MAP GQ-239

DEPARTMENT OF THE INTERIOR
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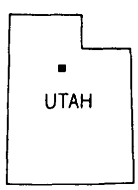
GEOLOGIC QUADRANGLE MAPS OF THE UNITED STATES

GEOLOGY
OF THE
ASPEN GROVE QUADRANGLE
UTAH

By
Arthur A. Baker



QUADRANGLE LOCATION

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ASPEN GROVE QUADRANGLE, UTAH

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INTRODUCTION

The Aspen Grove quadrangle includes a part of the Wasatch Range east of its crest which follows the north-trending ridge of Mt. Timpanogos. The west margin of the range is about 7 miles west of the quadrangle coincident with the east boundary of the Basin and Range province. All drainage from the quadrangle is into the Great Basin, mainly through the Provo River; part of Deer Creek Reservoir on the Provo River is in the east-central part of the quadrangle. A few square miles in the northwest corner of the quadrangle drains into the Great Basin through American Fork, which flows southwestward less than a mile beyond the northwest corner of the quadrangle. A segment of the Alpine Scenic Highway passing through Aspen Grove and connecting the highways in Provo River Canyon and American Fork Canyon crosses the southwestern part of the quadrangle.

A zone of thrust faults of large regional extent trends eastward across the northern part of the quadrangle. As described previously (Baker, 1947; Baker, Huddle, and Kinney, 1949), this zone of faulting separates dissimilar sections of sedimentary rocks. The dissimilarity is primarily in the rocks of Late Mississippian, Pennsylvanian, and Permian age, which are nearly ten times thicker in the plate above the main thrust fault than in the block below it. The thicker facies appears to represent almost continuous deposition from Late Mississippian into Permian time, whereas the rocks of the thinner facies seem to be the result of intermittent deposition or possibly in part the result of a slower rate of deposition. Stratigraphic sections of rocks older than Late Mississippian or younger than Permian are not exposed in both the thin and thick facies within the Aspen Grove quadrangle, but comparisons on a regional basis do not show marked differences in these strata between facies.

After discovery of the zone of thrust faults near Charleston on the Provo River in 1938, mapping was extended into the Aspen Grove quadrangle in 1939 and continued intermittently in 1940 and after World War II in 1948 and 1949 as part of a regional mapping project in the central Wasatch Mountains. Some additional data were gathered subsequently. Effective assistance in the mapping was provided by P. E. Dennis and H. J. Bissell in 1939 and by D. C. Duncan, R. R. Clawson, and Oral Franson at different times in subsequent field seasons. Through field visits and laboratory studies the paleontologic work of J. Steele Williams, Mackenzie Gordon, Helen Duncan, and L. G. Henbest was especially helpful in dating and correlating the rocks.

PRECAMBRIAN ROCKS

Big Cottonwood Formation

The oldest rocks exposed in the quadrangle crop out in the zone of thrust faults between the Deer Creek Reservoir and the canyon of Provo Deer Creek. They consist of greenish-white, and white to purplish-red, medium- to coarse-grained and conglomeratic quartzite with quartzite pebbles as much as 3 inches in diameter. Greenish micaceous shale and sandstone are interbedded with the quartzite. The rocks are contorted and shattered but appear to be 1,000 to 1,500 feet thick west of Decker Creek, where some Tintic Quartzite is probably included in the mapped unit. Although the lithology differs from that of the Big Cottonwood Formation at its type locality in Big Cottonwood Canyon (Crittenden, Sharp, and Calkins, 1952, p. 3-4), by the presence of purple quartzites and interbedded greenish shale and sandstone, it resembles the lithology of the Big Cottonwood Formation where it crops out in normal stratigraphic succession below typical tillite outside the quadrangle in Slate Canyon a few miles southeast of Provo.

CAMBRIAN SYSTEM

Tintic Quartzite

The Tintic Quartzite is believed to be represented in part in the undifferentiated Cambrian and Precambrian quartzites that were mapped along the zone of thrust faulting east of Provo Deer Creek, but the contact between the Tintic and the older quartzite was not recognized. From Provo Deer Creek westward the rock between the Charleston and the Upper Charleston thrust faults is included in the Tintic Quartzite. As seen in discontinuous outcrops, it consists mainly of white to light tan, medium- to coarse-grained quartzite, in places gritty, and with a few pink, red, or lavender bands. Only a few hundred feet of the quartzite is exposed, in contrast with a thickness of 1,080 feet as measured in Slate Canyon south of Provo (Baker, 1947) and about 1,300 feet in American Fork Canyon (Baker and Crittenden, 1961). Both top and bottom of the Tintic Quartzite are sheared off by the Charleston thrust faults at nearly all outcrops in the Aspen Grove quadrangle. In Provo Deer Creek east of Cascade Springs and farther east along the fault zone, greenish shale and sandstone of the Ophir Formation overlie the Tintic Quartzite.

The Tintic Quartzite is included in the Cambrian on the basis of its regional stratigraphic relationships which show it to be unconformable upon the underlying Precambrian and to be gradational with the overlying Ophir Formation of Middle Cambrian age.

