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Preliminary Geologic Map of the Nephi 30' by 60' Quadrangle, Carbon, Emery, Juab, Sanpete, Utah, and Wasatch Counties, Utah

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Preliminary geologic map of the Nephi 30' x 60' quadrangle, Carbon, Emery, Juab, Sanpete, Wasatch, and Wasatch Counties, Utah

by

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This map is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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1985
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INTRODUCTION

The U.S. Geological Survey is engaged in a program of field studies designed to present the geologic framework of the United States on easily read topographic maps. The maps selected as a base for these geologic data are part of the Army Map Service (AMS) series of 1° × 2° quadrangles at a scale of 1:250,000. The Price, Utah AMS 1:250,000 quadrangle is one of these maps (Fig. 1). For certain areas, however, chiefly those sectors of the country involved in the Geological Survey’s coal exploration program, the geologic data are being compiled on newly developed base maps at a scale of 1:100,000. On these new maps the configuration of the land is shown by contours having a 50-’ contour interval. One of these new maps has been used as a base for this geologic map of the Nephi, Utah, 30° × 60’ quadrangle, the northwestern quadrangle of the Price sheet.

THE PRICE, UTAH 1° × 2° AMS (1:250,000) SHEET

The geologic data compiled on the Nephi sheet are part of a much larger geologic pattern best displayed on the Price, Utah 1° × 2° quadrangle. The Price quadrangle contains parts of three major physiographic provinces: the Colorado Plateaus, the Basin and Range, and the Middle Rocky Mountains. Most of the sheet, including the central and eastern parts, underlies the western margin of the Colorado Plateaus. Within this part of the Plateaus are the southern edge of the Uinta Basin (expressed as the southward-facing, sinuous escarpments formed by the Book and Boon Cliffs), the northern part of the Canyonslands Section (expressed by the northeast-trending San Rafael Swell), and the northernmost of the High Plateaus of Utah (the Wasatch Plateau). The western part of the sheet includes the eastern edge of the Basin and Range province (the Great Basin). A small wedge of the Middle Rocky Mountains province—the southernWasatch Mountains—dominates the northwest corner of the sheet.

THE NEPHI, UTAH, 30° × 60’ (1:100,000) QUADRANGLE

All three physiographic provinces are represented in the Nephi quadrangle, although the boundaries between them are somewhat indistinct; uncertainty exists as to where one province ends and the other begins. The sector between the western edge of the Colorado Plateaus (the western flank of the Wasatch Plateau) (Fig. 2), and the eastern edge of the Basin and Range province (the Wasatch fault zone) probably is a zone transitional between the two provinces. Two facts support this concept of a transition zone: the strata that form the Wasatch Plateau continue westward and underlie the Gunnison Plateau and the Cedar Hills. And in both the Gunnison Plateau and the Cedar Hills, these same rocks, almost undisturbed on the Wasatch Plateau, are intensely deformed locally into structures as common in the Basin and Range Province. We, therefore, include the Gunnison Plateau and the Cedar Hills within the Colorado Plateaus.

The Middle Rocky Mountains province is represented by the wedge-like mass of the southern Wasatch Mountains that tower above the western half of the quadrangle. The eastern edge of this wedge, beyond the Wasatch fault zone, falls within the Basin and Range province, and includes a long, narrow, north-trending ridge formed by Long Ridge and the West Hills.

Wasatch Plateau

The Wasatch Plateau, the northernmost of the High Plateaus of Utah, is a
Figure 1.—Sketch map showing regional physiographic features of the Price 1° x 2° quadrangle. Hachures outline Nephi quadrangle.

Figure 2.—Sketch map showing physiographic features of the Nephi 30' x 60' quadrangle.
flat-topped mass about 130 km (80 mi) long that extends from Salina Canyon on the south to the valleys of Soldier Creek and Price River on the north (fig. 3). The plateau trends about N. 20° E., maintains a nearly constant width of about 40 km (25 mi), and its top is at an altitude of about 3,050 m (10,000 ft). It separates Sanpete Valley, on the west, from Castle Valley on the east.

The plateau is underlain by flat-lying Cretaceous and Tertiary beds, most of which are well exposed in the dissected cliffs that delineate its eastern flank. These strata flex down sharply along the western flank of the plateau to form the Wasatch monocline. Westward-flowing consequent streams on the monocline have locally cut through the tilted beds exposing them along the walls of deep, serpentine canyons that extend far back toward the crest of the plateau.

Wasatch monocline

The Wasatch monocline (fig. 3) faces westward and is well exposed along U.S. Highway 89 which follows the base of the monocline northward from near Sterling to Thistle. Limestone beds, mostly the Flagstaff Limestone, form the impressive sloping surface of the monocline. Older units, chiefly the Nephite and Sanpete formations, are exposed locally in the canyons cut into the monocline, whereas younger units, including the Colton, Green River, and Crazy Hollow formations, form low, westward-dipping cuestas west, and in front, of the monocline's slope. In places, south of the Nephite quadrangle, as near Ephraim and Mount Nebo (fig. 3), the lower slopes of the monocline are overlain by a chaotic jumble of beds, chiefly Colton strata, that slid westward off the tilted Flagstaff Limestone. In these same areas, huge earthflows also extend westward from the monocline onto the alluviated floor of Sanpete Valley. Comparable earthflows and landslides, but neither as large nor as extensive, are in the east fork of Sanpete Valley near Milburn and Fairview.

The top of the plateau, and the Wasatch monocline, are broken by north and northeast-trending high-angle normal faults, many of which are paired to form narrow, elongate grabens. Of these grabens, the most spectacular is Joes Valley graben, which extends into the Nephite quadrangle in the Bald Mountain and Miller Flat Reservoir sector.

Only the northern half of the Wasatch Plateau extends into the Nephite quadrangle, but the same geologic and structural pattern that marks the southern half persists through the northern half; the plateau is a geologic entity.

Gunnison Plateau

A high tableland that separates Sanpete Valley from Juab Valley (fig. 2) is known to geologists as the Gunnison Plateau, to local inhabitants as the West Mountains, and to some Federal agencies as the San Pitch Mountains.

In gross aspect, the Gunnison Plateau can be viewed as two interrelated segments: a northern third that is tilted southeastward at least as far south as the Spring Mountains, and the remainder of the plateau, southward, beyond Price, that appears as a south-plunging syncline. Locally, the plateau is marked by unusual structural complexities. For example, the strata, in a very narrow zone along the east side of the plateau, commonly dip steeply westward and locally are vertical or overturned to the west. If one excludes the narrow zone of steeply tilted to overturned beds that delineates the east flank of the plateau, however, most of the other beds along the east flank dip gently westward.
Sanpete Valley

San Pitch River flows southwestward and, near the town of Gummeron, joins the Sevier River, which flows northeastward (fig. 3). The valley of the San Pitch River is known as "Sanpete Valley", the name resulting from a garbled version of "San Pitch Valley". Sanpete Valley trends about N. 10° E. from its junction with Sevier Valley, and separates the high mass of the Gummeron Plateau on the west from the Wasatch Plateau on the east. Near Moroni (fig. 2), the valley bifurcates and forms two arms, both, oddly enough, known as Sanpete Valley. For purposes of discussion we refer to the east arm, which contains the San Pitch River, as the "east fork of Sanpete Valley", and the west arm, which is essentially a dry valley, as the "west fork of Sanpete Valley".

South of Moroni, Sanpete Valley is about 13 km (8 mi) wide; each fork is about 5 km (3 mi) wide.

Deposits of economic value in the valley include sand and gravel, building stone chiefly from the Green River Formation, and gypsum and salt deposits in the Aparian Shale.

Middle Rocky Mountains Province

Southern Wasatch Mountains

The Wasatch Range, the backbone of Utah, extends for about 240 km (150 mi) from near the Idaho border to Nephi in central Utah. In general, the range can be divided into two segments: a northern part that extends from the Idaho border southward to Spanish Fork Canyon, and a southern part that extends from Spanish Fork Canyon southeastward to Nephi (inset map A, fig. 3). It is this southern part that extends into the Nephi quadrangle and forms the southern Wasatch Mountains.

The southern Wasatch Mountains trend slightly east of north, and are about 48 km (30 mi) long. The Wasatch normal fault zone truncates their west flank, which consequently appears as an imposing, straight, steep, north-trending mountain front. The eastern edge of the mountains is less impressive chiefly because it has been deeply eroded. Younger Cretaceous and Tertiary rocks overlie this eastern edge and appear in a dissected range of low hills—the Cedar Hills—that lie along the east flank of the mountains.

The southern Wasatch Mountains are part of the huge eastward-directed Charleston-Nebo thrust plate that extends from near Salt Lake City southward to Nephi (inset map A, fig. 3). The plate is floored by the Charleston-Nebo thrust fault (p. 6), one of a series of thrust faults that reach from Montana southwest to Nevada and that have brought thick basin facies over thinner shelf rocks to the east (Crittenden, 1961).

The southern Wasatch Mountains appear as one limb of an intensely dissected, large, overturned, almost recumbent anticline—the southern part of the Charleston-Nebo thrust plate. At the northern end of the southern Wasatch mountains, near Santiquin, the Paleozoic beds are right-side-up and dip moderately southeastward, but southeast the dips increase and near Nephi the beds are vertical. Still farther south, at the southern end of the mountains, near Nephi, the beds are overturned and dip moderately northward; these overturned strata are exposed in the towering mass of Mt. Nebo, northeast of Nephi. Here and there, patches of Cretaceous and Tertiary beds unconformably overlie parts of the overturned anticline.

Cedar Hills

The Cedar Hills, along the southeastern flank of the southern Wasatch Mountains (fig. 2), are a much dissected, thickly forested upland. Bounded on
the east by the east fork of Sampete Valley and the valley of Thistle Creek, and on the southeast by the west fork of Sampete Valley, the Cedar Hills appear as a southeast-pointing wedge that gradually diminishes in height southeastward. Consequently streams flow both to the northeast and southwest from their crest.

The Cedar Hills consist of gently folded Cretaceous and Tertiary sedimentary rocks that locally are concealed beneath a cover of Tertiary volcanic rocks. Where the sedimentary and volcanic mantle has been removed, steeply dipping and locally overturned older rocks (chiefly of Jurassic and Cretaceous age) unconformably underlie the Cretaceous-Tertiary mantle.

Basin and Range Province

Long Ridge and West Hills

A sinuous, north-trending, narrow range marked by a shallow saddle midway along its length forms the west side of Joub Valley (fig. 2). Utah State Highway 132 uses the saddle as it passes from Joub Valley into Dog Valley on the west fork of Joub Creek (fig. 3). The landscape north of the saddle is known as Long Ridge, that south of the saddle as the West Hills. In the past, both segments have been arbitrarily grouped and called Long Ridge (Hussig, 1951, p. 3). Long Ridge, bounded on the west by both Goosen and Dog Valleys and on the east by Joub Valley, is about 32 km (20 mi) long, and in general, averages 3 km (2 mi) in width. Its crest rises gradually from about 1,750 m (5,740 ft) near its southern end to about 1,900 m (6,235 ft) near its northern end. Almost all streams are intermittent; Currant Creek, which drains Mona Reservoir, is the only perennial steam.

West of Mona Reservoir, Long Ridge is divisible into two different parts. The northern part, an irregular belt of tilted and rotated fault blocks, is cut by high-angle normal faults. The rocks are mostly of Earliest and Middle Paleozoic age, with a few sparse late Precambrian rocks exposed on the west side and there. The Paleozoic rocks are similar to units exposed along the flanks of the southern Wasatch Mountains. Coarse clastic sedimentary rocks of the North Basin are prominent, very much like those that lap onto the dissected east flank of Mt. Nebo, unconformably overlie these Paleozoic units.

The southern part of Long Ridge consists chiefly of Oligocene volcanic rocks, which locally are tilted and rotated fault blocks extend to the west, where extensive deposits have been mapped by Norris (1977). The Paleozoic rocks crop out locally in this southern part of the range, and re-appear in the West Hills to the south; from these outcrops we infer that the sheet of broken Paleozoic rocks underlies all of Long Ridge.

