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PETROLOGY AND PETROGRAPHY OF THE IGNEOUS ROCKS OF THE STANSBURY MOUNTIANS, TOOELE COUNTY, UTAH

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PETROLOGY AND PETROGRAPHY
OF THE IGNEOUS ROCKS OF THE STANSBURY MOUNTAINS,
TOOELE COUNTY, UTAH

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ABSTRACT

The igneous rocks of the Stansbury Mountains consist of several hypabyssal intrusions of intermediate and basic composition and four patches of extrusives.

Two sills, one sole injection, and two plugs represent an andesitic to trachyandesitic phase of intrusion and three or four diabase dikes appear to be volcanic fissures. Minor rock types include augite andesite, syenogabbro, and olivine and augite calci-phonolite.

The first stage of volcanic extrusion, probably contemporaneous with intrusion, effused a series of andesite and hornblende andesite flows, tuffs, and tuffaceous volcanic breccias, and very minor amounts of basalt. Two major areas of these effusives, one each on the eastern and western flanks of the range, appear to have been once continuous. Slightly later extrusive activity poured forth calcic phonolites and soda-basalts from fissures farther to the north. On the west flank the series measures 905 feet thick; on the east flank near South Willow Canyon the total section is 1630 feet thick.

Some low-temperature hydrothermal alteration exists in the area although no contact metasomatic zones have been recognized.

Igneous activity is dated as Eocene to Oligocene and appears to have had the following history: (1) intrusion of stock-sized pluton with projecting cupolas, dikes, and sills of trachyandesite or andesite, (2) extrusion of intermediate composition flows contemporary with stage 1, (3) extrusion of near-basic to locally undersaturated flows, and (4) normal faulting, tilting, and erosion of the flows to their present condition.

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I would especially like to thank Dr. Kenneth C. Bullock, chairman of the thesis committee, and Dr. J. Keith Rigby, committee member, for their untiring help in technical matters and in the preparation of illustrations.

I would like to thank my wife Dixie for her support in this program. Appreciation is due to Lloyd Burckle for his assistance in the early field work. Mr. Edward John worked with me in the field during the late spring. I received instruction and valuable data from Dr. Wm. Revell Phillips, Messers William Berge, John S. Berge, and Clarence Erickson, Jr., concerning identification of mineral species with the universal stage technique.

Much of the expense of field and laboratory work has been defrayed by a scholarship from General Petroleum Corp., and funds from Bear Creek Mining Company were received in the later stages of the program which helped in thin section preparation and in the publication of this paper.

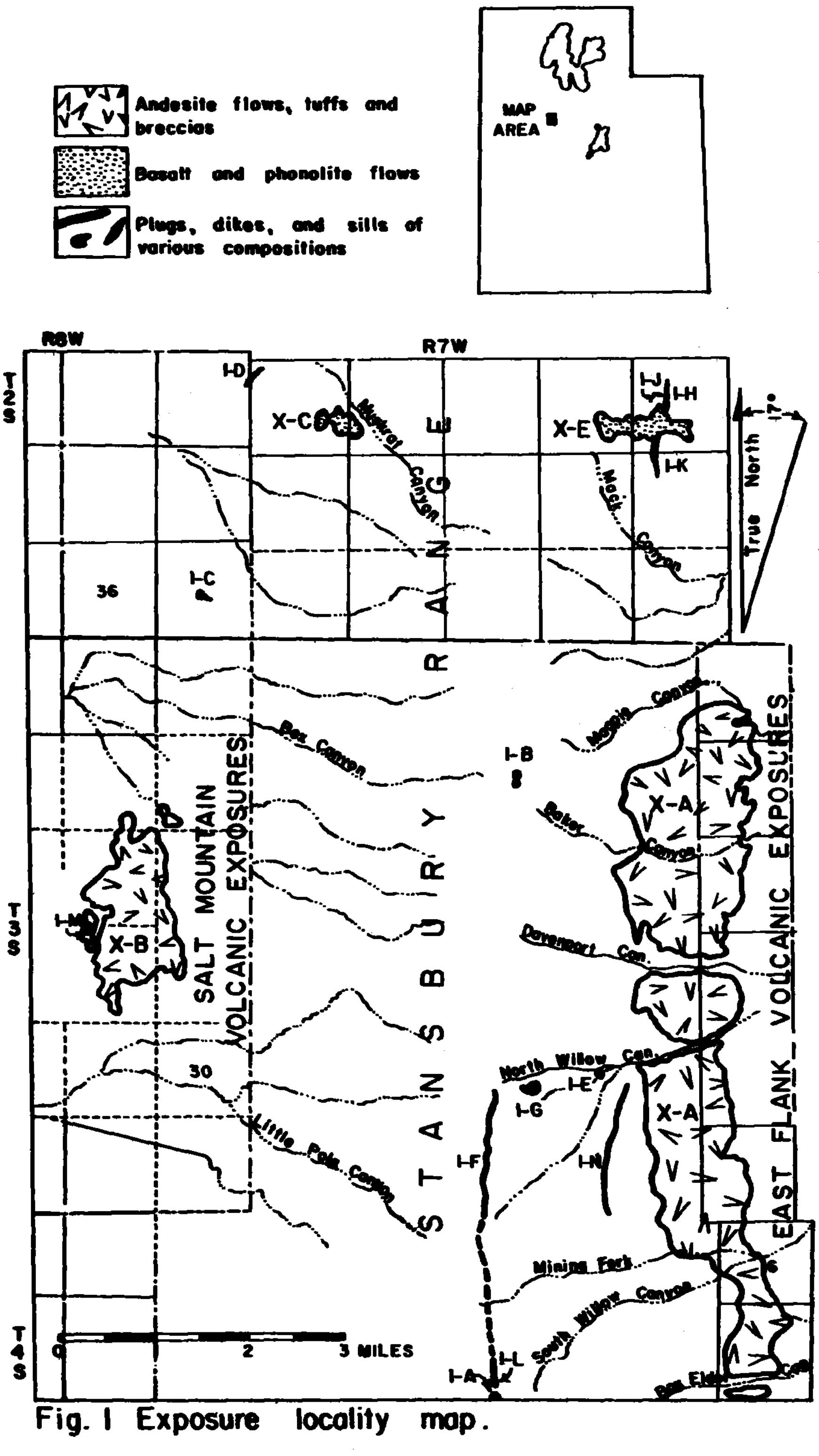


Fig. I Exposure locality map.

INTRODUCTION

LOCATION AND DESCRIPTION OF THE AREA

The Stansbury Mountains lie 45 miles south-west of Salt Lake City and 5 miles west of Grantsville in Tooele County, Utah. It is an elongate range running nearly north-south and extending from the small railway stop called Timpie on U. S. highway 40-50 to Johnson's Pass to the south, a distance of about 27 miles. The index map shows the township and range boundaries.

Several good roads give quick access to the range. Along the east flank is a partly paved State highway (36) that connects St. John to Grantsville and gives access to North and South Willow Canyons, East Hickman Canyon, and Box Elder Canyon. U. S. highway 40-50 continues from Grantsville northward around the end of the range, junctioning with the Dugway Proving Ground road, also paved, on the north-west end. This latter highway follows the range on the west flank through Skull Valley and meets the Johnson's Pass road just east of the proving ground entrance. From these main highways fair unimproved roads and poorer jeep tracks enter most of the Canyons.

The mountains are steep and rugged. Pediments and terraces, however, lead up the range proper with slighter gradient on the west flank from Skull Valley, and on the east flank from Rush Valley. The range is situated midway between the Oquirrh Mountains to the east and the Cedar Mountains to the west, and continues structurally as the Onaqui Mountains to the south of Johnson's Pass.

The surrounding valleys are essentially playas containing salt marshes and flats. Vegetation here is meager, and of hardy types, but the higher elevations of the range are more hospitable where juniper, cedar, pine, cottonwood, willow, and fir grow abundantly. Springs are common in many of the canyons; along the west side over thirty springs emerge from beneath the bahadas. These help to support several farms and ranches in this area. Indian Hickman, North and South Willow, Davenport Canyons, and restricted lengths of other canyons contain perennial streams most of which supply culinary water and irrigation water to Grantsville and surrounding ranches.

PREVIOUS WORK

Heretofore there has been no attempt to study the igneous rocks of the Stansbury Mountains in detail. Recently the general geology and structural features of the range have been studied by Rigby (1958).

The surrounding ranges, especially to the east and south-east, have been studied in great detail for the purpose of developing the already existing mineral wealth or in hopes of opening up new areas for exploitation. Gilluly (1932) published an intensive study of the geology and ore deposits of the Stockton and Fairfield Quadrangles which include the Oquirrh Mountains and adjacent smaller hills, the Traverse Range, the Bingham copper pit, and several small mining camps.

The mineralization of the West Tintic Mining District was studied by Bronson Stringham (1942) in some detail, and also in summary form by Gardner (1954).

Lindgren and Loughlin (1919) completed an exhaustive study of the igneous geology in the Tintic Mining District. In this contribution the rocks and alteration processes were studied in detail, and a complete history of the igneous activity including a theory for differentiation in this area was proposed. Lovering (1949) worked with rock alteration in the East Tintic District.

Cohenour in a Ph. D. thesis (1957) describes the monzonite and granite stocks along with minor igneous bodies that intruded or extruded upon the Precambrian metamorphic complex of the Sheeprock Range. There has not been discovered any mineralization of economic importance, however, in that area.

Harris (1958) mapped the geology of the Dutch Peak area of the Sheeprock Range and briefly described the Sheeprock Stock and minor related hypabyssal igneous bodies.

Thomas (1958) investigated the igneous rocks and mineralization of the Indian Springs Quadrangle in the Simpson Mountains and reported rock types and alteration processes similar to those observed in the Stansbury Mountain area.

Of general academic interest and of some use in correlation is Eardley's (1955) short discussion of the Tertiary pyroclastics of north-central Utah.

Some preliminary work on the igneous rocks of the Stansbury Mountains was included in Rigby's paper on the general geology of the range. Some important ideas concerning the structure and age of the extrusives have been brought forth in this paper, and therefore there will be frequent references to his work.

The reason for reviewing the descriptions of the adjacent areas is an economic one as well as petrographic. Most of the surrounding areas show major igneous intrusions along with important zones of mineralization. It would be interesting to compare the composition of the igneous rocks within all of these provinces and the mineralization trends and associations. This can be done only superficially, of course, on the basis of information supplied by the papers previously mentioned; a comprehensive comparison of the provinces being beyond the scope of this paper.

METHODS OF INVESTIGATION

The field work for the study was conducted during the fall of 1958 and the spring of 1959. Most of the intrusive bodies were studied first so as to be out of the high altitude country before snows arrived.

Samples of both intrusives and extrusives were systematically collected and labeled, and measurements of intrusive dimensions and of volcanic sections were made with a steel tape. Where mining properties were associated with the intrusives, or appeared to have some basis for development, additional samples were taken for study.

Detailed mapping of the extrusives in the central part of the range was carried out on U. S. Forest Service air photos.

Standard petrographic techniques were employed in describing the thin sections. Where necessary the Universal stage was used, mainly for the measurement of 2V angles and optic signs. A systematic collection of thin sections of all intrusive and extrusive units of the area has been curated by the Geology Department of Brigham Young University. Occasional samples taken from mines or areas suspected of alteration were qualitatively checked for various metals.

In the description and classification of the rock types, Johannsen's unique method is employed. In each of the sections describing the rock in Table I, Johannsen's rock name and number is included. Many of the terms used in the Johannsen system were originally proposed for rocks of a specific occurrence. Therefore, when the proposed classification does not adequately connote the composition of the sample described, such types were prefixed according to his suggested method.

Finally, samples collected in the field were labeled "X" or "I" for extrusive and intrusive, respectively, the individual exposures then being labeled A, B, C, etc. The geologic maps of Figs. 1, 6, and 8 make use of this designation.

Appendix A is a brief summary of the stratigraphy of the range given in order to orient the reader with the formations of the Stansbury Mountains and their relation to the igneous rocks.

INTRUSIVE ROCKS

GENERAL STATEMENT

The intrusive bodies within the range are all small and of apparent near-surface emplacement. The largest plug measures less than 400 feet along the greatest dimension. The leucocrates are confined to the central part of the range, and only a few diabasic dikes are associated with the extrusives on the flanks of the range.

Extrusive names were given to the intrusive rocks, except for one (I-E), because of the textures present and occasional glass content.

The index map, Fig. 1, includes the locations of both extrusive and intrusive exposures of the range. Table I is a compilation of much of the petrographic data of the igneous rocks, and, in the case of the intrusive bodies, includes one set of data for each locality.

FIELD RELATIONSHIPS AND PETROGRAPHY

Augite Syenogabbro

(I-E)

The only intrusive outcrop of this composition in the range is located between the Dragon and Monarch mines in North Willow Canyon where the creek divides into three small tributaries. It appears as a small semi-circular knob of loose boulders with a few solid bedrock exposures. The entire outcrop zone is less than 100 feet across.

Megascopically, most of the rock is a very dark gray, medium grained phanerite composed mainly of augite in euhedral stubby laths, biotite, and a dark plagioclase feldspar. It usually has a definite sparkly crystalline appearance, though some samples collected have almost an aphanitic grainy texture.

In thin section the rock is hypidiomorphic-granular. The grain and crystal contacts are both sutured and interlocking. In places biotite has grown around the augite and both of these along with much plagioclase are enclosed in large optically continuous and Carlsbad-twinned plates of orthoclase, thus showing good poikilitic texture (Fig. 1, Pt. II). The average grain size for the entire slide is .24 mm. with the maximum being 2.8 mm. (orthoclase) and the minimum .02 mm.

Twinning in the augite takes the form of multiple twins, seams, and single twin planes. Biotite is twinned occasionally. As determined by mineral associations and grain contacts the crystallization sequence appears to be: minor accessories, followed by augite, labradorite, biotite, and orthoclase.

