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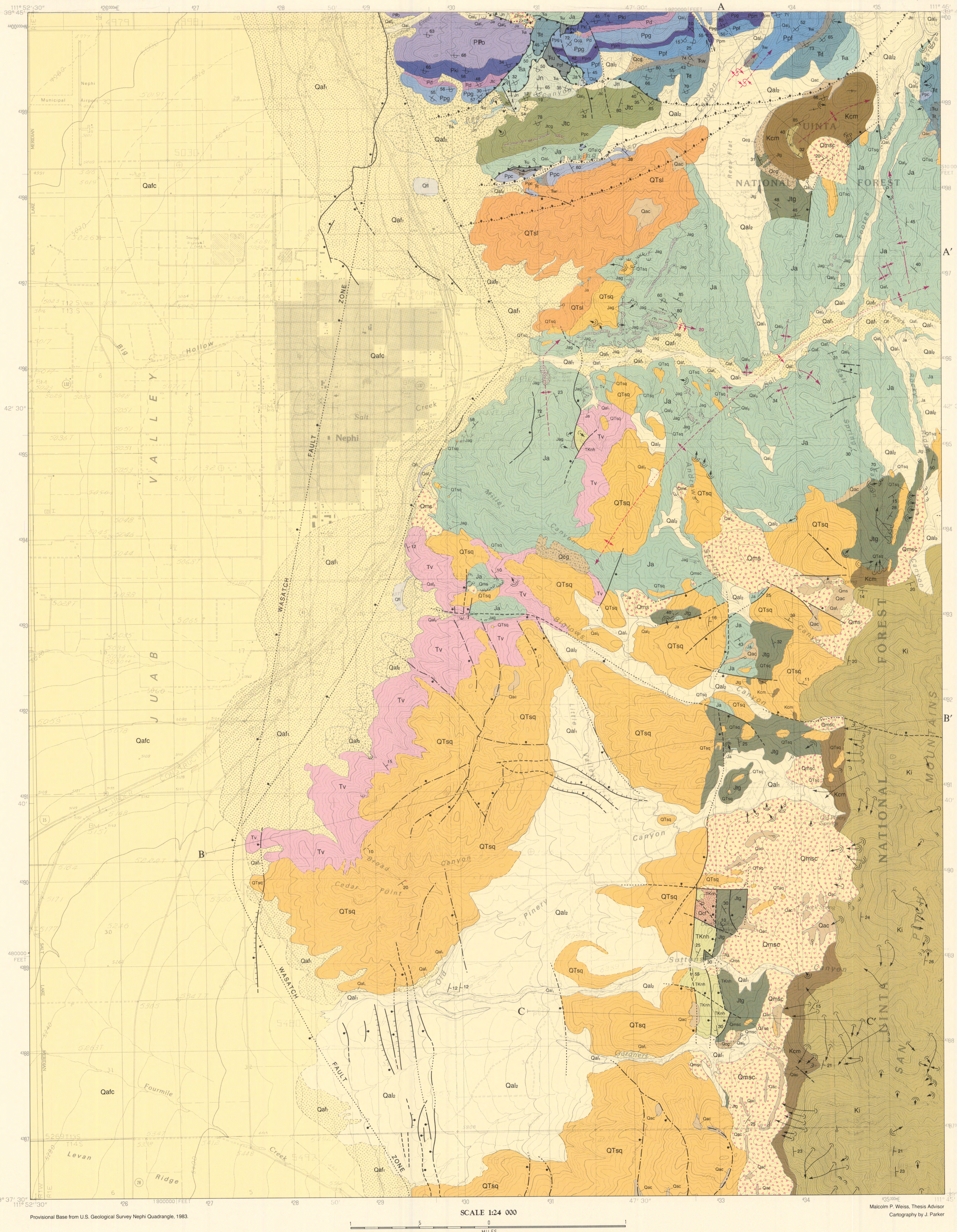


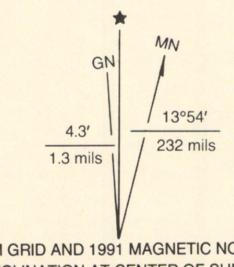
Provisional Base from U.S. Geological Survey Nephi Quadrangle, 1983.

Malcolm P. Weiss, Thesis Advisor
Cartography by J. Parker

SCALE 1:24 000

MILES: 1 .5 0 1
FEET: 1000 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10 000
KILOMETERS: 1 .5 0 1 2
METERS: 1000 0 1000 2000

CONTOUR INTERVAL 40 FEET
SUPPLEMENTAL CONTOUR INTERVAL 20 FEET



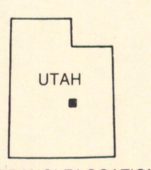
UTM GRID AND 1991 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

