

IGNEOUS COMPLEX
AT WAH WAH PASS
BEAVER COUNTY, UTAH



Utah Geological and Mineralogical Survey

Special Studies 17

UNIVERSITY OF UTAH

James C. Fletcher, Ph.D., President

BOARD OF REGENTS

Edward W. Clyde	Chairman	George C. Hatch	Member
Donald B. Holbrook	Vice Chairman	Robert H. Hinckley	Member
Reed W. Brinton	Member	Carvel Mattsson	Member
Wilford W. Clyde	Member	Calvin W. Rawlings	Member
John A. Dixon, M. D.	Member	Roy W. Simmons	Member
Richard L. Evans	Member	Briant H. Stringham	Member

James C. Fletcher	President, Univ. of Utah, Ex-officio Member
Clyde L. Miller	Secretary of State, Ex-officio Member
Joseph F. Worthen	President, Alumni Assoc., Ex-officio Member
George S. Eccles	Treasurer
Parry D. Sorenson	Secretary

UTAH GEOLOGICAL AND MINERALOGICAL SURVEY

ADVISORY BOARD

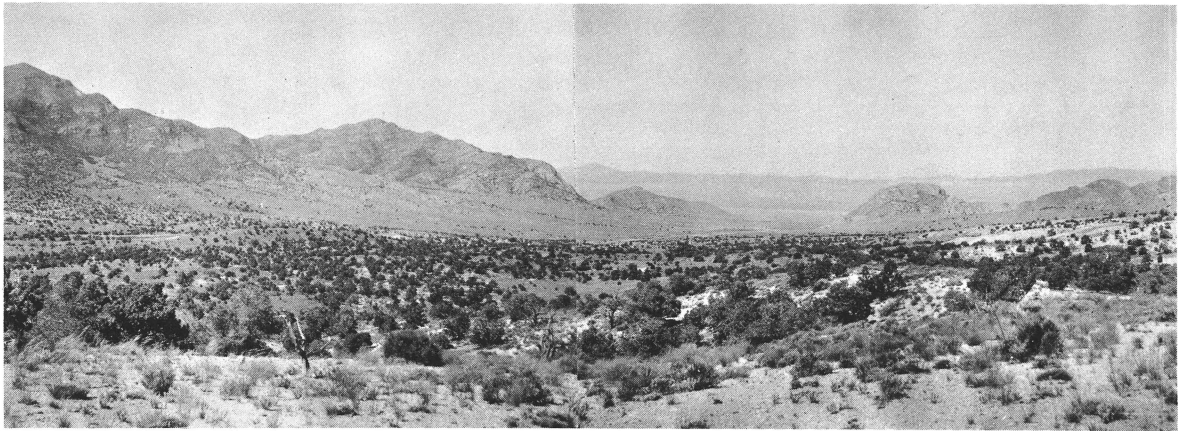
John M. Ehrhorn, Chairman	U. S. Smelting, Refining & Mining Co.
Graham S. Campbell	Petroleum Geologist
Ballard H. Clemmons	U. S. Bureau of Mines
LaVaun Cox	Utah Petroleum Council
L. W. Folsom	Mountain Fuel Supply Co.
John K. Hayes	U. S. Steel Corporation
Lowell S. Hilpert	U. S. Geological Survey
Lehi F. Hintze	Brigham Young University
Walker Kennedy	Liberty Fuel Company
Ezra C. Knowlton	Utah Sand & Gravel Products Corp.
E. Jay Mayhew	Apex Exploration Company
Roy E. Nelson	American Gilsonite Company
Howard Peterson	Utah Center of Water Resources Research
Miles P. Romney	Utah Mining Association
Raymond T. Senior	Attorney
Nels W. Stalheim	Federal Resources Corp.
William L. Stokes	University of Utah
Alvin J. Thuli, Jr.	Kennecott Copper Corp.
J. Stewart Williams	Utah State University
William P. Hewitt	Director, U. G. M. S., Ex-officio Member
George R. Hill	Acting Dean, College of Mines Ex-officio Member

STAFF

William P. Hewitt	Director
Eugene Callaghan	Senior Geologist
Robert E. Cohenour	Research Geologist
Neva E. Nielsen	Secretary
Clara H. Warr	Bookkeeper
Barbara S. Childers	Editor

IGNEOUS COMPLEX AT WAH WAH PASS BEAVER COUNTY, UTAH

by Max P. Erickson



View from summit of Wah Wah Pass looking east toward the San Francisco Mountains



Utah Geological and Mineralogical Survey
affiliated with
The College of Mines and Mineral Industries
University of Utah, Salt Lake City, Utah

CONTENTS

	Page
Abstract	1
Introduction	1
Geography	1
Field and laboratory methods	3
Acknowledgements	3
Regional geology	3
Structure and physiography	3
Stratigraphy	4
Paleozoic sedimentary rocks	4
Tertiary volcanic rocks	5
Andesite and dacite flows	5
Dacite ignimbrite	5
Rhyolite ignimbrite	5
Pleistocene (?) mudflow or landslide unit	6
Pediment gravels and recent alluvium	6
Intrusive igneous rocks	6
Intrusive rhyolite porphyry	6
Dioritic rocks	6
Western stock	7
Middle stock	8
Eastern stock	8
Petrogenesis	9
Metamorphic rocks	10
Marble	10
Skarn	10
Hydrothermal alteration	11
Rhyolite porphyry	11
Intrusive dioritic rocks	11
Andesite flows	12
Mineralization	12
Breccia zone	12
Carbonate rocks	12
Skarn rocks	13
Magnetometer survey	13
Recommendations	14

ILLUSTRATIONS

Figure 1. Local index to study areas	2
Plate 1. Geologic map and sections of the Wah Wah Pass area, Beaver County, Utah	Pocket
Plate 2. Map showing distribution of magnetic intensities in the Wah Wah Pass area, Beaver County, Utah.	Pocket

IGNEOUS COMPLEX AT WAH WAH PASS BEAVER COUNTY, UTAH

by Max P. Erickson¹

ABSTRACT

Three small dioritic stocks exposed in Wah Wah Pass have associated rock alteration features which suggest the possibility of related economic mineralization. Most significant is the argillic alteration and introduced disseminated pyrite of a breccia zone in the easternmost stock. Reconnaissance geochemical analyses did not reveal anomalous concentrations of copper, lead, zinc, or molybdenum in the surface exposures.