This plug is unusual when compared to the other intrusives in the range. It is much darker, equigranular, and compositionally unlike the others.

Andesite Porphyry

(I-A, I-F, I-N)

The dark dike rock I-A is exposed on the north wall of the Dry Lake Fork of South Willow Canyon in unsurveyed land. It is the only exposure of its type found in this area. The dike lies only 50 feet south of the Forest Service trail, it being exposed for a length of approximately 30 feet and having a width of 10 feet. The dike weathers to a dark greenish-gray and is covered by debris on the south slope so that it is not easily distinguished from the Tintic Quartzite (Cambrian), also weathering to dark hues. The dike has intruded vertically into the eastward dipping Tintic beds near the Deseret anticlinal axis.

This dike crops out just a few hundred yards south of exposure I-L, the southernmost exposure of the trachyandesite sill I-F, and lies directly on strike with it (I-F actually becomes discordant at its southern end, it crossing over the Deseret anticlinal axis somewhere near the Mining Fork of South Willow Canyon). If intrusion of I-F, I-L, and I-A took place along the same plane of weakness, I-A may be a slight differentiate of a more acidic magma. There is no proof, however, that would rule out the possibility of two independent injections in near proximity to each other.

Slight alteration is evident near the contact of I-A and consists of additions of iron oxides and calcite into the quartzite. The dike itself is considerably altered by weathering. Both the interior and the contact of the dike show much flow structure in the microlitic-glass groundmass; this along with border chilling has served to develop a foliation parallel to the contact. The foliated layer grades abruptly into the altered brown quartzite on the footwall side, whereas the hanging-wall contact is obscured by alluvial debris. The dike contains some joints that have a general attitude of N. 90° E., 80° N. E.

In the field I-A appears to be a diabase. The rock contains a considerable amount of ferromagnesian minerals but contains calcic andesine as the plagioclase variety.

Emplacement during cooling as a viscous fluid is shown by the prominent trachytic texture (Plate II). Masses of sub-parallel feldspar laths show definite flow between already solidified larger phenocrysts such as augite and biotite, and often show a piling up upon the sides of immovable grains in the path of flow. The rock is also porphyritic, having phenocrysts of biotite between .5 mm. and 1 mm. in size (maximum = 1.54 mm.). The average grain size of the entire sample is .04 mm.

The thin section studied contains considerable calcite and some secondary quartz. The origin of the calcite is discussed in a later section (Alterations, p. 48). The quartz is most likely introduced.

Samples from exposures I-L and I-F were taken near the crest of the range and on or near the Deseret anticlinal axis (for description of I-L see page 13). It is postulated that both igneous bodies are part of a continuous unit though parts are covered by glacial moraine in the Mining Fork of South Willow Canyon.

The northern 1½ miles of this body (I-F) is a sill. It dips westward between beds of Tintic Quartzite about 25 degrees. The sill can be divided into three parts, each separated by quartzite. Fig. 2 is a detailed field sketch and Fig. 3 a photograph of these structural relationships. Between this exposure and I-L the outcrops are poor and of limited extent. On each succeeding ridge outcrops diminish from north to south until the Mining Fork of South Willow Canyon is reached. Other small exposures have been reported by Rigby (personal communication) in this immediate area.

There has been considerable flow during consolidation of this sill as is evident by the almost "schistose" condition of the borders. The contacts of the sill with the quartzite are not abrupt but are gradational within a foot or so. Thin section study proved that the sill has been highly contaminated by the presence of the quartzite wall-rock. The sill is not resistant; rather it weathers into a slight slope having a light-brown to light-gray color. Even though the outside appears unaltered a fresh fractured sample shows considerable feldspar and ferromagnesian alteration.

This sill shows more alteration than any other outcrop of intrusives in the range. Whether the alteration is hydrothermal or due entirely to weathering processes is debatable.

Originally the rock consisted of andesine, biotite, hornblende, apatite, and possibly magnetite. Large phenocrysts of andesine are altered to sericite and calcite. Somewhat smaller euhedral crystals of biotite and hornblende are now altered to chlorite and other alteration minerals (Fig. 2, Pt. II). These are imbedded in a matrix of irregular shaped microlites having an average size of .03 mm. The phenocrysts average .25 mm. in diameter and reach a maximum of 3.2 mm.

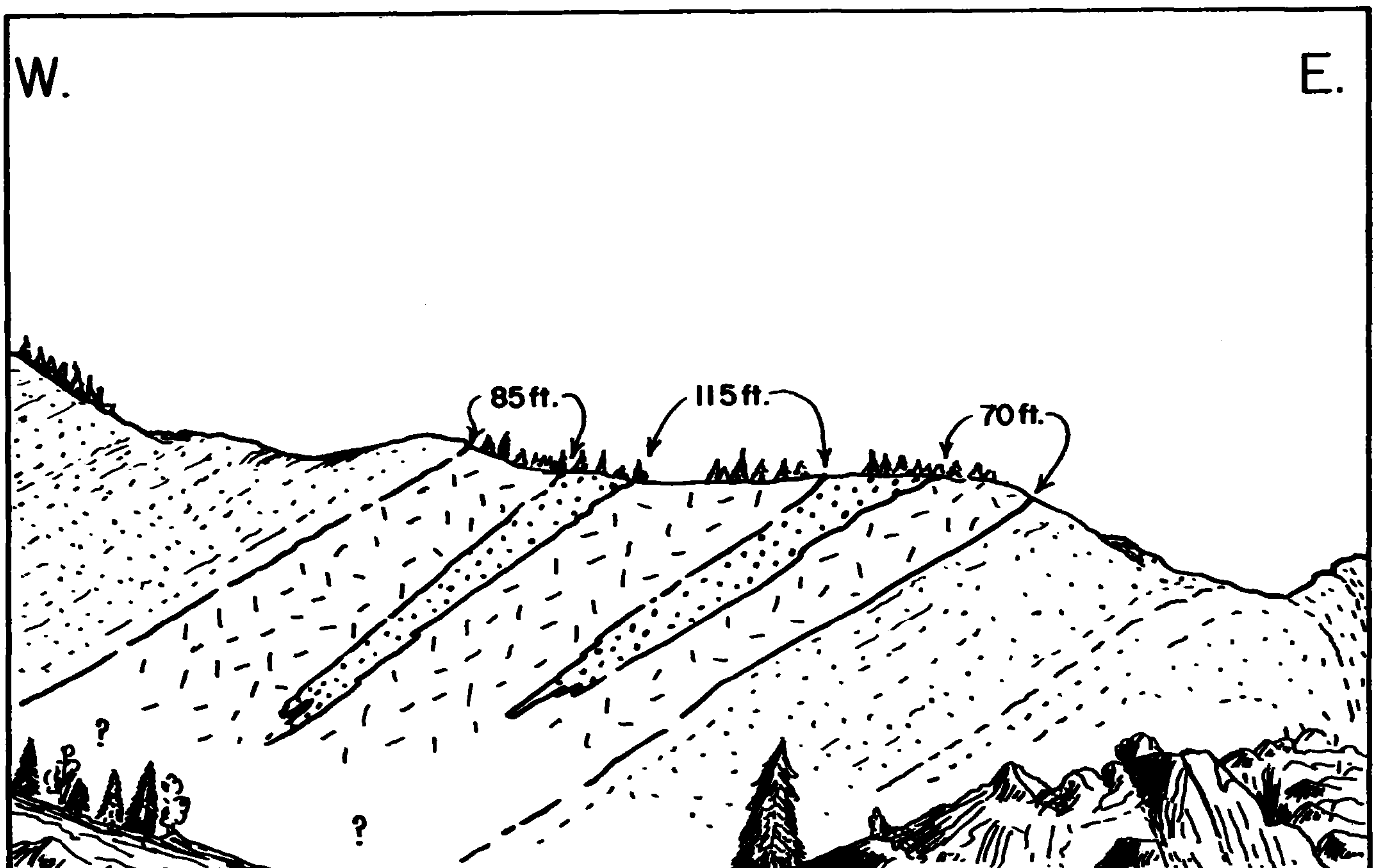


Fig. 2 Field sketch showing details of sill I-F, North Willow Canyon.

Fig. 3 - Sill I-F with two contained quartzite wedges. Looking north-west showing position and attitude as exposed on the ridge south of North Willow Canyon. Deseret anticlinal axis, a, at right margin of photograph.

Fig. 4 - Plug I-G exposed in ridgecrest approximately one-quarter mile east of sill I-F (Fig. 3).

Although in the original composition andesine composed 92 per cent, and hornblende and biotite 8 per cent, very little (less than 20 per cent) of the minerals remain unaltered. Calcite from feldspar alteration takes up at least 50 per cent of the rock while the hornblende and biotite, indistinguishable except for occasional outlines of the original crystal, are now represented by magnetite and chlorite. The magnetite is almost entirely restricted to within the borders of the other ferromagnesian minerals. Minor amounts of clay, and other iron oxides are also present. The only mineral unaffected in the thin section is the apatite. Quartz grains are common throughout the rock as an introduction. Although I-L to the south contains some orthoclase none can be positively identified from this rock.

Sill I-N, 1½ miles in length, parallels the belt of East Flank extrusives along its western border. The sill is well exposed at the north end and here consists of a massive, coarsely aphanitic center bounded by flow-banded and jointed zones 3 or 4 feet wide. The attitude of this segment is N. 15° E., 57° N. W. Along the entire length of the sill it separates the upper and lower members of the Pine Canyon (Miss.) Limestone. Joints in the sill strike N. 80° W., and dip 8° N. E.

The rock weathers light-gray but is streaked with iron stains. On fresh fracture the rock is medium-gray and contains phenocrysts of relatively unaltered biotite and hornblende. The sill, as measured at the north end, is 45 feet in width.

The texture of this rock in thin section is orthophyric; short stubby plagioclase laths in non-linear arrangement constitute the entire groundmass. The phenocrysts are of hornblende and biotite and an occasional zoned plagioclase lath.

The groundmass averages .02 mm. in grain size and the phenocryst size average is .48 mm.

Trachyandesite Porphyry

(I-B, I-L, I-H, I-K, I-G)

Exposure I-B is a small plug of trachyandesite outcropping on the exact crest of the range separating Baker Canyon on the east flank, from Box Canyon on the west. The outcrop pattern is bowling-pin shaped with the long axis paralleling the ridge. The length of the plug is 231 feet, and it is 117 feet wide. There is some question as to whether the plug contains a roof pendant of Tintic Quartzite (into which it intrudes) or whether there is really two small plugs.

The plug weathers light-gray with a spalled outer surface. Prominent joints strike N. 10° W., and dip 40° N. E. Fresh fracture reveals a porphyritic texture of partly altered plagioclase in a light-gray groundmass containing small amounts of biotite and hornblende.

In thin section the rock has an orthophyric texture. Phenocrysts of plagioclase are imbedded in a matrix of stubby xenomorphic microlites of both plagioclase and orthoclase composition. The biotite is often multiple twinned and albite, pericline and Carlsbad twinning is prominent in most of the phenocrysts. Some of these phenocrysts as well as introduced quartz grains show extensive resorbtion (Fig. 4, Pt. II).

I-L, a trachyandesite porphyry outcrop of no more than 10 square feet in exposed area, is located on the divide between the Pocket Fork and Dry Lake Fork of South Willow Canyon. It weathers into a rounded mass with a spalled outer surface of pinkish-gray to dirty-yellow color. On a fresh fracture plagioclase phenocrysts and smaller flakes of biotite are visable, but even more conspicuous are the few quartz xenoliths derived from the Tintic Quartzite wallrock. The outcrop is probably discordant, but the small size of exposure inhibits better examination of the structural relationships.

Thin section study reveals an orthophyric texture. The plagioclase microlites, the exact composition of which is unknown, have definite normal zoning but only poorly developed polysynthetic twinning. The noticeable structures are due to alteration and stress from viscous flow. The biotite shows bent cleavage in many places in the thin section. The grain dimensions are as follows: groundmass average = .02 mm. phenocrys average = .33 mm.; phenocryst maximum = 2.5 mm.

Many of the phenocrysts of oligoclase are altered and contain introduced hematite and limonite. These oxides are also present in fractures, cavities, and as alteration halos surrounding the hornblende. Associated with these iron oxides are translucent pinkish incrustations, most likely opal, some of which do not line cavities but form massive patches in the groundmass. Some chlorite and zeolites have also resulted from biotite alteration.

Some parts of the section show phenocryst resorbtion, limonite and calcite having entered and located along the resorbed borders.

Another igneous body of similar composition has intruded the thrust plane of the Broad Canyon fault. Segments I-H and I-K are extensions of this sole injection from beneath the soda-basalt and augite calci-phonolite flow series X-E, and thus they will be considered together in this description.

Both segments weather light-gray and stand up as resistant vertical tabular masses. Biotite flakes give the rock a speckled appearance. The injection exhibits good flow lineation at both contacts. There has been some bleaching and iron oxide introduction affecting the intruded Laketown Dolomite (Silurian) and Manning Canyon Shale (Miss.-Penn.); this is most well developed in the northern segment (I-H). This segment protrudes from beneath the flows for a distance of about 250 feet and has a width of 30 to 40 feet. In general the whole sole injection strikes due north.

In thin section both segments I-H and I-K are very similar. The andesine phenocrysts are mottled with blebs and cavaties, some containing iron oxides, but otherwise little alteration is present in the rock. The texture is typically porphyritic with microlites and glass composing the groundmass. The phenocrysts average over 1 mm. in diameter but the maximum size is almost 3 mm. Average grain size for the matrix is .05 mm. The microlites are both square and elongated andesine and orthoclase laths, mostly euhedral, and contain minor interstitial glass, calcite, and zeolites. Zoning and slight resorbtion characterizes the phenocrysts and occasionally thin rims of a second stage of andesine surrounds the resorbed borders. Twinning occurs in the andesine according to the albite, Carlsbad, and pericline laws.

Most of the alterations consist of iron oxides and clay that fill the blebs, stringers, and networks of rounded cavaties within the andesine phenocrysts. Some calcite and analcite or chabazite also exists in the groundmass.

