally, however, where prevolcanism folds were beveled by erosion before the volcanism, the angularity of the unconformity is great.

These relations do not imply complete crustal quiescence between the last Laramide movement and the ignimbrite volcanism. Faulting did occur within this time span, and there may have been regional uplift, but the vertical component of such movements did not vary much from place to place - in other words, there was very little tilting.

In the northwestern part of the area studied - in the central Egan Range, the Grant Range, the White Pine Mountains, and the Pancake Range - the regional disconformity (except where Laramide structural features are overlaid) at the base of the volcanic sequence changes into an angular unconformity. In most places in these ranges, however, the angularity is not great: the volcanic rocks commonly dip in the same direction as the underlying Paleozoic rocks but at somewhat lesser angles.

Prevolcanism Faults

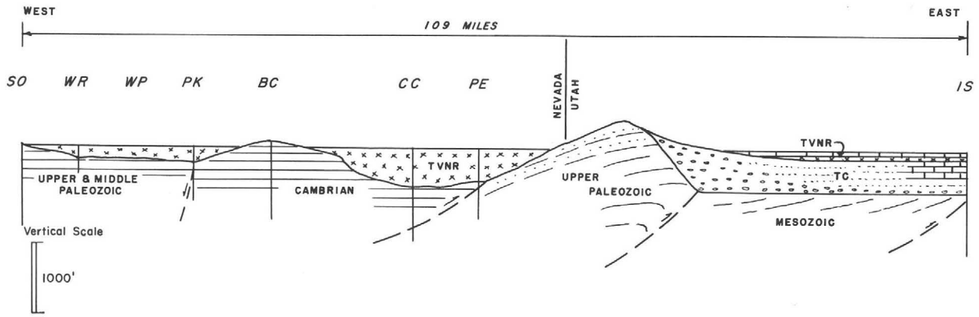
In the Egan Range, Kellogg (1960, p. 195-196) recognizes two groups of northeasterly trending faults: one that originated before deposition of the Eocene sedimentary rocks in the range, the other during the initial stages of uplift "in the latest Eocene or earliest Oligocene." In other ranges, prevolcanism northeasterly structural trends are reflected by local valley fills of Wasatch-type sediments and early ignimbrites. Difficulties encountered in tracing ignimbrites from south to north, contrasted with the facility with which they may be followed from east to west, strongly suggest that some of these northeast-trending faults were active during volcanism; the trends of the axes of thickest ignimbrite accumulation in the isopach maps of the four volcanic groups lend support to the hypothesis.

In the Egan Range, movement took place on the Shingle Pass fault, which strikes slightly north of east where it can most accurately be mapped, just before the start of the ignimbrite volcanism; large exotic blocks of limestone slid from the new fault scarp into a lake basin north of the fault (Kellogg, 1960, p. 196), to be buried soon after by tuffaceous sediments and ignimbrites.

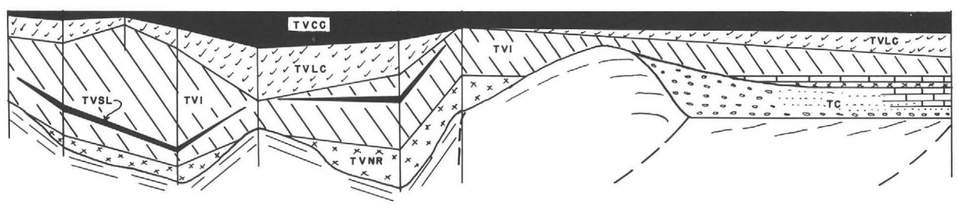
One cannot help being struck by the evidence of coincidence of northeast to east faulting and ignimbrite volcanism. The complex intrusive and extrusive rocks of the Robinson (Ruth) mining district near Ely, which mark that area as one of the most likely sources of the Group A ignimbrites, are in an easterly trending zone. But even if regional faulting did accompany volcanism, the "chicken-egg" question - did the flatulent magmas forcibly rupture their roof, thereby producing the faults, or did faulting of some other origin release the magmas - is far from solved.

Post-volcanism Horizontal Displacements

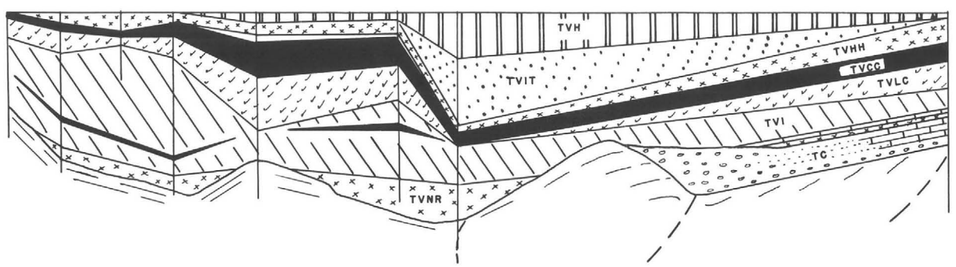
Although in several places in eastern Nevada and southwest Utah, Tertiary volcanic rocks have moved laterally on low-angle faults, and in a few places pre-Tertiary rocks rest upon Tertiary volcanic rock, nowhere has unequivocal evidence been presented that the volcanic rocks have participated in thrust faulting. Most of these occurrences can equally well or better be explained by gravity sliding.



A. Restored section at close of Needles Range time (late Oligocene). Some subsidence of the Nevada portion of this section immediately preceded the deposition of the Needles Range tuff, which rests directly on Paleozoic rocks in Nevada but is interbedded with penecontemporaneous sediments in Utah. The vertical scale is greatly exaggerated. The highland of Upper Paleozoic rocks is a Laramide thrust range; the fault beneath it is the Castle Cliff thrust. The two faults farther west are inferred, in order to explain changes in age of the Paleozoic rocks beneath the volcanic rocks.



B. Restored section after Condor Canyon volcanism. Subsidence in west greater than in east since Needles Range volcanism.



