BRIGHAM

YOUNG

UNIVERSITY

GEOLOGY STUDIES

Volume 9, Part 1 May, 1962

GEOLOGY OF THE SOUTHERN WASATCH MOUNTAINS AND VICINITY, UTAH

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Brigham Young University Geology Studies

Volume 9, Part 1 May 1962

Geology of the Southern Wasatch Mountains and Vicinity, Utah

a symposium

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Prepared for the 1962 meetings of the Rocky Mountain Section of the Geological Society of America held on the Brigham Young University Campus, May 10-12, 1962.

A publication of the
Department of Geology
Brigham Young University
Provo, Utah

Part I partially supported by the Rocky Mountain Section.

Officers of the Rocky Mountain Section, Geological Society of America, 1962.

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Geology of the Southern Wasatch Mountains and Vicinity, Utah

INTRODUCTION

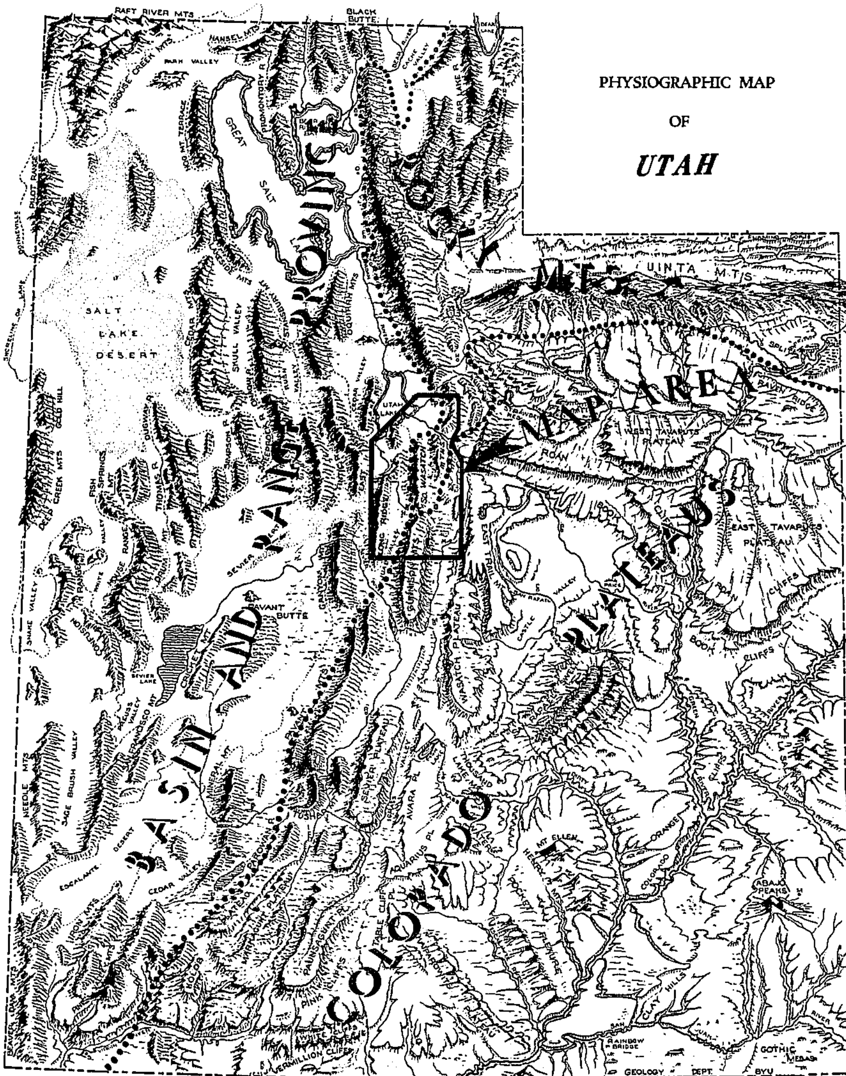
Utah is blessed with geologic features of unusual interest and great variety. The Canyon Lands, the Henry Mountains, the San Rafael Swell, the High Plateaus, the features of Lake Bonneville, the famous mining districts of Tintic, Bingham, and Iron Springs, the magnificent stratigraphic sections exposed in the Book Cliffs and in the Basin Ranges, all have revealed to geologists the tremendous sweep of geologic history and have been made classic through the writings of such pioneer geologists as C. E. Dutton, William M. Davis, C. D. Walcott, and G. K. Gilbert. So complex is Utah's geologic history and so numerous its problems that further detailed work, using improved procedures, continues to increase our understanding of this fascinating area. Each year some aspect is clarified and we wonder why it did not seem more obvious to us before.