Plug I-G, lying between sill I-F and plug I-E, is 350 feet long and 180 feet wide. It is an oval-shaped outcrop that weathers into a light-colored slope covered with debris (Fig. 4). The rock is highly fractured but systematic joints are not visable. At the western end of the outcrop considerable mixing of the rock with quartzite wall rock has taken place.

This plug is compositionally similar to the other trachyandesite bodies with the exception of a paucity of ferromagnesian elements; the prefix "leuco" has been added to the rock name to give this connotation. Texturally the rock is porphyritic with andesine phenocrysts of .92 mm. average size imbedded in a pilotaxitic groundmass of .04 mm. average grain size.

Olivine Diabase

(I-J, I-C, I-M)

Three olivine diabase dikes outcrop in the vicinity of the extrusives. On the basis of structural relationships and composition, the dike at Salt Mountain (I-M) is a source for the volcanics in that area, and I-J near the flow section X-E may also have been a minor source because of its nearness to them. I-C lies in the center of the Palmer Knolls and may or may not have acted as a source; it lies midway between flows X-B and X-C.

The Palmer Knolls dike weathers into a number of rounded boulder-like outcrops, most likely exfoliation knobs. They are colored dark purple-brown, are very hard and brittle, and texturally are compact to scoraceous. The vesicles are drawn out into a linear pattern that suggests viscous flowage.

Dike I-J is small, only 4 feet wide and twice as long, and weathers into a soft dark-gray mass containing amygdules of calcite.

A small dike of olivine basalt or diabase outcrops through a hornblende andesite patch at the south-west border of the Salt Mountain extrusive section. The unit is resting upon Garden City Limestone of attitude N. 13° E., 40° N. W. The dike is 75 feet wide and weathers into a resistant, but jointed, ridge of dark brown to black color. It is vesicular, glassy, and of similar composition to the basalts at the top of the Salt Mountain section.

The most conspicuous petrographic similarity of the three dikes is the presence of a small amount of olivine, with iddingsite coronas, and the high ferromagnesian mineral content. They differ from the dike in Muskrat Canyon (I-D) in that they do not contain sanidine or nepheline. They are texturally similar also, although the Salt Mountain dike contains much glass.

PLATE 1 - FLOW, BRECCIA AND DIKE EXPOSURES

Fig. 1 - North-dipping flow-banded andesite exposed at the head of Coal Pit Canyon, Sec. 30, T. 3 S., R. 6 W.

Fig. 2 - Intraformational-type volcanic breccia exposed 100 yards east of the tuff cliffs in South Willow Canyon, center of Sec. 6, T. 4 S., R. 6 W.

Fig. 3 - a. Dike I-D showing complex relations of the dike with the dolomite wall rock (Mississippian Gardner Dolomite ?).

b. Close-up view of a finger of dike I-D intruding bleached Gardner Dolomite (?), indicating joint control during emplacement.

PLATE I


1


3a


2


3b

PLATE 2 - CHARACTERISTIC INTRUSIVE COMPOSITIONS AND TEXTURES

Fig. 1 - Plug I-E; Dark brown biotite and lesser magnetite and augite enclosed in optically continuous plates of orthoclase (Or). X50

Fig. 2 - Sill I-F; Chloritized phenocrysts of plagioclase (C) in a dense groundmass of calcite and limonite. X50

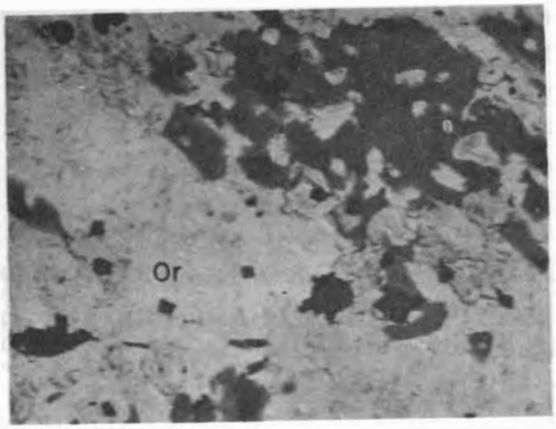
Fig. 3 - Dike I-A; Trachytic texture. Microlites of andesine (a) in both random and flow orientation with minor augite and magnetite occurring as small interstitial grains. X50

Fig. 4 - Plug I-B; Rounded and embayed boundaries of resorbed quartz grain (q) lying in orthophyric groundmass. Hornblende (h), and apatite (a) also visable. X 50

Fig. 5 - Dike I-D; Partially complete olivine (o) phenocryst surrounded by iddingsite (i) corona of dark orange color. Groundmass is intergranular. Magnetite and augite (with some olivine) disposed between plagioclase laths. X50

Fig. 6 - Cataclastic breccia occurring in south-east corner of soda-basalt flow X-C. Hydrothermal clay replacing large plagioclase phenocryst and containing unidentified non-birefringent border (n). Quartz grains (q), hornblende (h), and minor amounts of zeolites (?), magnetite, and calcite also present. X50

PLATE 2



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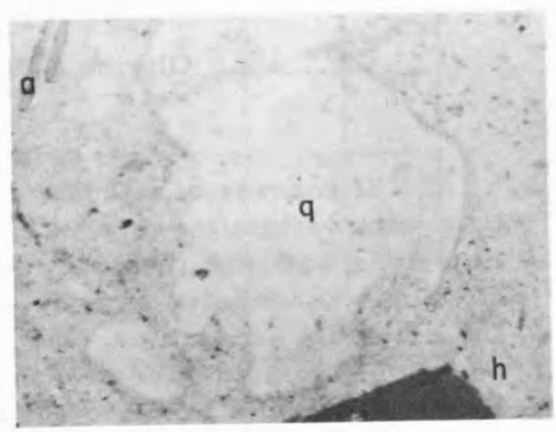

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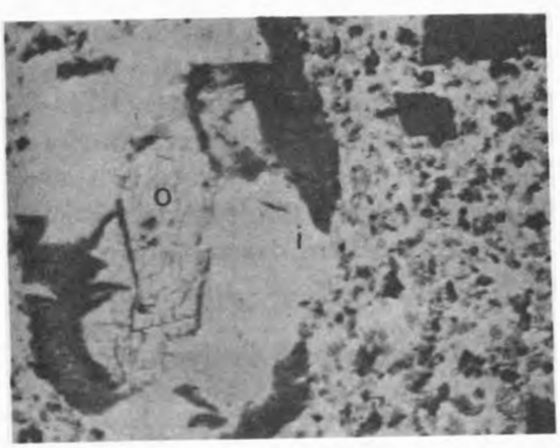

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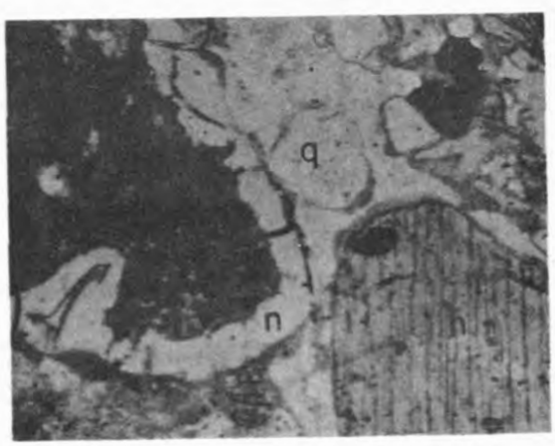

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The characteristic texture of these dikes is porphyritic with some variation in the groundmass. In I-J the phenocrysts are of augite and biotite and they lie in a dense groundmass of magnetite, augite, plagioclase laths, and olivine with iddingsite coronas. I-C has an intergranular matrix. Magnetite and augite (with possible olivine) occur as minute grains between the plagioclase laths. I-M actually is seriate-porphyritic and hyalophitic since olivine and augite occur as phenocrysts of all sizes in a matrix of labradorite microlites with dark turbid glass filling in the interstices.

Most of the olivine phenocrysts in these dikes have been completely replaced, or thickly rimmed, with iddingsite. In the case of dike I-M at Salt Mountain, augite surrounds iddingsite, and it is probable that the olivine was surrounded by reaction rims of augite during the cooling of this magma and was later completely altered to the iddingsite. The olivine has optic angles that vary between 75 and 84 degrees (optic sign negative) which would thus classify it as hyalosiderite or crysolite.

Olivine Calci-Phonolite

(I-D)

The manner of intrusion of this dike is unusual. Controlled by a joint system the dike interfingers considerably with the limestone wallrock (probably Mississippian Gardner), photographs of which are included as Figs. 3a and 3b of Plate 1. The limestone here is white and porous, and has been considerably bleached. Only occasional vesicles are present; otherwise the dike alters into a rounded series of brown knobs. These knobs compose a resistant ridge 40 feet wide and 150 feet long that trends N. 34° E.

Dike I-D differs markedly from the other melanocratic dikes because of the sanidine and nepheline content. The rock is poikilitic. As can be seen by Fig. 5, Plate I, the entire background is composed of plates of sanidine and nepheline which have sutured contacts. All other constituents are disposed in random orientation throughout this background. Since minute grains of augite and magnetite occur between adjacent plagioclase laths, the texture of the finer constituents is intergranular. The phenocrysts, mostly of olivine, are subhedral grains of .46 mm. average diameter and of 1.5 mm. maximum diameter. Average size of the groundmass constituents is about .02 mm.

This dike is most likely a source for the Muskrat Canyon flows because of the compositional similarities. Both the dike and the top section of these flows are phonolites, there being a variation only in the magnetite and augite content.

Table I. MINERAL COMPOSITION IN PER CENT OF THE IGNEOUS ROCKS, INCLUDING COMPARISONS FROM ADJACENT AREAS

NOTE: Glass content not included.

			ESSENTIAL					ACCESSORY								
NAME and LOCALITY	J. N.*	TEXTURE	Or Sa	Ne	Og	An	La	Ol	Ag	Bi	Mg	Hb	Lp	Ap	Al	I
Augite Syenogabbro I-E	2311P	Hypidiomorphic-granular, poik.	15				45		26 v.	7	5			1		1c
Luco-trachyandesite I-G	1211H	Porphyritic	5?			92				1		1				1q
Andesite Porphyry I-F	2212H	Porphyritic				18								1	80**	1q
Augite Andesite Porphyry I-A	2212H	Porphyritic				58			10 v.	12	3				10c	2q
Andesite Porphyry I-N	2212H	Orthophyric				93				2	1	3			1c	
Trachyandesite Porphyry I-H	2211H	Porphyritic	15-25			50-55				5	Tr	8		1	6 c, z	
Trachyandesite Porphyry I-K	2211H	Porphyritic	25?			65				7	Tr	3		Tr		
Trachyandesite Porphyry I-L	2211H	Orthophyric	25		60					7		4		1		
Trachyandesite Porphyry I-B	2211H	Orthophyric	15-20			55-60				3		1		1		Tr q

* Johannsen Number

** See text, p. 12.

Table I (Continued)

NAME and LOCALITY	J. N.*	TEXTURE	ESSENTIAL Or Sa	Ne	Og	An	La	ACCESSORY Ol	Ag	Bi	Mg	Hb	Lp	Ap	Al	I
Olivine Calci-Phonolite I-D	2218H	Poikilitic	60	4		8		5 v.	10	2	10			1		
Olivine Diabase I-J	2312H	Porphyritic					55?	6 v.	18	1	18			Tr	2i	
Olivine Diabase I-C	2312H	Intergranular					50	3 v.	27		20			Tr		
Olivine Diabase I-M	2312H	Seriate-hyalophitic					55	1 v.	11		1				3i	
Hornblende Andesite X-B	2212E	Seriate-trachytic				72-80			3		1	2-10 v.	Tr		1Mg	
Andesite Porphyry X-A	2212E	Porphyritic - hyalopilitic				90			3		1				1?	1q
Olivine Soda-basalt X-B	2212E	Porphyritic - felted				85		1 v.	8		Tr			Tr	1?	
Olivine Basalt X-B	2312E	Porphyritic - trachytic					75	1-2 v.	3		1	1	1		Tri	
Olivine Soda-basalt X-C	2212E	Intergranular				65		5 v.	7		20			Tr	3i	

*Johannsen Number

v. = Varietal accessory
Tr = Trace

Or = Orthoclase
Sa = Sanidine
Ne = Nepheline
Ap = Apatite

Og = Oligoclase
An = Andesine
La = Labradorite

Ol = Olivine
Ag = Augite
Bi = Biotite

Mg = Magnetite
Hb = Hornblende
Lp = Lamprobolite

Al = Alterations (Mg = magnetite; i = iddingsite, c = calcite, q = quartz, z = zeolites)
I = Introductions (c=calcite, q=quartz)

Table I (Concluded)

NAME and LOCALITY	J. N.*	TEXTURE	ESSENTIAL					ACCESSORY								
			Or Sa	Ne	Og	An	La	Ol	Ag	Bi	Mg	Hb	Lp	Ap	Al	I
Olivine Soda-basalt X-E	2212E	Intergranular				65		2? v.	10		20			Tr	3i	
Augite Phonolite X-C	2218E	Poikilitic	55	5		Tr		2	30 v.	3	2			1	2i	
Augite Calci-phonolite X-E	2218E	Poikilitic	40-60	5-10		25		Tr	15 v.	Tr	5			Tr		
Tuff X-A (White Rocks Can.)	-	-								Tr?		1?				10q
Hornblende Vitrophyre X-A[1]	-	-				60?					2	10- 30v.				Trq
Augite Andesite X-A[2]	2212E	Porphyritic - microlitic				70			17 v.		2	1			1Mg	
Hornblende Diabase[3]	2312H	Seriate-Felted					50		5	5	1	13 v.				1c
Andesite Vitrophyre[4]	2212E	Hyalopilitic-Porphyritic				40				5	1	5		1		2q
Olivine Basalt[5]	2312E	Microporphyritic					58	8 v.	25		3			1	5	

* Johannsen Number

[1] So. Willow Canyon section
[2] Breccia frag., South Willow Canyon
[3] Step Mountain (see text, p. 24)
[4] Camp Williams (see text p. 24)
[5] West Canyon (Gilluly, p. 48)

EXTRUSIVE ROCKS

GENERAL STATEMENT

The extrusive rocks of the range consist of four main masses; two basalt flows on opposite flanks of the range in the northern section; and two heterogeneous and laterally variable series of flows on opposite flanks of the range in the central section. The two basalt flows (designated X-C and X-E; see index map of Fig. 1) occur exactly east-west of each other. X-C is a semi-circular patch of both vesicular and dense flows on the south-west wall of Muskrat Canyon. X-E is a patch of similar size located high up on a ridge separating Miner's Canyon (northward) from Mack Canyon. Maximum elevation of the flow is 7600 feet.