Ophir Formation

The Ophir Formation crops out only discontinuously between the Charleston and Upper Charleston thrust faults east of Provo Deer Creek. Along Provo Deer Creek east of Cascade Springs, the Ophir consists of three members: a lower unit of interbedded olive-green micaceous shale and sandstone 150 feet thick; a middle unit 38 feet thick consisting of gray limestone mottled with brownish yellow on bedding planes; and an upper member consisting of olive-green, medium-grained, micaceous sandstone 100 feet thick. Its total thickness of 288 feet contrasts with a total thickness of 510 feet measured in the lower part of the canyon of American Fork; there the lower member is 250 feet thick, the middle member 90 feet thick, and the upper member 170 feet thick (Baker and Crittenden, 1961). Part of the upper member may be absent at the Provo Deer Creek locality as a result of erosion prior to the deposition of the overlying rocks of Mississippian age. The three units of the Ophir are also exposed on the ridge in the south-central part of sec. 20, T. 4 S., R. 4 E. Elsewhere the outcrops of the Ophir consist mainly of greenish shale. Fossils collected from the Ophir Formation in the Wasatch Mountains, including fossils from the basal bed of the middle limestone member east of Cascade Springs, have been identified by A. R. Palmer as Middle Cambrian types.

The Maxfield Limestone of Middle Cambrian age normally overlies the Ophir Formation in the central Wasatch Mountains but is absent at the limited outcrops in the Aspen Grove quadrangle. In this area the Maxfield was removed by erosion before deposition of rocks of Mississippian age.

MISSISSIPPIAN SYSTEM

Fitchville Formation

The Fitchville Formation of Early Mississippian age unconformably overlies rocks of Cambrian age in the central Wasatch Mountains. No rocks of Ordovician, Silurian, or Devonian age have been recognized in the vicinity of the Aspen Grove quadrangle unless a thin bed of gritty sandstone generally found at the base of the Fitchville proves to be of Devonian age. The Fitchville Formation has been recognized at only one locality in the quadrangle, on the east side of Provo Deer Creek opposite Cascade Springs in the fault block between the Charleston and Upper Charleston thrust faults. In a small outcrop at that locality the formation consists of brecciated, fine-grained, medium- to light-gray dolomite about 25 feet thick characterized by numerous vugs an inch or more in diameter that are filled or partially filled with calcite. The top of the formation is absent against the Upper Charleston thrust fault, and the gritty sandstone generally found at the base was not observed at this locality. The normal thickness of the formation is 170 to 260 feet in the central Wasatch Mountains.

The Fitchville Formation formerly was designated the Jefferson (?) dolomite by Gilluly (1932, p. 20-22), and that name was widely used. However, the correlation with the Jefferson Dolomite of Devonian age was never established, and the formation is now included in the Lower Mississippian on the basis of fossils collected from it at several places in central Utah. The name Fitchville has been applied to the unit in the East Tintic Mountains by Morris and Lovering (1961, p. 82).

Gardison Limestone

The outcrop of the Gardison Limestone, like the Fitchville, is limited in the Aspen Grove quadrangle to one small area on the east side of Provo Deer Creek opposite Cascade Springs. The outcrop is adjacent to the Upper Charleston thrust fault and only the upper part of the formation is exposed. It is about 320 feet thick at this locality as contrasted with thicknesses of 500 feet or more measured at nearby localities in the central Wasatch Mountains. At its outcrop in Provo Deer Creek it consists of a lower unit 200 feet thick of thick-bedded gray dolomite with blue-gray limestone in the lower part, and an upper unit 120 feet thick consisting of thin-bedded, very fossiliferous, medium-gray limestone.

The rocks included in the Gardison formerly were named the Madison Limestone, but because they do not conform with the definition of that formation, the new name, Gardison, has been applied in the Tintic district, Utah (Morris and Lovering, 1961, p. 89). The age of the Gardison is Early Mississippian.

Deseret Limestone

The Deseret Limestone conformably overlies the Gardison Limestone. It crops out in the Aspen Grove quadrangle only discontinuously adjacent to and above the Upper Charleston thrust fault. Its full thickness is exposed only in a small area on the east side of Provo Deer Creek east of Cascade Springs. At that locality the formation is 585 feet thick. The lower half consists principally of massive beds of medium-gray dolomite that weathers dull brownish gray and contains abundant chert. The upper half of the formation consists of thick beds of light-gray dolomite and limestone interbedded with medium-gray, dark brownish-gray-weathering dolomite and with abundant black and light-brown-weathering chert. In an outcrop about three-quarters of a mile long west of Decker Creek the exposed part of the Deseret Limestone has an estimated maximum thickness of 500 feet and rests on the Upper Charleston thrust fault. Approximately the same thickness of the Deseret Limestone crops out in a continuous band above the Upper Charleston thrust fault on the south side of Bear Canyon west from Provo Deer Creek. Across the divide in Mill Canyon the Deseret Limestone overlies the Tintic Quartzite at a thrust-fault contact and is in turn overlain by volcanics of Tertiary age.

The Deseret Limestone is correlated with the Deseret Limestone of the Oquirrh Mountains, which was assigned to the Upper Mississippian by Gilluly (1932, p. 26). On the basis of fossils collected from the basal unit of the Deseret in the East Tintic Mountains, Morris and Lovering (1961) also included all the Deseret in the Upper Mississippian. In American Fork Canyon, however, fossils collected from beds 100 to 200 feet above a bed of black phosphatic shale that is assumed to correlate with a similar shale at the base of the Deseret Limestone at other localities in the region, indicated an Osage age for these beds. On the basis of such correlation, therefore, the Deseret Limestone in the American Fork area includes rocks of Early Mississippian age, but it is possible that the lower contact has not been selected at the same horizon throughout the region.