Magnetic readings from 400 gammas to 1,000 gammas above background were obtained over the dioritic stocks; local anomalies range to 9,000 gammas. The anomalies, which do not correlate with observable surface features, are most numerous over the brecciated and altered eastern stock; further exploration by other geophysical methods, by more intensive geochemical techniques, or by drilling may disclose subsurface economic mineralization in this area.

The Wah Wah Pass region was selected for investigation as an area of possible economic significance, as it includes extensive areas of hydrothermally altered and contact-metamorphosed rocks associated with small intrusive igneous bodies.

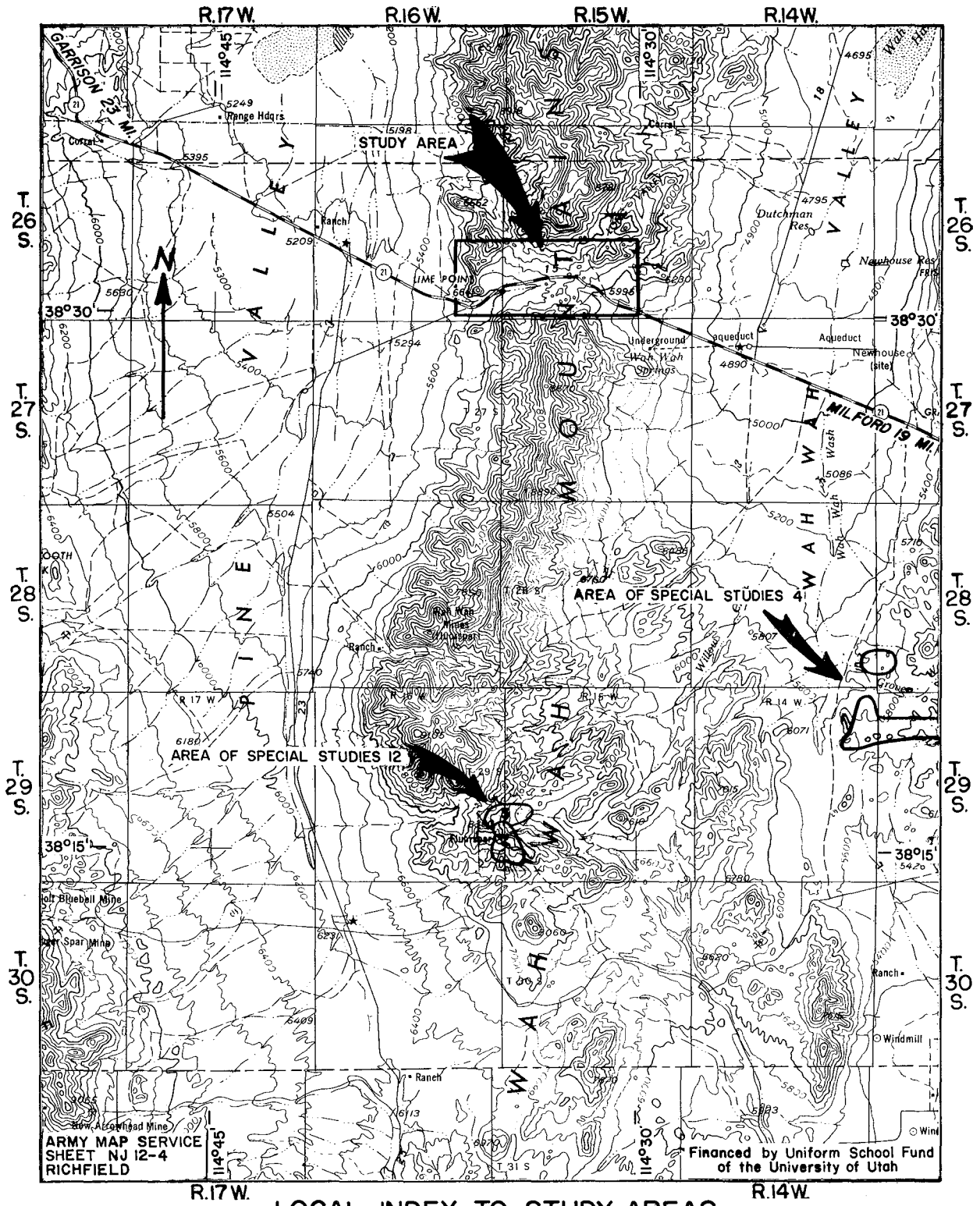
Geography

Wah Wah Pass is in northwestern Beaver County, Utah where State Highway 21 crosses the Wah Wah Range and connects the area with Milford, Utah, 32 miles to the east, and with Garrison, Utah, 44 miles to the northwest. (See fig. 1) The only permanent dwelling within 25 miles is a ranch a few miles to the southeast.

The north-south-trending Wah Wah Range is above 8,000 feet elevation throughout most of its length with several peaks reaching to nearly 9,000 feet. Wah Wah Pass is a conspicuous break in the range with an elevation of 6,445 feet. The main ridge which ranges from 6 to 19 miles in width extends 16 miles to the north of the pass and 22 miles to the south. The base of the mountains is at about 5,500 feet elevation on the east side and 6,000 feet on the west; the playas on the valley floors are about 800 feet lower.

1. Department of Mineralogy, University of Utah.

FIGURE 1.



ARMY MAP SERVICE
SHEET NJ 12-4
RICHFIELD

Financed by Uniform School Fund
of the University of Utah



No springs or permanent streams are present at Wah Wah Pass. Junipers and piñon pines are the only common trees, but even these are missing from large areas on pediment and alluvial fan surfaces, especially in the western part.