PROVISIONAL GEOLOGIC MAP OF THE NEPHI QUADRANGLE, JUAB COUNTY, UTAH

by

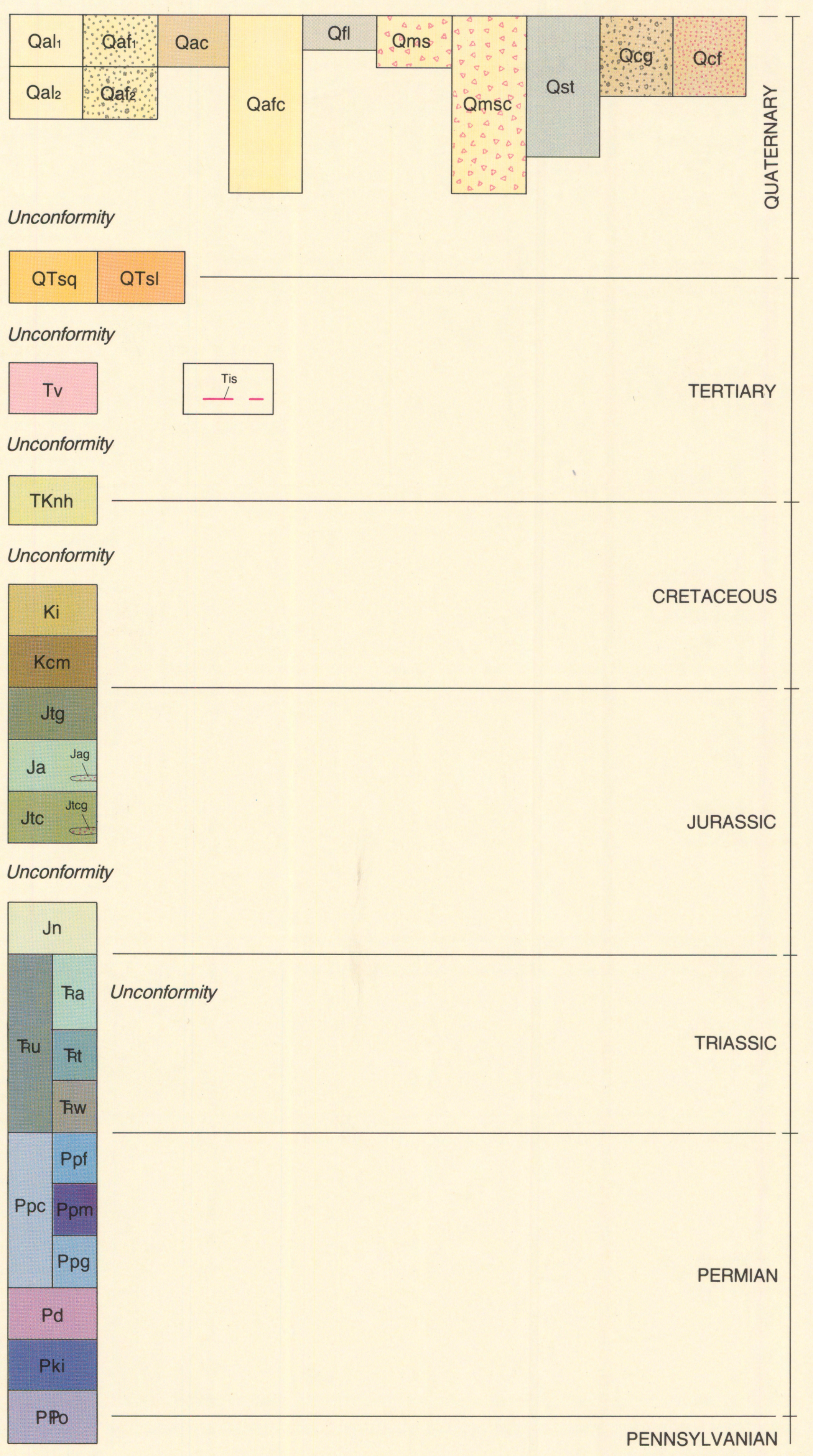
Robert F. Biek

1991



QUADRANGLE LOCATION

CORRELATION OF MAP UNITS



MAP SYMBOLS

Note: Symbols dashed where approximate, dotted where concealed.

24 Strike and dip of bedding
40 Approximate strike and dip of bedding
65 Strike and dip of overturned bedding
Spring or seep
Debris-flow scarp and path
Rotational slump scarp and path
Small mass movement
Contact
Normal fault; bar and ball on downthrown side, hachures show scarp
Normal fault inferred from air photos; may be slump scarp
Thrust fault; teeth on upper plate
High-angle reverse fault; teeth on upper plate
Strike-slip fault
Contact of ancient landslide unit
Plunging anticline
Plunging syncline
20 Overturned plunging anticline
Inverted synformal anticline
Inverted antiformal syncline

DESCRIPTION OF MAP UNITS

QUATERNARY

Qfl — Artificial deposits: *Fill used to build dams, retaining ponds, and other man-made structures.*

Qac — Slope-wash deposits: *Generally fine-grained colluvial debris modified by fluvial processes.*

Qcg — Gravelly colluvial deposits: *Coarse gravel.*

Qcf — Fine-grained colluvial deposits: *Fine-grained sand and silt derived from the Twist Gulch Formation and overlying regolith.*

Qal1 — Level-1 alluvial deposits: *Coarse-grained, poorly sorted, locally derived, gravel, sand, and silt. Often with a soil profile on surface. Up to about 50 feet (15 m) thick.*

Qal2 — Level-2 alluvial deposits: *Poorly sorted, locally derived, sand, gravel, silt, mud, and boulders. Deposits are elevated relative to active streams and are dissected by level-1 alluvial deposits. Upper surfaces of deposits are planar and slope away from mountains.*

Qst — Calcareous spring tufa: *Light to medium gray, vesicular, calcareous tufa.*

Qms — Holocene mass-movement deposits: *Very poorly sorted boulder- to clay-sized material deposited by slumps, debris flows, and avalanches. Most are on or at the base of steep slopes. Many were active in 1982 and 1983.*

Qmsc — Pleistocene mass-movement deposits: *Very poorly sorted boulder- to clay-sized material deposited primarily by slow periodic creep as toreva blocks, but also by debris flows and avalanches. Most have been dissected by streams, and surfaces have been subdued by erosion.*

Qaf1 — Level 1 alluvial-fan deposits: *Moderately to poorly sorted, locally derived material deposited at or near current base level near the mouths of canyons. Most fans are small and still actively forming.*

Qaf2 — Level 2 alluvial-fan deposits: *Moderately to poorly sorted, locally derived boulder- to clay-sized material deposited at or near the mouth of canyons. These deposits have been incised and isolated by down-cutting streams.*