C. Restored section after Hiko volcanism (early Miocene). Subsidence during later volcanism shifted eastward.

FIGURE 36. Restored sections across Southeast Nevada and Southwest Utah. Reconstructions are based on measured sections shown in Figure 6. Units shown are Hiko Tuff - Tvh; Irontown member of the (early Miocene) Page Ranch Formation - Tvit; Harmony Hills Tuff - Tvhh; Condor Canyon Formation - Tvcc; Leach Canyon Tuff - Tvlc; Pahrocksequence - Tvp; Petroglyph Cliff Ignimbrite - Tvsl; Needles Range Formation - Tvnr; Claron Formation - Tc.

report, as determined by Ralph Roberts and others in the Battle Mountain and Antler Peak, Nevada, areas (Toiyabe quartz latite); by Charles Vitaliano in the Gabbs, Austin, and Tonopah areas; and by others in the vicinity of Virginia City, Silver Peak, Beatty, and the A. E. C. Nevada Test Site.

Gulf sponsored the field work during the summers of 1955 and 1956. A grant from the Geological Society of America allowed one month of field work in 1957. Gulf, the Geological Society, and the University of Idaho financed the laboratory work, which was carried out at the University of Washington and the University of Idaho.

Progress on this project was materially aided by fruitful suggestions and the clarification of concepts that came out of discussions and correspondence with Paul Williams and Roger Martin (both of whom worked with me in the field), as well as Felix Chayes, R. L. Christiansen, J. H. Mackin, R. L. Smith, C. M. Tschanz, and C. J. Vitaliano. Paul Williams, Stuart Hill, and William Page made the petrographic analyses on which the histograms are based. The paper profited greatly from the constructive criticism of Mackin and Martin.

ROCK AND ROCK UNIT NAMES USED IN THIS REPORT

Most of the volcanic rock units of eastern Nevada are ignimbrites, that is, sheet-like deposits of relatively nonsorted and nonstratified pyroclastic material. Used in this way, ignimbrite is a rock-unit term, and is not equivalent to welded tuff. An ignimbrite is a mappable rock unit, more or less equivalent to the "ash-flow cooling unit" of Smith (1960b, p. 157), except that an ignimbrite may be made up of material that is not tuff, and was only in part ash during emplacement. Most of the eastern Nevada ignimbrites are largely welded tuff, but some of them are made up chiefly or entirely of nonwelded tuff, and at least one consists of tuffbreccia.

As Marwick (1946) pointed out, Marshall's (1932, p. 200) original definition of ignimbrite refers neither to the degree of welding nor to the size of ejecta. Perhaps unfortunately, Marshall's additional definitions (1935, p. 323, p. 360) appear to require such rocks to be acid, tuffaceous, and welded.[2] These statements led logically to the conclusion that ignimbrite equals welded tuff (Cotton, 1952, p. 204; American Geological Institute, 1957, p. 146).

Marshall made no distinction between rock unit and rock type: he used ignimbrite for both, as have many later authors. In the United States, most authors have preferred welded tuff for the same dual purpose, possibly because it is a less genetic term. Belated recognition that welded tuff is an inappropriate name for a rock unit that is partially or even wholly nonwelded has led to a proposal (Cook, 1955, p. 1544; 1957b, p. 197-198; 1960a, p. 134; Mackin, 1960, p. 84-86) that ignimbrite be defined as a rock-unit term, freed of the welding, size-range, and composition restrictions that some have read into Marshall's definitions of 1935. Solving the same problem in a different way, Ross and Smith (1961, p. 3) used ash-flow tuff as "...an inclusive, general term for consolidated ash-flow beds and rocks that may or may not be either completely or partly welded."

Welded tuff and sillar are here used as rock-type terms. Sillar is nonwelded tuff or tuffbreccia of nuée ardente or ash-flow origin (Fenner, 1940, 1948) commonly poorly sorted; the name is used to distinguish such material from waterlaid or airfall tuff, characteristically more or less well sorted.

[2] It should be pointed out that Marshall did describe many nonwelded structures in his ignimbrites and that some of his type ignimbrites are nonwelded.

Fisher's classification (1960, p. 1864-65) of size terms, slightly modified, is used in this paper:

Clast Size	Clast Name	Rock Name (if majority of clasts are in the size range)
over 256 mm	coarse blocks	pyroclastic breccia
64 - 256 mm	fine blocks	
2 - 64 mm	lapilli	lapillistone
1/16 - 2 mm	coarse ash	tuff
less than 1/16mm	dust (or fine ash)	

Tuffbreccia denotes those rocks in which abundant blocks and lapilli lie in a tuffaceous matrix that comprises at least 25 percent of the rock.

Although the Wentworth and Williams (1932) classification of tuffs as vitric, crystal, or lithic - according as most of the particles are glass, crystals, or rock fragments - may

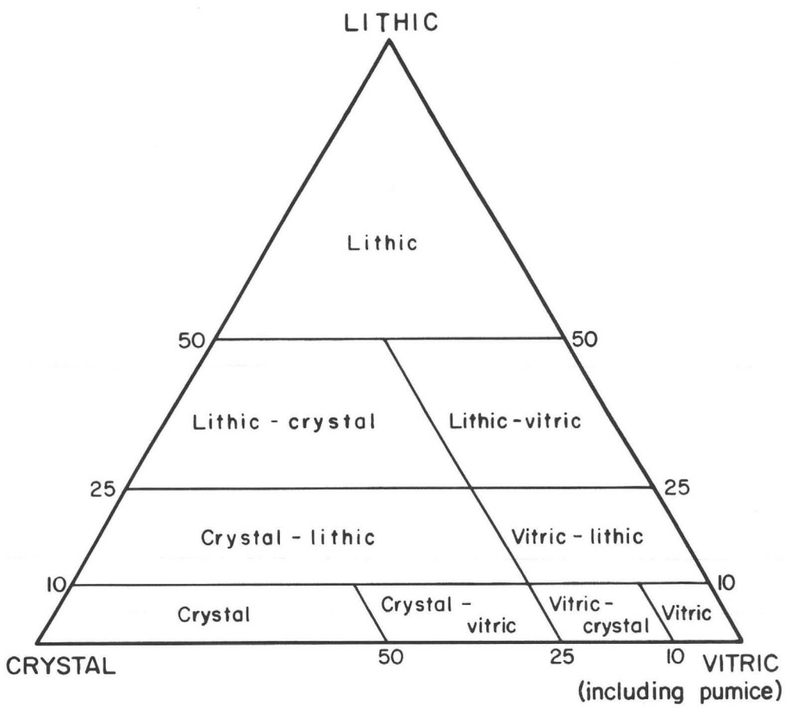


FIGURE 2. Mechanical composition triangle for ignimbrite rock types.