Field and Laboratory Methods

Detailed field mapping, specimen collecting, and laboratory mineralogic and petrologic studies were carried out during the summer and fall of 1964. Reconnaissance magnetometer surveys were conducted during the summer of 1965. The rock units shown on plate 1 were mapped on an enlarged portion of the U. S. Geological Survey advance sheet equivalent to the southeast quarter of the Wah Wah summit quadrangle. The scale of the advance sheet (1:24,000) was enlarged to 1:13,000 for mapping purposes.

Thin sections of all significant rock types were studied and minerals were identified with the aid of the petrographic microscope and x-ray diffraction apparatus. Trace amounts of heavy elements from selected vein and rock samples were determined by colorimetric techniques.

Acknowledgements

Field work and publication were financed by a grant from the Uniform School Fund, University of Utah. The Utah Geological Survey provided the magnetometer used in magnetic studies. Merlin Bingham, Malin Moench and Don Rolfson were field assistants during the geologic mapping and Winston Erickson assisted with the magnetic survey.

REGIONAL GEOLOGY

The region is part of the Basin and Range structural province characterized by upfaulted mountain blocks separated by alluvium-filled valleys. Bedrock exposed in the Wah Wah Range and neighboring mountains consists of Precambrian metamorphic rocks, Paleozoic and Mesozoic sedimentary rocks, Tertiary volcanic rocks and intrusive igneous rocks of several ages. In the northern parts of the ranges, Paleozoic sedimentary rocks predominate and volcanic rock caps the ranges or laps on their flanks. To the south the volcanic rocks thicken and cover the pre-volcanic rocks except for a few small inliers. Intrusive porphyry occurs in the Wah Wah Pass area and perhaps also to the east under the alluvium.

Economic mineralization apparently is associated with small intrusive porphyries in the southern part of the Wah Wah Range and in neighboring ranges.

STRUCTURE AND PHYSIOGRAPHY

The Wah Wah Range is a fault block tilted eastward. Within the mapped area the Paleozoic strata are inclined 5° - 30° to the east or northeast but most dips are less than 20° . The dips probably do not indicate the degree of tilting of the range, because folding occurred before block faulting.

Faults are not apparent at Wah Wah Pass though several east-trending cross-faults with displacements of less than 50 feet are present on the west range front to the south of the pass. To the north of the pass the bedrock is cut by north-trending, high-angle faults parallel to the range front which have displacements up to 200 feet. There is presumed to be a fault along the west side of the range which is covered by alluvium.

The belt of intrusive bodies at Wah Wah Pass constitutes a major east-trending structure which transects the range. Since there is no apparent offset in the Paleozoic strata, the belt may reflect a structural feature of the basement rocks. The topographic "low" at Wah Wah Pass is due to the more rapid weathering of the igneous intrusive and associated contact metamorphic rocks compared to the Paleozoic sedimentary rocks in the higher portions.

STRATIGRAPHY

The Paleozoic sedimentary rocks and Tertiary volcanic rocks in Wah Wah Pass are older than most of the intrusive rocks and are therefore locally altered, metamorphosed, and mineralized. Post-intrusive sedimentary deposits consist of landslide and mudflow debris of Pleistocene (?) age, Recent pediment gravels, and minor alluvial deposits.

Paleozoic Sedimentary Rocks

Cambrian sediments at least 2,000 feet thick belonging to twelve named formations are exposed in the Wah Wah Range. The formations are as follows:^{1/}

Upper Cambrian	Notch Peak Formation Dunderberg Shale Orr Formation Weeks Formation
Middle Cambrian	Marjum Formation Wheeler Shale Swasey and Whirlwind Formations Dome Limestone Howell and Chisholm Formations Tatow Formation
Lower Cambrian	Pioche Shale Prospect Mountain Quartzite

The Orr and Weeks Formations are generally in contact with the intrusive igneous rocks in the pass area, and the Marjum Formation and Wheeler Limestone

1. Geologic map of Utah, Southwestern Quarter, by L. F. Hintze, 1963.

are in contact with the westernmost intrusive. Medium-bedded to laminated dark limestones and thin-bedded limestones interbedded with minor dolomite and shale are the lithologic types typically in contact with the intrusive rocks.

Tertiary Volcanic Rocks

Tertiary volcanic rocks lie on the east flank of the Wah Wah Range and probably extend eastward under the valley fill to the frontal faults of the San Francisco Range. Along the eastern approach to the pass are two conspicuous types: andesitic and dacitic flows, and a coarse blocky dacitic ignimbrite. Two minor outcrops of a dense rhyolitic ignimbrite occur west of the summit.

ANDESITE AND DACITE FLOWS

Flows of andesitic and dacitic composition crop out in gullies cut into the pediment and in ridges which stand above the pediment on the east side of the range. The flows are mostly medium-gray and are glassy to fine grained. All units are porphyritic and in some the phenocrysts comprise nearly 50 percent of the rock. Most phenocrysts are plagioclase, but hornblende, biotite, augite, and hypersthene in various combinations are conspicuous locally. Quartz is present in amounts up to 5 percent. Alteration of feldspar is common in some areas, and near the contact with intrusive rock the flows are highly stained with limonite. Air-fall pyroclastics similar in composition to the flows occur locally.

DACITE IGNIMBRITE

A coarse, blocky ignimbrite overlies the andesite and dacite flows at the eastern edge of the mapped area. Blocks of pink dacite up to 15 feet across are welded into a compact mass. The blocks contain quartz and plagioclase as the only conspicuous phenocrysts in a matrix which is fine-grained to glassy and banded. The unit does not appear to be affected by the local alteration or mineralization and therefore it was not studied in thin section.

RHYOLITE IGNIMBRITE

Rhyolite ignimbrite of uncertain relationship to the other volcanic rocks occurs about one mile west of the Wah Wah Pass summit. Outcrops of unaltered rock are rough and grayish brown. The rock is a strongly welded, crystal tuff about 75 percent of which is made up of shattered angular quartz crystals up to about 1/8 inch in diameter. The matrix is dense and composed of smaller broken quartz crystals and contorted, largely devitrified, glass shards. Angular rock fragments up to 2 inches in size consisting of rhyolite, granitic rocks, quartzite, and hornblende andesite are prevalent. The rhyolite ignimbrite is lighter colored and pinkish where altered.