The West Hills is about 24 km (15 mi) long, about 5 km (3 mi) wide, and its crest maintains a relatively even altitude of about 1,850 m (6,070 ft). Most streams are small and intermittent; only Chicken Creek, which flows westward and drains Chicken Creek Reservoir, is perennial.

The Long Ridge-West Hills topographic high decreases in altitude southwestward, but its volcanic cover thins as well; as a result, older rocks are conspicuously exposed in the West Hills. Upper Paleozoic rocks crop out particularly in the northern West Hills. Farther south, in an east-dipping monocline in the vicinity of the Interstate 15, the Plateau, Colton, and Green River Formations—form the higher parts of the range. These Tertiary beds are much like the same units exposed along the west flank of the Green River Plateau. Although patches of volcanic rocks and unconsolidated valleym-fill sediments obscure the relations between these Tertiary and the underlying Paleozoic rocks, the Tertiary rocks must lie unconformably on the older rocks of the Charleston-Nebo thrust plate.

In the West Hills, the Flagstaff and Green River Formations—both of lacustrine origin—contain abundant terrigenous clastic material, even as they do on the west side of the O unnion Plateau. From this area and the following of these beds farther to the west, we infer that the West Hills are near the ancestral shoreline of those lakes in which these strata were deposited.

STRUCTURAL GEOLOGY

Thrust faults

The overturned antcline that forms the core of the southern Wasatch Mountains (p. 6) is part of the Charleston-Nebo thrust plate, a mass of Paleozoic and Mesozoic rocks that has been moved laterally both eastward and southeastward along the well-known Charleston-Nebo thrust fault. What may be the distal edge of the thrust fault describes an arc, concave to the west, that extends from near Salt Lake City to Nephi. Although the sole of the Charleston-Nebo thrust fault may crop out near Nephi, co-author Wikind believes that, if so, it has been intensively modified by the intrusive movement of the Arapahone Shale (p. 5).

In our view, the exact position of the distal edge of the thrust plate— in eastern Jefferson and Utah Counties—remains unknown. On the east, the topographically high escarpment that marks the eastern edge of the southern Wasatch mountains may be an erosional feature formed by the plate, or it may be the distal margin of the plate, concealed beneath a cover of sedimentary and volcanic rocks that forms the Cedar Hills. On the west, overturned Paleozoic and Mesozoic strata at the northern end of the West Hills probably are a remnant of the thrust plate. On the south, the plate may extend at least as far south as Pigeon Creek, near Levan. Wikind (1983, p. 49) has interpreted a fold in Pigeon Creek, presumed to be overturned (Skitza, 1972, p. 78), to be an erosional outlier of the thrust plate. Norris (1983, p. 77) has suggested, however, that the underlying Charleston-Nebo thrust fault may merge, near Nephi, with the Leesville transcurrent fault. While Norris has located the Leesville thrust to the west, we have not been able to identify it in the Nephi area.

We are uncertain about the time of emplacement of the Charleston-Nebo thrust plate. The youngest rocks that occur in the overturned antcline are part of the Watton Canyon Member of the Twin Creek Limestone of Middle Jurassic (Bathonian) age. Locally, these Watton Canyon beds are overlain by sandstone and conglomerate beds of the North Horn Formation of late Cretaceous (Maastrichtian) age. The time of emplacement of the thrust block, then, must have been after Middle Jurassic (Bathonian) time and before late Cretaceous (Maastrichtian) time.

Strip faults

Speker (1949) and several of his graduate students have attributed various unusual stratigraphic relations and local structural complexities in the Sampete-Beaver Valley area to "strip faults." The term, coined by Bills (1965) in reference to a series of Paleozoic and Eocene beds—chiefly the Plateau, Colton, and Green River Formations—that were seemingly have been shoved eastward over older rocks along a thrust fault that followed a pre-existing unconformity. Co-author Wikind (1982a, pp. 22-23) believes that many of these strip features are better explained as a result of salt diapirs.
Normal faults

The Wasatch fault, the major high-angle normal fault in the area, has been described repeatedly (Marrill, 1964; Cluff and others, 1973; Swan and others, 1980), and no attempt is made to duplicate these descriptions here. In general, the fault zone is about 100 m wide along the west flanks of both the southern Wasatch Mountains and the Gunnison Plateau. The fault is active, and is marked by evidence of repeated movement. Modern scarps are low, near-vertical cliffs or small alluvial fans; these may be traced for several hundred feet or even a thousand feet along the movement direction, outlining a triangular pattern. The fault zone is about 30 m wide along the east-southeastern flanks of the Plateau, and 50 m wide along the west-southwest flanks of the Plateau.

A system of high-angle normal faults that range in trend from N. 10° E. to about N. 30° E. breaks the crest and west flank of the entire Wasatch Front. These extensive systems of normal faults are spaced such as 65 km (40 mi) long; most of the faults maintain a relatively constant width of about 3 km (2 mi). This fault system extends the full length and width of the Plateau, reaching from Salina Canyon (fig. 3) on the south to Spanish Fork Canyon (Soldier Creek) on the north, and from Castle Valley (east of this quadrangle) on the east to the Suntense Valley on the west. Most faults and grabens are remarkably straight; commonly the faults persist as single breaks, or very narrow fault zones, traceable for very long distances. The faults that bound the grabens invariably dip inward. Structural relief differs from graben to graben. In some grabens it is as little as 100 m (several hundred feet); elsewhere it is hundreds of meters. Spiker (1949, p. 43) suggested that the structural relief on some grabens may be as great as 915 m (3,000 ft).

In many places, the downthrown blocks are unbroken, and locally they are cut by a series of small internal faults that parallel the larger faults that bound the grabens.

The origin of the faults, and thus, of the grabens is uncertain. The faults may reflect widespread crustal spreading stemming from an episode of extensional tectonism that has dominated the western interior of the United States since Miocene time. If so, they are tectonic in origin. By contrast, the faults may be related, in one way or another, to the salt that underlies much of the Suntense-Savâier Valley area. If so, the grabens may be collapse features relating to withdrawal of salt (Stokes, 1952; Stokes and Boldes, 1954, p. 40). Noulton (1975, fig. 19) implies that many of the faults that break the crest of the Wasatch Plateau do not extend below the base of the salt-bearing beds. L. A. Standley of Cheyenne, W. D. A. (oral commun., 1984) also has suggested, on the basis of proprietary seismic reflection data, that those faults that bound large grabens, such as the Joes Valley graben (south of this quadrangle) are not salt-related. He suggests that at least some of the faults and grabens may be genetically related to withdrawal of salt.

The grabens that may stem from salt dissolution are not confined to the Wasatch Plateau. The Gunnison fault, which extends along the east flank of the Gunnison Plateau, dips eastwardly, is downthrown to the east, and locally has cut and offset Quaternary surficial deposits. Now, young normal faults in the area, however, such as those that mark the Wasatch fault zone, dip westwardly and are downthrown to the west. The eastward-dipping Gunnison fault, essentially following the projected trace of the Suntense-Savâier Valley salt diapir, would seem to be related to dissolution of part of that diapir. The Gunnison fault, thus, an extensional fault, begins where the Little Clear Creek thrust ends (p. 19); this suggests to us that salt dissolution may be a significant factor in the development of that graben.

A range-front fault, trends north, traces the basin, and forms concordant structures, possibly formed in a response to an outwash (valleyward) flowage of the salt, which was postulated by Baker (1933, p. 74) to explain the development of the grabens that are so common in the Paradox Basin of southeastern Utah and southwestern Colorado.

Complexly deformed rocks

Except for the overthrown anticline that forms the bulk of the Charleston-Beo thrust plate, most rocks in the Nuphe quadrangle are but moderately deformed. Here and there, however, are linear to sinuous belts of intensely deformed strata. In places, these strata are vertical or overturned; elsewhere, they are steeply inclined. Locally, one or more angular unconformities break the sedimentary sequence. In several places, two or more angular unconformities are exposed in a single outcrop, but such angular unconformities are not extensive laterally. These angular unconformities are separated by an angular unconformity, which traces laterally, become conformable in distances as short as three-fifths of a kilometer (half a mile). Furthermore, overturned beds become near-horizontal in unevenly short distances. The intense deformation is extremely localized.

These belts of intensely deformed rocks are not confined to the Nuphe quadrangle; they extend southward and are well exposed at various localities along the margins of the Suntense and Savâier Valleys (Wittkind, Weiss, and Brown, 1985). Expectably, they have been and still are the subject of considerable geologic controversy.

Alternative interpretations

Three interpretations have been offered to explain these complex structures: (1) multiple episodes of crustal disturbance (Spiker, 1946, 1949; Stanley and Collinson, 1979; Standley, 1982), (2) mobilisation of plastic mantle in the cleavage Shale (in a result of orogenic pulses (Collinson, 1963), and (3) multiple episodes of salt (halite) diapirism (Stokes, 1952, 1956; Wiltkaid, 1982a). For ease of discussion we here group Gilliland's views with Spiker's and other workers' interpretations, for it is clear from Gilliland's article that he believes, such as Spiker and the other workers do, that the deformation ultimately stems from eastward-directed orogenic pulses. Two contrasting interpretations are available, thus, to explain the deformations: multiple episodes of orogeny, and multiple episodes of salt diapirism. Definitive evidence in support of either hypothesis is not available, and both concepts are considered viable.

Multiple episodes of orogeny

Co-author Weiss favors the interpretation involving multiple episodes of orogeny. He believes that the underlying Jurassic beds, which underlie the eastern escarpment of the Wasatch Mountains, were deformed by the Central Utah salt diapir. Weiss believes that the question is moot on the basis of evidence from surface geology, and that the fault and fracturing cannot be fully discounted in the central Wasatch Mountains. The complex structural deformation of central Utah, but is uncertain how large that role was. Weiss believes the question is moot on the basis of evidence from surface geology, and that the question of the extent of the deformation cannot be fully discounted in the central Wasatch Mountains. Weiss attributes the intense deformation that marks the east flank of the Gunnison Plateau to an antiformal belt that lay just east of the Gunnison Plateau in latest Cretaceous and Paleocene time, and
that generally bent the end of the plateau block toward the west (Weiss, 1982). The welt may have been caused by compression from the east, diapirism, or both.

Multiple episodes of salt diapirism By contrast, co-author Witkind strongly favors an interpretation involving multiple episodes of salt diapirism, which has shaped this sector of central Utah. In his view, almost every complex structure is related, in whole or in part, to one or more salt-generated features.

In light of this scientific conflict among us, we have agreed to disagree. Consequently, the interpretations presented below by co-author Witkind express his views. Co-author Weiss agrees with some of the interpretations offered but not necessarily all.