Coincidence of Subsidence with Volcanism

Mackin (1960, fig. 3, p. 100) points out that the Claron sediments in southwest Utah were derived chiefly from Laramide thrust ranges to the northwest, and that the eruptions which produced the Needles Range ignimbrites must have been immediately preceded or accompanied by foundering of these thrust ranges, because the Needles Range ignimbrites are thicker in some places on the old highland terrain than they are on the Claron farther southeast.

Study of ignimbrite stratigraphy in southeastern Nevada and southwestern Utah along a line of sections extending west from the Iron Springs district (fig. 36) indicates a similar abrupt subsidence of western highlands coincident with early ignimbrite volcanism.

In northwestern Washington County, Utah, near the Bull Valley district, a Laramide thrust sheet is clearly the source of the Claron sediments in that area (Cook, 1960b, p. 32). The position of a thin unit of the Needles Range Formation within the upper Claron Formation shows that Claron sedimentation continued undisturbed for a short time after Needles Range volcanism. To the west in Nevada, the Needles Range Formation is considerably thicker and in most sections rests directly on Lower Paleozoic rocks: unless this part of Nevada had exterior drainage from which the Claron basin was isolated by a continuous divide, subsidence here had already started in Needles Range time. But subsidence couldn't have started long before the Needles Range eruptions, for in most of the southeast Nevada sections the Needles Range Formation lies on a clean erosion surface cut on Paleozoic rocks, without the sediments that would be expected from subsidence, especially from subsidence that either accentuated or produced a basin of interior drainage. There can be little doubt that such a basin existed at least from the onset of volcanism; otherwise, the ignimbrites would not have been so well contained within areas whose boundaries can be plotted with considerable assurance.

Following Needles Range volcanism, steptoes of Paleozoic rocks, standing above the ignimbrite plain, continued to provide limy sediments that accumulated in low places on the plain. This sedimentation was not confined to the Claron area of southwest Utah; far to the west in the Seaman Range of Nevada, white lacustrine limestone (section WR, fig. 6) and limestone conglomerate (section SO) overlies Needles Range tuff.

The Pahrock sequence, thin or absent in the Iron Springs district, thickens greatly but erratically westward in Nevada, where it extends beyond the area of Needles Range deposits. The conclusion seems inescapable that rapid subsidence provided the uneven-floored basin in which the Pahrock volcanic rocks accumulated in eastern Nevada. Abrupt changes in thickness of the Pahrock sequence suggest differential foundering along faults.

Relief produced by differential subsidence was obliterated by Pahrock volcanism, for the Leach Canyon Tuff and the thin Swett and Bauers Ignimbrites extend unbroken from the Colorado Plateau across southeastern Nevada, an extent that can only be explained in terms of a relatively flat pre-Leach Canyon surface.

Reflection of Subjacent Structure

In eastern Nevada the Tertiary volcanic rocks rest on sedimentary "basement" rocks ranging in age from Cambrian to Triassic. Because prevolcanism deformation was sharply localized along axes that trend east of north, leaving between the narrow belts of deformation broad areas of undeformed Paleozoic rocks, the ignimbrites in many sections

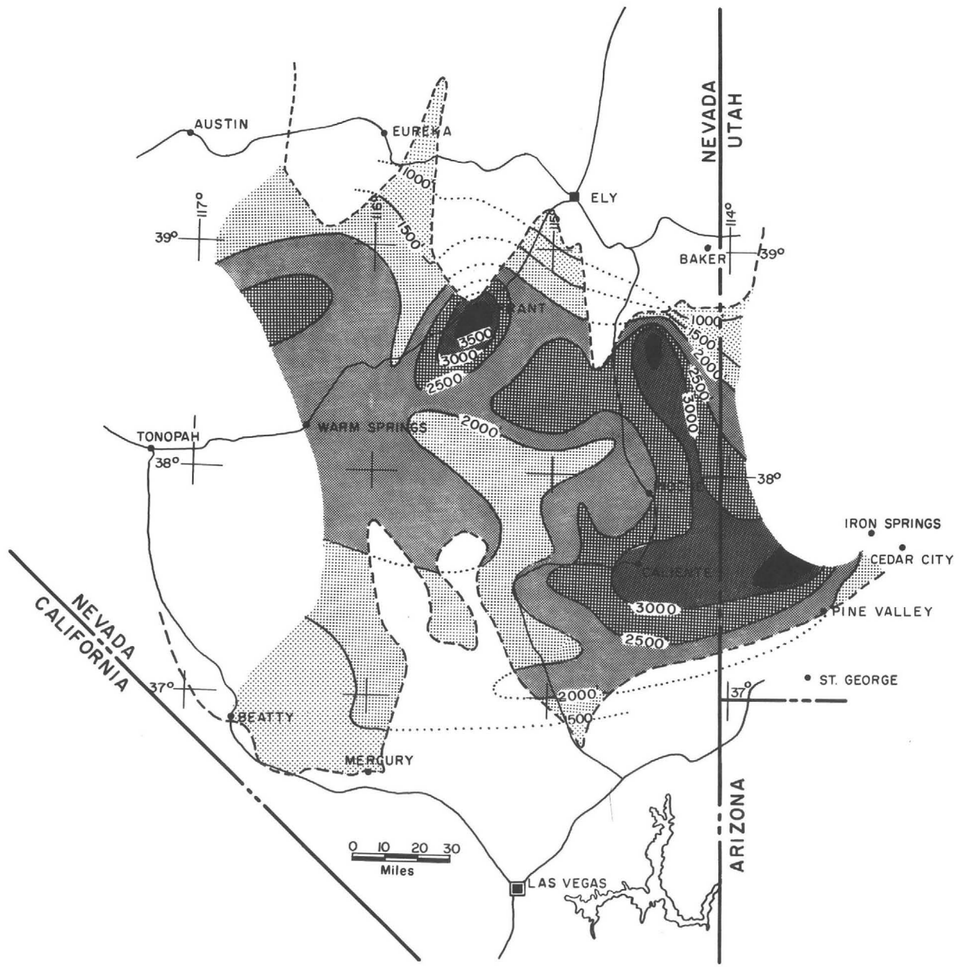


FIGURE 35. Composite isopach map of Tertiary volcanic rocks of eastern Nevada.

be applied to ignimbrite rocks, a modification of their classification has been found useful. All three elements are important in the constitution of ignimbrites, and it might seem that a classification should give equal weight to each, as the Wentworth and Williams definitions do. In field recognition of ignimbrites, however, accessory and accidental lithic fragments commonly play a greater role than their actual percentage would indicate; for example, there are ignimbrites containing 10 to 15 percent of lithic fragments in which those fragments are a striking and characteristic element. Consequently it is suggested that the lithic component be given greater emphasis than the other two, and that lithic enter the name whenever rock fragments make up more than 10 percent of the rock. Incidentally, it is only possible to apply the "lithic" adjective accurately if the pumice fragments, which may undergo a great change in volume vertically within an ignimbrite, are regarded as vitric rather than lithic.