Pleistocene (?) Mudflow or Landslide Unit

The landslide unit makes up a conspicuous ridge about 1 mile long and $\frac{1}{2}$ mile wide that projects into the pass below the steeper slopes of the north side of the pass. It is probably at least 200 feet thick and is composed of soil and unsorted, randomly oriented limestone blocks up to 500 feet long. It appears to have been derived from a steep, short canyon which extends to the northeast of the north end of the ridge. The ridge has been deeply eroded into a well-defined gully system.

Pediment Gravels and Recent Alluvium

A dissected pediment cut into both gravel and bedrock extends throughout the pass area. Locally derived gravel and alluvial sand covers the pediment surface, and recent extensive accumulations of sand occur in the dry washes.

INTRUSIVE IGNEOUS ROCKS

The several intrusive rock bodies occurring in an east-trending zone through Wah Wah Pass consist of small stocks and their satellitic dikes and sills. Diorite and quartz diorite are the most common types but rhyolite porphyry is important in one area.

Intrusive Rhyolite Porphyry

Intrusive rhyolite porphyry crops out in the pediment which extends into the west side of the pass. The exposures are widely separated but the grouping suggests that the rhyolite is continuous beneath the intervening pediment gravels and landslide debris and is therefore about 1 mile by $\frac{1}{2}$ mile in size.

The rock is light gray on fresh fracture. Phenocrysts of quartz and sanidine, some of which show resorption effects, make up at least 50 percent of the rock. The matrix is commonly fine-grained with a mosaic texture, although locally it has a coarse granitic texture. Small amounts of plagioclase (An 28-35), biotite, and augite were observed in most thin sections.

Dioritic Rocks

Intrusive rocks of dioritic to quartz dioritic composition are exposed discontinuously for a distance of 4 miles through Wah Wah Pass. Although much of the area is covered by pediment gravels, the dioritic rocks appear to occur in three separate plugs or small stocks with numerous dikes and sills of the same general composition present near their margins. The three stocks are each described in the following sections. The rocks vary considerably in quartz content and in the type of ferromagnesian minerals present, but otherwise appear to be closely related. Textures range from coarse, granular to porphyritic-aphanitic. Fresh surfaces are gray to brownish gray and weathered outcrops are mostly rounded with a loose, granular surface.

WESTERN STOCK

Exposures of medium-grained dioritic rocks in the western part of the Wah Wah Pass indicate an intrusive body which is possibly $1\frac{1}{2}$ miles east-west and about $\frac{3}{4}$ mile north-south. The western one-third is very well exposed and the contact with Paleozoic rocks can be easily traced for at least 1 mile along its western and northwestern margin. A smaller exposure at the eastern end of the stock reveals dioritic rock cutting intrusive rhyolite porphyry and rhyolite ignimbrite. An elongate exposure of diorite occurs about midway between the eastern and western ends, and the intrusive rocks are presumed to extend under the pediment gravels between the exposures.

The rock in the middle of the stock is essentially a biotite-augite diorite. Plagioclase, making up about 60 percent of the rock, occurs as randomly arranged, subrectangular or lath-shaped crystals comprising a uniform matrix in which numerous plagioclase phenocrysts are distributed. The average length of crystals is about $\frac{1}{2}$ mm, however, the length of phenocrysts is as much as $1\frac{1}{2}$ mm. Zoning is conspicuous in the phenocrysts but is also visible in some of the smaller crystals. As determined by optical methods the range in composition is An35 to An52, but the smaller crystals are uniformly close to An35. Orthoclase comprises as much as 3 percent of the rock and quartz comprises as much as 5 percent. Quartz and orthoclase occur mostly in interspaces between lath like plagioclase crystals rather than as phenocrysts.

Augite is second in abundance and is the dominant ferromagnesian mineral, making up about 15 percent of the rock. Biotite is present in nearly all thin sections in amounts of about 10 percent and is as abundant as augite in some. Minor amounts of hornblende and hypersthene were observed in some thin sections. Augite, hypersthene, and biotite crystals are comparable in size to plagioclase crystals.

The proportions of minerals are more variable in the rocks of the marginal zone of the stock; hornblende exceeds augite in some rocks and hypersthene is prominent in others. Locally the amount of orthoclase equals or exceeds that of plagioclase and the quartz exceeds 5 percent, so that the resulting rock could be designated properly quartz monzonite. Purple, titanium-bearing augite was found together with normal augite in one slide. Magnetite is universally present in amounts of about $\frac{1}{2}$ percent.

Textural variations are also greater in the marginal zone. In places the rock is fine-grained with the texture of andesite whereas in others it is coarser than any observed in the central, more homogeneous, part of the stock.

A short dike about 3 feet wide cuts rhyolite ignimbrite about 50 feet from the diorite of the eastern end of the stock. It is a biotite-plagioclase rock with a fine-textured, felted ground mass and plagioclase phenocrysts. Because of its composition it appears to be related to the diorite stock, and a few similar fine-grained dikes cut the stock itself.

MIDDLE STOCK

The middle diorite intrusive, just west of the summit of the pass, is the smallest ($\frac{1}{2}$ mile by $\frac{3}{4}$ mile) and best exposed of the three intrusives. Except for about 500 feet on the southwest side where it cuts intrusive rhyolite porphyry, the stock is in contact with Paleozoic rocks. About 800 feet of rhyolite porphyry separates the middle stock from the western stock.

The normal rock of the intrusive is a hornblende-biotite diorite or quartz diorite. Plagioclase ranging from An₃₀ to An₃₆ in composition makes up about 60 percent of the rock. The plagioclase in the groundmass is near An₃₀. Biotite and hornblende constitute the significant ferromagnesian minerals with biotite normally in greater abundance (up to 15 percent of the rock). Minor amounts of augite are present in some thin sections. Orthoclase is universally present in amounts up to about 5 percent, quartz exceeds 5 percent in some thin sections of quartz diorite, and magnetite occurs in amounts up to $\frac{1}{2}$ percent.