In this light we embark on a summary of the current knowledge of the geology of the Southern Wasatch Mountains. The area lies at the junction of three major physiographic divisions: the Middle Rocky Mountains, the Colorado Plateaus, and the Basin and Range Province. It includes sedimentary, igneous, and metamorphic rocks ranging in age from Precambrian to Quaternary, and representing dominantly marine deposits of the Early Paleozoic Cordilleran miogeosyncline, the later Paleozoic Madison and Oquirrh Basins, the Cretaceous Rocky Mountain exogeosyncline, and Cenozoic deposits in freshwater lakes. The area has been involved in major structural deformation in Precambrian time, in folding and thrusting in Late Cretaceous (Laramide) time, and in block faulting in later Cenozoic time. In all, a greater variety of geologic features can scarcely be found in so limited an area.

The area is part of what is sometimes referred to as the "transition zone" in Utah. The transition involves more than the change from Basin and Range landforms to those of the Plateaus, it also involves older transitions from Cretaceous orogenic elements on the west to depositional sites on the east, from Paleozoic cratonic deposition on the east to geosynclinal behavior on the west. Two previous guidebooks have discussed the transition zone in Utah: to the north the Intermountain Association of Petroleum Geologists 10th Annual Field Conference in 1959 considered the Wasatch-Uinta Mountains transition area; to the south the Utah Geological Society 4th Annual Field Conference in 1949 traversed the transition between the Colorado Plateaus and the Great Basin in central Utah.

GEOLOGIC MAP

The geologic map accompanying this report was compiled from a great many sources, most of them published and unpublished theses by graduate students of Ohio State University and Brigham Young University (see "Index to sources of data" printed on the map). The original mapping was done on a variety of base maps, some prepared by plane table, some from air photos, and some on U.S.



INDEX MAP.—Shows Southern Wasatch map area in relation to physiographic provinces.

Geological Survey topographic quadrangles. In transferring the mapping from these diverse bases to the common base used innumerable minor adjustments were made in order to fit the original mapping to the new base as well as possible. Air photos aided in making the transfer for it was sometimes necessary to transfer data from the original map to the photos and thence to the final map in case the original map was too distorted to use directly.

In addition, in cases where adjacent mappers disagreed, the compiler has attempted to resolve their differences as best he could in order to eliminate map boundary faults. Many problems, yet to be solved, became apparent during the compilation and it is hoped that the present map may serve as a means of pointing out these problems in their regional setting for the benefit of future students of this complex and interesting area.

ACKNOWLEDGMENTS

Although many famous pioneer geologists such as William M. Davis and G. K. Gilbert had made reconnaissance observations pertaining to the Southern Wasatch Mountains, the first modern areal mapping in the area was done by Armand J. Eardley in the early 1930's. All later workers are indebted to the perspicacity of his observations.

Impetus for further work in the area came from Professor Edmund M. Spieker who extended his earlier interest in the Mesozoic problems of central Utah by directing Ohio State University graduate students in areas surrounding that of his initial work with the U.S. Geological Survey. Under him, S. L. Schoff's work in the Cedar Hills in 1937 was followed by that of many others of whom the following did work in the area of the present report: Dorothy Taylor, H. D. Zeller, R. E. Hunt, S. J. Muessig, R. E. Metter, A. C. Fograscher, J. E. Cooper, M. A. Khin, R. E. Mase, J. D. Hayes, and G. E. Thomas. Professor George E. Moore, Jr., of Ohio State University acted as graduate thesis advisor for some of these students.