Humbug Formation

The Humbug Formation conformably overlies the Deseret Limestone. It crops out in the Aspen Grove quadrangle only in the fault block overlying the Upper Charleston thrust fault and forms a discontinuous belt of outcrop just south of the trace of the fault. The Humbug Formation consists of limestone and some dolomite interbedded with sandstone. The limestone beds are light to dark gray, thin to thick bedded, contain abundant chert, and in places are leached and porous. The sandy beds are medium to fine grained, light gray to buff, and limy or quartzitic. The buff sandstone interbedded with gray limestone gives a distinctive color to the outcrop, and generally the formation is readily recognizable even at considerable distance. The lower contact of the formation is placed arbitrarily at the lowest sandstone bed and may vary somewhat regionally. The thickness of the Humbug Formation was not measured in the Aspen Grove quadrangle, but it ranges from 518 feet in Rock Canyon east of Provo to 595 feet in Snake Canyon northwest of Midway, 646 feet in the headwaters of American Fork (Baker, 1947), and 800 feet in Boxelder Canyon (Baker and Crittenden, 1961).

THICK FACIES

MISSISSIPPIAN SYSTEM

Great Blue Limestone.--The name Great Blue Limestone is applied to a great thickness of rather homogeneous limestone that is recognized only in the thick facies of sedimentary rocks that characterize the overriding block of the Charleston thrust fault. The formation crops out mainly in the fault block between the Upper Charleston and Deer Creek thrust faults. One discontinuous belt of outcrop extends west from Deer Creek Reservoir nearly to the divide between the South Fork of Provo Deer Creek and the drainage of American Fork. Mainly the lower part of the formation is exposed in most of this belt, but, through stripping of the concealing mantle of volcanic rocks from a large area on the north side of the valley of the South Fork of Provo Deer Creek, almost the full thickness of the formation is exposed there, and the overlying Manning Canyon Shale crops out in an isolated exposure in the bed of the South Fork of Provo Deer Creek.

In the southern part of the quadrangle the Great Blue Limestone reappears in the Sulphur Spring and Aspen Grove windows, which have been eroded through the plane of the Deer Creek thrust fault. Along the gorge of the Provo River where it crosses the Sulphur Spring window, the Great Blue Limestone crops out in ledges and bluffs beneath flats formed by the Manning Canyon Shale. In the Aspen Grove window the Great Blue Limestone crops out for nearly a mile on the east side of the North Fork of Provo River and forms a high bluff facing Aspen Grove. A large area of outcrop extending eastward from the South Fork of American Fork in the adjoining Timpanogos Cave quadrangle (Baker and Crittenden, 1961) terminates against the West Aspen Grove fault in the northwestern part of the quadrangle.

The Great Blue Limestone consists of dark-gray to black limestone in thin, regular beds with some interbedded black shale and occasional thin beds of rusty-weathering fine-grained quartzite. The limestone weathers into flakes and slabs that are pale gray or pinkish. The thickness of the Great Blue Limestone is 2,800 feet as measured in Rock Canyon east of Provo (Baker, 1947) and 3,355 feet as measured by Gilluly (1932) in the Oquirrh Mountains. The Great Blue Limestone locally contains abundant fossils which establish a Late Mississippian age for the formation (Gilluly, 1932, p. 30; Bissell, 1959, p. 57).

PENNSYLVANIAN AND MISSISSIPPIAN SYSTEMS

Manning Canyon Shale.-The Manning Canyon Shale is part of the thick facies of rocks that occur above the Charleston thrust fault. It conformably overlies the Great Blue Limestone and is exposed in the Aspen Grove quadrangle only in the Sulphur Spring and Aspen Grove windows, which have been eroded through the Deer Creek thrust fault, and in an isolated outcrop in the South Fork of Deer Creek in the western part of sec. 26, T. 4 S., R. 3 E. The Manning Canyon Shale was the medium upon which the principal movement of the Deer Creek thrust fault appears to have occurred, and incomplete but varying thicknesses of the formation are found where it immediately underlies the thrust plane. A complete thickness of the formation has not been observed in the Aspen Grove quadrangle, as it appears to be in fault contact with overlying rocks at all outcrops in the quadrangle.

The Manning Canyon consists principally of black and brown shale with interbedded slabby sandstone, thin beds of rusty-weathering, gray fine-grained quartzite, beds of brown-weathering grit, and thin- to thick-bedded gray to black limestone. It is 1,645 feet thick as measured in Rock Canyon east of Provo, where it contains a prominent bed of fossiliferous gray limestone 90 feet thick and about 800 feet above the base of the formation. Fossils collected from the medial limestone at that locality were determined to be Pennsylvanian in age, and fossils of Mississippian age were found a few tens of feet below the limestone (Mackenzie Gordon, Jr., written communication, 1957).

PENNSYLVANIAN AND PERMIAN SYSTEMS

Oquirrh Formation.-The Oquirrh Formation is the uppermost unit of the thick facies exposed in the Aspen Grove quadrangle and is the principal bedrock in the southern part of the quadrangle. Normally the Oquirrh Formation is conformable with the underlying Manning Canyon Shale, but the two formations are in thrust contact at all outcrops in this quadrangle.