The series of flows and pyroclastics in the central part of the range are much more complex and variable in composition. They are also much more extensive, the Salt Mountain section being nearly 1½ square miles in area and the flows on the east side are at least 8 square miles in area. These flows will be henceforth known as the Salt Mountain volcanic section and the East Flank volcanic section, respectively, in the discussions to follow. The Salt Mountain section lies in the low hills just east of Salt Mountain. The East Flank series extends approximately from Magpie Canyon south to Martin Fork of Box Elder Canyon, a distance of 7 miles, and the belt averages 1 mile in width. Rigby (1958) who has studied the structural relations of the flows visualizes them as being post-thrusting but pre-major normal faulting in age.

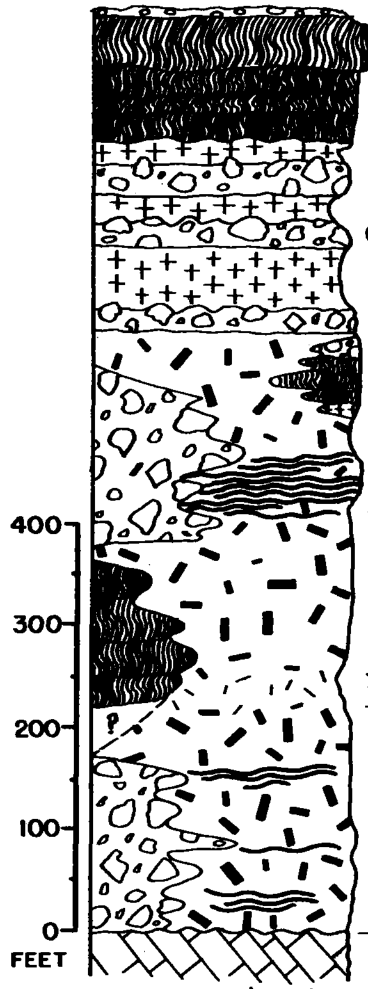
Table I (pages 22 and 23) contains petrographic data for various extrusive samples and includes data on a sample from Camp Williams and Step Mountain in Gilluly's area.

FIELD RELATIONSHIPS AND PETROGRAPHY

Salt Mountain Volcanics (X-B)

Though considerably less variable than the related andesites and tuffs on the east flank of the range, the Salt Mountain section varies somewhat in attitude and lateral composition. The strike of the volcanic

North South

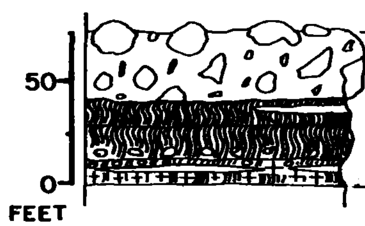


Thickness	Field Description
7) 115′	BASALT- Weathers brown and gray, vesicular near top. Gray and dense on fresh fracture. Cliff and ledge former.
6) 35′, 35′, 24′, 16′, 46′, 39′ — 195′	TUFF AND BRECCIA- Interbedded. Upper tuffs coarse, cross-bedded, and contain quartzite pebbles. Lower tuffs fine, massive. Breccia blocks of andesite, basalt, glass.
5) 115′	ANDESITE- Hornblende-rich, weathers pink and light gray, slope former. Soda-basalt and breccia tongues.
4) 60′	ANDESITE- Flow-banded and resistant, ledge former. Breccia to north.
3) 160′	ANDESITE- Weathers buff. Hornblende rich, with phenocrysts to 1 cm. Some flow-banding. Olivine basalt tongues on north border.
2) 30′-50′	ANDESITE- Hornblende-poor.
1) 230′	ANDESITE- Hornblende-rich. Weathers to tans and browns. Some glossy and flow-banded zones. Breccia tongue with glassy flow-banded clasts on north border.

905′-925′ = APPROXIMATE TOTAL THICKNESS

(Section A-A′, Fig. 6)

DETAILS OF SOUTH TONGUE OF UNIT 5



35′	76′	BRECCIA- Glassy clasts, tuffaceous, with little hornblende.
13′		SODA BASALT- Well bedded. Some tuff.
16′		SODA BASALT- Zones of welded breccia.
12′		ASH, LAPILLI- Indurated. Some flows.

VOLCANIC ROCK COLUMN OF SALT MOUNTAIN

Fig. 5

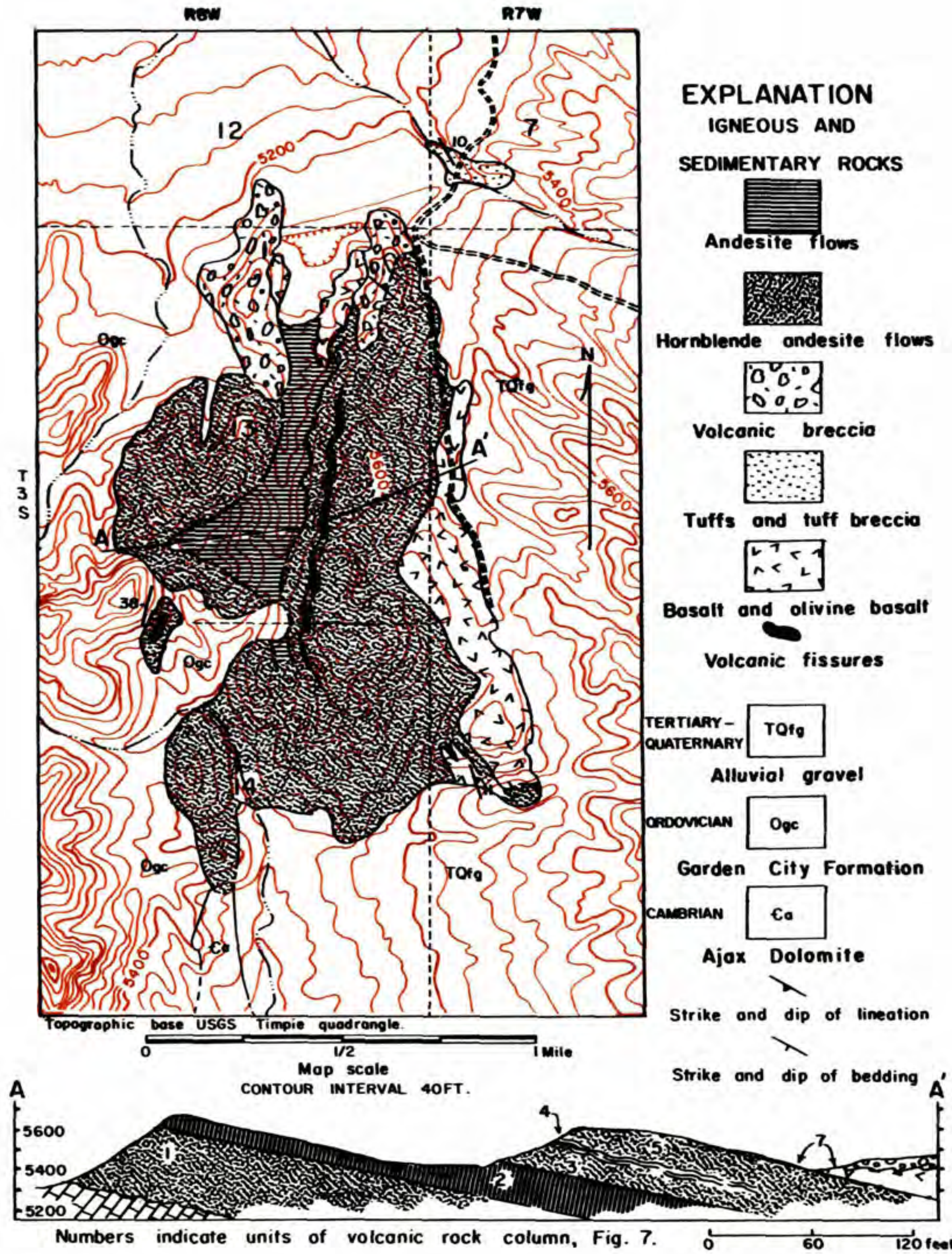


Fig. 6 Geologic map and cross-section of the Salt Mountain volcanic section.

rocks are generally north 10 to 20 degrees west and the dip 10 to 12 degrees to the north-east. Several local attitudes deviated considerably from this general one.

The area of exposure is easily accessable. Although the main section lies on the low hills to the east of Salt Mountain, a small body of tuffs and breccias is separated from this section by alluvial gravels and lake deposits near Delle Ranch. The Delle Ranch road goes through this patch and continues southward along the east border of the main flow series.

The series of volcanics have been divided into 7 units. In ascending order they are (1) hornblende andesite containing zones of flow banding, 230 feet in thickness; (2) andesite with much less hornblende than in Unit 1, 30 to 50 feet thick; (3) hornblende andesite, 160 feet thick; (4) hornblende andesite, mostly flow-banded and containing much glass, 60 feet thick; (5) massive hornblende andesite, 115 feet thick; (6) tuffs and breccias (near Delle Ranch), 195 feet thick; and (7) olivine and hornblende soda-basalts, 115 feet thick.

The total thickness measured is 905 feet although each unit may vary slightly, and the aggregate thickness will be plus or minus about 50 feet.

Unit 1 consists of interbedded glassy and nonglassy andesites; both are flow-banded and weather to gray, brown, and red-brown hues. Few actual outcrops occur on the slopes, and the characteristic weathering pattern is a mass of rounded cobbles and boulders imbedded in a bentonitic soil. Flow-banding in the rocks consists of allignment of hornblende phenocrysts; or a marked allignment of all of the constituents of the rock, thus making the rock cleavable along flowage surfaces. The flow-banding in Unit 1 is most pronounced near the middle. Toward the top flow-banding is scarce, but the rock becomes very rich in large hornblende phenocrysts, some of which are eleven millimeters long. They are well developed in both coarsely aphanitic and glassy grounmasses. This unit is 230 feet thick.

Unit 2 is a hornblende-poor rock which is exposed both at the crest of the hill composed of Unit 1 and down near the gulley at the base of the next hill to the east. This unit is thin and not well distinguished from the hornblende-rich units above and below it. Therefore the exact boundaries are questionable and are so indicated on the geologic map, Fig. 8. There is no doubt that the unit is highly gradational into the units above and below, and though it is 30 to 50 feet thick in the section measured (Fig. 5) it is not likely to be always present throughout the area.

Unit 3 continues up the hill as another hornblende-rich andesite with a slight amount of flow-banding near the bottom. Weathering tones are mainly light shades of gray-brown, buff, and red-brown. However, similar to Unit 1, there are parts of the section containing black, dense glasses that have large hornblende phenocrysts included. This is only seen on a freshly fractured surface as the rock weathers light gray. Total thickness of this unit is 160 feet.

Unit 4 has been set aside from the others on the basis of the marked flow-banding of the zone and the resistant manner of weathering. This is the only unit in the entire series of andesites that is resistant enough to form ledges and rocky terraces. Even then they are only continuous for stretches of several feet. The rock weathers light pink-gray to medium gray. The hornblende laths are of much smaller size than in the previous unit. Most of the flow-banding has crude allignment; however, some layers especially near the base of the unit show near-"schistosity". This unit is 60 feet thick.

Unit 5 is very rich in hornblende phenocrysts, and weathers much like the previously described hornblende-rich unit (Unit 3). At the southern end of the area the andesite wedges into the facies of breccias and basalts but still forms a well defined unit in most of the area. This massive hornblende andesite is 115 feet thick.

Most of Unit 5 is overlain by a thin layer of basalt. At the north-east border of the area, however, no basalts are present, and instead the tuffaceous andesites and breccias appear to pass beneath a slight alluvial cover into the tuff section, Unit 6, at Delle Ranch.

The exposures of Unit 6 at the ranch are good and, although some of the bedded tuffs have varying attitudes, the breccia units follow the topography in a manner suggesting an attitude of N. 30-40 W., 20 N. E. Local attitudes in the tuff units are N. 40 E., 30 N. W., and N. 30 W., 10 N. E. This again may be attributed to initial dips on irregular topography.

The basal bed at Delle Ranch is a massive tuff with some coarse breccia exposed at the gulley bottom. The breccia matrix weathers light gray whereas the clasts weather red-brown. Angular to partly rounded clasts of flow-banded glass, andesite, and vitrophyre are imbedded in the matrix. The rest of the unit, totaling 85 feet in thickness, is composed of light gray, mostly massive bedded, tuff.

The breccia overlying the tuff unit is only 16 feet thick but is very conspicuous. About 90 per cent of the fragments are badly weathered melanocrates, probably andesites. They weather dark gray to black; however occasional clasts of reddish-colored rock, also badly weathered, are present. The breccia is very resistant, however, and stands up as ridges between the underlying and overlying tuff beds.

The next member is a 24-foot series of well bedded tuff, containing layers that are conglomeratic. The fragments of these conglomerate lenses are small, less than 4 inches in diameter, and are mostly of quartzite and shale.

This is overlain by another 35-foot zone of volcanic breccia which contains fragments of dark colored and light colored andesite. Some of the boulders have diameters of over a foot.