For the past 25 years Professor Harold J. Bissell has been involved in problems relating to Utah Valley and the adjoining ranges. He has inspired a number of students to work in the West Mountain-Long Ridge-Southern Wasatch area and has served as adviser to most of the following Brigham Young University graduate students who have worked in this area: W. O. Abbott, R. S. Brown, R. S. Clark, L. C. Demars, J. H. Elison, D. R. Foutz, P. W. Gaines, R. W. Gates, T. A. Gwynn, H. D. Harris, R. A. Hodgson, K. D. Johnson, J. W. Madsen, D. F. Mecham, C. H. Peacock, H. N. Petersen, D. J. Peterson, D. O. Peterson, R. P. Peterson, J. R. Price, R. R. Rawson, J. A. Rhodes, S. F. Schindler, G. K. Sirrine, C. V. Smith, J. W. Swanson, and B. O. White.

Arthur A. Baker of the U.S. Geological Survey has mapped in the Wasatch Range from Spanish Fork Canyon northward and his work and advice have served as a guide to many of the above listed workers. In addition to the many people whose field work has made the present compilation possible, I wish to acknowledge the efforts of the authors of the papers in the present volume. I also wish to thank Professors Clyde T. Hardy and J. Keith Rigby for help in preparing the road log, and Mr. Colbeth Killip for drafting the geologic map.

The Editor

Igneous Rocks of North Central Utah

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Pyroclastic rocks and associated sediments comprising the Moroni Formation are distributed over more than 100 square miles on the back slopes of the Southern Wasatch Mountains and Cedar Hills between Thistle and Moroni, Utah. In the northern Gunnison Plateau east of Levan, Utah, a number of small monzonite porphyry intrusive bodies occur. Both the pyroclastics and the intrusives have been mapped by graduate students of Ohio State University and the present author has been asked to summarize their findings. In addition, a number of lamprophyre dikes are known from the Southern Wasatch Mountains and they are briefly described below.

MORONI FORMATION

Schoff (1937) named and described the Moroni Formation in his unpublished Ph.D. dissertation, but he did not formalize the usage of the name in his 1951 publication on the Cedar Hills, although Spieker (1949, p. 37) had mentioned the name in print earlier. The Moroni Formation was restudied in detail by Cooper (1956) in its type area north of the town of Moroni, and the following is summarized from his work.

Type locality is the highest point in the southern Cedar Hills about seven miles north-northeast of Moroni, known locally as The Cliff. Here the Moroni Formation consists of about 2,000 feet of stratified clastics largely of volcanic derivation. Roughly the lower half is composed of stream deposited pyroclastics intermixed with normal fluvial sediments, and the upper portion is made up largely of tuffs and welded tuffs or ignimbrites. The Moroni Formation lies unconformably on a base of sedimentary rocks showing appreciable relief. Several unconformities also exist within the formation itself.

The Moroni Formation lies unconformably on the Crazy Hollow Formation of Late Eocene age and is cut by faults apparently associated with late Tertiary Basin and Range faulting. Certain members of the Moroni bear similarities to Miocene tuffs in surrounding areas, and this age has been tentatively assigned.

Lithology of the Moroni Formation

Schoff originally divided the Moroni into four units with a sill separating portions of the upper unit. Cooper's re-evaluation incorporates the "sill" as a welded tuff and redefines the Moroni Formation in six members as follows:

Member 1.—Member 1 is an alluvial deposit of soft white volcanic ash which is never well exposed and is restricted to an area of about seven square miles immediately north of Moroni. Although the base of the member is nowhere exposed, 230 ft. can be measured to its upper contact where it grades into member 2. Member 1 may well represent only a lens within the more extensive member 2, since member 2 shows only a fraction of its normal thickness where it overlies member 1.

Petrographically member 1 is a stream-deposited tuff composed of about 50% pumice with major amounts of andesine and quartz and lesser sanidine and biotite. Rounded pebbles (1-6 mm.) of andesite flow rock are found in zones near the top. The rock generally resembles and is chemically equivalent to a rhyodacite porphyry.

Member 2.—Member 2 is by far the most extensive member of the Moroni and is exposed over about 65 sq. mi. in the southern Cedar Hills where it generally lies directly above the sedimentary formations previously described. In the central part of the area, member 2 reaches a thickness of about 1,500 ft., and its apparent minimum thickness is the 70 ft. which overlies member 1. The characteristic blues and greens of member 2 can be seen from the highways of Sanpete Valley in the foothills of the Cedar Hills.