Qafc — Coalesced alluvial-fan deposits: *Poorly to moderately well-sorted boulder- to clay-sized material deposited in large alluvial fans extending into Juab Valley. The material is coarser near the mountain fronts and becomes finer grained toward the center of the valley.*

QUATERNARY-TERTIARY

QTsq — Quartzite-rich unit of Salt Creek Fanglomerate; *Polymodal conglomerate, dominant quartzite with lesser limestone clasts; locally well cemented.*

QTsl — Limestone-rich unit of Salt Creek Fanglomerate: *Polymodal, polymictic conglomerate lacking quartzite clasts.*

TERTIARY

Tis — Lamprophyre sills: *Dark-green, highly altered, calcite-cemented sills, with biotite, chlorite, and minor quartz, plagioclase, magnetite, and apatite.*

Tv — Volcanic deposits: *Polymodal, polymictic, volcanic conglomerate with light-brown sandy and pebbly waterlain tuff.*

TERTIARY-CRETACEOUS

TKnh — North Horn Formation: *Light-gray to pale-red polymodal, bimictic, clast-supported, conlgomerate and orangish-red to reddish-brown mudstone and sandstone.*

CRETACEOUS

Ki — Indianola Group, undifferentiated: *Light-gray to moderate orangish-pink, polymodal, bimictic, clast-supported conglomerate. The lower portion has minor interbedded orangish-red to reddish-brown mudstone.*

Kcm — Cedar Mountain Formation: *Orangish-red to lavendar mudstone containing nodular and thinly bedded locally oncolitic limestone, layered chalcedony, gastroliths, and petrified wood; brighter orangish quartz sandstone; reddish-orange, polymodal, bimictic, clast-supported conglomerate.*

JURASSIC

Jtg — Twist Gulch Formation: *Light-brown to pale-red, mildly feldspathic siltstone, quartz sandstone, and minor gritstone.*

Ja — Arapien Shale: *Light-gray to light-greenish-gray, calcareous, locally gypsiferous, mudstone and shaley siltstone; lesser moderate-red gypsiferous and salt-bearing mudstone and siltstone.*

Jag — Gypsum beds in the Arapien Shale: *Large, continuous beds and pods of gypsum.*

Jtc — Twin Creek Limestone: *Pinkish to light-gray limestone and oolitic limestone; light- to greenish-gray calcareous silty shale, and argillaceous limestone.*

Jtcg — Gypsum beds in the Twin Creek Limestone: *Large, continuous beds and pods of massive, white gypsum.*

Jn — Navajo Sandstone: *Salmon-colored quartz sandstone, locally white; white reduction spots common.*

TRIASSIC

Ŧu — Triassic strata, undifferentiated: *Reddish mudstone and intensely fractured siltstone that may be parts of any of the Triassic formations described below.*

Ŧa — Ankareh Formation: *Variegated quartz sandstone with dark-reddish-brown clay chips and white reduction spots in the lower part; polymictic conglomerate in the middle part; variegated quartz sandstone, pebbly, polymictic, lavender to reddish-brown mudstone and siltstone, and lavender quartz sandstone in the upper part.*

Ŧt — Thaynes Limestone: *Brown-weathering, light- to greenish-gray argillaceous limestone with wavy fissility in the lower portion; light- to medium-gray limestone with interbedded sandstone and argillaceous limestone in the upper portion.*

Ŧw — Woodside Formation: *Uniform pale-red to pale-brown fine-grained quartz sandstone and siltstone.*

PERMIAN

Ppc — Park City Formation, undifferentiated: *Undifferentiated strata of either the Franson or the Grandeur Member of the Park City Formation.*

Ppf — Franson Member of the Park City Formation: *Light- to medium-gray limestone, locally with reddish-brown siltstone in the upper part.*

Ppm — Meade Peak Phosphate Shale Tongue of the Phosphoria Formation: *Bedded black chert with interbedded pale-brown-weathering medium-gray dolomite.*

Ppg — Grandeur Member of the Park City Formation: *Light- to pinkish-gray limestone and dolomitic limestone; locally sandy and crossbedded.*

Pd — Diamond Creek Sandstone: *Pale-yellow, locally pale-red calcareous quartz sandstone.*