In addition, because the crystal content of ignimbrites rarely exceeds 50 percent, it is proposed that crystal enter the name at 10 percent and that a rock containing more than 50 percent crystals be called crystal. A triangle illustrating these arbitrary limits is shown in figure 2. This triangle is based upon the composition of Great Basin ignimbrites; a study of published descriptions of ignimbrites from other localities; and a concern for the utility of nomenclature. Probably 90 percent of all ignimbrites will fall below the 10 percent lithic line and to the right of the 50 percent crystal line and will thus be represented by less than 10 percent of the triangle.

CRITERIA FOR IGNIMBRITE CORRELATION

Megascopic Criteria

In many of the Nevada ignimbrites lateral variation in composition and appearance is small, whereas the variety of units is great; hence individual ignimbrites may be recognized in widely separated sections. Correlation criteria include: the ratio between lithic, crystal, and vitric components; identifiable minerals and their proportions; vertical variations in welding as well as overall degree of welding within units; the presence and nature of planar and discoidal structures; color, hardness, and weathering characteristics; and position in the stratigraphic sequence.

Microscopic Criteria

During the winter of 1955-56, Paul Williams (1960) developed a correlation method that quickly proved its usefulness. It consists of identifying on a ground, etched, and cobaltinitrite-stained surface the crystals visible under low power with a binocular microscope, and then plotting in histogram form the relative areas occupied by quartz, sanidine, plagioclase, biotite, and hornblende.

The relative proportions of these crystals tend to remain fairly constant throughout a single ignimbrite, far more constant than degree of welding, color, or pumice content. Variations in phenocryst composition within individual ignimbrites is reflected in the histograms shown in numerical form on the sections in figures 5, 6, and 7. No statistical analysis has been made of the limits of variability within any single ignimbrite, but in most cases it is obvious that the differences in histograms between adjacent ignimbrites

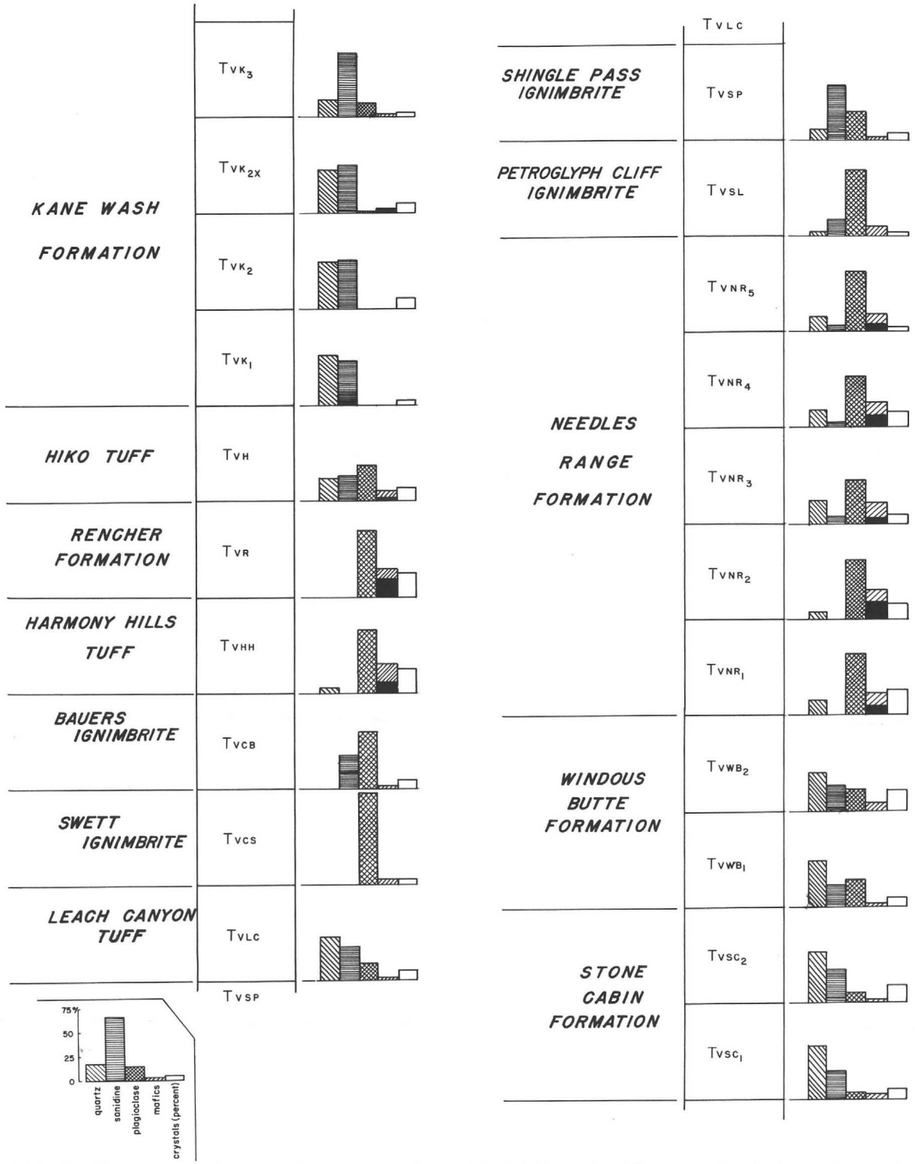


FIGURE 3. Histograms showing mineral composition of named ignimbrite units. The composite thickness of the units represented is about 5,300 feet. All are not present at any one place. Sedimentary and volcanic rock units of local extent are not shown.