DIAPIRC CONCEPT

by

Irving J. Witkind

Stokes (1952, 1956) first advanced the possibility that salt-generated structures might be responsible for most of the intense deformation in the Sanpete-Salt Lake Valley area of central Utah. Although subsequent workers also considered salt diapirism as one possible explanation for the deformation, they rejected it chiefly because they believed that insufficient salt underlay the area for it to have played an important role (Gilliland, 1963, p. 122-123; Standlee, 1982, p. 380). Indeed, only a small amount of salt is exposed, chiefly near Redmond (fig. 3), where the salt is mined from intensely deformed, near-vertical beds (Picard, 1980, p. 145). The mine exploits salt-bearing beds about 60 m (200 ft) thick, and the total thickness of all salt beds in the Redmond area ranges from 180 to 300 m (600 to 1,000 ft) (Pratt and others, 1981). Seismic surveys conducted during the past two decades suggest that much mudstone and interbedded salt does underlie the Sanpete-Salt Lake Valley area. More significantly, the Phillips Price N well (SE1/4, SE1/4 SW1/4, Sec. 15 S., R. 3 E.), in Sanpete Valley southwest of Moroni (fig. 3), penetrated a bed of salt and subordinate intermixed calcareous mudstone 610 m (2,000 ft) thick. In the West Hills, west of Juab Valley Plateau near the city of Benton, Howard 1-4 well (NE1/4, NW1/4 Sec. 15 S., R. 1 E.) cut about 170 m (550 ft) of salt. And Chevron's Chris Canyon No. 1 well (NE1/4, SW1/4, sec. 33, T. 16 N., R. 1 E.) near the center of the Gunnison Plateau, drilled through about 245 m (800 ft) of salt (fig. 2, p. 362). Little or no salt has been found in several other wells drilled in the region although almost all the wells penetrated mudstones of the Arapah Shale. I believe the absence of salt from these wells does not necessarily mean non-deposition, but rather migration toward the diapir. I concur with Seemenn's见解 (1968) that once salt diapirs begin to form, the0 bedded salt migrates laterally toward the areas of weaker rocks and away from areas of salt diapirism. The causative rock salt is contained within the Arapah Shale of Middle Jurassic age. Since Middle Jurassic time the salt has welled upward from the source, creating structural and paleotopographic highs against which younger sedimentary units thin and locally pinch out. This slow upwelling has been interrupted sporadically and repeatedly by sudden upward surges of the salt. These surges have forced up the enveloping Arapah
Figure 4.—Diagrammatic cross section through an erosional remnant of a former fan-shaped diapiric fold (Mitkid, 1982a). Sketch shows possible geologic relations between a salt diapir, the diapiric core, the Arapien Shale and the updip country rocks. Arrows denote general direction of movement of the plastic and mobile salt and mudstone.

km (7 mi) to the northeast. The fold deforms both the northern end of the Gunnison Plateau, as well as rocks that lap onto the erosional eastern margin of the Charleston-Nebo thrust plate.

The attitude of the consolidated sedimentary rocks, that flank the diapiric core of the Pole Creek fold, stem from the intrusive nature of the fold. Thus, the north end of the Gunnison Plateau is tilted southeastward reflecting the southeasterly flank of the fold. I believe that the northwesterly tilt of the bulk of the Charleston-Nebo thrust plate, near Neph, reflects the northwesterly flank of the Pole Creek fold.

About 8 km (5 mi) east of Neph, where the Mt. Nebo Scenic Loop Road joins State Highway 132 (near the KOA campground), the diapiric core of the fold, trending northeast and expressed as outcrops of amorphous reddish-brown Arapien mudstone, is clearly exposed between tilted layers of volcanioclastic rocks. Those volcanioclastics that overlie the northwesterly flank of the core dip northwestward; those that overlie the southeastern flank dip southeastward. From this point, the Pole Creek fold trends about 65° E., with its core and its southeastern flank well exposed in the Middle Fork of Pole Creek (cross section B-B'). The sedimentary strata, chiefly units of the Peter Ranch Formation (Fig. 2), are vertical adjacent to the diapiric core, but lessen in dip away from the core.

The fold has determined the structural pattern of the Cedar Hills. West of the Middle Fork of Pole Creek, all strata, volcanic as well as sedimentary, dip northwesterly toward the Charleston-Nebo thrust plate. East of the creek all strata dip steeply southeasterward; in a few places these beds are overturned to the southeast and dip steeply to the northwest. These steeply dipping to vertical strata, all part of the Indiana Group, are well exposed along Hop Creek Ridge and in Hop Creek.

Seemingly, the Pole Creek fold continues northwesterly, concealed beneath the volcanic mantle, and eventually reappears east of Thistle in Dry Hollow to form the Dry Hollow diapiric fold (no. 10, fig. 3).

Dry Hollow diapiric fold (No. 10, fig. 3)

East of Thistle, vertical to overturned beds of the Indiana Group, that strike about 65°, are exposed in a deep canyon known as Dry Hollow (cross section B-B'). The canyon, tributary to northwest-flowing Lake Fork, trends northwesterly, its course probably determined by the mudstone in the steeply dipping Indiana beds. These vertical to near-vertical strata are overlain with striking angular unconformity by gently dipping beds of reddish-brown conglomerate, sandstone, and mudstone of the North Horn Formation. These North Horn strata have been arched, apparently as a result of the upward movement of the underlying fold. Thus, North Horn beds that overlie the northwesterly flank of the fold dip northwesterward at about 35°; those North Horn beds that overlie the southeastern flank dip southeasterward at about 70°.

Only part of the diapiric fold is exposed in Dry Hollow. On the basis of limited exposures, the fold trends about 65° E. for some 6 km (4 mi), reaching from the head of Dry Hollow across Lake Fork and Soldier Creek to the north wall of Spanish Fork Canyon where the fold passes below North Horn beds. The fold probably continues southward, concealed beneath the volcanic mantle, and connects with the Pole Creek fold (no. 12, fig. 3).

Thistle Creek diapiric fold (No. 11, fig. 3)

In the Thistle area, a diapiric fold is suggested only by arched Cretaceous and Tertiary strata that overlie the erosional margin of the Charleston-Nebo thrust plate (cross section B-B'). Here, the erosional edge
of the thrust plate appears as an imposing ridge of steeply tilted beds of Navajo Sandstone overlain chiefly by gray, thin beds of the Twin Creek Limestone. All these beds are right-lying (up to about 45°) and are parallel to the fold but pass toward the northwestern flank of the moat Horon Formation, which in turn are overlain by the Flagstaff Limestone. East of the ridge the North Horn-Flagstaff sequence dips gently eastward; west of the ridge the sequence—plus younger units—dips gently westward.

I suggest that the erosional escarpment formed on the thrust plate was buried beneath nearly horizontal North Horn and younger strata. As a dip-slip fold developed beneath the thrust plate it raised the plate and in so doing arched the overlying younger rocks. Erosion has since removed the crested part of the arched sheet of North Horn and younger rocks and exposed that part of the escarpment by the Navajo and Twin Creek beds.

The Arapian Shale, the intrusive unit believed responsible for the upward of the thrust plate, crops out in this area along Thistle Creek, and near Thistle Creek in Soldier Creek, where it both deforms Tertiary strata and intrudes Twin Creek units.

Njorh Canyon dip-slip fold (No. 9, fig. 3)

Part of a northeast-trending dip-slip fold is exposed in Njorh Canyon (secs. 15, 16, 21, and 22, T. 11 S., R. 4 E.), some 3 km (2 mi) north of Indianola. This fold was first recognized and called the Rjark Creek dome by Rummin (1977, p. 76). Critical exposures, along the north wall of Njorh Canyon, consist of a diapiric core of Arapian Shale that trends about N. 40° E., bounded on each flank by beds of the Thistle Gulch Formation (Jtgl.).

Exposures are poor but I suggest that beds of the Cedar Mountain Formation are stratigraphically above the Thistle Gulch beds; on the map the Cedar Mountain (?) beds are included with Thistle Gulch strata. All units are unusually thin. Thistle Gulch beds that form the southeast flank of the fold striking about N. 45° E., are overturned to the northwest, with about 85° to the southeast. Thistle Gulch beds that form the southeast flank of the fold are on the right-side-up and dip southwardly between 35° and 85°. The outermost flanks of the fold are defined by units of the Indianola Group that dip about 20° north-northwestwardly onto the southeast flank, and about 85° south-southeastwardly onto the southeast flank. All beds that form the fold are locally unconformably overlain by evaporite units or the Horon Formation. As in the Dry Hollow fold, these younger beds appear to have been arched by an upward movement of the underlying strata, those North Horn beds that overlie the southeast flank of the fold dip westwardly at about 10°; those North Horn beds that overlie the southeast flank dip south-southeastwardly 30° to 50°. These southwest dips persist southeastward for about 1.6 km (1 mi) at which point the beds pass beneath the Horon volcanic beds of the Horon Formation. Beds of the Horon Formation are difficult to determine; southeast of the exposures described above, however, near Little Clear Creek, Markam, the Twin Creek beds are tilted with the westward dip of the Horon Formation. Beds of the Horon Formation reflect the northwestern flank of the Little Creek Clear diapiric fold (no. 8, fig. 3), which also trends northeast, and thus is parallel to and about 3 km (2 mi) southeast of the Njorh Canyon fold.

Little Creek Clear diapiric fold (No. 8, fig. 3)

Little Creek Clear has cut a deep, narrow canyon into the crest of a major diapiric fold that trends about N. 40° E. Twistle Gulch strata (Jtjg) form the crest of the fold, and these beds dip steeply away from the crest for much of the length of the fold. Thus, Thrull Gulch beds, on the northeastern flank, dip to about 85° to the southeast; comparable dips to the southeast, mark the southeastern flank of the fold. Only a narrow part of the southwestern flank of the fold, about 5 km (3 mi) south of the crest, is exposed and includes units of the Cedar Mountain and South Plat Formations and the Indianola Group. All these strata dip at high angles, commonly to the southeast, but locally some beds are vertical or are overturned to the southeast and so dip northwesterly. These steeply inclined units are unconformably overlain by a sequence of Price River—North Horn beds that dip southeast at about 35°.

The arched strata that either overlie (left) or are structurally part of the axial strata of the fold have two similar relations near the Riddle Creek, Dry Hollow, and North Canyon diapiric folds. I interpret these arched strata near all these folds to mean that formerly near-horizontal strata were bowed up as a result of the upward movement of the underlying dip-slip folds. Formation, dated at 32–33 m.y. (Ollogene) are involved in the arching, the impace intensity is strong that the diapiric folds were raised at some time during or after Ollogene time. If so, it seems unreasonable to attribute the folds to eastward-directed thrusting stemming from the Sevier orogeny (Sandlsee, 1982), which apparently ended in late Lateocene time.

Near Smith Reservoir (where the Rjark Canyon joins Lake Fork), the fold passes northeastward into a northeast—trending graben, the Dairy Fork graben of Njorh (1972, p. 79), that is collinear with the fold. Probably, the graben represents collapse of the axial part of the Little Clear Creek fold as a result of salt dissolution (cross section B-C).

Fairview dip-slip (?) fold (No. 7, fig. 3)

I propose that a major diapiric fold underlies the northern end of the east-west section of Little Creek Valley, as that part of the range extends from near Ephraim northeastward past Mount Pleasant and Fairview to the scrub nineteenth century settlement of Milburn. I call this fold the Fairview dip-slip (?) fold; the northern part of the fold referred to as the "North San Pitch River Valley diapir" by Rummin (1977, p. 76).

Whereas I recognize most diapiric folds in central Utah either by linear belts of Arapian Shale (the core of the diapiric folds) or by steeply dipping to overturned consolidated sedimentary strata (the flanks of the diapiric folds), neither of these features mark the Fairview dip-slip (?) fold. Instead its presence is suggested by downsloping strata that form the Wasatch monocline.

Elsewhere in this sector of the Colorado Plateau, late Tertiary and Quaternary strata are tilted with the fold point at the Wasatch monocline forming a structural structural framework of the plateau and range. It seems reasonable to conclude that the Wasatch Plateau was also shaped and influenced to some extent by faulting. All the major diapiric folds of the range are truncated at the northern boundary of the range. North Horn beds dip northwardly to the range crest; the beds at the range crest are in turn truncated at the southern boundary of the range. At this point the Wasatch Plateau is at least at present levels of exposure, failed by flexure rather than by faulting. Seemingly, the linearity and northeast trend of the monocline reflect movement along a causative fault. Although some of the
1,100 m (3,600 ft) of relief between the plateau crest and the floor of Sumpsite Valley must be the result of warping as a result of movement on this fault, I believe that some offset was due to subsidence as a result of gradual salivation or collapse.

Presumably, movement along this causative fault opened a conduit for the confined and compressed salt, which in its upward rise forced up the overlying strata and effectually obliterating the fault plane. The end result was a compound diapir whose length and trend reflected, to some extent, the length and trend of the causative fault. Elsewhere, my colleagues W. E. Page and I have proposed (1984) that some of the warpage that marks the Wasatch monocline is the result of subsidence stemming from the progressive dissolution of salt from that compound diapir. Removal of the salt caused the underlying strata to subside slowly into the developing void and thus steepen the monocline.