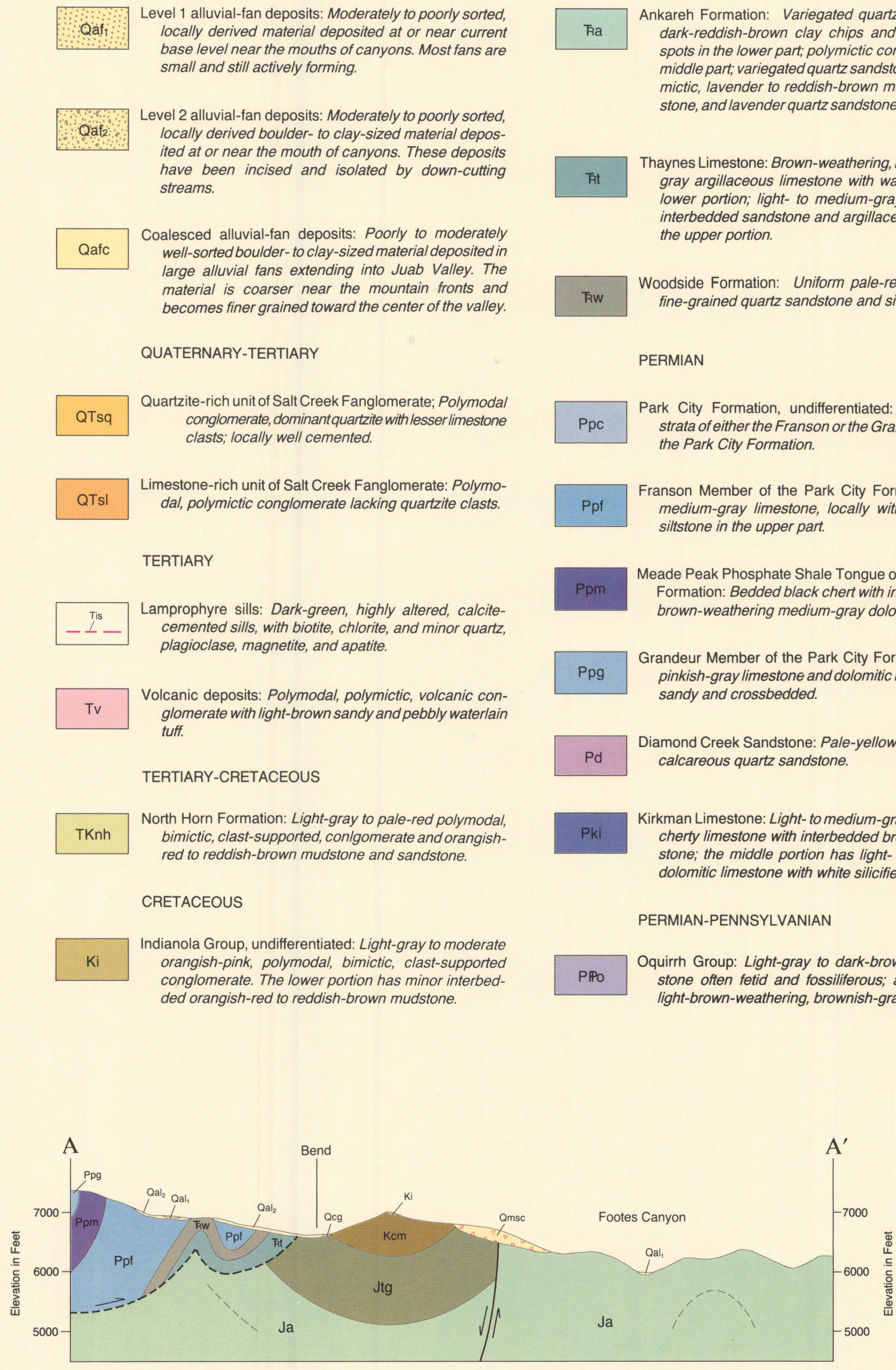
Pki — Kirkman Limestone: *Light- to medium-gray limestone and cherty limestone with interbedded brownish-gray siltstone; the middle portion has light- to medium-gray dolomitic limestone with white silicified fusilinids.*