Five crystal components of each unit were measured, as shown in the first four columns from the left. The mafic minerals in the fourth column include biotite (cross-hatched), and hornblende (solid black). In each case, the first four columns total 100 percent. Column five indicates the percentage of the rock composed of these crystals, taken collectively. Histograms of Tvwb2 (40/28/23/9//21) and Tvk1 (53/47/0/0//6), expressed in numbers, may be used to gain an idea of the histogram scale.

The percentages of crystals shown in the histograms include only grains large enough for identification by binocular study of stained slices. This percentage may be considerably lower than percentage based on study of thin sections with a petrographic microscope (Williams, 1960, p. 150). Classification of these rocks as crystal, crystal-vitric, and so on (see fig. 2) is not based on the percentages shown in the histograms, but on percentages as determined in thin section, under the petrographic microscope. It should also be emphasized that the phenocryst composition may have little significance in regard to the "chemical" name of the rock (rhyolite, dacite).

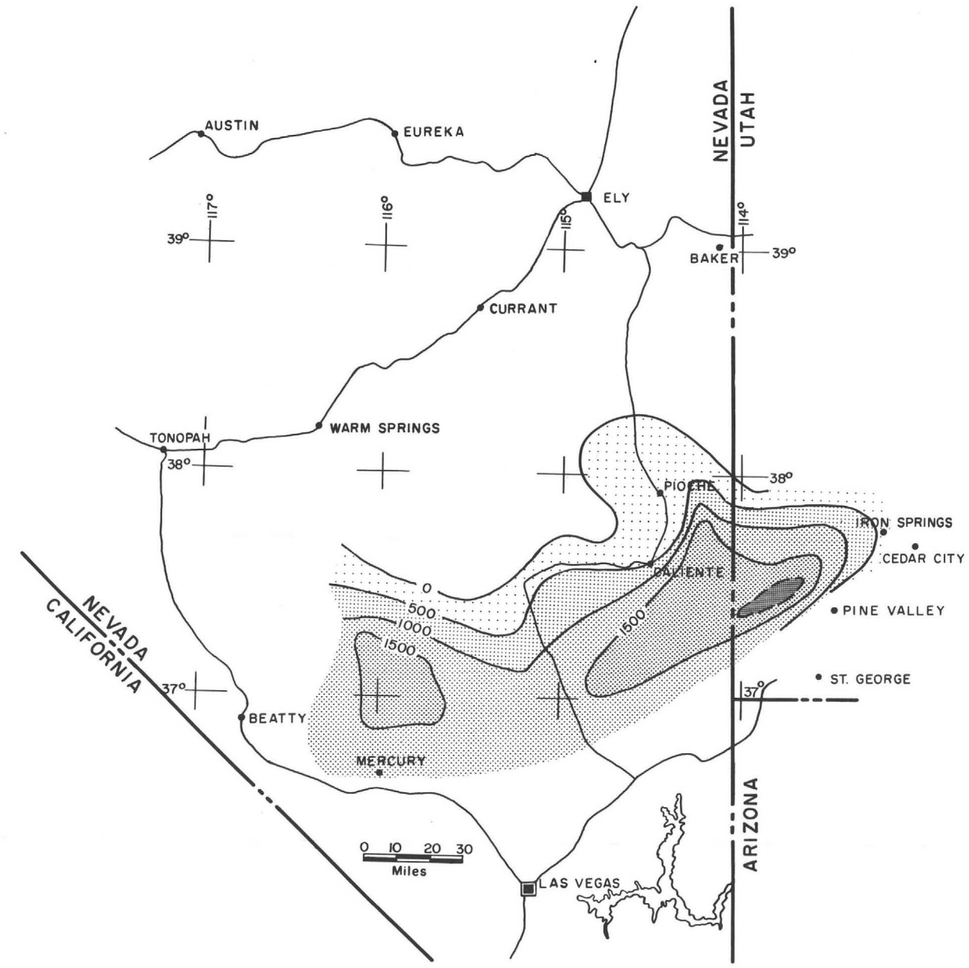


FIGURE 34. Isopach map of Tertiary volcanic group D -- the Rencher Formation, Page Ranch Formation, and Kane Wash Formation.