The Bridal Veil Limestone Member is the basal member of the formation. It is a medium- to dark-gray, thin- to thick-bedded limestone with some interbedded dark-gray to black shale, and it forms a prominent band below the tan slopes and cliffs of the overlying part of the formation. The Bridal Veil Limestone Member is 1,245 feet thick as measured near Bridal Veil Falls in Provo River Canyon south of the Aspen Grove quadrangle. Nearly the full thickness of the limestone is exposed in the cirque west of Aspen Grove, in the gorge of the North Fork of the Provo River near the southern boundary of the quadrangle, and near Bear Canyon east of Provo River. The thickness of the limestone member is affected by the beveling action of the Deer Creek thrust fault at the base; the member is absent on the west and north sides of the Sulphur Spring window and its thickness decreases northward along the east side of the Sulphur Spring window and along the west side of North Fork Ridge.

Above the Bridal Veil Limestone Member the Oquirrh consists of about 24,000 feet of gray to buff, limy or quartzitic sandstone and numerous beds of limestone. It was measured along the ridge crest north of Bear Canyon in the southeast corner of the quadrangle and eastward for about 6 miles along the crest of Wallsburg Ridge to a point south of Wallsburg where the top of the formation is exposed. In that section the formation contains strata representative of Pennsylvanian time zones ranging from Morrow in the Bridal Veil Limestone Member through Atoka, Des Moines, Missouri, and Virgil; it also includes the Permian time zones of Wolfcamp and Hueco. Within the Aspen Grove quadrangle only about 10,000 feet of the sandy portion of the Oquirrh is exposed, mainly in the southeast corner. These strata include beds of Atoka, Des Moines, and Missouri age; Oquirrh rocks of Permian age do not crop out in the quadrangle.

THIN FACIES

The rocks of the thin facies underlying the Charleston thrust fault include the Doughnut Formation of Mississippian age, the Round Valley Limestone and Weber quartzite of Pennsylvanian age, and the Park City Formation of Permian age. The oldest rocks crop out in the northwest quarter of the quadrangle; progressively younger formations up to the Twin Creek Formation of Jurassic age crop out toward the east. This sequence of strata ranging in age from Mississippian to Jurassic trends approximately at right angles to the trace of the Charleston thrust fault and to the rocks of the thick facies in the overriding block.

MISSISSIPPIAN SYSTEM

Doughnut Formation.-The Doughnut Formation crops out in several small areas in the northwest corner of the quadrangle. It conformably overlies the Humbug Formation but the contact is not exposed in the quadrangle. The basal unit of the Doughnut Formation is a bench-forming black shale with some thin interbeds of rusty-weathering, fine-grained, gray quartzitic sandstone. The shale is overlain by dark-gray to black thin-bedded limestone similar to limestone of the Great Blue. The Doughnut Formation is 1,300 feet thick as measured in the NW¼ sec. 3, T. 4 S., R. 3 E., just north of the Aspen Grove quadrangle, but it thins northward in American Fork to 250 feet in Dry Fork (Baker, 1947) and is less than 300 feet in the Cottonwood area (Baker and Crittenden, 1961).

The Doughnut Formation locally contains abundant fossils that show it to be Late Mississippian in age and appear to establish its correlation with some part of the Great Blue Limestone and possibly with the lower (Mississippian) part of the Manning Canyon shale.

PENNSYLVANIAN SYSTEM

Round Valley Limestone.-The lowest rocks of Pennsylvanian age in the thin facies are included in the Round Valley Limestone, which consists of medium to coarsely crystalline, light- to medium-gray limestone with black, white, and orange-red chert and some thin beds of buff to gray sandstone. Many of the fossils are silicified and have a distinctive orange-red color. At some places in the region a thin bed of quartz- and limestone-pebble conglomerate is present at the base of the Round Valley Limestone and presumably marks an erosional break between the Round Valley Limestone of Pennsylvanian age and the underlying Doughnut Formation of Mississippian age. The Round Valley Limestone is 225 to 400 feet thick in the upper part of the canyon of American Fork north of the Aspen Grove quadrangle. It is of Early Pennsylvanian age and appears to be equivalent to part or all of the Bridal Veil Limestone Member of the Oquirrh Formation.

Weber Quartzite.-The Weber Quartzite appears to overlie the Round Valley Limestone with conformity. It forms a broad band of outcrop extending northward from the trace of the Charleston thrust fault along the west side of the valley of Provo Deer Creek, including the divide between Provo Deer Creek and Mill Canyon. The formation consists mainly of gray to buff quartzite and quartzitic sandstone with some interbedded gray cherty limestone. As calculated from measured dips and width of outcrop the Weber Quartzite is about 8,000 feet thick along the ridge north of Bear Canyon and across the divide into the drainage of Mill Canyon. The Weber has a far greater thickness at this locality than is known in neighboring parts of the Wasatch Mountains. The thickness of 8,000 feet compares with calculated thicknesses of about 2,000 feet 2 miles north of the quadrangle on the divide near Sandy Baker Pass and about 1000 feet about 2½ miles north of the quadrangle in Snake Creek on the south side of Bonner Hollow, and with reported thicknesses of about 3,500 feet in the Park City district (Boutwell, 1912) and 1,500 feet north of Brighton in Big Cottonwood Canyon (Calkins and Butler, 1943). This abrupt thickening of the Weber Quartzite suggests that a transition from the thin to the thick facies may occur not far south and west beneath the area now occupied by the Charleston thrust, or possibly that the uplift and subsequent erosion of sediments deposited during Pennsylvanian time were irregular.

A few fossils have been collected from the Weber Quartzite in the Aspen Grove quadrangle and neighboring areas to the north and east. J. Steele Williams examined several fossil collections and all that were considered diagnostic were classed as Early Pennsylvanian in age. The Round Valley Limestone and the Weber Quartzite thus appear to be equivalent to the lower part of the Oquirrh Formation.