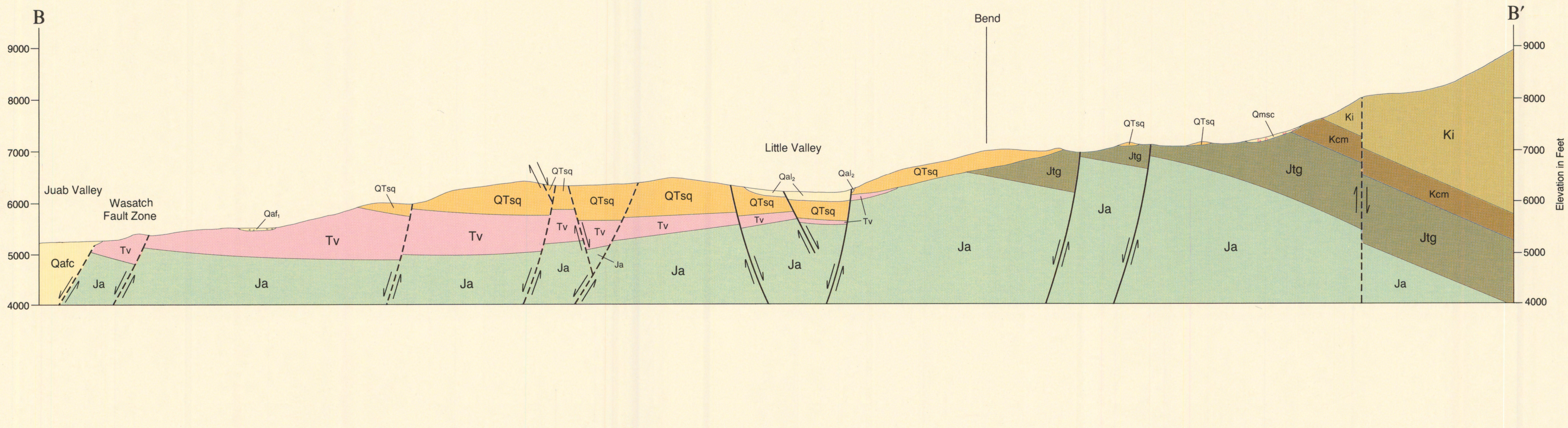
PERMIAN-PENNSYLVANIAN

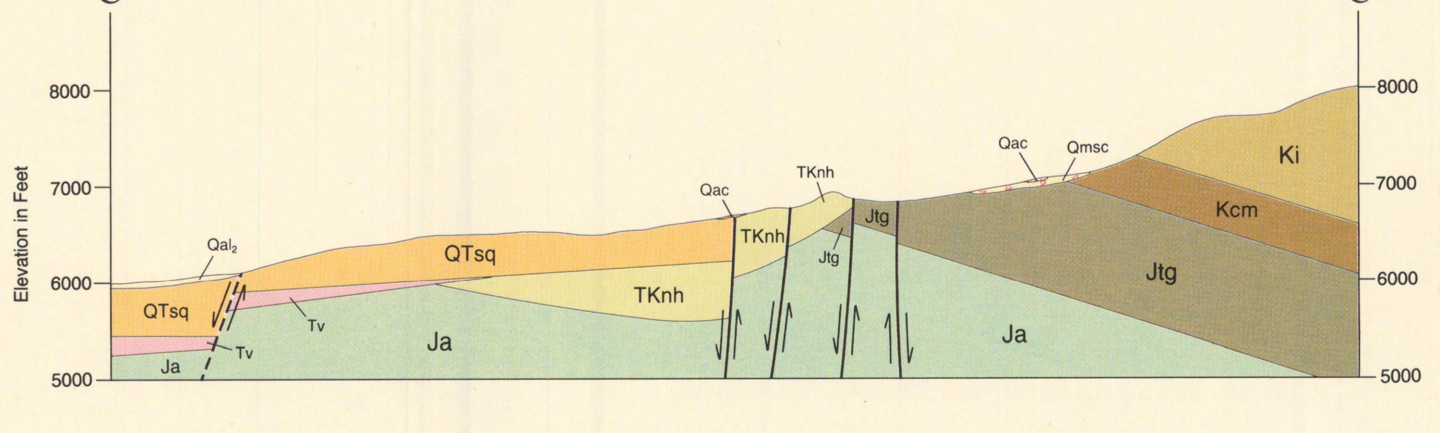
PIPo — Oquirrh Group: *Light-gray to dark-brownish-gray limestone often fetid and fossiliferous; and interbedded light-brown-weathering, brownish-gray limy siltstone.*

LITHOLOGY

SYSTEM	SERIES/STAGE	FORMATION	SYMBOL	THICKNESS Feet (Meters)	LITHOLOGY
QUATERNARY	Pleistocene-Holocene	younger unconsolidated deposits	Q	0-50+ (0-15+)	
		older unconsolidated deposits	Q	0-5200 0-1580	
TERTIARY	Mio.-Plio.	Salt Creek Fanglomerate	QTsq QTsl	0-500+ (0-150+)	
	Olig?	Tertiary Volcanics	Tv	0-500+ (0-150+)	
	Pal.	North Horn Formation	TKnh	0-600? (0-1837?)	
CRETACEOUS	Maa.				
	Cen(?)-Camp.	Indianola Group undifferentiated	Ki	7150 (2179)	
	Alb. / Apt.	Cedar Mtn. Formation	Kcm	500-680 (150-207)	
JURASSIC	Call(?)-Neo.	Twist Gulch Formation	Jtg	1200+ (366+)	
	Call.-Kimm(?)	Arapien Shale	Ja	3500-4000 (1067-1219)	
	Bath. / Baj.	Twin Creek Limestone	Jtcg Jtc	800 (245)	
	Hett-Aal.	Navajo Sandstone	Jn	1000? (305)?	
TRIASSIC	Carn.-Rhaet.	Ankareh Formation	Ŧa (Ŧu undifferentiated)	800-? (244-?)	
	Scythian	Thaynes Limestone	Ŧt (Ŧu undifferentiated)	700-800 (210-245)	
		Woodside Formation	Ŧw (Ŧu undifferentiated)	200-240 (60-73)	
PERMIAN	Guadalupian	Park City Formation: Franson Member	Ppf (Ppc undifferentiated)	650? (200)?	
		Park City Formation: Meade Peak Member	Ppm (Ppc undifferentiated)	130-150 (40-45)	
	Leonardian	Park City Formation: Grandeur Member	Ppg (Ppc undifferentiated)	650? (200)?	
		Diamond Creek Sandstone	Pd	20-300 (6-90)	
	Wolfcampian	Kirkman Limestone	Pki	300-400 (90-120)	
PENN.	Mor.	Oquirrh Group Undifferentiated	PIPo	11,500 (3505)	

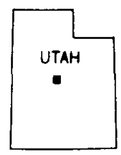






PROVISIONAL GEOLOGIC MAP OF THE NEPHI QUADRANGLE, JUAB COUNTY, UTAH

by
Robert F. Biek
Northern Illinois University



MAP 137 **1991**
UTAH GEOLOGICAL SURVEY
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R.F. Biek PROVISIONAL GEOLOGIC MAP OF THE NEPHI QUADRANGLE, JUAB COUNTY, UTAH
UGS MAP 137

PROVISIONAL GEOLOGIC MAP OF THE NEPHI QUADRANGLE, JUAB COUNTY, UTAH

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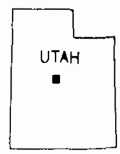
Northern Illinois University



MAP 137 **1991**
UTAH GEOLOGICAL SURVEY
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UTAH GEOLOGICAL SURVEY

2363 South Foothill Drive
Salt Lake City, Utah 84109-1491

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PROVISIONAL GEOLOGIC MAP OF THE NEPHI QUADRANGLE, JUAB COUNTY, UTAH

by
Robert F. Biek
Northern Illinois University

ABSTRACT

The Nephi quadrangle lies in central Utah in the transition zone between the Basin and Range, Middle Rocky Mountains, and Colorado Plateau physiographic provinces. Stratigraphic units range in age from Early Permian to early Holocene. They record: 1) relatively continuous Permian to Triassic sedimentation in the Cordilleran miogeocline, 2) development of the Jurassic Sevier orogenic belt in eastern Nevada and western Utah, 3) deposition of evaporite-bearing strata in a foreland basin east of this positive area, 4) Late Cretaceous Sevier orogenic activity resulting in eastward progradation of synorogenic sediments and emplacement of the Nebo allochthon, and 5) Cenozoic deposition of fluviatile volcaniclastics and normal faulting associated with basin and range extension.