The basalts comprise the uppermost volcanic sequence, Unit 7, and can be subdivided into two main flows: (1) a dense, but slightly vesicular olivine basalt that weathers into dark gray rounded blocks; and (2) a more vesicular (and amygdaloidal), ledge forming flow that weathers red-brown and gray. The base of the first flow is partly a dark dense glass with well developed hornblende phenocrysts. In the extreme southern part of the outcrop belt the basalt forms 20-foot cliffs and shows crude bedding, which when viewed from a distance along a strike, exhibits a dip of 11 degrees. The two flows were measured together and totaled 115 in thickness.

General distribution and position of the units in the Salt Mountain series can be seen from the column, map, and cross-section of Figs. 5 and 6.

This breakdown concerns the major units of the area but does not include the several facies units on the north and south borders of the area. Fig. 5 is an oriented igneous rock column that shows the relations of these tongues to the main series just described above.

On the north border of the area the major rock type beginning at the base is a coarse, ledge-forming, volcanic breccia constituting an entire low hill. The weathering hues of this tongue are predominately light-gray but many of the clasts, which weather into brown and red, give it a mottled appearance. The matrix is tuffaceous, but coarser lapilli fragments are also present. Here the clasts are mainly flow-banded glass and vitrophyre, and crystalline hornblende andesite is not common. A small gulley marks the southern limit of the tongue; the next hill southward is composed of normal hornblende andesite, Unit 1 of the main sequence.

The breccia passes eastward under an alluvial and lake-bed cover. Continuing up-section on the next hill there exists another tongue of olivine basalt. This rock weathers into several different colors; the dense varieties are colored medium- to chocolate-brown, and vesicular types have light-tan hues. On a freshly fractured hand sample it can be seen that the olivine has altered to red-brown iddingsite. Some samples show yellow grains, also alterations, in the matrix.

The basalt, in turn, grades into another zone similar to the basal breccia tongue. Outcrops on the west side of the hill are good, but over the top and on the east side the slope appears to be composed of a normal andesite flow. Both the breccia and flow (?) outcrops are tuffaceous in places; this points to a uniform connection to the tuffs and breccias exposed near Delle Ranch.

On the basis of stratigraphic position and types of clasts in the breccias it can be said that the first breccia tongue is laterally equivalent to the hornblende-rich andesites of Unit 1, main sequence, into which it abuts. The overlying basalt tongue is most likely equivalent to the hornblende-poor andesite, Unit 2, and part of the overlying hornblende-rich andesite, Unit 3. The breccia tongue following this should be the equivalent to the uppermost part of Unit 3, all of Unit 4, and most, if not all, of Unit 5.

Along the south border of the main sequence is a thin series of soda-basalts, breccias, and minor pyroclastics that are separated from the overlying basalts of Unit 7 (Unit 6 is missing here) by part of the andesites of Unit 5.

The igneous rock column of Fig. 7 attempts to show both the main units of the area and their thicknesses, and the thicknesses (by scale) and position of the tongues. It must be remembered that the Delle Ranch series of tuffs and breccias has been included in its correct stratigraphic position in this diagram even though the exposure itself is divorced from the main flow sequence.

The andesites of the Salt Mountain volcanics are, with the exception of varietal hornblende or lamprobolite, quite homogeneous. The following petrographic data is based on a type near the base of the first hornblende-rich zone, Unit 1 (see also Table I).

The rock tends to have a seriate texture combined with a trachytic groundmass. Augite and hornblende are the important phenocrysts but odd phenocrysts are also created by the rimming of smaller hornblende laths with augite grains. Compositional zoning is displayed in hornblende and augite rimmed with magnetite. The andesite is oddly zoned, the laths appear to be a series of concentric shells of alternating birefringent and non-birefringent material or just a non-birefringent core surrounded by normal andesine. This can be seen from the photomicrograph of Fig. 1, Plate III.

The matrix grain size averages .03 mm. in length, while the phenocrysts average .32 mm. and attain a maximum of 6.4 mm. Larger hornblende phenocrysts are present in other units of the area, however.

The 2 per cent alteration existing in this slide is made up of yellow amorphous blebs of unknown composition but possibly palagonite or opal.

A section cut from a higher unit (Unit 5) contains more of this alteration mineral and also appreciable secondary calcite. Some of the plagioclase of this unit has altered to clay and calcite.

Table I also includes petrographic data on the tongue of soda-basalts exposed at the southern border of the Salt Mountain volcanics. The groundmass texture is felted; the andesine occurs only as microlites imbedded in glass that has a refractive index just slightly lower than that of balsam. The groundmass grains and phenocrysts average .07 mm. and .3 mm. respectively; the largest phenocrysts measured in the section are 1.44 mm. in diameter. Augite clusters give the rock a glomeroporphyritic texture.

The alteration present takes the form of tiny golden-brown, sausage-shaped masses of outward radiating fibres. The photomicrograph, Fig. 2, Pt. III, shows that they are not associated with vesicles but are strung out randomly in the dense microlitic groundmass. The exact composition of the substance is unknown.

The olivine basalt tongue at the north border of the Salt Mountain area is similar to the tongue described above except for the plagioclase, which in this case is definitely labradorite, and the olivine phenocrysts, which have not altered to iddingsite but to a mass of brown turbid limonite.

The basalts and olivine basalts at the top of the Salt Mountain sequence are typically porphyritic and exhibit trachytic groundmasses. Fig. 4, Pt. III shows secondary magnetite rimming the amphibole phenocrysts. Occasionally the amphiboles are completely replaced by the magnetite. The groundmass constituents average .06 mm. in diameter, and phenocrysts . 54 mm. The phenocrysts attain a maximum size of 3 mm.

East Flank Volcanics

The long, narrow band of flows, breccias, and other pyroclastics on the east flank of the range in the central part are most complex in distribution (see geologic map, Fig. 8). The section measured, moreover, is not representative of the volcanic series as a whole.

The following are the major types of volcanic rocks existing within this belt:

Normal andesites, hornblende andesites, and welded andesitic tuffs.
Perlite and obsidian, and hornblende vitrophyre
Volcanic intraformational breccias, tuffaceous volcanic breccias, and tuff breccias
Massive and well bedded tuffs
Minor basalt

The volcanics on the east flank can be divided into three segments; the Davenport, North Willow, and South Willow Canyon sections.

The Davenport Canyon section includes the area north of this canyon and is characterized by considerable lateral variation of the units. The basal unit is a light colored andesite containing moderately sized (about 5 mm.) hornblende and biotite phenocrysts. In the saddle between Davenport and Baker Canyons the flow-banding in this unit is pronounced but dipping steeply to the west. The contacts and banding of nearly all other andesite beds of the east

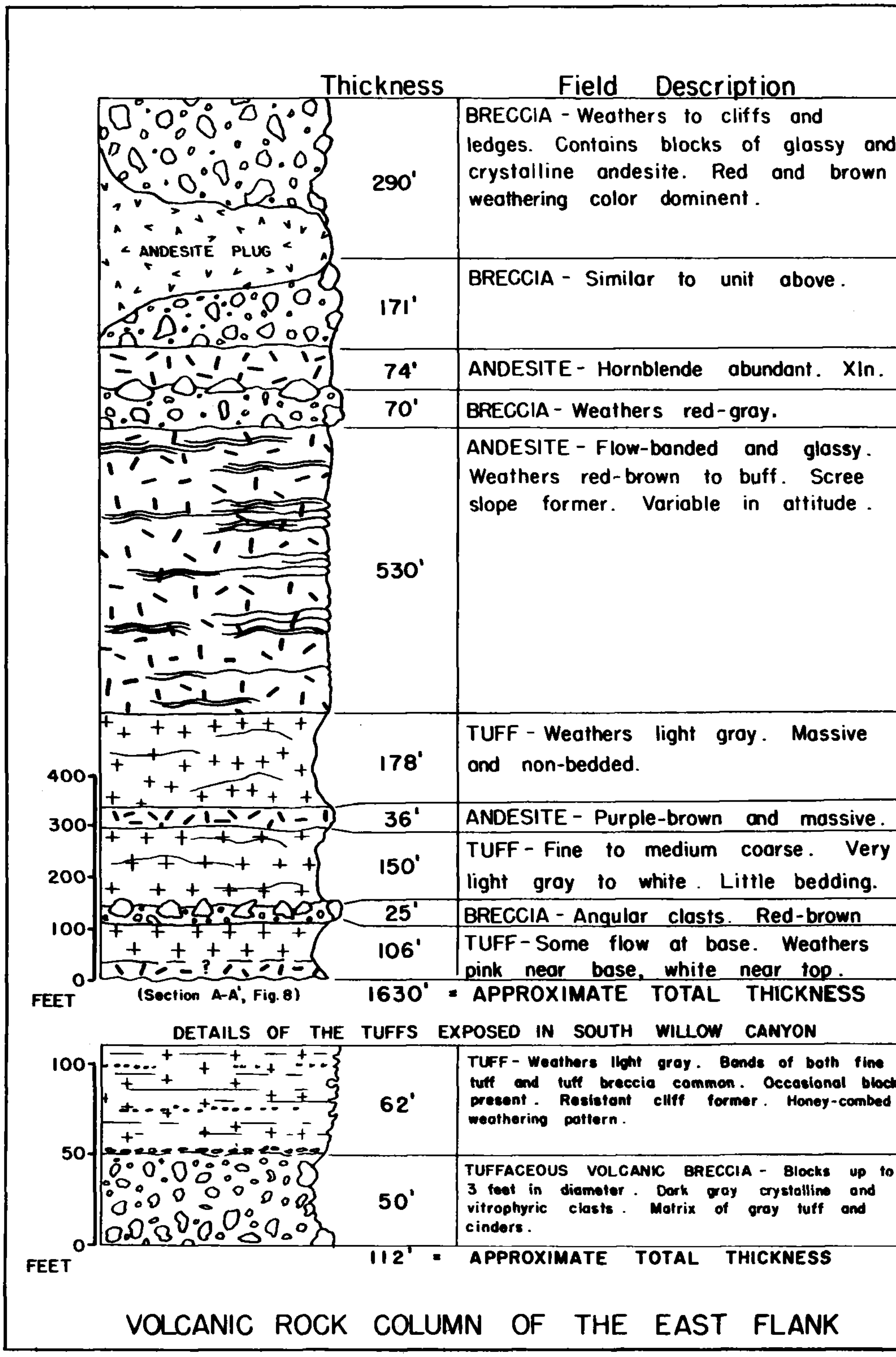

Thickness
Field Description
ANDESITE PLUG
290'
BRECCIA - Weathers to cliffs and ledges. Contains blocks of glassy and crystalline andesite. Red and brown weathering color dominent.
171'
BRECCIA - Similar to unit above.
74'
ANDESITE - Hornblende abundant. Xln.
70'
BRECCIA - Weathers red-gray.
530'
ANDESITE - Flow-banded and glassy. Weathers red-brown to buff. Scree slope former. Variable in attitude.
178'
TUFF - Weathers light gray. Massive and non-bedded.
36'
ANDESITE - Purple-brown and massive.
150'
TUFF - Fine to medium coarse. Very light gray to white. Little bedding.
25'
BRECCIA - Angular clasts. Red-brown
106'
TUFF - Some flow at base. Weathers pink near base, white near top.
400
300
200
100
0
FEET
(Section A-A', Fig. 8)
1630' = APPROXIMATE TOTAL THICKNESS
DETAILS OF THE TUFFS EXPOSED IN SOUTH WILLOW CANYON
100
50
0
FEET
62'
TUFF - Weathers light gray. Bands of both fine tuff and tuff breccia common. Occasional blocks present. Resistant cliff former. Honey-combed weathering pattern.
50'
TUFFACEOUS VOLCANIC BRECCIA - Blocks up to 3 feet in diameter. Dark gray crystalline and vitrophyric clasts. Matrix of gray tuff and cinders.
112' = APPROXIMATE TOTAL THICKNESS
VOLCANIC ROCK COLUMN OF THE EAST FLANK