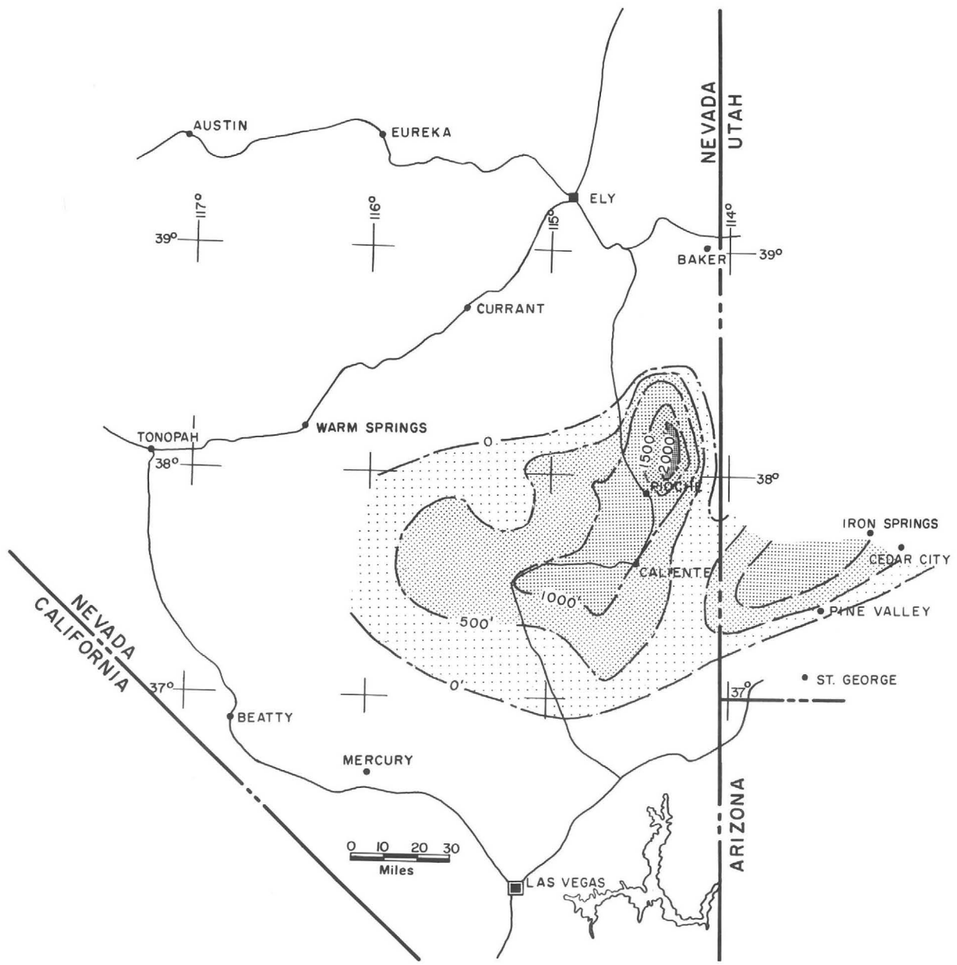


FIGURE 33. Isopach map of Tertiary volcanic group C -- the Leach Canyon Tuff, Condor Canyon Formation, Harmony Hills Tuff. This group equals the Quichapa Formation in southwestern Utah.

is far greater than the range of variability within either ignimbrite. It should be emphasized that the correlations made in this paper were made on lithologic criteria and on similarity in sequence from section to section. The histograms served as independent confirmation of established field correlations. In some areas, however, they provided the key to unraveling stratigraphic and structural relations.

Two specimens with similar histograms may or may not represent the same ignimbrite, but two specimens with widely different mineral proportions may confidently be regarded as representing different ignimbrites. Histograms showing average phenocryst content of all named units, and of some unnamed members of the Needles Range and Kane Wash Formations are given in figure 3.

DESCRIPTION OF NAMED VOLCANIC FORMATIONS

General Remarks

As may be quickly seen from the correlation chart (fig. 4) or any of the three lines of section (figs. 5, 6, 7), only the more extensive of the volcanic units are named and described in this paper.

No regionwide unconformity has been found within the ignimbrite sequence. However, at certain levels unconformities of considerable extent may represent shifts in centers of eruption; pauses in the eruptive activity that allowed local structural adjustments; or deformation that affected part but not all of the region.

Southwest Utah sections used in the correlation chart, in one of the lines of section (fig. 6), and in construction of the distribution and isopach maps, give a more complete picture and a link with the work of Mackin (1960) in that area.

In all the sections in southwest Utah and in several in eastern Nevada, the volcanic sequence rests upon nonvolcanic early Tertiary sedimentary rocks — largely freshwater limestone, siltstone, and conglomerate. Although some of these prevolcanism Tertiary sedimentary rocks have been called Miocene (Tschanz, 1960, p. 204), it now seems clear - if the stratigraphic relations of the volcanic units have been correctly interpreted, and if the few absolute age determinations available (see fig. 4) are correct - that none of them can be younger than Oligocene.

In southwestern Utah, the fluvial and lacustrine beds of the Claron Formation concordantly underlie the ignimbrite sequence, the lowest member of which is a Needles Range ignimbrite (Mackin, 1960, p. 101). In some places, Needles Range tuff is interbedded in the upper part of the Claron. The basal conglomerate of the Claron Formation, which unconformably overlies folded and erosionally truncated Jurassic and Cretaceous formations, spreads eastward as a thinning detrital sheet from Laramide thrust ranges. In most places the Claron consists of a sequence of fresh-water limestones with subordinate calcareous sandstone, limestone pebble conglomerate, and shale above a basal unit of sandstone lenses and quartzite cobble conglomerate. The formation ranges in thickness from 475 to 1,500 feet. Although the lower part of the Claron Formation may be as old as very Late Cretaceous, the upper part in which the tuff of the Needles Range Formation is interbedded is Oligocene, based on an age of 28-29 million years for the Needles Range Formation (Armstrong, 1963, p. 71).

ABSOLUTE AGE*	"GROUP"	UNIT NAMES USED IN THIS REPORT	GRANT, EGAN RANGES	SEAMAN, PAHROCK RANGES; PANACA AREA	HIKO, MEADOW VALLEY RANGES	SOUTHWESTERN UTAH: Mackin, 1960	SOUTHWESTERN UTAH: BULL VALLEY Blank, 1959	SOUTHWESTERN UTAH: PINE VALLEY MTS Cook, 1957a
MIOCENE	D	KANE WASH FORMATION			KANE WASH FORMATION		OX VALLEY TUFF; COVE MTN. FM.: CEDAR SPGS. M.; PILOT CK. BAS.	
		PAGE RANCH FM.: HIKO TUFF		PAGE RANCH FM.: HIKO TUFF; sillar, sandstone, flows	PAGE RANCH FM.: HIKO TUFF; sillar, sandstone	PAGE RANCH FM.: KANE POINT TUFF; IRONTOWN MEMBER	COVE MTN. FM.: RACER CANYON TUFF; WILLOW SPG. M.; MAPLE RIDGE POR.; SHOAL CK. BRECCIA	PAGE RANCH FORMATION; PINE VALLEY LATITE
		RENCHER FORMATION				RENCHER FM.	RENCHER FM.	RENCHER FM.
25 MY*	C	HARMONY HILLS TUFF		HARMONY HILLS TUFF; basalt; sillar	HARMONY HILLS TUFF	QUICHAPA FORMATION: HARMONY HILLS TUFF	QUICHAPA FORMATION: HARMONY HILLS TUFF; LITTLE CREEK BRECCIA	QUICHAPA GROUP: TV-3; ATCHINSON FORMATION
		CONDOR CANYON FM.: BAUERS IGNIMBRITE		CONDOR CANYON FM.: BAUERS IGNIMBRITE	CONDOR CANYON FM.: BAUERS IGNIMBRITE; 1-3 highly welded ignims.	BAUERS TUFF	BAUERS TUFF	TV-2
		SWETT IGNIMBRITE		SWETT IGNIMBRITE	SWETT IGNIMBRITE	SWETT TUFF		
		LEACH CANYON TUFF		LEACH CANYON TUFF	LEACH CANYON TUFF	LEACH CANYON TUFF	LEACH CANYON TUFF	TV-1
OLIGOCENE	B	PAHROCK Sequence:	ignimbrites	ignimbrites, flows	PAHROCK sequence (thin ignims., ls., cg.)	ISOM FM.: HOLE-IN-THE-WALL MEMBER BALDHILLS M.	ISOM FM.: HOLE-IN-THE-WALL TUFF BALDHILLS TUFF	CLARON
		SHINGLE PASS IGN.	SHINGLE PASS IGN.	SHINGLE PASS IGN.; ignimbrites, flows				
		PETR. CLIFF IGNIM.		PETR. CLIFF IGN.; ignims., flows, ls.				
28 MY		NEEDLES RANGE FM.:	NEEDLES RANGE FM.: $Tvnr_5$; $Tvnr_4$; $Tvnr_3$; $Tvnr_2$; $Tvnr_1$	NEEDLES RANGE FORMATION		NEEDLES RANGE FM.: MINERSVILLE T.; WAH WAH SPGS. T.	CLARON; NEEDLES TUFF	biotite tuff
32 MY	A	WINDOUS BUTTE FM.: Upper ignimbrite; Lower ignimbrite	WINDOUS BUTTE FM.: Upper ignimbrite; Lower ignimbrite			CLARON FORMATION	FORMATION	FORMATION
			sediments, andes.					
		STONE CABIN FM.: Upper ignimbrite	STONE CABIN FM.: Upper ignimbrite					
			seds., flows					
		Lower ignimbrite	Lower ignimbrite					
			sandstone; dacite flows, breccia					
36 MY		nonvolcanic sedimentary rocks	SHEEP PASS FORMATION					
EOCENE								