PERMIAN SYSTEM

Park City Formation. - The uppermost unit included in the thin facies is the Park City Formation of Permian age. It is incompletely exposed where it overlies the Weber Quartzite along the west side of the valley of Provo Deer Creek, and the upper part of the formation crops out in an arch exposed in the east wall of the valley. The Park City Formation also crops out in Mill Canyon in a fault block between the Charleston and the lower Mill Canyon thrust faults. The formation in this part of the Wasatch Mountains normally consists of an upper and a lower member of light-gray, sandy, and cherty limestone, in part leached, spongy, and brecciated with interbedded gray to buff limy sandstone, separated by a middle black shale member containing thin beds of oolitic phosphorite. As measured in Sid's Canyon about 1½ miles northwest of the northeast corner of the Aspen Grove quadrangle, the lower, middle, and upper members are 458, 60, and 352 feet thick, respectively. At the outcrop in Mill Canyon the middle shale member appears to be represented by a comparable thickness of brown-weathering, dark-gray shaly limestone; only occasional chips of oolitic phosphorite were noted. This thickness of 870 feet in the thin facies stands in sharp contrast to that of the thick facies in Hobble Creek east of Springville, where the Park City Formation is nearly 1900 feet thick. On the basis of numerous fossils collected from the formation in the vicinity of the Aspen Grove quadrangle, the entire Park City is regarded as of Permian age.

An hiatus at the base of the Park City Formation in the thin section is equivalent to much of the upper part of the Oquirrh Formation together with the overlying Kirkman Limestone, and Diamond Creek Sandstone of the thick facies and thus appears to be equivalent to much of Pennsylvanian and Permian time.

TRIASSIC SYSTEM

Woodside Formation

The Woodside Formation crops out only in the northern part of the Aspen Grove quadrangle and overlies the Park City Formation of Permian age as represented in the thin facies of sedimentary rocks below the Charleston thrust fault. It also crops out above the rocks of Permian age in the thick facies farther south in the Wasatch Mountains (Baker, 1947), where it has similar lithology. The Woodside Formation does not appear to reflect differences between the thin and thick facies that persisted from Late Mississippian through Permian time; it is the lowest of a series of formations that appear to have similar characteristics both above and below the Charleston zone of thrust faulting.

The Woodside Formation crops out on the east side of Provo Deer Creek where it is 315 feet thick and in Mill Canyon in the fault block between the Mill Canyon and Charleston thrust faults. It consists of interbedded red siltstone, shale, and fine-grained sandstone and is characterized by abundant ripple marks. Fossils have not been found in the Woodside in the Aspen Grove quadrangle, but the formation overlies rocks of Permian age and appears to be a part of the sequence of similar red beds that occur above and below the Thaynes Limestone of Early Triassic age. The Woodside is generally accepted as Lower Triassic.

Thaynes Limestone

The Thaynes Limestone is the surface rock in a wide area in the northeast corner of the quadrangle east of Provo Deer Creek; it also crops out in Mill Canyon in the fault block between the Mill Canyon and Charleston thrust faults. Brown-weathering, gray cherty limestone with some interbedded red-brown to buff limy sandstone and red shale is distinctive of this formation. It is 950 feet thick as measured across the ridge east of Provo Deer Creek near Cascade Springs. The Thaynes Limestone contains abundant fossils and the jauna is of Early Triassic age.

Ankareh Formation

The outcrop of the Ankareh Formation in the Aspen Grove quadrangle is limited to a small area extending from the trace of the Charleston thrust fault at the divide between Provo Deer Creek and Decker Creek northeastward to the alluvial fill of Heber Valley. As used in this report the name Ankareh applies to the rocks between the top of theThaynes Limestone and the base of the Nugget Sandstone. These rocks have a total thickness of 1,485 feet as measured in the valley of Decker Creek. They include three units. A lower unit, 1,000 feet thick, consists of thin regular beds of ripple-marked, reddish-brown sandy shale and shaly sandstone and a few beds of massive, blocky-weathering red sandstone. An upper unit, 450 feet thick, consists of red to variegated shale interbedded with gray to red and purplish red, fine-grained to conglomeratic sandstone mainly near the top of the formation. The upper and lower units are separated by a bed of coarse, sugary to quartzitic, gray to buff and red conglomeratic sandstone 35 feet thick. The lithology and stratigraphic relationships of the lower part of the Ankareh and the underlying Thaynes and Woodside Formations strongly suggest (Baker, 1947) the correlation of these three units with the Moenkopi Formation of central Utah. Similarly, the upper part of the Ankareh is believed to correlate with the Upper Triassic Chinle Formation of southeastern Utah, the conglomeratic sandstone at the base of the upper Ankareh being in the stratigraphic position of the Shinarump Member. Scott (1959) has summarized nomenclatorial usage for these units and has proposed the name Moenkopi Group to include the Woodside and Thaynes Formations with the Ankareh restricted to the lower unit of the Ankareh of this report. He also proposed application of the name Chinle to the upper unit of the Ankareh and applies the name Shinarump with a question mark to the underlying conglomeratic sandstone. This terminology is in conformity with the personal opinion of the writer with the exception of the tentative extension of the name Shinarump to a thin unit for which a local name probably would be more appropriate.

JURASSIC SYSTEM

Nugget Sandstone

The Nugget Sandstone crops out in a belt that crosses Decker Creek, where it is 1,500 feet thick and consists of homogeneous, medium-grained, gray, buff, and orange-brown, highly crossbedded sandstone. The Nugget Sandstone is correlated with the Navajo Sandstone of the plateau region of southeastern Utah.