Fig. 7

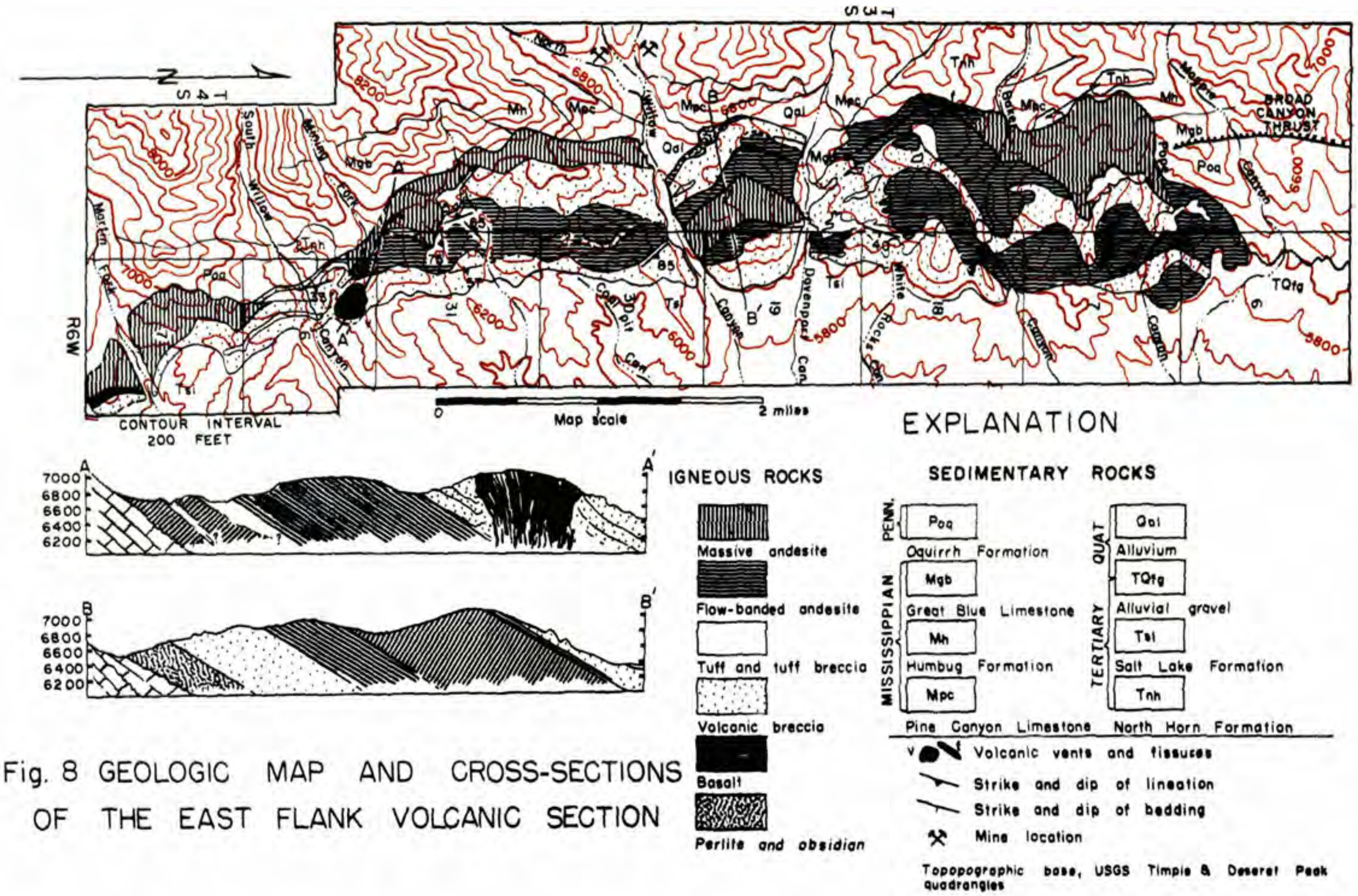


Fig. 8 GEOLOGIC MAP AND CROSS-SECTIONS OF THE EAST FLANK VOLCANIC SECTION

flank dip moderately eastward. Furthermore the zones of flow-banding of this unit are locally separated by columnar jointed, massive andesite. The significance of this local area as a fissure source is discussed further in a later section (see Local and Regional Relationships).

The second unit in this area takes on two aspects, a problem similar to that found at the top of Unit 5 in the Salt Mountain series. On the north side of the ridge between Davenport and Baker Canyon the rocks are predominately purple, flow-banded andesites. Practically the entire south side of the ridge, however, is composed of tuffaceous block and bomb breccias, tuff breccias, and "piles" of purer tuffs. The contact between individual tuff and breccia beds in this unit is always gradational.

The overlying unit consists of 242 feet of very well bedded tuffs and tuff breccias, as measured in a small tributary of Davenport Canyon.

This last unit of the Davenport section is a coarse breccia that has the typically purple-red weathering habit; it also stands up in resistant cliffs and ledges. Within this unit are zones of fractured, blocky weathering andesite flows that suggest a condition of near-brecciation that may have existed during consolidation.

At the very northern end of the volcanic series the same units may be recognized, but there is an increasingly greater proportion of flow rocks to pyroclastics going in that direction.

The North Willow Canyon section consists of a large hill of more uniform beds bounded on the north by Davenport Canyon and on the south by North Willow Canyon. At the very base of the section is an elongate band of perlite and obsidian, approximately 200 feet thick. The rock weathers gray to black and contains six-inch bands of glass that exhibit small-scale columnar jointing. Much of this glass is brecciated, and other zones are laminated; one zone high in the unit has the appearance of petrified wood because of the intense flowage.

The next unit up section is a true intraformational breccia. The rock weathers into resistant cliffs where this feature can be easily seen (Fig. 2, Pt I) The included fragments of the breccia have both aa and pahoehoe structure, some of the material being contorted and flow-banded while some fragments are angular. A once fluid flow apparently became viscous and formed a hard shell that eventually broke up and was included in the solidifying core. Both the matrix and fragments are composed of reddish to pinkish glass that weathers into a very rugged series of cliffs and ledges.

The unit above the breccia is a finely aphanitic brown and purple andesite, containing both flow-banded and massive sections, and is the characteristic type of andesite for the East Flank volcanics.

The uppermost unit here is much like the uppermost one exposed in the Davenport Canyon section. In addition to this usual red massive type, however, there is included an upper member of slope-forming medium coarse breccia that weathers light-gray and is somewhat tuffaceous.

The South Willow Canyon section lies between North Willow Canyon and Martin Fork of Box Elder Canyon. The lowest unit is not well exposed, but where present, as it is just south of North Willow Canyon, it is a very light gray massive andesite that correlates to the first unit of the Davenport Canyon section.

The second unit seems to pass laterally from breccias to tuffs and into a tuff-like rock which in reality is more crystalline and consolidated. At South Willow Canyon this unit consists of a very well exposed section of water-laid tuffs and tuff breccias that are resistant enough to stand up in vertical cliffs on both walls of the canyon. Where the unit is a true breccia the clasts consist of red-brown-weathering angular andesite which occasionally reach a diameter of six feet. This unit, as well as other like it, may have been deposited in nuees ardente fashion, an idea that is supported by the heterogeniety of the breccia fragments, the overall tuffaceous nature of the unit, and the welded appearance of parts of the andesite zones.

The next two units, as exposed between Coal Pit and North Willow Canyons, differ only in that the first predominates in breccias and the second predominates in flow-banded andesites.

The last unit of the section is again a volcanic breccia containing purple flow-banded vitrophyre, occasional andesite flow zones, and lenses of intraformational breccia.

The third unit in this area (predominately breccia) wedges out going south so that three-quarters of a mile north of the Mining Fork of South Willow Canyon it tongues into the tuffs and tuff breccias of the second unit. The fourth unit (predominately flow) also pinches out going south so that in South Willow Canyon there are no mappable flow units present.

The uppermost unit, a breccia, of this section has been intruded by a glassy andesitic plug on the north wall of the Mining Fork.

Although most of the attitudes taken on flow-banded units indicate a general attitude of N. 10-25^{o} W., 30^{o} N. E., several areas were aberrent in this way. The tuff section in White Rock Canyon varies from 57^{o} at the base to 16^{o} near the top within 100 yards horizontally and 200 yards stratigraphically. In addition to the odd attitude of the flow-banding around the fissure north of Davenport Canyon, previously mentioned, there exists a circular pattern of dips in the flows and tuffs in the center of the South Willow Canyon volcanic area (see geologic map, Fig 8). It is possible that a vent may lie beneath this area, although other interpretations may include slumping or slight faulting of the series at the western border, or deposition of the series upon a relatively high-standing hill.

Petrographically the East Flank volcanics are consistantly andesites. The flows of the North Willow Canyon section are mostly hornblende andesites containing zoned calcic andesine phenocrysts in minor amounts. Alteration has affected the hornblende considerably and zeolites are common in the vesicles and rock fractures. Little quartz is present, and this has been partially resorbed. Where glass becomes the dominant rock constituent the texture becomes hyalopilitic with tiny microlites and longulites oriented in position of flow in the surrounding glass. Table I includes the mineral and textural data for a typical andesite flow from the East Flank volcanics, and Fig 9 is a comparison of andesite from three East Flank volcanic localities along with samples from the other major volcanic areas of the range.

No attempt has been made to study in detail all of the tuff sections, breccia units, and minor types of extrusives within the range. The appearance of many of these units in the field is so similar that representative units will be described petrographically.

Several zones of vitrophyre exist in the flow areas. A good exposure of this type exists above the thick tuff breccia unit north of Mining Fork of South Willow Canyon. Characteristically it consists of large hornblende phenocrysts, often a centimeter or more in length, imbedded at random in a light-tan non-crystallitic glass. The only noticeable mineral in the rock is the hornblende.

A thin-section was cut from the well-bedded tuffs in White Rocks Canyon (between Baker and Davenport Canyons). The rock contains glass fragments, some unidentified ferromagnesian mineral fragments, and considerable introduced quartz (see photomicrograph, Fig. 6, Pt. III). The quartz was most likely picked up from the Tintic Quartzite or Precambrian crystallines from the walls of the volcanic conduit.

Table I gives the mineralogic composition of a typical breccia fragment. Here a peculiar type of plagioclase zonation is present, but this is described in detail in the petrography of the Salt Mountain volcanics where it is better displayed. Otherwise the rock is porphyritic (augite phenocrysts) with a pilotaxitic groundmass. Zeolites form thin rims in the few vesicles that are present.

Muskrat Canyon Olivine Soda-basalt
(X-C)

This patch of flows lies on the sectional line between sections 20 and 21 of T. 2 S., R.7 W., and is well exposed on the south wall of Muskrat Canyon.

Some tuffs are present locally at the base of the flows. At the east end of the flows the tuffs, pink colored and homogeneous, reach a maximum thickness of 100 feet. These tuffs thin rapidly, however, until only a trace of the unit is present at the western edge of the soda-basalts.

The basalts and related flows strike N. 80^{o} W., and dip 16^{o} N. E. The contact of the flows with the Cambrian Ajax Dolomite is easily seen when standing upon any of the surrounding ridge-crests. At places this contact contains a zone of silicification and calcification one to three feet thick. The silicification consists of massive yellow-brown chert or "jasper", and occasional bands of fine botryoidal chalcedony. Much of the country rock in this area contains bands of pure calcite presumably derived from solutions created during the baking of the Ajax dolomites.

Most of the flows are olivine soda-basalts, a term used by Johannsen to denote calcic andesine as the plagioclase type rather than labradorite. Some samples taken near the top of the flow sequence clearly are calcic phonolites. The dike (I-D) outcropping just west of the flows is composed of phonolite rock, and from this it is concluded that the last effusion of this area was slightly undersaturated.

Where best exposed the flows weather dark gray to black in rounded ledges and irregular masses. Most of the basalt is a semi-slope former, but at the top where it becomes red-brown and vesicular (in the phonolite zone) it stands out in resistant ledges.

As seen in thin section the normal olivine soda-basalts have an intergranular texture (minute grains of augite and magnetite imbedded between adjacent plagioclase laths). The phonolite rock shows good poikilitic texture; large (maximum diameter - 4. 8 mm.) oikacrysts of sanidine and nepheline enclose all other constituents of the rock (See Table I). The augite laths are aligned within the oikacrysts and the apatite occurs as myriads of tiny needles scattered throughout (Fig. 3, Pt. III).

In both rock types olivine has been completely replaced by iddingsite, The augite content is much less in the olivine soda-basalts than in the phonolite.

Sanidine as the oikacryst is questionable. The physical and optical properties determined for these groundmass plates do not fit those of sanidine completely. Considerable work with the Universal stage showed that most of the grains had moderate 2V angles, varying from 42 to 54 degrees, and were optically negative. Occasional simple twins, presumably of the Carlsbad type, were found to have the X-Y plane as the composition plane. Both Z and Y equals b. Sanidine should not have a 2V angle this large; but neither should orthoclase have an index of refraction equal to that of balsam, which is the case with this mineral.

Nepheline is suspected because other oikacrysts have 2V angles so small as to be considered uniaxial. In this case quartz is ruled out on the basis of refractive index and oligoclase is excluded because of the small 2V angle and the presence of small polysynthetically twinned laths already in the rock.

Mack Canyon Olivine Soda-basalts (X-E)

Due east two and one-half miles from the Muskrat Canyon flows is a similar type series that has been faulted in the center. Displacement is only 50 to 80 feet, however. The strike of the flows is nearly north-south and the dip is 20 degrees or less to the east, a fact that contrasts with the 35^{o} or greater dips eastward shown by the East Flank volcanic series farther south.

The series does not change aspect much from bottom to top. The flows lie high up on a ridge separating Mack Canyon from the south fork of Miner's Canyon. On the west side of the ridge the soda-basalts are predominately cliff-formers, while on the east side they subdue to slope and ledge-forming units. Most conspicuous are the two reddish oxidized zones in the flows; one, 25 feet thick, overlies a 15-foot cliff (on the east side) and crops out 95 feet from the base of the section; the other caps the flow series at the ridge-crest.

Large vents or fissures representing sources for these flows have not been found in the area although one 3-foot wide diabasic dike (I-J) is exposed just north of the soda-basalts and another possible dike, nearly 6 feet wide, crops out in a gulley floor southeast of the Western Star Mine. Approximate thickness of this section is 300 feet.

The Mack Canyon flows are almost identical in composition to those exposed in Muskrat Canyon on the west flank. Again both phonolites and olivine soda-basalts comprise the series; here, however, the phonolites contain a greater quantity of plagioclase. The Mack Canyon phonolites would actually be an augite calci-phonolite variety.

The phonolite oikacrysts are smaller in this flow, reaching a size of .13 mm. Phenocrysts, mostly of diopsidic augite (salite), average .38 mm. in size and attain a maximum of 1.4 mm. The grains of groundmass constituents average .02 mm.