The Wasatch monocline extends northeastward from Saline Canyon to its end near the northern end of the Wasatch Plateau. Near Indianola, however, the downwarped strata are flanked up and become part of the west flank of the Little Clear Creek diapirc fold. Between the north end of the Fairview diapirc(? fold, and the north end of the Oquirrh Range fold, the intervening strata are warped to form a south-plunging syncline best exposed along the south flank of Black Hawk, some 3 km (2 mi) east of Indianola.

Sumpsite-Savvier Valley diapirc fold (No. 1, fig. 3) Only the northern end of the Sumpsite-Savvier Valley diapirc fold, one of the dominant folds in central Utah, extends into the Nephite quadrangle. The fold extends about 125 km (75 mi) from near Richfield on the south to Freedom on the north. The core of the fold, expressed as a continuous belt of Arapian mudstone, extends from near Richfield to near Manti where it disappears beneath the alluvial floor of Sumpsite Valley. Oil test wells in Sumpsite Valley indicate that the Arapian mudstones underlie the surface of the Sumpsite Valley fill. The typical mudstone to overturned beds that mark the east flank of the Gunison Plateau are remnants of the fold s eroded west flank indicating that in this sector, at least, the fold abuts the east edge of the Gunison Plateau.

Just as the structural pattern of the Cedar Hills has been determined by the Pole Creek fold, so also has the configuration of the Sumpsite-Savvier Valley diapirc fold been determined by three diapirc folds. The rocks that underlie the north end of the Gunison Plateau dip southeasterly, reflecting the southeastern flank of the Pole Creek fold. This southeasterly dip is lost near Freedom; from that point southward the Gunison Plateau appears as a south-plunging syncline. The synclinal aspects of the plateau stem from the intrusive action of two flanking diapircic folds: upward movement of the Carlin diapirc fold (west of the plateau) warped up the west flank of the plateau; upward movement of the Sumpsite-Savvier Valley fold (east of the plateau) warped up the east flank. The plunging aspect of the syncline is due to the upward movement of the Pole Creek fold (north of the plateau), which warped up the north end of the plateau.

West Hills diapirc(?) fold (No. 5, fig. 3) West Hills, along the west side of Juab Valley, is an elongate upwar, about 24 km (15 mi) long, that trends about N. 10° E. The fold is part of West Hills Gap (south of this quadrangle) on the north to Utah State Highway 132 on the north, where the fold passes beneath part of a thrust plate that likely is an erosional remnant of the Charleston-Nebo thrust plate. Although the

Arapian Shale is nowhere exposed in the West Hills, recent drilling by Placid Oil Company (Haward Wall No. 1, W. 1/4, NW 1/4, sec. 5, T. 14 S., R. 1 W.) penetrated about 1,120 m (3,666 ft) of Arapian Shale (D.A. Sprinkle, Placid Oil Co., oral comm., 1980). Thus, I suspect that the anticausal configuration of the West Hills is the surface expression of still another large diapirc fold.

SURFACE-WATER RESOURCES Details about the surface-water resources of the Nephite quadrangle are contained in a companion publication, U.S. Geological Survey Miscellaneous Investigations Map I-1512 (Price, 1984).

ECONOMIC DEPOSITS Materials of economic interest, in and near the Nephite quadrangle, include gypsum and salt (in the Arapian Shale), sand and gravel (chiefly in alluvial fan deposits), and building stone (chiefly from the Green River and Flagstaff Formations). In the past, small mines along the west flank of the southern Wasatch monocline produced some lead, zinc, and silver. At no time were the amounts of ore minerals mined large enough to affect the economy of the region. Large deposits of bituminous coal underlie the Wasatch Plateau; some of it is being mined today. Underground workings near Scofield and Clear Creek. Most of the coal, however, is deeply buried. A few thin coal beds crop out locally throughout the Sumpsite-Savvier Valley, but these are thin and discontinuous and of no significant economic interest. In general, the search for oil and gas has been unsuccessful, although a few hydrocarbon and carbon dioxide gas pools are within the confines of the Wasatch Plateau. Some small deposits of asphalt-impregnated strata, oil shale, and oncorite are also in the area.

Nonmetallic mineral deposits

Gypsum Extensive gypsum deposits are in the Arapian Shale. Most known commercial deposits, however, are concentrated some 65 km (40 mi) south of the Nephite quadrangle between Saline and Sigurd (fig. 2). Along the north edge of the Gunison quadrangle, small deposits of commercial gypsum are in Salt Creek (east of Nephi), and in both Pigeon and Chicken Creeks (east of Lavan). Most mined gypsum is transported by truck to commercial plants near Vernal (west of the Nephite quadrangle) or near Salt Lake City. Some gypsum, however, is trucked to several gypsum plants at Sigurd where it is fabricated into plaster board.

The Arapian Shale crops out in five places within the Nephite quadrangle: (1)—the west flank of the Gunison Plateau, (2)—Salt Creek (the north end of the Gunison Plateau), (3)—Pole Creek, (4)—North Canyon, and (5)—the Thistle Creek-Spanish Fork Canyon area. Despite this patchiness of gypsum exposures, we believe that much of the western half of the Nephite quadrangle is underlain by the Arapian.

The extensive exposures of the Arapian along the west and north flanks of the Gunison Plateau, part of the diapirc cores of the Lavan and Pole Creek folds, are the only exposures that contain commercial deposits of gypsum. Most of these deposits appear as disconnected pods and sheets. In both Pigeon and Chicken Creeks, the gypsum pods and lenses appear to have been intruded into the thinly bedded Twin Creek Limestone. Only a few of these intrusive lenses and pods are in Pigeon Creek; by contrast, many are in Chicken Creek, and these have been mined extensively in the past.

Most outcrops of the Arapian Shale contain minor amounts of gypsum, chiefly as small knobs and lenses. The gypsum is light gray to white, and
commonly weathers as grayish, granular knobs that stand out above the surface of the surrounding mudstones of the Arapieem Shale. These small, scattered occurrences may be misleading, for extreme irregularity of thickness, width, and location is characteristic of many gypsum deposits. What may appear as a thin pod of gypsum on the outcrop may thicken and widen rapidly in the subsurface to become significant. In general, we estimate that the range in thickness of gypsum lenses is from about 15 to almost 105 m (50 to 350 ft). In like fashion, the width and length are also highly irregular; we estimate that some lenses are as much as 305 m (1,000 ft) wide, and about 210 m (700 ft) long.

Salt

Little rock salt (halite) is exposed at the surface, although drill data indicate that much salt probably underlies the Sanpete–Sevier Valley area. Likely much salt has been removed from the area. The names by early settlers to many of the geographic features bespeak the presence of salt, for example, Salt Creek, Little Salt Creek, Salt Spring Creek, Salina. Salt occurs within the Arapieem Shale, mined from near-surface deposits near Redmond (about 80 km (50 mi) south of Nephi) (fig. 2). The salt appears as near-vertical, much-contorted beds interlaced with reddish-brown mudstones. The salt, commonly reddish brown as a result of a thin film of red clay, is used chiefly for livestock and along highways during winter months.

In the Nephi quadrangle, salt was once mined through underground workings from a salt bed in the Arapieem Shale exposed in Salt Spring Creek, a tributary to Salt Creek. The mined salt was then transported some 8 km (3 mi) southward to a small processing plant near the junction of the Mt. Nebo Scenic Loop Road with Utah State Highway 132. The mine is now abandoned, the adits closed, and only remnants of the former plant remain at the KOA campground, some 8 km (5 mi) east of Nephi.

The salt is extremely mobile and plastic. Chevron Oil Company was forced to abandon their Chrise Canyon well before reaching the reservoir rock because of salt continually creeping casing of the well (L.A. Standlee, Chevron Oil Co., oral comm., 1982).

Sand and gravel

Vast amounts of sand and gravel are exposed in the Nephi quadrangle, chiefly along the base of the southern Wasatch Mountains and the Wasatch and Guadalupe Plateaus. Most of the material was deposited as broad, low alluvial fans that coalesced to form extensive aprons. These large alluvial fans partly fill broad valleys. Gravel pits have been opened in the various deposits with most sand and gravel produced used extensively for both highway and building construction.

The deposits are crudely sorted and commonly contain cobbles, boulders, and much mudstone. The chief salt or mudstone, containing much of the material must be crushed, sized, and purified before it is suitable for use. In places, discontinuous lenses of salt interleaved in the sand and gravel deposits are also exposed. Details on the sand and gravel deposits throughout much of the Nephi quadrangle are available from the Materials and Research Division of the Utah Transportation Department.

Building stone

Although several formations within the quadrangle contain sedimentary units suitable for use as building stone, the lithologic unit most favored by the local inhabitants is the light-tan to ivory, locally foliated limestone contained within the upper limestone unit of the Green River Formation. This limestone is an excellent dimension stone, is easily quarried and worked, and is generally free of closely spaced fractures. Many of the older homes and storage houses in the area, built by the early settlers, are constructed of this attractive limestone. The rock has also been used for monuments, curbstones, and flagstones, for it stands up well in the dry climate of central Utah.

Other lithologic units that have been used locally as building stone include sandstone from the Cretaceous Dakota Formation and welded tuff from the Horion Formation. These units are either not as pleasing or not as durable as the stones from the Green River Formation.

Near Birdseye, in the Thistle area (fig. 3), beds of the Flagstaff Limestone unusually rich in oolites (small, rounded concretions) have been quarried for buildings. The local limestone is a "cemented marble", is a light-gray to light-tan attractive rock commonly used as facing for fireplaces and other interior trim. The abandoned Birdseye Quarry is atop a high ridge in the NE 1/4, sec. 30, T. 10 S., R. 4 E., about 2.5 km (1 1/2 mi) east of Birdseye.

Mineral fuels

Coal

Of the six coal fields in and near the Price 1st x 2nd quadrangle (the Wasatch Plateau, Book Cliffs, Salina Canyon, Mount Pleasant, Wales, and Sterling fields), only the Book Cliffs and Salina fields are beyond the boundaries of the Nephi quadrangle. Of these fields or parts of fields within the quadrangle, only the Wasatch Plateau field contains large deposits of coal that are economically significant at present, but many of these deposits, although large, are deeply buried (Spiker, 1931; Doelling, 1972a, 1972b).

Seams and beds of bituminous coal crop out west of the Wasatch Plateau— in the Idaho salt basins, in the Mount Pleasant and adjoining fields of the Wasatch Plateau. These beds, however, are just beginning to be explored. Of these beds, most of these beds are thin, discontinuous, and of poor quality. These beds were mined until the thicker, higher quality, and more continuous beds that are exposed along the eastern edge of the Wasatch Plateau were worked.

Data from test holes drilled by the U.S. Bureau of Mines, however, indicate that at least three mineable coal beds, ranging from 1 to 7 m (4 to 6 ft) in thickness, are in the subsurface in the Mount Pleasant area at depths between 280 m (955 ft) and 350 m (1150 ft) (Doelling, 1972b, p. 30).

Coal in the Nephi quadrangle is contained chiefly within five units of Tertiary and Cretaceous age: the North Horn, Blackhawk, and South Flats (probably correlative with the Blackhawk) Formations, the Shoshone Formation of the Independence Group, and the Perton Sandstone Member of the Wasatch Formation. Of these, only the Green River m (25 ft) coal beds that are either exposed or are buried beneath an overburden of 305 m (1,000 ft) or less.