Although the rocks of the middle stock differ slightly in mineralogy from those of the western stock, the textures and grain sizes are very similar. Both are porphyritic with phenocrysts of plagioclase, biotite, and hornblende.

As in the western stock, the marginal facies of the middle stock is highly variable in mineralogy and in textural features, and some rocks have compositions markedly different from the normal facies. One rock is a pyroxene syenite, composed essentially of coarse-grained orthoclase, a pyroxene with an intense green color, and only minor amounts of plagioclase. Another is a hornblende-plagioclase rock with a fine-grained andesitic texture.

Several satellitic dikes cut the Paleozoic rocks in a zone about 500 feet wide around the intrusive. Some are fine-grained with phenocrysts of hornblende and plagioclase, and would be classed as intrusive andesite porphyry. Hornblende, the chief ferromagnesian mineral in the dikes, has either the normal green color or is reddish brown. The latter type of hornblende, sometimes referred to as basaltic hornblende, indicates a higher temperature of formation. A few of the dikes which are coarse-grained and granitoid have, in addition to hornblende, orthoclase in amounts equal to, or slightly greater than, plagioclase and would therefore be classed as monzonites.

EASTERN STOCK

The southern margin of the eastern stock, about $1\frac{1}{2}$ miles east-west by $\frac{1}{2}$ mile north-south, is covered by pediment gravels. The contact on the north and west is well exposed. The intrusive nature is easily established by the presence of cross-cutting relationships, dikes extending into the country rock, and the presence of skarn and other contact metamorphic effects.

at the contact of the stock, the rocks resemble those of the western and middle stocks. Though exposures are limited within the body, they are not typical of intrusive stocks. Fine-grained porphyritic textures predominate and highly altered, coarse, blocky breccia is common. Limited exposures failed to show conclusively the age relations of the breccia and the firm rock.

The rocks in the interior part of the eastern stock are composed mainly of plagioclase, orthoclase, hornblende, biotite, and quartz and, as in the other two stocks, magnetite is present. Most are fine grained and porphyritic, and would be classed as latite porphyry or quartz latite porphyry. Two types of groundmass can be distinguished on the basis of texture. One is characterized by a felted aggregate of elongate plagioclase microlites intermixed with equidimensional orthoclase grains. The other is characterized by orthoclase and plagioclase grains of the same crystal habit forming a fine-grained mosaic pattern. In the coarse granitoid rocks near the contacts, quartz comprises nearly 10 percent and orthoclase is almost as abundant as plagioclase. These rocks would be classed as quartz monzonite.

The breccia zone within the stock extends for almost its full length and has an exposed width of about 1,000 feet. The exposures are limited to the sides of the main drainage channel which heads in the summit of the pass.

The breccia is composed of angular blocks up to several feet across, none of which is shaped or vesicular. Feldspar phenocrysts are somewhat altered and the rock is slightly stained with limonite. The material between the blocks which is more highly altered and more heavily stained with limonite is soft and crumbles readily. The blocks and matrix are jumbled with no apparent layering. The breccia possibly occupies a volcanic vent.

Associated dikes which cut the limestone as far as 1,500 feet to the north of the stock are mostly biotite- and hornblende-bearing quartz latite. They are fine-grained porphyritic rocks similar to most of those within the stock.

PETROGENESIS

Dioritic intrusive rocks extend, with only minor breaks, in an east-west trend for about 4 miles through Wah Wah Pass and possibly continue under the valley alluvium to the east. It seems probable that they constitute a single, continuous intrusive slightly below the present erosion level. The three stocks probably occupy volcanic conduits through which andesitic flows and pyroclastics were extruded. If this is true, the volcanic rocks associated with the two western centers were removed by erosion following the uplift of the Wah Wah Range. Greater erosion and uplift on the west side was due to eastward tilting of the Wah Wah fault block. Andesite flows and pyroclastic rocks were preserved only on the east flank of the range. Some of the lowermost vent breccia is preserved in the eastern volcanic center which was not uplifted as much nor as deeply eroded as the other two.

Several features suggest progressive differentiation of the stocks from west to east. Orthoclase and quartz increase eastward indicating higher content of potassium and silica to the east. The plagioclase in the eastern stocks increases in albite molecule indicating an enrichment of sodium. The anhydrous pyroxenes of the western stock give way to hydrous amphiboles and biotite in the other two indicating an increased water content when the eastern stocks crystallized.

The observations noted above suggest that volcanic activity terminated in the three centers in west-to-east sequence. Volatiles which were concentrated in the magma of the last active center provided the residual emanations that caused alteration and pyritic mineralization of the eastern stock. The breccia zone which provided permeable material for the passage of the solutions shows the greatest alteration and mineralization.

METAMORPHIC ROCKS

An irregular contact metamorphic aureole surrounds the three stocks in a zone varying from 200 to 2,000 feet in width, although an elongate projection of metamorphosed rock extends nearly 1 mile northwest from the middle stock. Where wide, the metamorphic zones contain dikes which probably project upward from parts of the stocks a short distance below the surface. Narrow zones probably represent rather steep igneous contacts.

Marble

Marble, the dominant metamorphic rock, is generally bleached to a lighter color and recrystallized to a coarser grain size than the carbonate rock from which it is derived. Coarse grains of recrystallized calcite constitute the only visible mineral in most of the marble. Because of the larger grain size the marble weathers readily into loose, coarse granules of calcite. The outer margin of bleaching and recrystallization is gradational. A unit of white, compact, fine-grained, porcelain-like marble near the contact contains microscopic grains of brucite¹ with squarish outlines associated with the dominant recrystallized calcite. Such a rock must have been derived from an almost pure dolomite or magnesian limestone.