Twin Creek Formation

The youngest formation of Mesozoic age in the Aspen Grove quadrangle is the Twin Creek Formation. The top of the formation is concealed beneath the fault block overlying the Charleston thrust fault but almost the entire formation crops out along the shore of the Deer Creek reservoir just east of the quadrangle; the exposed portion is within the expected thickness of the formation, which ranges from 1,100 feet in Spanish Fork Canyon to the south (Baker, 1947) to 2,800 feet in Parleys Canyon to the north (Crittenden and others, 1952). The Twin Creek Formation is composed dominantly of gray limestone with some interbedded shale overlain by interbedded gray to green shale, gray to buff limy sandstone, and occasional bands of red-brown siltstone and silty sandstone. The fauna of the Twin Creek Formation is of Jurassic age.

TERTIARY SYSTEM

Tibble Formation

The youngest consolidated rocks in the Aspen Grove quadrangle are included in the Tibble Formation. It has been named from prominent outcrops along American Fork near the mouth of Mill Canyon and the adjoining Tibble Fork (Baker and Crittenden, 1961) about a mile west of the quadrangle. There the formation includes ledge-forming conglomerates interbedded with boulder-bearing, greenish-gray to reddish-brown tuffaceous sediments and at least one thin bed of white fresh-water limestone. The boulders are generally well rounded and as much as 6 feet or more in diameter. They are mostly gray to red andesite or latite. A few of the larger boulders are quartzite but smaller and generally less rounded boulders are quartzite, gray limestone, brown-weathering limestone similar to the Thaynes, and red sandstone like that of the Ankareh or Nugget. Along American Fork the conglomeratic beds have a dip of 30° to 50° NE and appear to be about 2,500 feet thick. The base of the formation appears to rest on an erosion surface but it is possible that the western limit of the formation is determined by the West Aspen Grove normal fault. At the top the formation is cut by the Deer Creek-East Aspen Grove normal fault. The principal outcrop of the red conglomerate in the Aspen Grove quadrangle is on a ridge spur south of Mill Canyon in secs. 16 and 17, T. 4 S., R. 3 E.

Above the conglomerate a belt of volcanic rocks covers a wide area long the divide at the head of the South Fork of Deer Creek and extends to Deer Creek Reservoir. The volcanic layer appears to be about 600 feet thick along the drainage divide in sec. 16 at the head of a tributary of Mill Canyon and may not be substantially thicker elsewhere in its belt of outcrop. The base of the volcanic rocks is at an elevation of about 8000 feet along the divide and slopes generally eastward to an elevation of about 5400 feet on the shore of the Deer Creek Reservoir; the volcanic material does not extend eastward beyond the reservoir. Throughout its extent the outcrop of the volcanic rocks is mainly a boulder-strewn surface with boulder composition comparable to that observed at the mouth of Tibble Fork. In a roadcut near the summit of the Alpine Scenic Highway, pale-brown bedded tuff dipping 25° SE., and water-laid tuff with lenses of grit outcropping on the shore of Deer Creek Reservoir near the east quarter corner of sec. 32 show the nature of the boulder matrix. The widespread layer of water-laid volcanic agglomerate seems closely allied in distribution and lithology to the material exposed near the mouth of Tibble Fork, and for the purposes of this report it is included with the Tibble Formation although its thickness probably is not more than a quarter of the thickness of the red conglomeratic facies at the mouth of Tibble Fork. Furthermore, the large fault which according to present structural interpretations forms the northern boundary of the Tibble Formation in lower Mill Canyon does not offset the mantle of volcanics on the divide at the head of the South Fork of Deer Creek. It is concluded, therefore, that the Tibble Formation includes volcanic rocks of two ages and that the widespread mantle of volcanic rock is the result of a later episode of volcanism than that which accounted for the volcanic material associated with the conglomerate beds along American Fork.

No direct evidence for the age of the volcanic material was obtained in the Aspen Grove quadrangle. It may be contemporaneous with similar volcanic material of the Norwood Tuff which has yielded vertebrate remains originally considered to be Oligocene in age (Eardley, 1944, p. 845) but now considered to be late Eocene in age (Gazin, 1959, p. 137, and written communication, 1959).

QUATERNARY AND RECENT DEPOSITS

Quaternary and Recent deposits have been broadly categorized as landslides, mudflows, outwash and alluvial cones, valley fill, terrace gravel, and moraine and glacial outwash. Landslides are visible at several places but only one in the northwest corner of the quadrangle is shown on the map. Similarly, the only mudflow shown is a large one composed of volcanic materials that moved down the valley of Provo Deer Creek. Outwash and alluvial cones mantle bedrock at many places in the area, especially at the mouths of canyons or gullies draining steep slopes. A conspicuous alluvial cone is developed at the mouth of Sunday Canyon in the southeast corner of the area and is one of a series of coalescing fans that extend eastward into Round Valley.

Moraines and glacial outwash are widely distributed in the quadrangle. Glaciers feeding on the east flank of the range on which Mt. Timpanogos is located deposited morainal material along the valley of the North Fork of Provo River from near the southern boundary of the quadrangle north to the divide at the head of the North Fork and beyond the divide into the headwaters of the South Fork of Provo Deer Creek. Another principal area of moraines extends down Provo Deer Creek beyond Cascade Springs, the material having been derived from gathering areas to the north along the divide between Provo Deer Creek and American Fork.