The lower portion, defined as unit 1 by Schoff, is composed of the finer detrital sediments. These sandstones and siltstones are made up largely of typical igneous minerals (e.g. quartz, feldspar, biotite, etc.); however, some are highly calcareous. Vivid blue and green coloration is supplied to these sediments by a blue-green micaceous mineral of questionable identity which is also present in very appreciable amounts.

The upper part of member 2 (Schoff's unit 2) is represented by coarse, blue-gray conglomerates composed of rounded boulders, averaging six inches in diameter, of andesite, quartz diorite, rhyolite, scoria, pumice, limestone, quartzite and chert lithified by a siliceous cement.

Member 3.—Member 3 (Schoff's unit 3) lies uncomformably on a weathered zone at the top of member 2 and assumes a thickness of from 10 to 100 ft. before it grades into member 4 above. Like member 1, member 3 consists of a series of light colored, friable, porous tuffs deposited by streams; and, like member 1, it forms inconspicuous outcrops mostly in the foothills immediately north of Moroni.

Chemically equivalent to a rhyolite or rhyodacite, member 3 is composed largely of glass shards in an ashy matrix with fragments of feldspar, quartz, biotite and small rounded pebbles of igneous rock.

Member 4.—Member 4 grades downward into member 3 and is distinguished from it only by a slight color difference and by an increase in glass content. Upward, the soft, porous tuff becomes more compacted until it grades into member 5 as a dense welded tuff which forms the resistant cap rock defending many ridges in the area. Where member 5 is not present, the compaction and welding is not observed at the top of member 4. These effects are, therefore, attributed to the heat and pressure of the overlying *"nuee' ardante"* deposit which Schoff described as a sill. Member 4 is widely distributed throughout the southern Cedar Hills, but only as small patches. In the south and central parts of the area, it reaches a thickness of nearly 200 ft. and thins to about 75 ft. in the north. Stream erosion has completly removed member 4 in local areas where member 5 rests directly on member 3.

Member 4 is nearly 80% glass shards with an ashy matrix containing fragments of common igneous minerals and is chemically equivalent to a rhyodacite.

Member 5.—Member 5 is a black welded tuff, 50 ft. thick, containing small white grains of quartz and feldspar and described by Schoff as a sill within his unit 4. It grades downward into member 4 and upward into member 6 and is attributed by Cooper to a *"nuee' ardante"* eruption. Both members 5 and 6 are absent in the southern part of the area near Moroni, indicating a northward source for the volcanics.

From petrographic examination, the rock is found to be 85% glass and 10% andesine with minor amounts of sanidine, biotite and quartz. The lower part shows a few subrounded pebbles, up to 10 mm., of igneous rock having the same composition as the host rock. These are attributed to the eruptive process. The rock has been described as a "rhyodacite porphyry."

Member 6.—Member 6 completes the Moroni Formation and is described by Cooper as a "typical *nuee' ardante*" deposit showing all of the classical characteristics described by writers in other areas. It grades from member 5 at the bottom as a strongly welded tuff to a loosely consolidated tuff at its upper limit. This member has a maximum thickness of about 200 ft. and is a dark red "quartz latite porphyry" near the bottom grading to a white, porous, poorly consolidated tuff at the top which is attributed to the "great black cloud of the *nuee' ardante.*"

Geologic History of the Moroni Formation

Cooper paints the following picture of the origin of the Moroni Formation:

Members 1, 2 and 3 were deposited on flood plains by streams washing largely volcanic debris from some unknown source, with a period of erosion between members 2 and 3. The lower part of member 4 displays a similar origin; however, the upper part represents a *nuee' ardante* eruption which was responsible for the gradational compaction and welding of member 4. A second *nuee' ardante* followed quickly, depositing member 5 and further welding the top of member 4 only to be followed in rapid succession by yet a third *nuee' ardante* flow which deposited member 6. The great black cloud of the last *nuee' ardante* settled slowly forming the porous, loosly consolidated deposit capping the completed Moroni Formation. Finally, minor folding and faulting during the Late Tertiary deformed all beds of the Moroni in local areas.