The northern part of the quadrangle area consists of complexly folded and thrust-faulted rocks emplaced by the Nebo overthrust while the southern part consists of moderately dipping strata of the Gunnison Plateau. Between the two areas, complexly deformed Arapien Shale is folded into a large, doubly-plunging anticline interpreted to be a forebulge bent to the northeast during emplacement of the Nebo allochthon after late Albian time. Outcrop patterns indicate that the Nebo overthrust is nearly horizontal, except in Red Canyon where it is locally arched. Diapirism of gypsiferous Arapien Shale is an important, though secondary, structural control in the quadrangle. The trace of the Wasatch fault zone trends north-south and has about 23 feet (7 m) of Holocene offset in the quadrangle. Numerous subsidiary faults with smaller amounts of Holocene offset also occur.

Primary economic resources in the quadrangle are gypsum, sand, and gravel. Geologic hazards of concern are earthquakes, flash floods, and mass movements. The Ankareh, Twist Gulch, and Cedar Mountain Formations, the Arapien Shale, and the basal Indianola Group are especially susceptible to slope failure.

INTRODUCTION

The Nephi quadrangle is located about 70 miles (113 km) south of Salt Lake City along the eastern margin of Juab County, central Utah. It is traversed north to south by Interstate 15, and east to west through Salt Creek Canyon by Utah State Highway 132. Nephi, the Juab County seat, is located at the junction of these roads. Access to more remote parts of the quadrangle is facilitated by numerous well-maintained and unimproved dirt roads.

The Nephi quadrangle lies at the junction of three major physiographic provinces: Basin and Range, Middle Rocky Mountains, and Colorado Plateau (Callaghan, 1947). It encompasses portions of the southern Wasatch Range and the Gunnison Plateau (San Pitch Mountains), two distinct provinces bridged by extensive exposures of deformed Jurassic Arapien Shale. Effects of the Sevier orogeny, the Laramide orogeny, and basin and range extension are superimposed, leading to conflicting stratigraphic and structural interpretations. Complexities in the area have been variously ascribed to: 1) compression during thrusting, followed by regional extension (Spieker, 1946, 1949; Armstrong, 1968; Standlee, 1982; Lawton, 1985; Villien and Kligfield, 1986); 2) repeated upward surge and then collapse of Jurassic evaporites and mudstones (Stokes, 1952, 1956, 1982; Baer, 1976; Witkind, 1982, 1983; Witkind and Page, 1984; Witkind and Weiss, 1985); and 3) diapirism activated by compression (Gilliland, 1963; Moulton, 1976).

Early geologic investigations of central Utah include the Fortieth Parallel Survey of the 1870s under the direction of Howell, Wheeler, and S.F. Emmons. Louglin (1913) and Eardley (1933a, 1933b, 1934) outlined the geology of the southern Wasatch Range. Spieker and Reeside (1925) and Spieker (1946, 1949) outlined the stratigraphy and structural history of the nearby High Plateaus to which the Gunnison Plateau belongs. Boutwell (1904), Loughlin (1913), and Phillips (1940) have studied economic resources of the area. Geologic hazards along the Wasatch fault zone have recently received considerable attention (McKee and Arabasz, 1982; Zoback, 1983, 1987; Crone and Harding, 1984; Machette, 1984; Schwartz and Coppersmith, 1984; Smith and Bruhn, 1984; and Jackson and Ruzicka, 1988).

Hunt (1950) first presented a general geologic map (1:32,000) of the northern Gunnison Plateau. Johnson (1959) produced a general geologic map (1:21,850) of the southernmost Wasatch Range. Black (1965) later remapped much of the same area as Johnson at 1:31,680. Le Vot (1984) mapped the southern Wasatch Range from Nephi to Payson, including portions of the Cedar Hills (1:48,470). Witkind and Weiss (1985) mapped the Nephi 30 x 60-minute quadrangle at 1:100,000.

Informal names for several topographic features are used in this report that do not appear on the base map. These are: Round Top Hill, located in the northeast corner of section 27 and northwest corner of section 26; J-Hill, located near the center of the west border of section 27; Miners Ridge, located in the southeast quarter of section 27, all in T. 12 S., R. 1 E.; and Indianola Cliffs, located along the quadrangle's southeastern margin.

STRATIGRAPHY

The Nephi quadrangle includes two major stratigraphic sequences of rocks: 1) 6,500 feet (1,980 m) of allochthonous Permian to Jurassic strata that form the overturned, north- to northwest-dipping beds of the upper plate of the Nebo overthrust, and 2) 10,500 feet (3,200 m) of autochthonous Jurassic to Tertiary strata of the Gunnison Plateau. These sequences are separated by a structurally and stratigraphically complex expanse of Jurassic Arapien Shale.

PENNSYLVANIAN AND PERMIAN SYSTEMS
Oquirrh Group (PIPo)

The Oquirrh Group (Morrowan to early Wolfcampian) consists of about 20,000 feet (6,090 m) of limestone, sandstone, quartzite, and shale deposited in the Oquirrh basin of north-central Utah and southern Idaho. Only the uppermost 1600 feet (488 m) of the Oquirrh Group is exposed within the Nephi quadrangle. Fusilinids collected from the quadrangle, *Pseudofusulinella* sp., *Schwagerina* sp., and *Pseudofusulina* sp., along with the smaller foraminifera *Clymacammina* sp., indicate an Early Permian (Wolfcampian) age.

In the Nephi quadrangle, limestone makes up slightly more than half of the Oquirrh Group, with interbedded siltstone and lesser fine-grained sandstone as the remainder. Some limestone beds are sedimentary breccias. These beds contain limestone intraclasts up to 3 inches (8 cm) in diameter and 3 to 5% silt-size quartz and traces of feldspar. Black chert nodules and lenses are common and are often partly replaced by euhedral dolomite. The black chert is usually enclosed by well-indurated, thin, light-gray-weathering, dark-gray micrite beds. This micrite locally contains 5 to 10% authigenic, euhedral quartz microlites.