STRUCTURE

The Aspen Grove quadrangle and adjoining parts of the Wasatch Range are characterized by large-scale overthrust faults and later normal faults (Baker, 1959). The zone of thrust faults exposed in the quadrangle can be traced almost continuously from the Uinta Basin near Strawberry Reservoir westward through Heber Valley and across the Aspen Grove quadrangle to American Fork Canyon. Beyond American Fork Canyon the traces of the thrust faults are interrupted by normal faults, but the zone of thrust faults reappears at the surface on the west face of the Wasatch Range in the vicinity of the Traverse Range. On a larger scale, this structure is probably part of a system of thrust faults extending from southern Idaho to southeastern Nevada. Within the Aspen Grove quadrangle the lower Charleston, Mill Canyon, Upper Charleston, and Deer Creek are probably all imbricate slices related to this great thrust system.

The major normal faults are the East and West Aspen Grove faults, which limit a graben in which Aspen Grove is located. Numerous small normal faults are present and appear to be, in large part, adjustments resulting from movement on the thrust faults. Folds in the quadrangle also appear to be, in part at least, associated with the movements on thrust faults. Steep dips are common in association with the faulting but generally appear to be unrelated to regional folding. A possible exception is the east-dipping monocline in the northern part of the quadrangle north of the zone of thrust faulting.

THRUST FAULTS

Charleston thrust fault.-The lower Charleston fault is regarded as the sole of a series of thrust faults. It appears to have the greatest stratigraphic displacement, and, in contrast with other faults in the series, involves the movement of older rocks over younger. East of the Mill Canyon-Provo Deer Creek divide, eastward-dipping rocks ranging in age from Pennsylvanian (Weber Quartzite) to Late Jurassic (Twin Creek Formation) in the northern part of the Aspen Grove quadrangle are overridden along the lower Charleston thrust fault by older rocks of Precambrian and Cambrian age. West of the divide, the Tintic Quartzite of Cambrian age overrides steeply dipping rocks of the Park City (Permian) and the Woodside and Thaynes Formations (Triassic). The fault plane appears to be nearly flat at places and to dip 35° or more at other places; the dip of the fault plane is 17° on the shore of Deer Creek Reservoir. In Mill Canyon the trace of the Charleston thrust fault is cut off by the East Aspen Grove normal fault.

Mill Canyon thrust fault.-The Mill Canyon fault appears to be a lower thrust fault branching from the Charleston thrust fault on the Mill Canyon-Provo Deer Creek divide, and the two faults bound a wedge of rocks that widens westward. Although it has been interpreted as a thrust fault, the Mill Canyon may be a normal fault. The Mill Canyon fault terminates against the East Aspen Grove normal fault a short distance west of the boundary of the quadrangle and east of a large spring in American Fork Canyon. Steeply dipping rocks of Park City, Woodside, and Thaynes Formations of Permian and Triassic ages appear to be thrust over rocks of the Doughnut, Round Valley, and Weber Formations of Mississippian and Pennsylvanian ages. The fault plane dips 20° to 30° S.

A similar further split that may be a thrust or normal fault occurs in the western part of sec. 1, T. 4 S., R. 4 E., where a wedge of rock consisting of Doughnut Formation widens westward into the adjoining Timpanogos Cave quadrangle to include the underlying Humbug Formation and appears to be thrust over the Doughnut Formation.

Upper Charleston thrust fault.-The Upper Charleston thrust fault is above and approximately parallel to the lower Charleston thrust fault. Although the band of rocks between the two faults pinches and swells, the faults are nowhere separated by more than a few hundred feet of strata. The intervening rocks are Tintic quartzite of Cambrian age west of Provo Deer Creek, but east of that creek, in addition to the Tintic Quartzite, are rocks of the underlying Big Cottonwood Formation (Precambrian) and the overlying Ophir Formation (Cambrian); immediately east of Cascade Springs a sliver of Fitchville Formation appears to underlie the Upper Charleston thrust fault. Limestones of Mississippian age in the overriding block have been thrust over the older rocks throughout the known extent of the Upper Charleston thrust fault. Like the Charleston thrust fault, the Upper Charleston fault is cut off toward the west in Mill Canyon by the East Aspen Grove fault. Toward the east the trace of the Upper Charleston thrust can be observed on the east shore of Deer Creek Reservoir, but beyond that locality outcrops of the Tintic Quartzite have not been observed. The Upper Charleston thrust fault may disappear by merging with the Charleston thrust fault, or its trace may be concealed below the alluvium in Heber Valley.

Deer Creek thrust fault.-The Deer Creek thrust fault is the highest of the major thrust faults in the Aspen Grove quadrangle. It is an especially prominent structural feature as the fault plane is relatively flat lying and is rather close to the surface in much of the quadrangle, and the trace of the fault appears at the margins of two windows that have been eroded through the overriding block. The Deer Creek thrust fault splits from the Upper Charleston thrust on the east shore of Deer Creek Reservoir east of the town of Charleston. At that locality a thin sliver of Manning Canyon Shale separates the Upper Charleston and Deer Creek thrust faults. The sliver widens westward to include part of the Humbug and Great Blue Formations on the west side of Deer Creek Reservoir, and in the headwaters of the South Fork of Deer Creek it includes part of the Deseret, the Humbug, the Great Blue, and part of the Manning Canyon Formations before it is inferred to terminate against the East Aspen Grove normal fault. Through the valley of Provo Deer Creek the trace of the Deer Creek thrust fault at the northern limit of the overriding block is concealed, mainly by volcanic rocks, but its position is inferred from scattered bedrock outcrops. The trace of the fault reappears around the margins of the Sulphur Spring window, in which the rocks of the overridden block are exposed in a wide area in the valley of lower Provo Deer Creek and the valley of Provo River below the mouth of Provo Deer Creek. It is again present in the Aspen Grove window, where the thrust fault has been offset along the East Aspen Grove normal fault.