In the North Horn Formation, a thin bed of dark-gray to brownish-gray lignite crops out in secs. 7 and 8, T. 13 S., R. 5 E. in Dry Creek Canyon, east of Milburn (Pratt and Callaghan, 1970, p. 59). The named lignite was formerly used as a fuel by turkey farmers and used as a soil amendment. Principal coal reserves in the combined Salina Canyon, Mount Pleasant, Wales, and Sterling fields are about 350 million short tons (Doelling, 1972a, p. 88). Yet the reserves in the Wasatch Plateau coal field probably are

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greater than this, and the presence of rich coal beds that crop out either along the east flanks of the Wasatch Plateau, or underlie the Plateau, has led to tentative plans for the construction of a series of coal-fired power plants in the Bear River quadrangle, Wasatch Plateau, and three for areas west of the Plateau (Nicklin, 1979). The Intermountain Power Plant, now under construction near Labyrinth (west of the Green River Basin), is one of these; the Piney Lake Limestone, member of the Nyecliff, and the "Coochern Sandstone" (probably the Cedar Mesa Sandstone of the Curlew Formation), and the "Coochern Sandstone" (probably the Cedar Mesa Sandstone of the Curlew Formation). Significantly, these beds have served as good reservoir rocks mainly because they are strongly fractured, and apparently not because of high primary porosity. Now severally a unit has been fractured may determine its suitability as a reservoir rock.

Oil and gas

In the past decade, central Utah has been the scene of an intensive search for oil and gas. Seismic surveys have traversed the area repeatedly; new surveys are launched even as previous ones end. Many wells have been drilled to test geologic concepts, favorable structures, and sedimentary units. As of late 1964, the search in the Sanpete-Sevier Valley area, on the whole, has been unsuccessful. Most test wells were either dry or had too little of the oil or gas to make them commercially attractive to the area of the Wasatch Plateau and carbon dioxide gases. Although some petroleum company geologists are interested in the area, they have shifted their attention elsewhere, other companies are undeterred and apparently believe that the area has a strong potential for oil and gas.

Source rocks.

Possible source rocks for oil and gas include the Bancroft Shale of Late Devonian age, the Shafter Formation (Pennsylvanian age), and the Arapahoe Shale of Middle Jurassic age.

Three exploratory wells drilled near Moroni in Sanpete Valley penetrated the entire thickness of the Bancroft Shale, composed chiefly of black, marine, sedimentary rocks. The easternmost test well, Hanson Oil Corporation's well No. 1 A-X Moroni (SE 1/4, NW 1/4, sec. 14, T. 15 S., R. 3 E.) cut about 2,135 m (7,000 ft) of the Bancroft Shale. About 2.4 km (1.5 mi) to the west, the Tennessee Gas Pipeline's well No. 1 J. W. Irons well No. 1 (C, SE 1/4, SE 1/4, sec. 16, T. 15 S., R. 3 E.) penetrated about 1,700 m (5,500 ft) of Bancroft which also cut the Bancroft Shale. The westernmost well, the Phillips Petroleum Company's well No. 1 Price-N (SE 1/4, SE 1/4, sec. 29, T. 15 S., R. 3 E.) cut only about 610 m (2,000 ft) of Bancroft Shale. Seemingly, the Bancroft Shale thins markedly westward, implying a shoaling of the Bancroft sea near the east edge of the Gunnison Plateau. How much of the Neph quadrant is underlain by the Bancroft is uncertain; we suspect that it underlies most of the Wasatch Plateau and Sanpete Valley, at the very least (cross section A-A').

The Wasatch Plateau is another black, marine, sedimentary unit that may underlie the area at depth. This shale, like the Bancroft, is rich in an oil-source rock. Recently Kirkland and Evans (1981) suggested that calcareous mudstones deposited in highly saline, marine evaporitic basins may be rich source rocks. Considerable uncertainty exists, however, about the suitability of the Arapahoe Shale as a source rock for oil and gas because of its apparent low content of total organic carbon (R. J. Coale, Forest Oil Company, oral commun., 1962).
medium- to coarse-grained sandstone beds, although some limestone beds are also impregnated (Pinell, 1972, p. 120). The oil is thick and viscous, and is perhaps best described as "asphalt-like". Seemingly, the intensity of the oil is greatest on the surfaces of the oil-impregnated rocks. Those rocks that are strongly saturated are dark gray to black; those less so are light gray to gray. The oil-impregnated material generally forms an ill-defined zone, about 6 to 9 m (10 to 20 ft) thick, that is traceable laterally for hundreds of meters.

Oosorite

Oosorite is a brown to black, parasitic-like mineral that is used in insulation and polishes. After conversion to ceresin (a white wax resulting from the bleaching of oosorite) and added, as an extender, to asphalt, it has been used as a waterproof sealant. One of the larger oosorite zones in the United States is in the Soldier Summit area. The zone, about 19 km (12 mi) long, and 2 to 6 km (1 to 4 mi) wide (Robinson, 1917, p. 76-77), extends from near Colton on the east to Tucker on the west (on T. 10 and 11 S., Rs. 7 and 8 E.). One deposit in this zone, about 1 km (1/2 mi) east of Colton, has been mined intermittently for years. The oil-impregnated oosorite deposits occur as a series of small veins that fill fissures that strike about W. 10° W. and that dip steeply southwest (Casshon, 1964, p. 66; Henderson, 1964, p. 166). No veins are greater than 1 m (3 ft) wide, all are discontinuous and irregular in length. Stratigraphically, the veins are in a transition zone that includes the uppermost beds of the Colton Formation and the lowermost beds of the Green River Formation. The origin of the oosorite is uncertain; it is probably related to emissions from petroleum.

Oil shale

Although oil shale is in the Soldier Summit area, it is economically unimportant and far less significant than the much richer oil shale that crops out farther south, in the Uinta Basin to the west of the Soldier Summit area. Shale zones are recognized by Henderson (1958): an upper zone that consists of light-brown, paper-thin shale, and a lower zone that contains massive beds of dark-gray, thin shale. Bruce Bryant (U.S. Geol. Survey, oral commun., 1985), as a result of his geographic mapping north of this quadrangle, recognizes a third, middle zone some 1200 ft (400 m) below the upper zone, and correlates this middle zone with the well-known Hohengany zone of eastern Utah and western Colorado. None of the zones exposed in this quadrangle contain oil shale that could be characterized as rich. Details about the oil shales in the Soldier Summit area are in Henderson (1958), and Prescott (1956).

Winchester (1916, p. 141), considering oil shale exposures along the west flank of the Gunnison Plateau, commented "Before petroleum was discovered in Pennsylvania, the oil from shale near us, where the ruins of an old still can yet be seen." Subsequently, he cited (1923, p. 114) a partial measured section of Green River strata that contained several thin (0.2 to 0.3 ft) oil shale beds at the "south end of town," oil in Coal Canyon, southeast of Juab, Utah. This locality, some 8 km (5 mi) southeast of Levan, is now spelled Chrisn (pronounced Chris'n), and is south of this quadrangle near the north edge of the Manti (11000) sheet. Crawford (1941) has described an old retort that had been constructed at the site noted by Winchester. Apparently much of the oil shale mined came from an old nearby shaft that has since collapsed.

Uraniferous deposits

Small uranium prospects and an abandoned uranium mine are in a complex deformed area along the southwest flank of Mount Hebo. The area reportedly has produced some uranium ore (Robert Steele, Nephi, Utah, oral commun., 1984), and disseminated, secondary, yellow uranium-vanadium minerals, chiefly tyuyamunite(?) mark some outcrops. Blush-green secondary copper minerals (malachite) appear to be associated with the uranium minerals. The area, known as the "Steele Uranium Property", is about 6 km (4 mi) northeast of Nephi, and occupies parts of sec. 15 and 22 of T. 12 S., R. 1 E., (unsurveyed). Best exposures are high above the stream floor along the uppermost part of the south valley wall of Birch Creek, and are readily reached via an unimproved road that extends northward from Gardner Creek. The area has been drilled repeatedly by various companies in an attempt to locate significant ore bodies; all drilling has been fruitless. As far as can be determined the area has no measurable ore reserves. Most of the uranium mining has been confined to eolitic limestone beds of the Slide rock Member of the Twin Creek Limestone that appear to have been modified by hydrothermal solutions.

Metallic mineral deposits

A series of small mines, abandoned for decades but that once produced small amounts of lead, zinc, and silver, are scattered along the west flank of the southern Wasatch Mountains, chiefly near the mouths of benches, Bear, and North Canyons. Most mines, clustered some 6 to 11 km (4 to 7 mi) east and northeast of Mona, are grouped within the Mt. Hebo mining district. Over the years, much money has been invested in the search for ore deposits in the mountains, but the ore mined has never approached the amount invested (Phillips, 1940, p. 6-7). The value of ore production has been less than $400,000 (Bullock, 1962, p. 88). The ore bodies that have been found are small, discontinuous, generally of low metal content, and are at or near the surface.

Phillips (1940) undertook a detailed study of the Mt. Hebo mining district and concluded that a close relaation exists between a series of lamprophyre dikes and the ore minerals. Seemingly, the dikes and the mineralizing solutions used the same fissures, with the dikes being emplaced first, followed shortly after by the mineralizing solutions. Major ore minerals are galena, sphalerite, and cinnabar. Minute amounts of gold and silver were also found in the galena. The richest deposits are rather as replacements of bedded Mississippian limestone, or as fissure fillings. Small amounts of copper, of no economic significance, appear to be related to a Cambrian diabase lava flow (Cdf) intercalated in the Tintic Quartzite. Tintic beds directly above the flow contain minute amounts of chalcopyrite, anarite, and malachite. Some chalcopyrite and pyrite are disseminated through the flow. On the basis of the ore deposits found so far, we suspect that any new ore bodies found will be small, of low to moderate metal content, and likely confined to Mississippian limestone. Deposits above and their metal content are included in Bullock (1962) and Phillips (1940).
REFERENCES

Numbered references are keyed to the "Sources of geologic data" index map


Billings, M., 1933, Thrusting younger rocks over older: American Journal of Science (Fifth Series), v. 25, no. 146, p. 140-165.


29. Johnson, R. S., 1959, Structure and stratigraphy of the Mount Nebo-Salt Creek area, southern Wasatch Mountains, Utah: Brigham Young University Geology Studies, v. 6, no. 6, 49 p.


37. Pashley, E. F., Jr., 1956, Geology of the western slope of the Wasatch Plateau between Spring City and Fairview, Utah: Columbus, Ohio, Ohio State University, M.S. thesis, 115 p.


Shuey, R. T., 1969, Ground magnetic survey of the Fountain Green-Morral area, Sanpete County, Utah; Utah Geological and Mineralogical Survey Map 28.


Taylor, D. A., 1948, Geology of the Gumison Plateau front in the vicinity of Wais, Utah; Columbus, Ohio, Ohio State University, M. S. thesis.
Preliminary geologic map of the Nephi 30' x 60' quadrangle, Carbon, Emery, Juab, Sanpete, Utah, and Wasatch Counties, Utah

by

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Part II—Description of map units

Open-file Report 85-466

This map is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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SURFICIAL DEPOSITS

Qcl ALLUVIUM (HOLOCENE)—Dark-brown to gray, thin-to thick-bedded, locally massive, crossbedded in places. Unconsolidated. Consists of clay, silt, sand, granules, pebbles, and sparse cobbles of fluvial origin. Deposits form narrow to broad, even surfaces of low relief. As mapped, unit locally includes higher patches of "older alluvium" of Pleistocene age. Thickness ranges widely, generally less than 15 m (50 ft) thick

Qcl COLLUVIUM (HOLOCENE)—Brown to dark-brown, heterogeneous, unsorted mixture of fragments of many sizes that locally mantles lower valley walls and accumulates at the base of some steep cliffs. Unconsolidated to semiconsolidated debris. Thickness ranges from a few centimeters (one inch) to as much as 15 m (50 ft)

Qd DUNE SAND (QUATERNARY)—Light-brown, unconsolidated, loose quartzose sand of eolian origin. Forms low mounds and ridges. Surface is bare to sparsely covered by vegetation. Thickness ranges from 0 to as much as 10 m (35 ft)

Qf ALLUVIAL-FAN DEPOSIT (HOLOCENE)—Light-brown to brown, locally gray, unconsolidated to semiconsolidated, moderately well-sorted silt, sand, granules, pebbles, and cobbles at stream mouths. Of fluvial origin. Deposit commonly is lobate. Thickness uncertain, probably as much as 15 m (50 ft) locally

Qcf COALESCED ALLUVIAL-FAN DEPOSIT (HOLOCENE)—Brown to dark-brown or gray, thin- to thick-bedded, commonly crossbedded, unconsolidated to semiconsolidated sediments of fluvial origin. Unit consists of silt, sand, granules, pebbles, cobbles, and sparse boulders. Formed as a result of the overlapping and interfingering of adjacent alluvial fans; forms broad, low, sloping aprons at the feet of adjacent highlands. Thickness uncertain

Qff VALLEY-FILL DEPOSIT (HOLOCENE)—Light-brown to brown, unconsolidated, interbedded clay, silt, sand, and gravel. Lithologies reflect rocks exposed on adjacent hills. Thickness ranges from 0 to as much as 8 m (25 ft) near center of deposit

Qs GRAVEL DEPOSIT (QUATERNARY)—Light-brown, unconsolidated to semiconsolidated, thin- to thick-bedded, moderately well-sorted clay, silt, sand, and gravel. May be related to deposits formed during the Bonneville lake cycle

Qe SILT DEPOSIT (QUATERNARY)—Light-brown to tan unconsolidated silt, sandy, and some clay that is locally interbedded with pebble gravel. Contains some ripple marks. Thickness uncertain; possibly as much as 8 m (25 ft) thick. Probably related to lacustrine deposits of the Bonneville lake cycle.
SLOPE WASH DEPOSIT (HOLOCENE) — Light- to dark-gray, unconsolidated to weakly cemented, thin- to thick-bedded, faintly crossbedded detritus of fluvial origin. Consists of clay, silt, sand, granules, and some pebbles. Forms broad, gently sloping sheets. Thickness ranges from a thin film to as much as 8 m (25 ft).