The limestone is often fossiliferous and contains large well-preserved fusilinids as much as ¼-inch (0.6 cm) long and large crinoid fragments. It is thin- to very thick-bedded but usually medium-bedded, weathers light to dark gray to brown, and is dark bluish gray to dark gray when fresh. The fossil fragments and intraclasts are micritic in nature and weather out differentially above the sparry host to a light-brown color. Locally they are partially replaced by chert and chalcedony. Limestone similar to and slightly less abundant than the fossiliferous limestone just described tends to be a lighter bluish-gray and lacks visible fossils in hand specimens.

The thinly laminated to thinly bedded, light- to dark-brown-weathering, medium- to dark-brown calcareous siltstone and fine-grained sandstone occur as very poorly exposed, float-covered intervals between resistant ledges of limestone. Microspar cement, often partially replaced by euhedral dolomite, makes up 5-15% of most samples. The rock often weathers to small, mottled reddish-brown blocky fragments.

The contact of the Oquirrh Group and the overlying Kirkman Limestone is conformable and gradational within the Nephi quadrangle and is not easy to trace. Although both units contain similar interbedded siltstone and black chert, the carbonate strata are sufficiently distinct to allow placement of a useful mapping contact. Limestone of the upper Oquirrh Group occurs in dark bluish-gray fossiliferous beds which are not continuous along strike. The limestone of the overlying Kirkman Limestone tends to be lighter gray, highly fractured, and lacking in abundant fossils.

PERMIAN SYSTEM
Kirkman Limestone (Pki)

The Kirkman Limestone (middle to late Wolfcampian) is mostly a regressive shallow marine carbonate sequence deposited during the closing episode of Oquirrh basin sedimentation. From 300 to 400 feet (90 to 122 m) of Kirkman Limestone is present within the Nephi quadrangle. Although its boundaries are not obvious, the Kirkman Limestone can be divided into lower and upper portions of roughly equal thickness, separated by a 50-foot-thick (15 m) middle section. Sedimentary and tectonic breccias and nodular and lenticularly bedded black chert are common in the lower and upper portions.

The lower part of the Kirkman Limestone is a thin- to medium-bedded, light-gray-weathering, medium-gray, fetid, dolomitic packstone or wackestone with lesser interbedded siltstone and limestone. The packstone and wackestone often have sand- to pebble-sized subrounded intraclasts, and up to 25% poorly preserved, silicified to partly silicified crinoid fragments and fusilinids which weather out as white lumps. The poorly exposed, mildly feldspathic quartz siltstone is thickly laminated to very thinly bedded, light brown weathering, medium brown, with a calcareous, often dolomitic, microspar cement.

The middle portion is a cliff- to ledge-forming, medium- to very thickly bedded, light-brown-weathering, light- to medium-gray to grayish-brown silty dolomite and dolomitic wackestone. The silty dolomite contains less than 5% white silicified fusilinids which weather out of the microspar host. Well-sorted, medium to coarse quartz silt with only traces of feldspar makes up 25-30% of the rock. The dolomitic wackestone contains 10-15% quartz silt and is often fetid. Poorly preserved crinoid fragments and other unidentifiable fossils occur in a dolomitic microspar matrix. The fossils are generally white and partly silicified. Some weather out in relief, but most are of calcite spar which weathers more readily than the host, giving the weathered surface a pitted appearance.

The upper portion is a medium- to thickly-bedded, light-gray-weathering, light- to medium-gray brecciated dolomite with interbedded siltstone. It contains dolomitic packstone and wackestone similar to the lower portion. It is generally intensely fractured with the angular fragments cemented with sparry calcite. The weathered surface reveals a very closely spaced network of anastomosing hairline fractures which weather in negative relief. Because it is highly brecciated, it usually breaks or shatters irregularly.

The upper contact of the Kirkman Limestone is conformable and gradational. I concur with previous workers (Johnson, 1959; Black, 1965; Le Vot, 1984) who have placed the upper contact at the stratigraphically highest limestone bed, including "tongues" of Diamond Creek Sandstone in the Kirkman Limestone. In the Nephi quadrangle the overlying Diamond Creek Sandstone is poorly exposed, but the uppermost beds or "tongues" of Kirkman Limestone are well exposed and form an obvious topographic and lithologic demarcation between the two units. This interfingering is best illustrated in exposures 1,000 to 3,000 feet (300 to 915 m) northeast of Round Top Hill.

Diamond Creek Sandstone (Pd)

The Diamond Creek Sandstone (late Wolfcampian to Leonardian) was deposited in beach and eolian environments that interfingered with and finally superseded the last stages of Oquirrh basin carbonate sedimentation. Rocks of the Diamond Creek Sandstone are primarily quartz arenite, with lesser amounts of subfeldsarenite and feldsarenite. They are generally very thin to medium bedded, cross bedded, yellowish gray to brownish yellow, fine to medium grained. Locally, pale-red, pale-reddish-brown, and very light grayish-yellow to yellowish-white varieties occur. All three lithologies are very well to poorly indurated and tend to be porous (about 5%). Calcareous cement usually predominates, however, quartz overgrowths and chert cementation are locally prominent. Coarser grained samples usually show a well-developed bimodality with respect to both grain roundness and size. White coarser laminae containing well-rounded grains are cemented largely by quartz overgrowths while the finer laminae containing subangular grains have a calcareous cement which imparts the characteristic yellow hues.

The Diamond Creek Sandstone maintains a fairly constant thickness of 300 feet (90 m) in outcrops east and northeast of Round Top Hill. However, in the vicinity of the J-Hill, it thins to less than 20 feet (6 m), probably due to deposition over a paleotopographic high.