*Absolute ages from Armstrong, 1963.

FIGURE 4. Correlation chart for the Tertiary volcanic rock units of eastern Nevada and southwestern Utah.

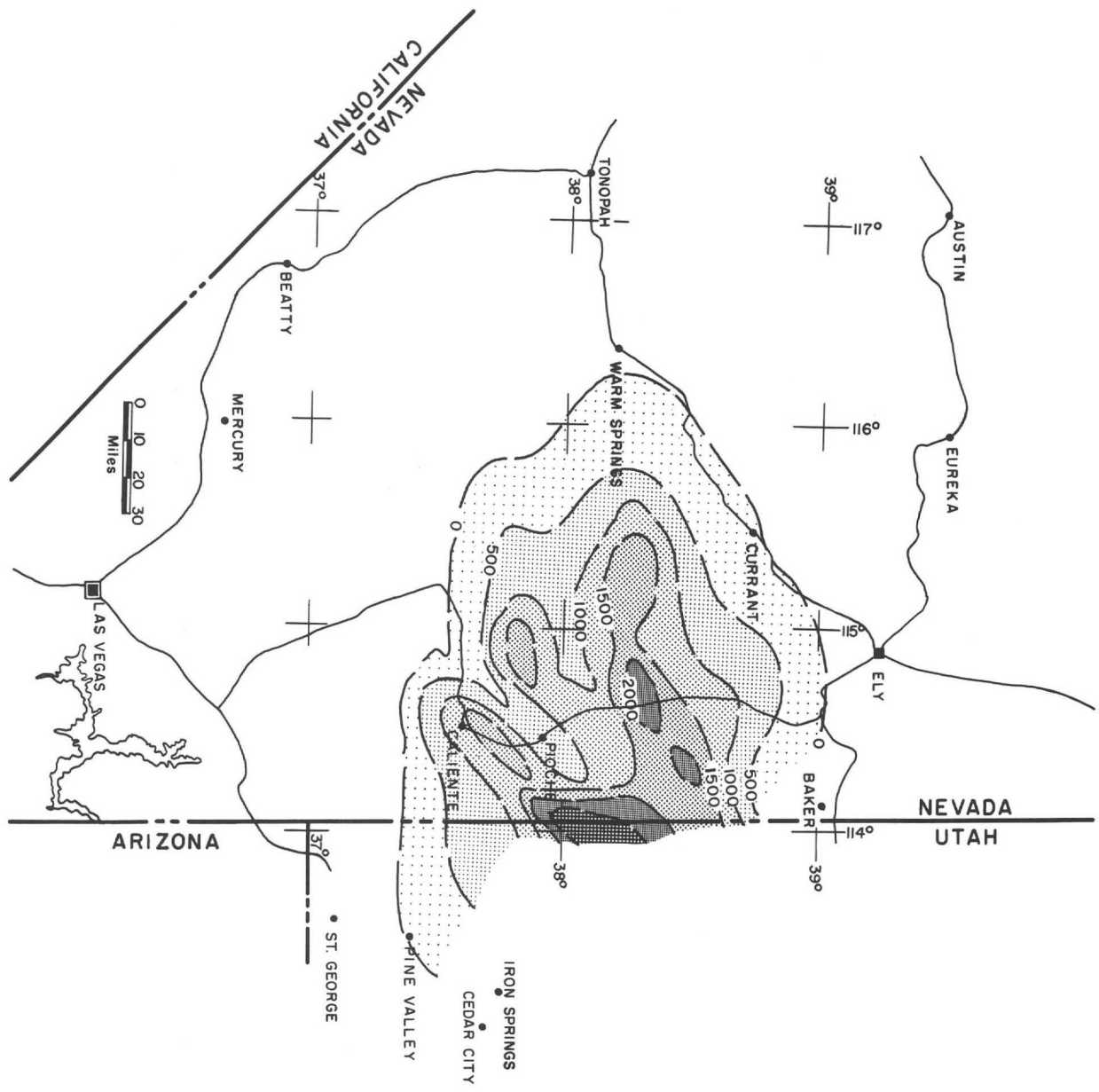
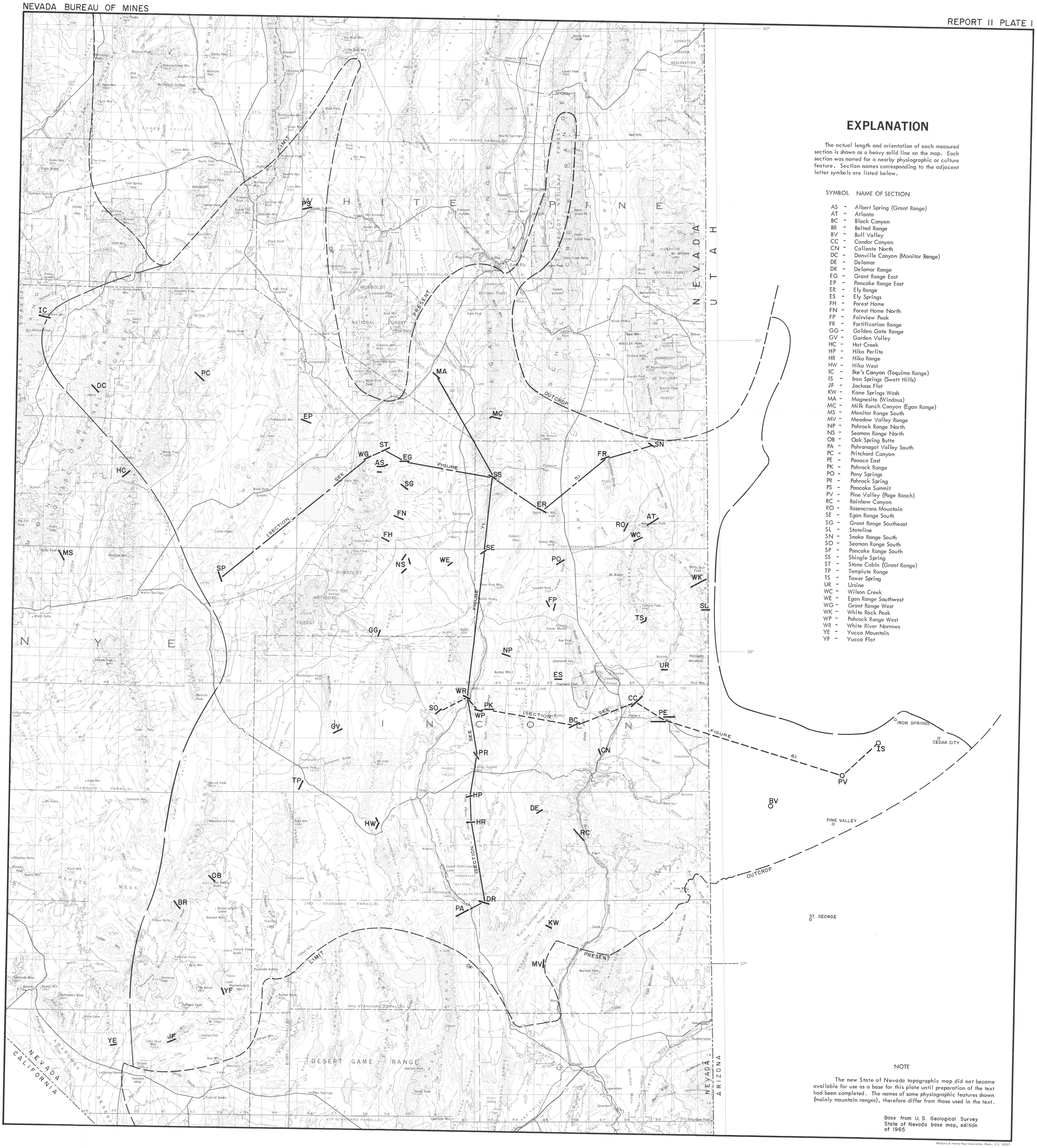