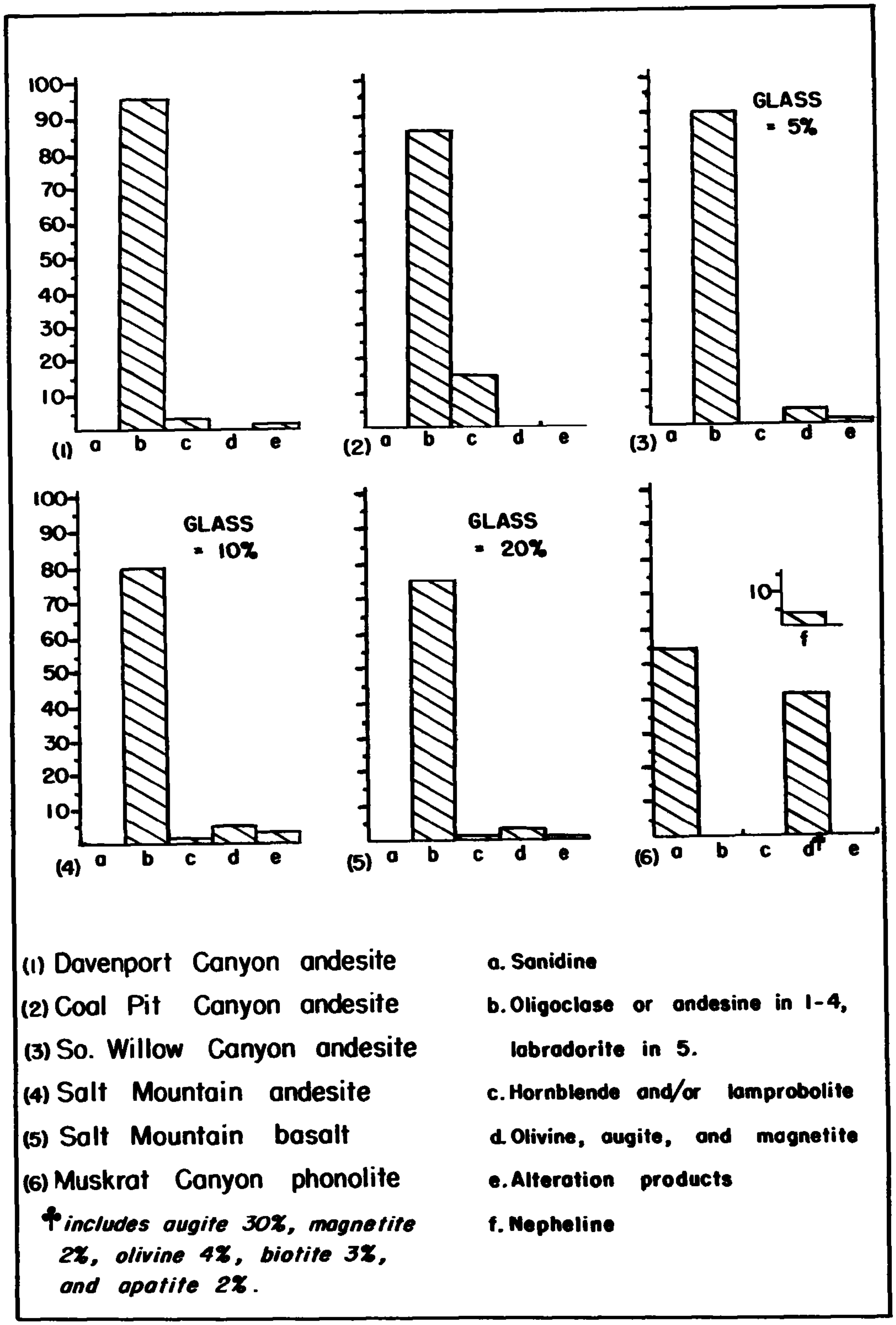


Fig. 9 Mineral compositions of various extrusives occurring within the Stansbury Mountains.

PLATE 3 - CHARACTERISTIC EXTRUSIVE COMPOSITIONS AND TEXTURES

Fig. 1 - Unusual zoning in plagioclase microlite of the type found in both Salt Mountain and East Flank andesites. X200

Fig. 2 - X-B; Lampropolite phenocryst rimmed with secondary magnetite and lying in microlitic groundmass. Unit 5 X50

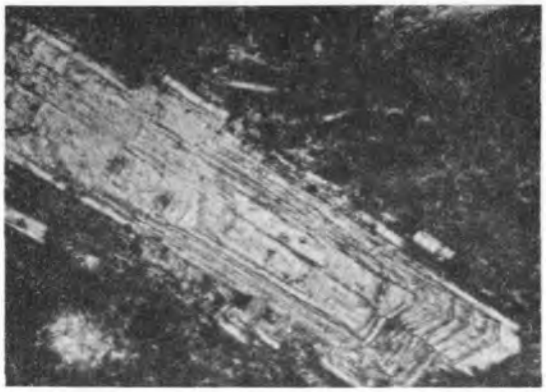
Fig. 3 - X-C; Pseudomorphs of iddingsite (after olivine) and augite, magnetite, and minor plagioclase lying in poikilitic plates of sanidine (s). Nepheline may be present with the sanidine. X50

Fig. 4 - X-B; Sausage-shaped alteration of unknown composition surrounding finer grained center, also of unknown composition. Soda-basalt tongue in Unit 5 along south border of Salt Mountain section. X100

Fig. 5 - X-A; Quartz (introduced) grains (q), turbid glass, and altered ferromagnesian minerals. Tuffs at White Rocks Canyon. X50

Fig. 6 - X-B; Secondary magnetite replacing hornblende, and resorbtion and secondary alteration of andesine phenocryst (an). Groundmass microlitic and somewhat altered. X50

PLATE 3



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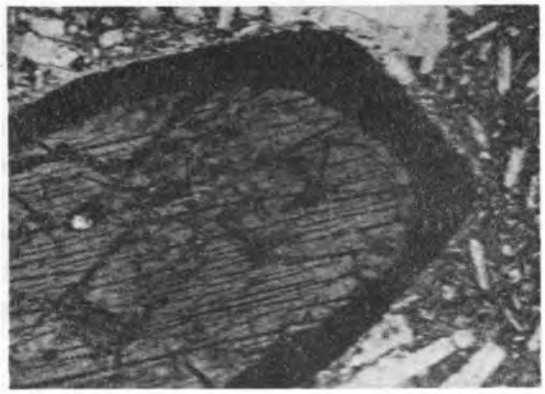

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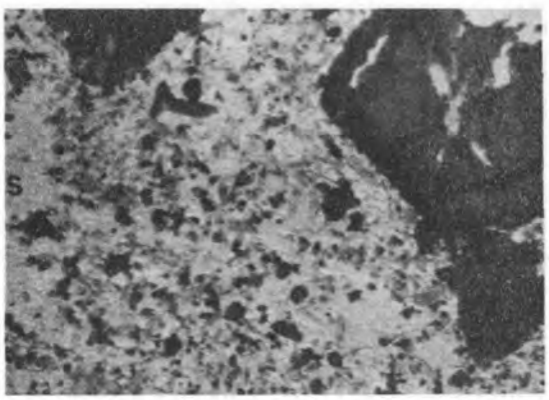

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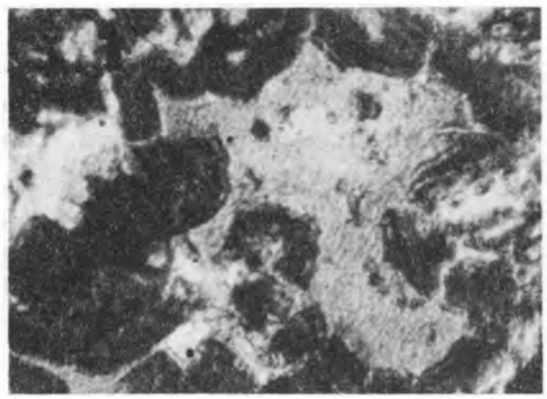

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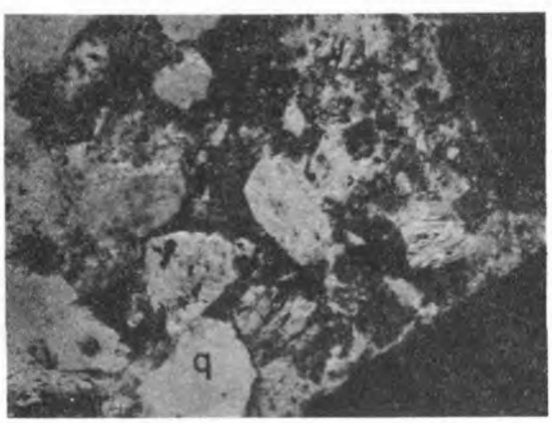

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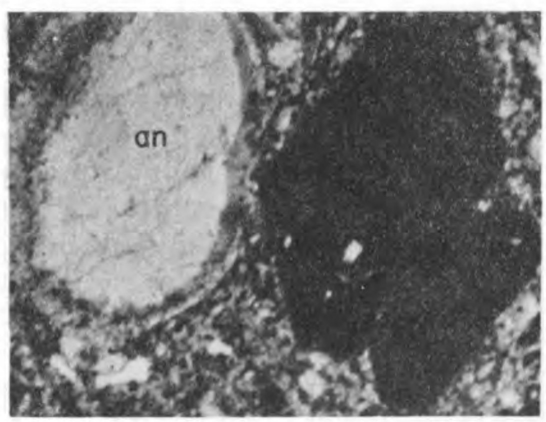

6

LOCAL AND REGIONAL RELATIONSHIPS

The results of this study have shown that there are many small hypabyssal igneous bodies intruding the limestones and quartzites, and that they are all confined to a fifty square-mile block in the center of the range. The light colored andesite and trachyandesite intrusives are even more restricted, although there is the possibility of others existing under the pediment and bajada covers on the flanks. These light colored types are very fine grained, and sometimes contain significant glass. From this general picture, it has been concluded that a stock-sized pluton lies within the core of the range and that erosion has exposed only its uppermost cupolas, dikes and sills. The intermediate series of extrusives have effused from vents and fissures also located in this central section.

The darker, more undersaturated flow rocks in the northern part of the range have likewise effused from fissures on each flank; along with a small number of diabasic and phonolitic dikes, some of which are sources for the flows, they constitute a different sub-province of the igneous rocks.

Structural control of emplacement is obvious throughout the range. Both sills I-F and I-N have permeated bedding weaknesses along the flanks of the Deseret anticline, the largest structural unit in the central part of the range. Beneath the phonolite and soda-basalt flows to the north the trachyandesite (I-H and I-K) has forced or assimilated its way up the plane of the Broad Canyon reverse fault in preference to massive limestones and dolomites underlain by quartzite. Moreover, no brecciation is visable along the hanging-wall or foot-wall contacts while the near "schistose" condition of parts of the sole injection indicates considerable fluidity during emplacement. I feel that for this reason much more of the Broad Canyon fault surface has been penetrated.

The small phonolite dike near the Muskrat Canyon flows appears to have intruded complexly a series of joints that may have resulted from previous intense normal faulting. The limestones are bleached and silicified and the composition of the dike points to assimilation as an aid to intrusion.

In the more central part of the range the Broad Canyon thrust again appears to be the conduit. The thrust goes beneath the

East Flank volcanics at the northern end and is not mappable again until 5 miles to the southeast. Two major areas of abnormal flow-banding in this area suggest fissure sources beneath the flows. One zone, just north of Davenport Canyon at the base of the flow series, contains flow-banding that dips steeply (50° to vertical) westward. This area lies very close to the trend of the Broad Canyon thrust as it disappears beneath the volcanics at Pope Canyon one mile northward.

The other zones lies in the center of the South Willow Canyon section and consists of a circular pattern of attitudes in the flow-banding suggesting a domal structure. The Broad Canyon thrust could possibly be projected that far but slumping or deposition upon irregular topography could also account for this phenomena.

The existance of a flow on one flank of the range duplicated by another of very similar characteristics on the oposite flank leads to the conclusion that the series of volcanics was once much more extensive than it is at present. Vent and fissure sources have been located on both flanks of the range but it seems very probable that the flows were one continuous unit over parts of the range prior to the uplift and tilting movements that took place during the late Tertiary.

The rock types of surrounding areas are generally more acidic than those of the Stansbury Mountains. The predominate types of these areas are monzonites. Gilluly (1932, pp. 94-51) describes stocks, sills and dikes of monzonite and quartz monzonite, and extrusive rhyolite flows, in the Stockton and Fairfield quadrangles. Lindgren and Loughlin (1919) worked in an area in which the igneous rocks were all rhyolites, latites, and monzonites. Cohenour (1957), in the Sheeprock Range to the south, found monzonites, and granites as the most common intrusive types.

A few of the shallow intrusions in the Stansbury Mountains have enough potash feldspar to classify them as trachyandesites, but an equal number of others have none that is detectable by ordinary petrographic means. Were these small intrusives of a greater crystallinity, there is the likelyhood that a higher potash feldspar content would modify this classification. Gilluly had the same difficulty with his aphanitic rocks and upon chemical analysis he proved that they were (chemically) latites rather than andesites. The same results could easily occur upon chemical analysis of these rocks.

Some parallelism exists in the sequence of volcanics between this area and those of the Tintic Mining District and the Stockton and

Fairfield quadrangles. In general the series of these areas begins with effusion of latite or rhyolite flows, followed by pyroclastic and breccia accumulations, intrusion of minor dikes, sills (and larger bodies in the case of the Stockton-Fairfield area), and final extrusion of minor amounts of basalt. This is also the general sequence of events in the Stansbury area. There is no way of telling whether the trachyandesite bodies preceeded the intermediate flow and pyroclastic series or not, but they certainly preceed the effusion of the soda-basalts and undersaturated rock types. Similarity of composition between the leucocratic intrusives and the first-stage extrusives indicate that they intruded the range nearly contemporaneously.

Slight undersaturation has also been found in other areas. Gilluly (1932, pp. 26-63) described a nephelite basalt containing olivine, biotite, nepheline, diopside, and minor accessories.

GENESIS AND AGE RELATIONSHIPS

The force that triggered upward movement and emplacement of the Stansbury magmas most likely resulted from late Laramide orogenic pulses that accomplished thrusting and folding of the Paleozoic and Mesozoic sediments. Assuming that no differentiation took place in the magma chamber, the original composition of the first intrusives and extrusives were as they are now; intermediate and saturated. In this phase it appears that extrusion was of both Pelean and Strombolian forcefulness. In the first part of the phase the effusives were predominately quiescent flows that soon became viscous forming local patches of intraformational breccia. Pelean-type eruption predominated during the last half of this phase. Although of the same composition, these rocks were mostly medium to coarse tuffs and breccias that formed from nuees ardente eruptions.

The best evidence for dating the effusions exists near Mack Canyon where the soda-basalts overlie the sole injection of trachyandesite (I-H and I-K). This shows that the effusions in the northern part of the range are post-magmatic intrusion.