The Manning Canyon Shale is the principal material upon which movement along the Deer Creek thrust fault occurred. In the Sulphur Spring window at the southern edge of the quadrangle most of the Bridal Veil Limestone Member of the Oquirrh Formation is present at the base of the overriding block. There is a general northward beveling at the base of the overriding block through which the Bridal Veil Limestone Member is cut out in lower Provo Deer Creek and progressively higher rocks are beveled until rocks in the Oquirrh Formation about 10,000 feet above the base rest on the Manning Canyon Shale east of Deer Creek Reservoir at Charleston.

NORMAL FAULTS

Two large normal faults, one west and another east of Aspen Grove, mark the boundaries of a graben ½ mile to 1¼ miles wide that extends along the west side of the quadrangle from the southern border to Mill Canyon.

The West Aspen Grove fault is one of the major normal faults. From the headwaters of Tibble Fork in sec. 17, T. 4 S., R. 3E. it extends south, crossing the cirque about a half mile west of Aspen Grove. South of the quadrangle it crosses Provo River about three-fourths of a mile west of the mouth of South Fork, then crosses the crest of the range south of Provo River and reaches the west front of the Wasatch Range at Springville. The eastward dip of the fault in the Aspen Grove quadrangle is 70° or more. The displacement is at least 2,500 feet at Provo River and is fully that much at Aspen Grove and north of the Alpine Scenic Highway near the northwest corner of sec. 28.

The East Aspen Grove fault crosses the quadrangle line at Mill Canyon, where it appears to be the extension of the Deer Creek normal fault that crosses the range north of Boxelder Peak and reaches the west front of the Wasatch Range near Alpine (Baker and Crittenden, 1961). In the vicinity of American Fork and Mill Canyon the Deer Creek fault is a normal fault of large displacement and dip of 35° separating the Tertiary volcanic conglomerates from the older rocks. Although largely concealed along the west face of North Fork Ridge, the East Aspen Grove fault appears to be a high-angle fault with about 3000 feet of displacement separating the sandstones of the Oquirrh Formation above the Deer Creek thrust fault in the graben at Aspen Grove from the Great Blue Limestone below the Deer Creek thrust fault in the bluffs east of Aspen Grove. Near the head of the gorge of the North Fork of Provo River in sec. 14, T. 5 S., R. 3 E., sandstone of the Oquirrh Formation is faulted against the Bridal Veil Limestone Member. The East Aspen Grove fault extends several miles south of Provo River and may extend as far as Hobble Creek east of Springville, but its full extent is not known at present.

AGE OF FAULTING

The youngest rocks involved in the thrust faulting in the Aspen Grove quadrangle are in the Twin Creek Formation of Late Jurassic age. Farther east, however, the Mesaverde Formation of Late Cretaceous age is involved in the thrust faulting (Bissell, 1952) and the faults are concealed by the Tertiary rocks of the Uinta Basin. The oldest Tertiary rocks that conceal the fault are not definitely known, but it appears that the coarse conglomerates in the Price River Formation of Late Cretaceous age east of the Wasatch Range were deposited subsequent to the major structural disturbance caused by the thrust faulting. Available evidence thus points to the Late Cretaceous as the time of movement on the thrust faults.

Normal faults with displacements up to a few hundred feet such as the numerous faults in the valley of Provo River south of Deer Creek Reservoir and normal faults displacing the Bridal VeilLimestone Member of the Oquirrh Formation on the east side of the North Fork of Provo River, are closely associated with thrust faults and appear to be minor adjustments related to such faulting, and hence contemporaneous with it.

The large East Aspen Grove normal fault offsets the thrust faults of the Charleston zone and in Mill Canyon in the Timpanogos Cave quadrangle the Deer Creek normal fault, presumed to be its continuation, offsets the earliest volcanic rocks of the Tibble formation. Within the northwest corner of this quadrangle, however, the East Aspen Grove fault does not offset the youngest volcanic rocks on the divide between Mill Canyon and the South Fork of Provo Deer Creek. The East Aspen Grove normal fault and the related parallel West Aspen Grove fault are therefore younger than the thrust faulting and are post-early volcanics or at least Eocene in age. The East Aspen Grove fault and its continuation, the Deer Creek normal fault, follow a great arc that cuts across the Wasatch Range west of the Aspen Grove quadrangle. Similarly, the West Aspen Grove fault slices across the crest of the Wasatch Range east of Provo and appears to be terminated by the Wasatch fault at the front of the Range near Springville. Despite their large displacement, these two great normal faults have little effect on the present topography of the Range. They are therefore believed to represent an episode of normal faulting that is appreciably older than the Wasatch zone of normal faults along the west face of the Range that account for so much of its present relief.

Recent elevation of the Wasatch Range relative to the back valley occupied in part by the Deer Creek Reservoir is indicated by the altitude of the bedrock floor beneath the dam, which is at least 100 feet higher than the bottom of a water well at Charleston drilled to a depth of 325 feet without reaching bedrock.

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