Skarn

Dark skarn rock, mostly brown or greenish brown, is less abundant than marble but occurs locally, especially near the contacts. Microscopic examination reveals both partially and completely silicated types. The partly silicated contact rocks are mostly aggregates of calcite and forsterite, indicating a parent rock of dolomite with limited amounts of siliceous impurities. The completely silicated contact rocks contain no calcite; most are grossularite-chlorite rocks, grossularite-diopside-anorthite rocks, and grossularite-diopside-idocrase rocks. The pre-metamorphic rocks must have been siliceous, magnesian limestone or dolomite with shaly impurities. One contact rock is composed almost entirely of anorthite which indicates its derivation from an original marl of almost equal calcareous and shaly components.

1. Dr. J. D. Stevens has reported hydromagnesite from roadcuts in this area.

orid igneous rocks which occur locally in the skarn zone are mostly coarse-grained aggregates of orthoclase, plagioclase, and pyroxene; hornblende is present in some. The textures are essentially igneous, but much of the material was derived from the skarn. Rounded diopside grains from the skarn are rimmed with augite to form euhedral crystals, and blocky anorthite grains have overgrowths of soda-bearing plagioclase of elongate habit. The rocks appear to have been formed by penetration of magma along grain boundaries resulting in disaggregation of the skarn. Immersed rounded diopside grains reacted with the magma to produce augite or they served as nuclei for the overgrowths of augite. The crystals developed with euhedral forms because they grew in a liquid medium. In a similar manner the anorthite added rims of soda-bearing plagioclase or reacted to form soda-bearing plagioclase. The hybrid rocks are highly variable because of the different proportions of material derived from igneous and metamorphic sources. All contain large and conspicuous euhedral sphene crystals which apparently do not occur in the skarn nor in the igneous rock.

HYDROTHERMAL ALTERATION

Only the igneous rocks are affected significantly by hydrothermal alteration. Its varying effects in different igneous rock types are discussed below.

Rhyolite Porphyry

Alteration of both intrusive and extrusive rhyolite is spotty and nowhere is it intense. Altered rock is conspicuously whiter than unaltered rock. In thin section altered rock contains sericite diffused through the groundmass and replacing feldspar phenocrysts in patches. Some sections show considerable amounts of hematite in the form of small, elongate single crystals or in groups of radiating crystals. Limonite staining is present on joint surfaces but is not intense.

Intrusive Dioritic Rocks

The diorites of the western and central stocks are essentially fresh and unaltered. The eastern stock outside of the breccia zone has minor local alteration consisting mainly of leucoxene replacements of ferromagnesian phenocrysts.

Dike rocks near the middle and eastern stocks are altered in a similar fashion. Some dikes contain basaltic hornblende which represents a high temperature transformation of normal hornblende, and some glassy dikes show devitrification which may be related to hydrothermal activity.

The breccia zone of the eastern intrusive is intensively, but not uniformly, altered. The large breccia blocks are generally less altered than the surrounding finer material. Many thin sections show a mass of cloudy, irresolvable, clay-like alteration products pervading the groundmass and replacing feldspar phenocrysts. Other sections show considerable introduction of sericite and

fine-grained silica. Pyritic alteration is indicated by variable, but heavy limonite staining throughout the zone. Unweathered pyrite is also prevalent just below the surface of many outcrops.

Andesite Flows

Alteration effects in the andesitic flow rocks are confined mostly to rocks near the contact with the breccia zone of the intrusive; the alteration is similar to that of the breccia zone. At one place near the breccia the andesite is cut by closely spaced, nearly vertical silica veinlets. Away from the breccia zone there is only mild pyritic alteration indicated by limonitic material on joint faces. Some devitrification also occurs in glassy types.

MINERALIZATION

Breccia Zone

Mineralization in the breccia zone of the eastern dioritic stock is represented by the widespread occurrence of introduced disseminated pyrite. The pyrite itself is not valuable but its presence leads to the speculation that introduced valuable sulfides or other minerals of value might be associated with the pyrite or might occur in local concentrations within the mineralized zone. The weathering, which has converted pyrite at the surface to limonitic stain, would also affect ore minerals by removing them or by making their detection difficult. Secondary copper carbonates, which often form if primary copper minerals are present, were not observed in the mineralized zone.

Geochemical tests were run on twelve samples collected from the highly iron-stained breccia zone to detect the presence of copper, zinc, lead and molybdenum. The analyses were made by colorimetric methods and showed copper from 10 to 35 parts per million, zinc between 50 and 150 ppm, lead from 5 to 15 ppm, and molybdenum 1 or 2 ppm. No anomalous concentrations appear to be indicated by the samples and the results are inconclusive.

Carbonate Rocks

Iron mineralization occurs in several places to the north of the dioritic intrusives along the outer edge of the marble or in the limestone just beyond the marble zone. The iron occurs as tabular to irregular pipelike accumulations of red and brown iron oxides. The outcrops are suggestive of gossans and most of them have been prospected by shallow pits or shafts.

Normal vein minerals such as calcite, quartz and pyrite are absent and the only introduced material appears to be hematite which is partially weathered to limonite.

Some of the hematitic deposits are closely associated with dioritic dikes which are probably satellitic to the nearby diorite stocks. It appears probable,

that most of the hematite deposits occur in fractures which are continuations of those occupied by dikes at depth and that the deposition of hematite took place from emanations escaping as the dikes crystallized. It seems unlikely that the mineralization resulted in significant concentrations of valuable minerals. Colorimetric analyses of material from the deposits indicate only trace amounts of copper, zinc, lead and molybdenum.

Skarn Rocks

Silication of carbonate rocks is sometimes associated with scheelite mineralization. The skarn rocks surrounding the dioritic intrusives were examined under ultra-violet light for scheelite but none was found. The skarn rocks contain no other evidence of mineralization involving valuable metals.

MAGNETOMETER SURVEY

A reconnaissance magnetic survey was conducted over the entire zone of intrusive rocks and in a zone several hundred feet wide over the surrounding country rock. The data were obtained with a hand-held flux-gate magnetometer which measures total magnetic intensity. Readings were made along 32 north-south traverse lines spaced 750 feet apart. They were made at intervals of approximately 200 feet over the western and middle intrusives and at intervals of about 100 feet over the eastern intrusive. Magnetic determinations totaled 1,013.