If the bedded tuffs exposed beneath the Muskrat Canyon soda-basalts are equivalent to the tuffs exposed beneath the olivine basalts in the Salt Mountain section, then the time interval between the extrusions in these two areas is very short. Both the tuffs and flows of these areas are not similar enough in texture and composition to support this, however.

On the other hand the soda-basalt and related flows north of Mack Canyon dip on eroded Paleozoic limestones at a 20-degree angle eastward whereas to the south the East Flank volcanic section dips from 30 to 50 degrees eastward. Such a situation would exist if some activity along the normal faults at the western side of the range occurred prior to the last stage of vulcanism.

Basin and range faulting cannot be accurately dated, however, and since no new and conclusive evidence concerning the dating of either the faulting or the vulcanism has been found, the age of the vulcanism can at best be placed as Eocene to Oligocene.

ALTERATIONS

There are no important contact metamorphic zones associated with the intrusives. However, minor low-temperature hydrothermal alteration exists in the intrusives, extrusives, and in at least one fault-breccia. Some of the intrusives have bleached and silicified the limestone country rock.

In the sill I-F practically no ferromagnesian mineral has escaped chloritization. No other intrusive contained this much alteration; and, because of the assemblage of chlorite, calcite, and clay in the rock, I believe that the alteration is hydrothermal. Considerable calcite exists in the augite andesite dike I-A, but little other alteration has taken place here.

There are four possible sources for the calcite in the intrusives; (1) it is an original magmatic constituent, (2) it is a later hydrothermal replacement or introduction, (3) it has resulted from weathering of calcic ferromagnesian or feldspar constituents, and (4) it has been introduced by groundwater solutions.

In dike I-A, the calcite is intimately associated with the augite. Zeolites, especially along the border of the dike, are commonly associated with the calcite. Because of its irregular appearance in the thin section, its presence as an original magmatic constituent is improbable. The lack of calcite in the Tintic Quartzite eliminates groundwater as a source. Therefore, the calcite in most of the intrusives is probably the result of weathering and/or hydrothermal introduction.

In the hornblende andesites of Salt Mountain, mainly beneath the olivine basalts, hornblende and lamprobolite have been rimmed to completely replaced by magnetite. In this and other areas where olivine is present in the rocks, iddingsite has also rimmed or completely replaced the olivine. The complete replacements by magnetite and iddingsite are pseudomorphic, the original crystal outlines remaining in perfect condition. It is in this Salt Mountain section that considerable amounts of unidentified non-birefringent to fibrous secondary minerals (or mineraloids) are present (see page 31).

In the Salt Mountain volcanics these alterations may be the result of incoming solutions from the source or of deuteric solutions.

"Jasperization" has been noticed underneath the flows both at Salt Mountain and at Muskrat Canyon. In Muskrat Canyon the zone is two or three feet thick in places. On the surrounding hillsides, patches of chalcedony, massive calcite, vein calcite, and red-brown and yellow chert are common in the limestones. The cause for this phenomena is unsettled; the silicifying solutions may have come from either the vent upward or through the flows downward into the limestones.

Two of several "gossans" have been investigated. They are extensive on the south-west side of the range between Indian Hickman and Antelope Canyons where normal faults have apparently controlled the movement of iron-bearing solutions. The "gossan" material consists of black limonite and hematite that does not contain any significant boxwork.

A two-foot zone of cataclastic breccia that resulted from minor late movement along a normal fault near the south end of the Muskrat Canyon flow has been partially replaced by secondary clays. The alterations seems to be selective, since most of the plagioclase is altered, but other plagioclase fragments have not been touched. The remainder of the rock is composed of some ferromagnesian minerals, quartz grains, and minor accessories imbedded in a fine limonite and calcite groundmass. A hydrothermal origin for the alterations in the breccia is evident.

Qualitative analysis of two "ore" samples from the Western Star Mine and Dragon Mine revealed nothing but iron and a possible trace of silver.

ECONOMIC POSSIBILITIES

At one time there were supposed to have been a few mines on the east flank that produced some silver from the limestones. There is no mine in constant operation at the present time.

The range is barren of mineralization at the surface. Because the core of the range is composed of Tintic Quartzite and underlying Precambrian metamorphic rocks, little mineralization can be expected there. The flanks of the range are the only area where the rock type is hospitable to replacement. On these flanks chalcedony and chert contact zones underlie the flows, occurrences of which also exist in the Tintic District. Lindgren and Loughlin (1919, p. 154) feel that these contact zones are related to ore deposition in that area.

Other evidences of mineralization, if they exist, are covered by high-level pediment gravel on both flanks of the Stansbury Mountains.

STRUCTURAL DEFORMATION OF THE IGNEOUS ROCKS

The only deformation of the igneous rocks of the Stansbury Mountains has taken place during extrusion or during basin and range faulting.

At the time of extrusion minor slumping may have taken place and was probably responsible for the abnormal attitudes of the flow-banding found in both the Salt Mountain and East Flank volcanic section. Such zones are present near the top of Unit 5 at Salt Mountain, and in the vicinity of Coal Pit Canyon of the South Willow Canyon section.

Tilting of the range block during the late Tertiary has resulted in a possible displacement of 10 to 12 thousand feet of the extrusives (Rigby, 1958, p. 77). Just east of the Salt Mountain section a few abnormally tilted exposures of volcanics can be seen beneath the pediment gravels, thus indicating the existence of subsidiary faults cutting the volcanics on the west side of the range about one and one-half miles west of the main normal fault.

A small normal fault also cuts the soda-basalt and phonolite flows near Mack Canyon, but displacement here is less than 100 feet (see page 40).

SUMMARY OF IGNEOUS ACTIVITY AND CONCLUSIONS

The igneous activity of the Stansbury Mountains occurred during the Eocene or Oligocene and appears to have had the following history: (1) intrusion of a stock-sized pluton with projecting cupolas, dikes, and sills of andesite and trachyandesite, (2) extrusion of intermediate composition flows with minor tuffs and breccias, followed by extrusion of major amounts of breccia and tuff with minor flows, (3) extrusion of near-basic to locally undersaturated flows, and (4) major basin and range (normal) faulting, tilting and erosion to their present condition.

Stage (2) is near-contemporaneous with stage (1). A minor phase of normal faulting took place prior to any vulcanism, and some movement along the normal faults occurred prior to stage (3).

The Stansbury area contains igneous rocks that are lower in silica content than any surrounding area; and, with a few exceptions, the rocks are slight variations of andesite and basalt. In comparison with the surrounding areas the Stansbury Mountains represent a different petrographic province. Upon investigation of areas to the north and west, the province could possible be extended in this direction.

The stock believed to be in the core of the range was emplaced probably by both assimilation and forceful intrusion, though the former method was probably dominent. The smaller exposed igneous bodies have used structural weaknesses as an aid to emplacement.

No contact metasomatic zones have been found in the area, and alteration, although being hydrothermal as well as from weathering, has not considerably affected the rock. No known mineral deposits of economic importance exist within the range at the present time.

APPENDIX A

STRATIGRAPHIC SECTION OF THE STANSBURY MOUNTAINS

AGE		FORMATION	THICKNESS IN FEET	LITHOLOGIC DESCRIPTION
DEVONIAN	U	Stansbury Fm.	0-1700	Pbl & cbl cgl in north; ls dolo & sh in south
DEVONIAN	M	Simonson Dolo.	0-230	Drk & lt gry xln dolo
DEVONIAN	L	Sevy Dolomite	0-60	Lt gry fnly xln dolo w/ sm snd
SIL	M	Laketown Dolomite	0-660	Drk gry med-mssv bdd dolo
ORDOVICIAN	U	Fish Haven Dolo.	0-260	Drk gry mssv bdd med-xln dolo
ORDOVICIAN	M	Kanosh Shale	0-270	Grn & blk grpt sh w/ arg sh, ls
ORDOVICIAN	L	Garden City Fm.	1100-1300	Chrty ls & dolo; med gry arg ls; evnly bdd arg ls & stsn w/ intrfm cgl; chrty & sndy ls
CAMBRIAN	Croixan	Ajax Dolomite	750-910	Thk bdd drk gry ldg fmg dolo w/ abnt chrt nod & strngs
CAMBRIAN	Croixan	Dunderberg Shale	18-150	Thn bdd arg ls & dolo w/ grn sh
CAMBRIAN	Croixan	Opex Formation	450-500	Intbdd ls oo dolo & sh; slp & ldg frmr
CAMBRIAN	Albertan	Cole Canyon Dolo.	320-370	Alt drk & lt gry dolo
CAMBRIAN	Albertan	Bluebird Dolomite	0-80	Thn drk gry med xln thk bdd dolo
CAMBRIAN	Albertan	Bowman Limestone	0-435	Drk ol-grn & tn sh w/ intbdd ls
CAMBRIAN	Albertan	Herkimer Limestone	0-145	Med to thk bdd nod arg ls
CAMBRIAN	Albertan	Dagmar Dolomite	0-30	Med gry fnly xln dolo w/ blky we
CAMBRIAN	Albertan	Teutonic Limestone	800-1100	Intbdd blu-gry ls, calc sh, & thk bdd to mssv dolo. Top has thk to med bdd arg mttld ls
CAMBRIAN	Albertan / Waucoban	Ophir Group*	1110-1350	Consists of several formations of med to mss bdd ls, qtzte, algal ls, arg sh.
CAMBRIAN	Waucoban	Tintic Quartzite	4200	Prpl argil & prpl-marn qtzt pbl cgl at base; wht to rddsh qtzt in middle; rd-brwn ldg frmg well bdd qtzt at top.

* For breakdown of the Ophir Group see Rigby (1958) pp. 10-13.

AGE		FORMATION	THICKNESS IN FEET	LITHOLOGIC DESCRIPTION
QUAT.		Alluv., lake beds		
TERTIARY	Upper / Middle	Salt Lake Formation	0-1300	Tuffaceous conglomerate; igneous pebbles at base, carbonate pebbles near top.
TERTIARY	Middle / Lower	Volcanic Series	0-1800*	Intbdd andst flows, breccia, tuffs w/ minor basalt. Plugs and fissure dikes present. **
TERTIARY	Lower	"North Horn" Fm.	0-400	Red-brwn calc & arg pbl-cbl cgl
PENNSYLVANIAN		Oquirrh Formation	15, 000	Intbdd clastic ls, calc sndstn, calc sh, x-bdd sndstn, qtzte and minor sh. Cyclic nature
MISSISSIPPIAN	Chesterian	Manning Canyon Fm.	200-1600	Lower blk sh; medial drk gry pred. ls; upper blk sh & qtzte
MISSISSIPPIAN	Chesterian	Great Blue Limestone	980-1300	Pure med to drk gry ls, clstc to xln w/ sm chrt and sndstn
MISSISSIPPIAN	Merimec.	Humbug Formation	710-900	Intbdd sndstn, orthoqtzte, crin ls, and pure ls. Semi-slp frmr
MISSISSIPPIAN	Merimec.	Pine Canyon Fm.	710-950	Intbdd drk gry ls & sltstn w/ much blk chrt bds & strngs
MISSISSIPPIAN	Os.	Upper Gardner Dolo.	475-1100	Thn bdd fsslfs blu-gry ls
MISSISSIPPIAN	Kind.	Lower Gardner Dolo.	200-650	Somb drk gry dolo w/ sm ls
		Pinyon Peak Ls.	0-85	Plty yllw strkd arg ls, thn bdd
		Stansbury Formation		

* See text for revised thickness. ** Revised description

(Thicknesses and descriptions from Rigby (1958), pp. 8-55)

REFERENCES CITED

Cohenour, R. E., 1957, Geology of the Sheeprock Mountains, Tooele and Juab Counties, Utah: Unpublished Ph. D. Thesis, University of Utah, 209 pp., illus.

Eardley, Armand J., 1955, Tertiary History of North-central Utah, in Utah Geol. Soc. Guidebook, no. 10, pp. 37-44, illus.

Everett, K. R., 1958, Geology and Groundwater of Skull Valley, Tooele County, Utah: Unpublished Master's Thesis, University of Utah, 92 pp.

Gardner, Weston C., 1954, Geology of the West Tintic Mining District and Vicinity, Juab County, Utah: Master's Thesis, University of Utah.

Gilluly, James, 1932, Geology and Ore Deposits of the Stockton and Fairfield Quadrangles, Utah: U. S. Geological Survey Prof. Paper 173, 171 pp., illus.

Harris, DeVerle, 1958, The Geology of the Dutch Peak Area, Sheeprock Range, Tooele County, Utah: Brigham Young University Research Studies, Geology Series, Vol. 5, No. 1, 82 pp., illus.

Lindgren, W., and Loughlin, G. F., 1919, Geology and Ore Deposits of the Tintic Mining District, Utah: U. S. Geological Survey Prof. Paper 107, 282 pp., illus.

Lovering, T. S., Rock Alteration as a Guide to Ore--East Tintic District, Utah: Econ. Geol. Monograph 1, 1949.

Rigby, J. Keith, 1958, Geology of the Stansbury Mountains, Eastern Tooele County, Utah: Utah Geol. Soc. Bull., no. 13, pp. 1-135, illus.

Rogers, Austin F., and Kerr, Paul F., 1942, Optical Mineralogy: New York, McGraw Hill Book Co., Inc., 390 pp.

Stringham, Bronson F., 1942, Mineralization in the West Tintic Mining District, Utah: Geol. Soc. America Bull., vol. 53, no. 2, pp. 267-290, illus.

Thomas, Glenn H., 1958, The Geology of Indian Springs Quadrangle, Tooele and Juab Counties, Utah: Brigham Young University Research Studies, Geology Series, Vol. 5, no. 4, 34 pp., illus.

Williams, Howel, Turner, F. H., and Gilbert, C. M., 1958, Petrography, and Introduction to the Study of Rocks in Thin Sections: San Francisco, W. H. Freeman and Company, 406 pp.