TERRACE DEPOSIT (QUATERNARY) — Light- to dark-brown, unconsolidated to semiconsolidated, thin- to medium-bedded, crossbedded, river terrace deposits of silt, sand, granules, pebbles, cobbles, and a few boulders. Clasts—chiefly siltstone, sandstone, and limestone—are derived mainly from formations exposed in adjacent uplands. Forms narrow, sloping benches adjacent to major rivers and tributaries. Thickness ranges from about 3 to 6 m (10 to 20 ft).

TUFA DEPOSIT (QUATERNARY) — Light-gray to light-tan, low, rounded, mound of calcium carbonate. Consists of thin, soft, cellular, porous layers. Deposit encircles spring that formed along a major high-angle normal fault that extends along the east front of the Gunnison Plateau.

BOULDER DEPOSIT (QUATERNARY) — Light-gray to brown, unconsolidated and unsorted chaotic debris of angular boulders on steep slopes. Deposits are hummocky and locally lobate. Ranges in thickness from a few meters to as much as 45 m (10 to 150 ft).

EARTHFLOW DEPOSIT (QUATERNARY) — Brown to dark-brown, unconsolidated to semiconsolidated sand, granules, pebbles, cobbles, and boulders in an unsorted matrix of clay and silt. Consists of masses of debris that flowed downslope to form elongate, hummocky, lobate landforms. Thickness varies widely; probably as much as 45 m (150 ft) thick locally.

LANDSLIDE DEPOSIT (QUATERNARY) — Brown to dark-brown and gray, heterogeneous mixture of fragments of diverse size and shape. Forms irregular to lobate masses of bedrock that have slid downslope to form chaotic, hummocky accumulations of rubble. Some deposits form concentric ridges. Thickness varies widely; may be as much as 45 m (150 ft) thick locally.

MASS-WASTING DEPOSIT (QUATERNARY) — Brown to dark-brown, heterogeneous masses of mixed country rock of diverse size and shape that have slid downslope repeatedly as both small slumps and large debris flows. Locally includes small and large earthflows. Thickness varies widely; probably does not exceed 61 m (200 ft).

GLACIAL DEPOSIT (PLEISTOCENE) — Brown to dark-brown masses of unsorted, unconsolidated to semiconsolidated morainal rubble of glacial origin. Fragments range in size from clay to boulders. Characterized by lobate outlines and knob-and-kettle topography. Some deposits, here mapped as mass-wasting deposits (Qw), may have been water-saturated till that flowed downslope. Thickness as much as 61 m (200 ft).

GLISER ALLUVIUM (QUATERNARY) — Much like alluvium (Qa) in color, bedding, and composition. Forms small, discrete, rounded to irregular masses of fluvial origin generally exposed 15 to 45 m (50 to 150 ft) above adjacent valley floors. Thickness varies greatly, ranging from about 3 to 10 m (10 to 200 ft).

LANDSLIDE DEPOSIT OF BLOCKS OF GREEN RIVER FORMATION (QUATERNARY) — Coherent blocks and detritus of the Green River Formation (Tg) that have slid into their present position along a westward-sloping glide plane. The blocks have rotated and been tilted somewhat in their downward movement and now discordantly overlie the country rocks.

DEPOSITS OF THE BONNEVILLE LAKE CYCLE

NEAR-SHORE DEPOSITS OF THE BONNEVILLE LAKE CYCLE (PLEISTOCENE) — Light-gray to gray, moderately well-sorted, even-bedded deposits of crossbedded silt, sand, gravel, and sparse cobbles. Chiefly of deltaic origin. Thickness uncertain; may be as much as 76 m (250 ft) thick.


UNDIFFERENTIATED SURFICIAL DEPOSITS OF THE BONNEVILLE LAKE CYCLE (PLEISTOCENE) — Includes generally well-sorted, even-bedded deposits that form terraces, spits, and bars along the shoreline of former Lake Bonneville. Thickness varies widely; locally as much as 23 m (75 ft) thick.

QUATERNARY AND TERTIARY DEPOSITS

COALESCED ALLUVIAL FAN DEPOSITS (HOLOCENE TO PLEISTOCENE) — Brown to dark-brown or gray, unconsolidated to semiconsolidated, thin- to thick-bedded, commonly crossbedded sediments of fluvial origin. Deposits consist of silt, sand, granules, pebbles, cobbles, and sparse boulders. Formed by the overlapping and interfinger
ing of adjacent alluvial fans; forms broad, low, sloping apron at foot of adjacent highlands. Includes Sevier River Formation of "late Pliocene or early Pleistocene" age (Young and Carpenter, 1965, p. 20). Thickness uncertain; possibly as much as 30 m (100 ft) locally.

VALLEY-FILL DEPOSIT (HOLOCENE TO PLEISTOCENE) — Light-brown to brown silt, sand, and gravel deposit that forms major valleys. Essentially an interbedded mixture of alluvium and colluvium. Thickness uncertain; possibly as much as 30 m (100 ft) locally.
FEDIMENT MANTLE (HOLOCENE TO PLEISTOCENE)—Light-brown to brown, gray, or locally reddish-brown, unconsolidated to well cemented, massive to crudely bedded sediments of fluvial origin. Consists of a poorly bedded mixture of silt, sand, granules, pebbles, cobbles, and boulders derived from adjacent uplands. Surfaces are even and slope gently away from the uplands, but are somewhat deformed locally in the valleys of the San Pitch and Saviors Rivers. Ranges in thickness from about 3 m to more than 45 m (10 to 150 ft). Includes deposits mapped by Spiker (1949, p. 38) as the Anteil Formation, which he suggests is "probably of late Tertiary" age.

DIAPHRAGM INTRUSIONS

T(Ja) INTRUSIVE MASSES OF THE ARAPIEN SHALE (QUATERNARY TO MIDDLE JURASSIC)—Carbonate mudstone; thin to medium bedded; even-bedded, locally amorphous; generally light gray marked by pale-red blebs, but in places is wholly drab gray or wholly reddish brown. Includes intercalated thin, lenticular beds and seams of yellowish-gray to light-brown siltstone and sandstone, and sparse limestone beds. Contains thick beds of rock salt (halite), gypsum, and other evaporites. Selenite crystals are abundant on many outcrops. Of marine saline-basin origin. Formation is complexly deformed and shows evidence of intense compression. Weathers to badlands topography. Thickness uncertain because of intense deformation; estimates range from about 1,220 m (4,000 ft) to as much as 3,950 m (13,000 ft) (Spiker, 1949, p. 17; Gililland, 1948, p. 30; Hardy, 1949, p. 16, 17).

Probably the salt component (and possibly other evaporites) in the Arapien Shale have been moving ever since they were deposited during the Middle Jurassic (Nitchie, 1982). Some of this movement has been a slow, almost imperceptible upwelling. At times, however, the salt seems to have surged upward rapidly, and has forced the overlying mudstones of the Arapien Shale to bow up the country rock to form elongate, narrow diapiric folds. Subsequent removal of the salt resulted in collapse of the upwarp. Such major diapiric upwellings of the salt may have occurred during the Late Cretaceous, early Palaeocene, and the late(?)(Eocene) or Miocene. A localized upward surge of the salt, probably during the Pleistocene, apparently deformed semiconsolidated sediments in the southern part of Sampite Valley. The formation, thus, has several ages: its depositional age is Middle Jurassic, but its emplacement ages have changed repeatedly. Symbol T(Ja) reflects both the depositional age (J, Jurassic), and the time of major emplacement (T, Tertiary).
COLTON FORMATION (ROCENE)

West of the Wasatch Plateau—Mostly claystone and mudstone
variegated in shades of reddish brown, light gray, or light greenish gray. Locally includes beds of yellowish-gray to yellowish-brown siltstone and channel-fill sandstone, and reddish-brown conglomerate, as well as sparse, interlayered thin beds of gray, light-gray, dense, finely crystalline limestone. Of mixed fluviatile and lacustrine origin. Volkar (1980) discussed details of the stratigraphy and petrology on the Gummison Plateau. Ranges in thickness from 100 to 260 m (325 to 850 ft)

East of the Wasatch Plateau—Chiefly reddish-brown mudstone with intercalated beds of light-brown sandstone and siltstone that thicken and thin irregularly. Locally the mudstone is variegated in shades of brown, purple, and gray. Of fluvial origin. About 457 m (1,500 ft) thick (Spikes et al., 1946, p. 139).

FLAGSTAFF LIMESTONE (ROCENE AND PALEOCENE)—Light-gray to yellowish-gray to light-brown, thin- to thick-bedded, locally massive, fine-grained, dense limestone and minor dolomite containing some algal nodules. Red to pink near subjacent red units of Jurassic age. Unit contains subordinate interbedded dark-gray, gray, and greenish-gray calcareous shale. Oncolite-rich limestone beds locally abundant (Weiss, 1965). Of lacustrine origin. Forms resistant ledges and prominent hogbacks. Ranges in thickness from zero in the central part of the Gummison Plateau to about 305 m (1000 ft) on the Wasatch Plateau.