Although the volcanics of the Moroni formations all have been derived from unknown sources, the absence of the ignimbrites in the southern extremity of the Cedar Hills suggests a northward source, probably not more than 35 to 40 miles north of the town of Moroni.

MONZONITE PORPHYRY INTRUSIVES

Location and Extent.—In 1949 Zeller reported a number of shallow intrusives near the eastern side of the Gunnison Plateau; and a year later, R. E. Hunt supplied a brief description of these intrusives as part of his Ph.D. thesis on the general geology of the northern portion of the plateau. Without describing any single intrusion in detail, Hunt notes a number of disconcordant intrusive masses which crop out at various points from Fourmile Canyon southward to Little Salt Creek and beyond, with greatest concentration occurring southwest of Levan. The largest mass crops out over an area of about one square mile and forms the prominent salient of the plateau front south of Levan. It is bounded on three sides by faults and is described as a probable volcanic neck. Although most of the small intrusives are dike-like in attitude, one large sill intrudes the Twist Gulch Formation in the vicinity of Chicken Creek. Still other small intrusives may exist beneath rather extensive pyroclastic deposits near the northern end of the plateau and are proposed by Hunt as a source of andesite pebbles found in the pyroclastics.

If one may assume all these small intrusives to be of similar age, they may be dated with assurance only as post-Green River, since these Late Eocene beds are the youngest of the sediments to be intruded; and, if pyroclastics of probable Miocene age cover andesite intrusions near Nephi, intrusion should have occurred between Late Eocene and Miocene. Hunt suggests early intrusion of monzonite followed by andesitic magmas.

All exposed intrusives are composed of a similar rock type described as monzonite porphyry. Texture varies from aphanitic near intrusive boundaries to porphyritic aphanitic or even microaphaneritic in the interior. Phenocrysts are largely laths of brown hornblende up to one-half inch long; and sandine, zoned plagioclase, clinopyroxene, biotite and minor quartz, apatite, zircon, sphene and "iron ore" are present in the groundmass.

On the north side of Deep Canyon, limestone beds of the Arapien in contact with a monzonite mass have been extensively replaced by magnetite and hematite with accompanying calcite, garnet, pyrite, biotite and quartz.

LAMPROPHYRE DIKES

Several rare lamprophyre dikes crop out over a narrow zone about three miles long on the mountain front northeast of Mona. A similar dike is also reported by Loughlin about 7 miles to the north in Santaquin Canyon, and a small one is exposed in the foothills just east of Springville.

Lamphophyres are fine-grained, black to pale gray-green and usually highly altered in outcrop. Bronze-colored biotite supplies the characteristic lamprophyre luster and is the only megascopic mineral, although limonite specks mark the sites of former augite phenocrysts.

The most common rock type in dikes east of Mona is an ultrabasic tabbed by Phillips (1940) with the unusual rock name "garewaite." It is composed largely (90%) of olivine and augite as comparatively large (0.5-2 mm.) euhedral grains with minor magnetite, biotite and hornblende. About 5% of the rock is an interstitial, devitrifying groundmass composed largely of fibrous feldspar.

Other outcrops in the vicinity of Bear Canyon east of Mona and the Santaquin dike represent a less basic rock type. Loughlin (1919) has called these rocks "albite minette"; however, Phillips (1940) prefers the name "kersantite," neither naming being entirely appropriate. The major mineral in this rock type is biotite, making up about 20% of the rock, with lesser amounts of augite, olivine and accessory apatite, magnetite and rutile. About 50% of the rock is again a vitreous groundmass with radiating, fibrous sodic-feldspar and patches of probable zeolites.

Age and source of the dikes are not readily apparent. Youngest sediments cut by the dikes are of Mississippian age. A small, Archean granitic mass in Santaquin Canyon, which acts as host rock for the Santaquin dike, is thus eliminated as a possible source. Nearest plutonic bodies of younger age are the monzonite porphyries near Levan, the Tertiary intrusives in the Cottonwood-American Fork area 35 miles to the north, and the Tintic monzonite 20 miles to the west. Tertiary andesites and latites, however, are common east of Mount

Nebo, and these flows may have an ultimate source common to the lamprophyres. In view of the great predominance of Tertiary igneous activity throughout Utah, Loughlin has proposed a Late Tertiary age.

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