The measurements were plotted areally and isogammas were constructed on a 200 gamma interval using an assumed datum. The resulting map showing the distribution of magnetic intensities in the area is shown in plate 3.

Over the Paleozoic rocks the readings range generally between 100 and 250 gammas. Over most of the area underlain by dioritic intrusives the range is between 250 and 1200 gammas. Abrupt magnetic gradient changes occur at or near the exposed contacts. The 400 gamma contour closely marks this break in gradient and can be used to project approximate contact location under the alluvium with considerable confidence.

Magnetic lows with values down to - 500 gammas are present locally over Paleozoic sedimentary rocks near the intrusive contacts. Along these lows the contact metamorphic zone is narrow which suggests a steeply dipping contact or a contact which dips toward the intrusive.

Several local highs with values between 1000 and 9000 gammas occur within the general highs over the dioritic rocks. These are more prominent and more numerous over the middle and eastern intrusives than over the western one. The reasons for the presence of their local highs are not apparent in rock compositions or visible structures.

Linear highs over alluvium or volcanic rocks to the south and east of the east stock possibly represent dikes. Over the volcanic rocks generally the readings are quite erratic with great differences in magnetic intensity over short distances, and no interpretation is possible for the reconnaissance data of this investigation.

RECOMMENDATIONS

Zones of mineralization of possible value occur within a general area which is geologically favorable. The eastern intrusive appears to have been intensely altered and mineralized with pyrite. The pyrite-bearing zone, however, is a fairly large area in which minerals of value may be present locally. It is recommended that detailed geophysical and geochemical surveys be carried out in order to detect the presence of greater sulphide concentrations within this zone.

Since pyrite is present in surface outcrops, it is possible that self-potential measurements may be an effective method. Other electrical methods such as induced polarization surveys may give significant information.

Various types of geochemical determinations may also be useful. The distribution of trace amounts of copper, lead and zinc over the area should be determined. Another method of possible value is the mercury halo technique which has been used recently in some districts with success.



EXPLANATION

QUATERNARY

- Qal: Pediment and Recent Alluvium
- Qml: Mudflow and Landslide Unit

TERTIARY

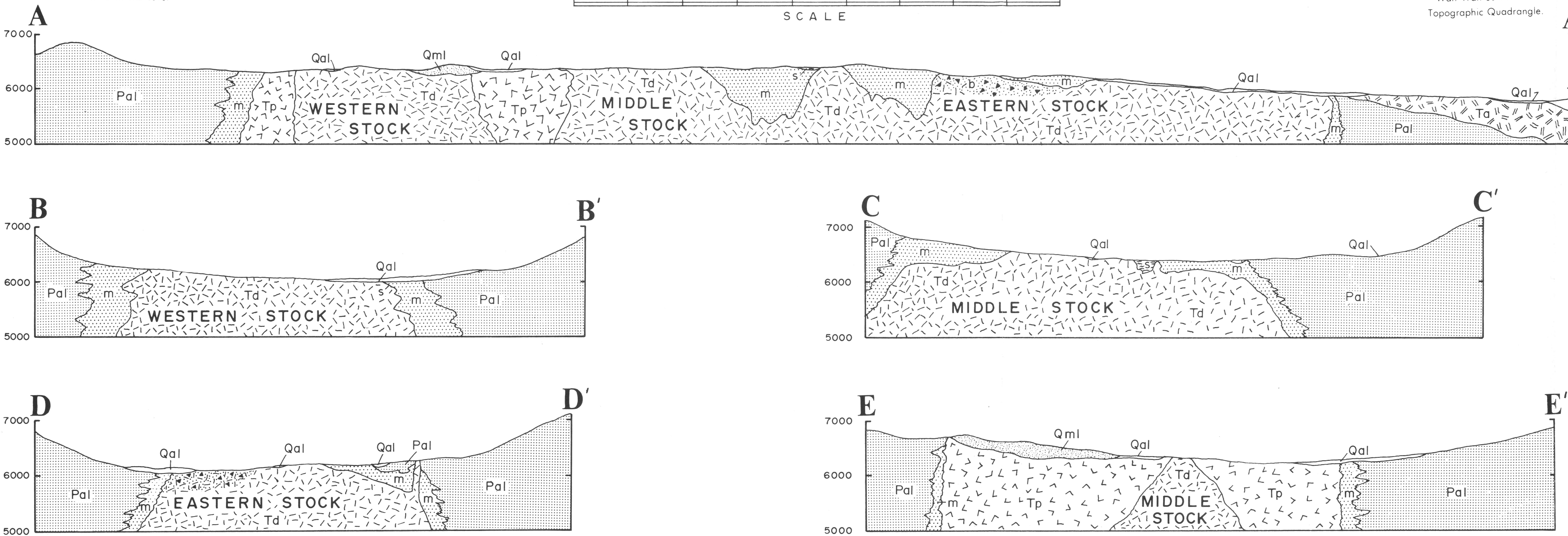
- Td: Diorite and related rocks, a - altered area, b - brecciated (intrusive and vent pyroclastics)
- Tp: Rhyolite Porphyry, a - altered area
- Tri: Rhyolite Ignimbrite
- Tdi: Dacite Ignimbrite
- Ta: Andesite and Dacite Flows