COLTON FORMATION AND FLAGSTAFF LIMESTONE, UNDIVIDED

Units combined locally for cartographic purposes

TERTIARY AND MESOZOIC SEDIMENTARY ROCKS

NORTH HORN FORMATION (PALEOCENE AND UPPER CRETAEOUS)—Red to reddish-brown to brown mudstone, claystone, sandstone, and conglomeratic sandstone, conglomerate, all of fluvial origin, and sparse fresh-water limestone; lithologies alternate irregularly. Mudstones are thick bedded to massive; sandstones vary from thin to thick bedded, are commonly crossbedded, and are fine to medium grained. Limestone beds are thin and dense, locally arenaceous. Formation contains minor coal beds and carbonaceous seams along east flank of Gummison Plateau near Wals (south of this quadrangle). Formation is unstable and is marked by many slumps, landslides, earthflows, and other forms of mass wasting. Ranges in thickness from about 152 to 915 m (500 to 3,000 ft)

FLAGSTAFF LIMESTONE AND NORTH HORN FORMATION, UNDIVIDED

Units combined locally for cartographic purposes

MESOZOIC SEDIMENTARY ROCKS

PRICE RIVER FORMATION (UPPER CRETAEOUS)—Gray to light-gray, thin- to thick-bedded, locally massive, commonly well-cemented conglomerate, conglomeratic sandstone, and sandstone with minor shale. Coarse conglomerate beds contain well-rounded cobbles of light-brown and purple quartzite, light-gray quartz, light-gray and black chert, and sparse dark-brown limestone. Sandstones are fine to coarse grained. Of fluvial origin. Forms steep slopes and low cliffs. (On cross sections includes Castlegate Sandstone, Ec). Ranges in thickness from 0 to about 365 m (1,200 ft)

CASTLEGATE SANDBSTONE (UPPER CRETAEOUS)—Light-brown to brownish-gray, thinly to thickly bedded, locally conglomeratic, irregularly bedded, massive, fine- to coarse-grained sandstone. Locally includes some thin, dark-gray, shaly siltstone units and some beds of carbonaceous material. Of fluvial origin. Ranges in thickness from about 15 to 150 m (50 to 500 ft)

INDIANOLA GROUP, UNDIVIDED (UPPER CRETAEOUS)

Chiefly Gummison Plateau—Reddish-brown and gray, thick-bedded to massive, well-cemented conglomerate. Consists of sand, granules, pebbles, and well-rounded cobbles of white, purple, green, grayish-green, and light-brown quartzite, light-brown to light-gray chert, white quartz, and some gray to dark-brown limestone. Unit contains more carbonate clasts than Price River Formation, and less than North Horn Formation. Of fluvial (synorogenic) origin. Ranges in thickness from 30 to 4,370 m (100 to 15,000 ft)

Chiefly Cedar Hills—Divisible into four interbedded marine and nonmarine units that are essentially correlative with the following formations as exposed in Sominole Canyon along the west flank of the Wasatch Plateau (in descending order): Simile Canyon Formation (conglomerate, conglomeratic sandstone, and sandstone), Funk Valley Formation (conglomeratic sandstone and sandstone), Alvin Valley Shale, and Sampete Formation (conglomeratic sandstone and sandstone) (Jefferson, 1982).

SOUTH FLAT FORMATION OF HUNT (1950) (UPPER CRETAEOUS)—Light-brown, brown, and grayish-brown, medium-grained, quartzose sandstone beds containing intercalated conglomerate lenses and beds. Sandstone beds are even bedded and vary from thin to thick bedded. Formation locally contains discontinuous coal seams and carbonaceous material. Plant remains common. Exposures are generally limonite stained. Probably correlative with the Blackhawk Formation. As much as 870 m (2,850 ft) thick (Hunt, 1950, p. 60).
BLACKHAWK FORMATION (UPPER CRETACEOUS)—Sandstone, shaly siltstone, shale, carbonaceous shale, and coal of continental and deltaic origin. Sandstone beds are light gray, light brown, and brownish gray, and locally reddish brown, thin to medium-bedded, cross-bedded, and fine to medium-grained. Many thin to thick coal zones are in lower part; a major thick coal zone at base directly overlies Star Point Sandstone. (On cross sections includes Star Point Sandstone, Kap). Ranges in thickness from about 200 m to 305 m (700 to 1,000 ft).

STAR POINT SANDSTONE (UPPER CRETACEOUS)—Light-brown to brown, thin- to medium-bedded, fine- to medium-grained sandstone, shale, and shaly siltstone of near-shore and beach origin. Consists of three sandstone units (in descending order): Spring Canyon, Storna, and Panther Tongues. Sandstone units are separated by beds of shale and shaly siltstone. Formation ranges in thickness from about 61 to 305 m (200 to 1,000 ft); generally about 107 m (350 ft) thick.

MANCOS SHALE (UPPER CRETACEOUS)—Consists of five members throughout much of the Wasatch Plateau (in descending order): Upper part of the Blue Gate Shale Member, Emery Sandstone Member, Blue Gate Shale Member, Ferron Sandstone Member, and Tumuck Shale Member. In this quadrangle, most are concealed in the subsurface. For cartographic purposes the five members are grouped on the cross sections into three units: Upper part of the Blue Gate Member, Emery Sandstone Member, and lower part of the Mancos Shale (which includes the lower part of the Blue Gate Shale, the Ferron Sandstone, and the Tumuck Member).

Upper part of Blue Gate Member (UPPER CRETACEOUS)—Light-gray to gray, thin- to medium-bedded, even-bedded, fissile shale, shaly siltstone, and minor interbedded sandstone. Thickness uncertain; possibly as much as 245 m (800 ft) thick.

Emery Sandstone Member (UPPER CRETACEOUS)—Consists of upper and lower sandstone units separated by a middle shale unit. Member is about 90 m (285 ft) thick.

Lower part of Mancos Shale (UPPER CRETACEOUS)—Includes units of the Blue Gate Shale, Ferron Sandstone, and Tumuck Shale.

BLUE GATE SHALE MEMBER—Light-gray, bluish-gray and dark-gray, thin- to medium-bedded shale and shaly siltstone. Includes sparse discontinuous ledges of silicified shale. As much as 610 m (2,000 ft) thick.

Ferron Sandstone Member—Chiefly light-brown, thin- and even-bedded, cross-bedded, very fine to fine-grained sandstone. Locally contains many large round concretions. In places, contains a middle light-gray to dark-gray shale unit. About 50 m (160 ft) thick.

Tumuck Shale Member—Light-gray to dark-gray, thin- to medium-bedded, even-bedded shale and shaly siltstone. Ranges in thickness from 120 to 200 m (400 to 650 ft).

DAKOTA SANDSTONE (UPPER CRETACEOUS)—Tan to light-brown, thin-bedded, cross-bedded, fine-to medium-grained, quartzose sandstone. Contains thin, discontinuous, carbonaceous seams. Of beach to marginal marine and deltaic origin. Thickness ranges from 0 to 9 m (0 to 30 ft). Only in the subsurface in this quadrangle.

CEDAR MOUNTAIN FORMATION (LOWER CRETACEOUS)—Dominantly massive to thick-bedded mudstone, variegated in shades of purple, red, gray, and green. Contains sparse, interleaved, discontinuous, thin beds of conglomerate, sandstone, and fresh-water limestone. Commonly characterized by abundant light-gray rounded limestone nodules. On discussion Plateau, from Christ's Canyon northward, thin orange-red conglomerate beds in upper part grade upward to red and gray massive conglomerate beds of Indiana Group. Thickness ranges from about 18 m (60 ft) to about 427 m (1,400 ft).

TWIST GULCH FORMATION (UPPER AND MIDDLE JURASSIC)—Reddish-brown, thin- to medium-bedded, even-bedded; fine-grained, marine sandstone, shaly siltstone, and shale. Locally includes light-gray, thin, interbedded, laminated or crossbedded sandstone. North of this quadrangle, equivalent rocks are grouped with the Preus Sandstone. Thickness estimated at about 914 m (3,000 ft) (Hardy, 1952, p. 23).

ARAPAH SHALE (MIDDLE JURASSIC)—(Described above under "Diapiric intrusions").

TWIN CREEK LIMESTONE (MIDDLE JURASSIC)—Dominantly light- to dark-gray, thin- to medium-bedded, even-bedded, dense, argillaceous marine limestone. In places, intensely folded and fractured. Includes seven members (in descending order): Giraffe Creek, Leeds Creek, Waton Canyon, Boundary Ridge, Rich, Sliderock, and Gypsum Spring. All units except the Giraffe Creek are exposed in this quadrangle. Twin Creek Limestone and Arapah Shale are completely interrelated in this general area (Sprinkel, 1982). Thickness uncertain, possibly 150 to 305 m (500 to 1,000 ft).

NAVADO SANDSTONE (LOWER JURASSIC AND UPPER TRIASSIC)—Light tan and reddish-brown, thick-bedded to massive, fine- to coarse-grained, friable, quartzose sandstone. Crossbedded in large sweeping tangential festoons. Moderately well cemented by calcium carbonate and iron oxides; forms cliffs and steep slopes. In places, sandstone is light-tan with large irregular, reddish-brown nodules. Thickness ranges from 425 to 460 m (1,400 to 1,500 ft).
ANKAREH FORMATION (UPPER AND LOWER TRIASSIC)—Reddish-brown to dark-red, thick- to medium-bedded, even-bedded, shaly siltstone, and fine- to medium-grained, ripple-marked sandstone. Some sandstone units are cross-bedded. Forms gentle to moderate slopes and long strike valleys. About 425 m (1,400 ft) thick

THAYNES LIMESTONE (LOWER TRIASSIC)—Reddish-gray, thin- to medium-bedded, even-bedded limestone containing some interlayered beds of red and gray shale. Forms moderate slopes and rounded hills. Thickness about 380 m (1,250 ft)

WOODSIDE FORMATION (LOWER TRIASSIC)—Reddish-brown to dark-red, thin- to medium-bedded, even-bedded, shaly siltstone and fine-grained sandstone. Weakly cemented by iron oxide and calcium carbonate. Moderately resistant; forms valleys and gentle slopes. Thickness about 60 m (200 ft)

THAYNES LIMESTONE AND WOODSIDE FORMATION, UNDIVIDED
Units combined locally for cartographic purposes

TRIASIC STRATA, UNDIVIDED—Includes the Ankareh Formation, Thaynes Limestone, and Woodside Formation. Units combined locally for cartographic purposes

PALEozoIC SEDIMENTARY ROCKS

PARK CITY FORMATION (PERMIAN)—Light-brown to light-gray, thin- to medium-bedded, even-bedded, resistant limestone that contains nodules and thin beds of light-gray to black chert. Forms rounded hills and moderate slopes. Thickness about 215 m (700 ft)

DIAMOND CREEK SANDSTONE (PERMIAN)—Light-brown to orange-brown, thin- to medium-bedded, even-bedded, resistant sandstone. Well cemented by calcium carbonate; forms cliffs and steep slopes. About 280 m (900 ft) thick

KIRKIAN LIMESTONE (PERMIAN)—Light-gray to dark-gray, thin- to medium-bedded, even-bedded, dense limestone that contains some intraformational breccia. About 90 m (300 ft) thick

DIAMOND CREEK SANDSTONE AND KIRKIAN LIMESTONE, UNDIVIDED (PERMIAN)—Units combined locally for cartographic purposes

QUERN GROUP (PERMIAN AND PENNSYLVANIAN)—Brown, grayish-brown, and grayish-blue interbedded limestone, sandstone, and quartzite. Carbonate rocks dominate the lower part of sequence; clastic rocks the upper part. Thickness uncertain, but likely about 3,335 m (11,000 ft) (Johnson, 1959, p. 8)

MANNING CANYON SHALE (PENNSYLVANIAN AND MISSISSIPPIAN)—Dark-gray to brownish-gray shale containing interbedded lenses of brown quartzitic sandstone and bluish-gray limestone. Forms prominent strike valleys locally mantled by large sandblowes and loam earthflows. Thickness ranges from 305 to 520 m (1,000 to 1,700 ft) (Rigby and Clark, 1962, p. 21)

GREAT BLUE LIMESTONE (UPPER MISSISSIPPIAN)—Light-blue-gray to bluish-gray limestone and some shale. The limestone is chiefly thick bedded to massive and has been much fractured. About 91 m (300 ft) thick

HUMBIE FORMATION (UPPER MISSISSIPPIAN)—Light-brown to brown, thin- to medium-bedded sandstone interbedded with light-gray sandy limestone, and minor shale and dolomite. Sandstone beds are locally quartzitic. A section measured through part of the Humbie totalled about 107 m (350 ft) in the Long Ridge area (Muegg, 1951, p. 210). The formation ranges from 183 to 245 m (600 to 800 ft) in the southern Wasatch Mountains (Rigby and Clark, 1962, p. 21)

DESEET LIMESTONE (UPPER AND LOWER MISSISSIPPIAN)—Dark-bluish-gray thin-bedded limestone with abundant interlayered lenticular black chert. Chert is characteristic and is found wherever the formation is exposed. Limestone beds commonly are medium to coarsely crystalline. A few thin shale beds are near base. Includes minor interbedded dolomite. Thickness ranges from 183 to 275 m (600 to 900 ft) (Rigby and Clark, 1962, p. 19)

GARDISON FORMATION (LOWER MISSISSIPPIAN)—Dark-bluish-gray thin-bedded fossiliferous limestone containing minor interbedded dolomite. Highly fossiliferous beds are characteristic. Contains abundant black and light-gray chert as nodules and thin seams. Lower part of formation is marked by acre-covered slopes, upper part forms prominent cliffs and steep slopes. Likely Correlative with the Madison Limestone of Montana, Wyoming, and northern Utah. Ranges in thickness from 183 to 275 m (600 to 900 ft) in the southern Wasatch Mountains (Rigby and Clark, 1962, p. 19)

FITCHVILLE FORMATION (UPPER DEVONIAN)—Dark-gray to black, medium- to massive dolomite, and minor interbedded black shale. The dolomite has a fetid odor when broken, and locally is moderately fossiliferous, chiefly with horn corals but also crinoids and gastropods. Formation is about 70 m (230 ft) thick in the Long Ridge area (Brady, 1965, p. 24), but ranges from about 30 to 91 m (100 to 300 ft) in and near the southern Wasatch Mountains (Rigby and Clark, 1962, p. 19)
MISSISSIPPIAN AND DEVONIAN ROCKS, UNDIVIDED—Includes units of the Desert Limestone and Cardison Formation (Mississippian), and the Fitchville Formation (Devonian). Units combined locally for cartographic purposes.