FIGURE 32. Isopach map of Tertiary volcanic group B -- the Needles Range Formation and Pahroc Sequence.



EXPLANATION

The actual length and orientation of each measured section is shown as a heavy solid line on the map. Each section was named for a nearby physiographic or culture feature. Section names corresponding to the adjacent letter symbols are listed below.

SYMBOL	NAME OF SECTION
AS	Albert Spring (Grant Range)
AT	Atlanta
BC	Black Canyon
BR	Belted Range
BV	Bull Valley
CC	Condor Canyon
CN	Caliente North
DC	Danville Canyon (Monitor Range)
DE	Delamar
DR	Delamar Range
EG	Grant Range East
EP	Pancake Range East
ER	Ely Range
ES	Ely Springs
FH	Forest Home
FN	Forest Home North
FP	Fairview Peak
FR	Fortification Range
GG	Golden Gate Range
GV	Garden Valley
HC	Hot Creek
HP	Hiko Perlite
HR	Hiko Range
HW	Hiko West
IC	Ike's Canyon (Toquima Range)
IS	Iron Springs (Swett Hills)
JF	Jackass Flat
KW	Kane Springs Wash
MA	Magnesite (Windous)
MC	Milk Ranch Canyon (Egan Range)
MS	Monitor Range South
MV	Meadow Valley Range
NP	Pahrock Range North
NS	Seaman Range North
OB	Oak Spring Butte
PA	Pahranagat Valley South
PC	Pritchard Canyon
PE	Panaca East
PK	Pahrock Range
PO	Pony Springs
PR	Pahrock Spring
PS	Pancake Summit
PV	Pine Valley (Page Ranch)
RC	Rainbow Canyon
RO	Rosencrans Mountain
SE	Egan Range South
SG	Grant Range Southeast
SL	Stateline
SN	Snake Range South
SO	Seaman Range South
SP	Pancake Range South
SS	Shingle Spring
ST	Stone Cabin (Grant Range)
TP	Tempiute Range
TS	Tower Spring
UR	Ursine
WC	Wilson Creek
WE	Egan Range Southwest
WG	Grant Range West
WK	White Rock Peak
WP	Pahrock Range West
WR	White River Narrows
YE	Yucca Mountain
YF	Yucca Flat

NOTE

The new State of Nevada topographic map did not become available for use as a base for this plate until preparation of the text had been completed. The names of some physiographic features shown (mainly mountain ranges), therefore differ from those used in the text.

Base from U. S. Geological Survey State of Nevada base map, edition of 1965

Williams & Heintz Map Corporation, Wash., D.C. 20027

LOCATIONS OF MEASURED TERTIARY VOLCANIC ROCK SECTIONS

By Earl F. Cook, 1965

Scale 1:500,000
1 inch equals approximately 8 miles

10 0 10 20 30 40 Miles

10 0 10 20 30 40 50 Kilometers

CONTOUR INTERVAL 500 FEET