PALEOZOIC

- Pal: Sedimentary Rocks and Metamorphic Equivalents, m - marble, s - scarn

SYMBOLS

- Contact
- Strike and Dip
- Line of Section

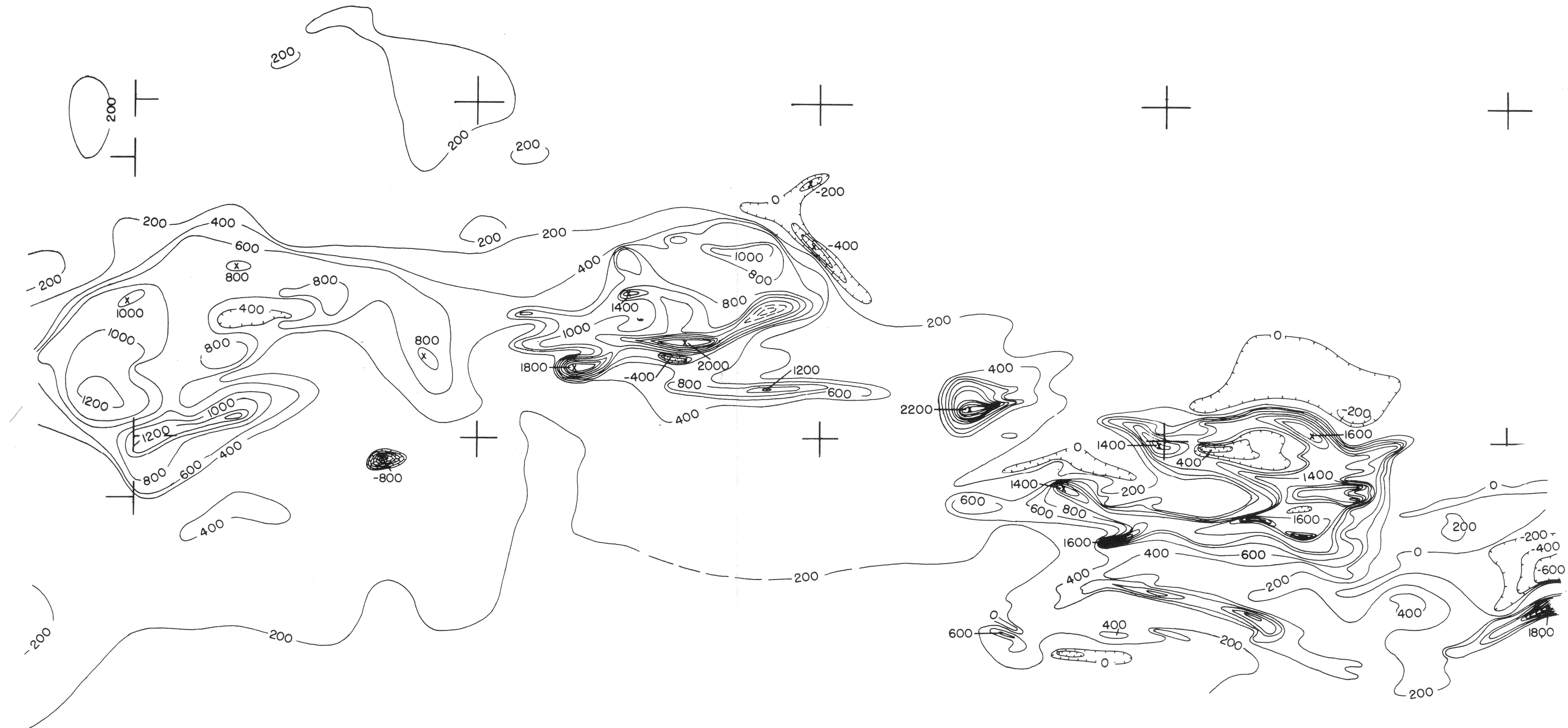


GEOLOGIC MAP AND SECTIONS OF THE WAH WAH PASS AREA, BEAVER COUNTY, UTAH

Geology by Max P. Erickson
 Assisted by Merlin Bingham, Malin Moench, and Don Rollson

1966
 Revised: February 1967

Drafted by K. C. Thomson
 Assisted by J. W. Gwynn



MAP SHOWING DISTRIBUTION OF MAGNETIC INTENSITIES WAH WAH PASS AREA, BEAVER COUNTY, UTAH

1966

by Max P. Erickson
Revised: February 1967

UTAH GEOLOGICAL AND MINERALOGICAL SURVEY

103 Civil Engineering Building
University of Utah
Salt Lake City, Utah 84112

THE UTAH GEOLOGICAL AND MINERALOGICAL SURVEY since 1949 has been affiliated with the College of Mines and Mineral Industries at the University of Utah. It operates under a director with the advice and counsel of an Advisory Board appointed by the Board of Regents of the University of Utah from organizations and categories specified by law.

The survey is enjoined to cooperate with all existing agencies to the end that the geological and mineralogical resources of the state may be most advantageously investigated and publicized for the good of the state. The *Utah Code, Annotated, 1953 Replacement Volume 5, Chapter 36, 53-36-2*, describes the Survey's functions.

Official maps, bulletins, and circulars about Utah's resources are published. (Write to the Utah Geological and Mineralogical Survey for the latest list of publications available).

THE LIBRARY OF SAMPLES FOR GEOLOGIC RESEARCH. A modern library for stratigraphic sections, drill cores, well cuttings, and miscellaneous samples of geologic significance has been established by the Survey at the University of Utah. It was initiated by the Utah Geological and Mineralogical Survey in cooperation with the Departments of Geology of the universities in the state, the Utah Geological Society, and the Intermountain Association of Petroleum Geologists. This library was made possible in 1951 by a grant from the University of Utah Research Fund and by the donation of collections from various oil companies operating in Utah.

The objective is to collect, catalog, and systematically file geologically significant specimens for library reference, comparison, and research, particularly cuttings from all important wells driven in Utah, and from strategic wells in adjacent states, the formations, faunas, and structures of which have a direct bearing on the possibility of finding oil, gas, salines or other economically or geologically significant deposits in this state. For catalogs, facilities, hours, and service fees, contact the office of the Utah Geological and Mineralogical Survey.

THE SURVEY'S BASIC PHILOSOPHY is that of the U. S. Geological Survey, i.e., our employees shall have no interest in Utah lands. For permanent employees this restriction is lifted after a 2-year absence; for consultants employed on special problems, there is a similar time period which can be modified only after publication of the data or after the data have been acted upon. For consultants, there are no restrictions beyond the field of the problem, except where they are working on a broad area of the state and, here, as for all employees, we rely on their inherent integrity.

DIRECTORS:

William P. Hewitt, 1961-

Arthur L. Crawford, 1949-1961