DEVONIAN ROCKS OF UNCERTAIN CORRELATION—Probably includes units of the Playon Peak Limestone and the Victoria Quartzite.

Playon Peak Limestone—Dark-gray to gray silty to argillaceous limestone. Commonly mapped as part of the Fitchville Formation. Thickness ranges from 21 to 91 m (70 to 300 ft) (Rigby and Clark, 1962, p. 19).

Victoria Quartzite—See description below.

DEVONIAN AND ORDOVICIAN ROCKS, UNDIVIDED—Includes the Victoria Quartzite and Opoho Limestone. Units combined locally for cartographic purposes.

Victoria Quartzite (Devonian)—Light-brown quartzose sandstone with minor interbedded dolomite. About 2 m (7.0 ft) thick on Long Ridge; possibly absent from the southern Wasatch Mountains (Rigby and Clark, 1962, p. 18).


UPPER CAMBRIAN ROCKS, UNDIVIDED—Includes units of the Opex Formation and Axia Dolomite.

Opex Formation—Dark-bluish-gray dolomite that contains some cherty beds and a few oolite beds. Ranges in thickness from about 30 to 165 m (100 to 475 ft).

Axia Dolomite—Light-gray to dark-gray mottled dolomite, with minor limestone. About 27 m (90 ft) of Axia is exposed on Long Ridge. Uncertain whether Axia is exposed in the southern Wasatch Mountains (Hinze, 1962, p. 14).

MIDDLE CAMBRIAN ROCKS, UNDIVIDED—Includes units of the following formations (in descending order): Cole Canyon Dolomite, Bluebird Dolomite, Herkimer Limestone, Daggar Dolomite, and Teutonic Limestone.

Cole Canyon Dolomite—Alternating light- and dark-gray beds of dolomite that locally contain sparse, small twiggly-like roots. Ranges in thickness from 88 to 152 m (290 to 500 ft) on Long Ridge, and from 70 to 140 m (230 to 460 ft) in the southern Wasatch Mountains (Hinze, 1962, p. 13).

Bluebird Dolomite—Dark-bluish-gray dolomite characterized by white sinuous twig-like roots of dolomite ("twiggy bodies") scattered irregularly through the formation. Ranges in thickness from 30 to 52 m (100 to 170 ft) on Long Ridge, and from 30 to 58 m (100 to 190 ft) in the southern Wasatch Mountains.

Herkimer Limestone—Blush-gray limestone characterized by abundant orange-mottled siltstone. Similar in appearance to the Teutonic Limestone, but separated from that unit by the white Daggar Dolomite. Cliff forming. About 91 m (300 ft) thick on Long Ridge; ranges in thickness from 70 to 137 m (230 to 450 ft) in the southern Wasatch Mountains (Hinze, 1962, p. 12).

Daggar Dolomite—Light-gray to white, dense, thin-bedded dolomite that contrasts sharply with both the underlying and overlying darker limestone units. About 30 m (100 ft) thick.

Teutonic Limestone—Blush-gray limestone characterized by abundant orange-mottled siltstone. Ranges in thickness from about 85 to 145 m (280 to 475 ft).

OPHIR FORMATION (MIDDLE CAMBRIAN)—Pale-green to olive-green phyllitic shale. Light-gray sandstone beds are interlayered in basal part and light-brown limestone beds are common in the middle. Forms gentle slopes between cliffs and steep slopes formed on underlying Tintic Quartzite and overlying Teutonic Limestone. About 91 m (300 ft) thick on Long Ridge, and 76 m (250 ft) thick in the southern Wasatch Mountains (Hinze, 1962, p. 11).

DIFABS LAVA FLOW (CAMBRIAN)—Dark-grayish-red to purplish-gray, porphyritic, amygdaloidal diabasic lava flow. Occurs chiefly in lower part of the Tintic Quartzite. Crops out between North Creek and Dry Canyons in the southern Wasatch Mountains. Primary minerals are labradorite, augite, magnetite, and ilmenite. Locally altered to serpentine, kaolinite, sericite, calcite, and iron oxides are secondary minerals. (Bullock and Abbott, 1951, p. 119). Ranges in thickness from 6 to 27 m (20 to 90 ft) (Abbott, 1951, p. 8).

TINTIC QUARTZITE (MIDDLE CAMBRIAN)—Light-brown to orange-brown, thin- to medium-bedded, fine- to medium-grained quartzite. Grains are coated with limonite. Locally contains basal conglomerate. Forms resistant steep edges and slopes. Ranges in thickness from about 275 to 335 m (900 to 1100 ft) in the southern Wasatch Mountains (Hinze, 1962, p. 11).

TINTIC QUARTZITE AND OPHIR FORMATION, UNDIVIDED—Units combined locally for cartographic purposes.
PRECAMBRIAN METAMORPHIC ROCKS

PTc BIG COTTONWOOD FORMATION (MIDDLE PROTEROZOIC)—Maroon quartzite, arkosic sandstone, and siltstone containing interbedded green, red, brown, and yellowish-green phyllicic shales. Thickness uncertain, possibly as much as 375 m (1230 ft) thick (Nessig, 1951, p. 218).

PF2 FARMINGTON CANYON COMPLEX (EARLY PROTEROZOIC)—Dark-gray to reddish-gray fossiliferous rocks, chiefly chert, granitoid gneiss, and amphibolite, that have been intruded by dikes of pegmatite and medium- to coarse-grained granite. Thickness unknown.

EXTRUSIVE IGNEOUS ROCKS AND THEIR PRODUCTS

T11 LAGUNA SPRINGS LATTICE (OLIGOCENE)—Chiefly latitic and andesitic tuffs with interbedded volcanic ash flows, and volcanic mudflow breccias. Thickness of Laguna Springs Lattice uncertain, possibly as much as 300 m (1,000 ft) thick (Nessig, 1951, p. 119).

Main body—Tuffs are light gray to dark gray, fine to coarse grained and contain small to large fragments of sedimentary and igneous rock. Flow are dark gray and coarse, porphyritic with orthoclase, plagioclase, hornblende, and biotite as common phenocrysts. Thickness unknown. Where breccia predominates, it is mapped as a separate unit (T11f).

T11f Volcanic mudflow breccias (associated with the Laguna Springs Lattice) (OLIGOCENE)—Dark-gray to brownish-gray, locally reddish-gray, thick bedded to massive breccia consisting of a heterogeneous mixture of small to very large angular to subangular fragments of dark-gray andesites, gray latite, and some blocks of sedimentary rock enclosed in a fine-grained matrix. Weathers to rounded boulder-strewn slopes. Thickness unknown.

T1g GOLDSMITH RANCH FORMATION OF NUSSIG (1951) (OLIGOCENE)—Volcaniclastic and pyroclastic rocks including tuff, and stream-deposited conglomerate and sandstone. The main rock unit is a light-gray to light gray volcaniclastic sandstone containing rounded igneous (andesite and latite) and sedimentary (quartzite, limestone, and sandstone) clasts. Tuff is light gray to light brown and contains sparse, small igneous pebbles. Includes Sage Valley Limestone Member and a few interbedded lava flows. Sage Valley Limestone Member is light gray, crystalline, and about 30 m (100 ft) thick (Nessig, 1951, p. 98); it contains abundant plant remains. Goldens Ranch Formation intervenes with breccia associated with Laguna Springs Lattice (Nessig and Lanning, 1961, p. 126). Thickness unknown; at least 305 m (1,000 ft) thick. Likely correlates with the Moroni Formation.

TM MORONI FORMATION (OLIGOCENE)—Volcaniclastic and pyroclastic rocks, including ash-flow tuff, and stream-deposited conglomerate, and sandstone. Tuffs commonly are porous and friable, but locally include light-gray, gray, brown, light-red, and greenish-gray pyroclastic welded ash-flow tuff containing sparse rounded andesite pebbles. Phenocrysts in ash-flow units are abundant and consist of quartz, alkaline feldspar, biotite, and some plagioclase. Conglomerate beds are crudely bedded and commonly poorly sorted, and contain volcanic cobbles and pebbles, and well-rounded clasts of tan quartzite, dark-blue limestone, and sandstone. Thickness of unit ranges greatly throughout area; maximum thickness is about 610 m (2,000 ft) (Cooper, 1956, p. 21). Probably correlates with the Goldens Ranch Formation of Nussig (1951).

T1f VOLCANIC ROCKS OF UNCERTAIN CORRELATION AND AGE.—Volcaniclastic and pyroclastic rocks similar to the Goldens Ranch and the Moroni Formations in appearance, lithology, and contained clasts.

INTRUSIVE IGNEOUS ROCKS OF THE LEVAN AREA (JOHN, 1972)

Tap STERNOBORITE PORPHYRY (OLIGOCENE? TO UPPER EOCENE)?—Light greenish-gray, syenite porphyry stock near Levan. Phenocrysts (20 percent of rock) consist of plagioclase (both oligoclase-andesine) (about 8 percent), hornblende (about 1 percent), and biotite (about 1 percent). Accessory minerals are apatite, sphene, and magnetite. Groundmass includes plagioclase, orthoclase, and quartz.

Tlm MONZONITE (OLIGOCENE? TO UPPER EOCENE)?—Light-gray to gray, fine-grained, slightly porphyritic monzonite intrusion in the Levan area. Phenocrysts (10 percent of rock) consist of plagioclase (oligoclase-andesine) (about 8 percent), hornblende (about 1 percent), and biotite (about 1 percent). Accessory minerals are apatite, sphene, and magnetite. Groundmass includes plagioclase, orthoclase, and quartz.

Tap MONZONITE PORPHYRY (OLIGOCENE? TO UPPER EOCENE)?—Light-gray to gray, porphyritic dike and two small stocks of monzonite porphyry in the Levan area. Phenocrysts (32 percent of rock) consist of plagioclase (andesine) (about 20 percent), hornblende (about 10 percent), and biotite (about 2 percent). Accessory minerals consist of apatite, magnetite, sphene, and zircon. Groundmass consists of plagioclase, orthoclase, and quartz.

T1 INTRUSIVE IGNEOUS ROCKS—Small dikes, sills, stocks, and bosses of differing composition. Most are exposed near Levan and consist of intermediate-composition rocks such as diabase, monzonite, and syenodiorite (John, 1972). Includes felsite dikes and sills in the Cedar Hills (Schaff, 1951, p. 636). Also includes, elsewhere in the area, a few dark-gray to black, thin (1 to 2 m (3 to 6 ft)), porphyritic lamprophyre dikes and sills, chiefly minor in biotite, that are intruded into the sedimentary rocks (Phillips, 1962, p. 68-69; Loughlin, 1910, p. 103).
DESCRIPTION OF MAP UNITS

[Note to Readers and Editors: See accompanying technical material for "Description of map units."]