The Diamond Creek Sandstone weathers to form colluvial slopes between resistant ledges of the Kirkman Limestone and the Grandeur Member of the Park City Formation. The contact of the Diamond Creek Sandstone and the overlying Grandeur Member of the Park City Formation is conformable and gradational, and it interfingers locally across a vertical distance of 20 feet (6 m).

Park City and Phosphoria Formations

The Park City and Phosphoria Formations, and their equivalents, represent a complex, intertonguing, shallow marine to shelf margin sequence of carbonates, fine-grained clastic sediments, and organic-rich phosphatic mudstone and chert. In the Nephi quadrangle, the Park City Formation is represented by the Grandeur and the Franson Members, which are separated by the Meade Peak Phosphatic Shale Tongue of the Phosphoria Formation. Thrusting and later normal faulting preclude obtaining an accurate thickness of the sequence in the Nephi quadrangle. However, the total depositional thickness is no more than 1,450 feet (442 m).

Grandeur Member of the Park City Formation (Ppg)

The Early Permian Grandeur Member (Leonardian) consists of an estimated 650 feet (198 m) of medium-bedded, light- to medium-gray to pinkish-gray, often sandy and fossiliferous limestone, dolomitic limestone, and dolomite. Nodular, and less commonly lenticularly bedded, black and beige chert is common and accounts for 1-2% of the member. Collophane is ubiquitous, though not abundant. Most often it occurs as a cement or pore filling and rarely as fossil fragments.

The basal portion of the Grandeur Member is generally light-gray sandy dolomite and dolomitic sandstone; it weathers very light gray and is often cross bedded. The sand grains are fine- to medium-grained and exhibit a bimodal size and roundness similar to that of the underlying Diamond Creek Sandstone. Dark-brown-weathering knots and lenses of very well indurated, sandy, dolomitic biomicrite weather out above their cross-bedded host; they have been selectively silicified and are more resistant to weathering. This biomicrite contains small micritized brachiopod and echinoderm fragments whose interiors are often completely replaced by megaquartz.

The thin middle portion of the Grandeur Member contains interbedded limestone and brecciated limestone. The latter is sedimentary breccia consisting of subrounded granule- to pebble-size carbonate and chert clasts identical to the encompassing unbrecciated beds. Minor well-indurated, thin- to medium-bedded, light-brown-weathering, brownish-gray, very fine- to fine-grained calcareous quartz arenite occurs also.

The upper portion of the Grandeur Member consists of medium to thick beds of light-gray limestone, dolomitic limestone, and dolomite. It is capped by a laterally consistent, medium-bedded, light-brown-weathering, medium-gray, 30- to 35-foot-thick (9 to 10 m), fossiliferous, often ledge-forming limestone which is locally cut by abundant white calcite veins. It contains abundant brachiopods and lesser crinoid and echinoderm fragments which are often silicified. Hematite locally stains these fragments reddish brown.

Meade Peak Phosphatic Shale Tongue of the Phosphoria Formation (Ppm)

The Early Permian Meade Peak Phosphatic Shale Tongue (Leonardian to Guadalupian) is composed of a monotonous, laterally consistent, 130- to 150-foot-thick (40 to 46 m) sequence of dolomite and interbedded black chert. This sequence is very thin to thin, even bedded, rarely medium bedded, light brown to pale yellowish brown weathering, medium gray to brownish gray, and often fetid. It forms characteristic brown to black subdued slopes between the light-gray ledgy slopes of the Grandeur and Franson Members and is invaluable in distinguishing these two members.

Black chert makes up 30-50% of the Meade Peak Tongue. The chert usually occurs as irregular knots 2 to 4 inches (5 to 10 cm) in diameter, often interspersed with smaller white chalcedonic knots. Black chert also occurs in even to lenticular beds up to 4 to 5 inches (10 to 12.7 cm) thick and is often partly replaced by euhedral dolomite.

The dolomite, composing 50-70% of the tongue, is very uniformly colored and consists of very fine to fine euhedral grains. No fossils were found. Megaquartz, chalcedony, and lesser euhedral magnetite are common fracture-filling minerals. Collophane often accounts for 5-10% of the rock and occurs as cement or irregular blebs.

Only one phosphatic bed was observed. It is laterally continuous, 8 to 12 inches (20 to 30 cm) thick, and is composed of oolitic phosphorite. It marks the base of the member throughout the mapped area. It is porous, soft, black, slightly sandy, extremely fetid, and cemented by chert. Chert and amorphous phosphatic intraclasts are the most common nuclei; sand and a few shell fragments make up the remainder. It contains about 35-40% collophane as oolites.

The contact between the Meade Peak Phosphatic Shale Tongue and the Franson Member corresponds to the first appearance of medium- to thick-bedded, light-gray limestone and dolomitic limestone which overlie very thin- to thin-bedded, light-brown-weathering, brownish-gray dolomite and black chert.

The Franson Member of the Park City Formation (Ppf)

The Early Permian Franson Member (Guadalupian) consists of medium to thick, evenly bedded, light- to medium-gray limestone, dolomitic limestone, and dolomite. It is locally fossiliferous and contains common white and lesser black nodular and lenticular chert. Deformation precludes measurement of an accurate section within the Nephi quadrangle, however, it is estimated to be less than 650 feet (198 m) thick.

Fine- to coarse-grained, light- to medium-gray dolomite is more common in the basal half of the Franson Member, and the remainder locally has interbedded, reddish-brown, calcareous sandstone and siltstone. The dolomite often has many fractures healed with sparry calcite. Fossils in the dolomite are generally ghost-like and unidentifiable, though locally silicified brachiopods and echinoderms are present. The siltstone and similar very fine-grained, poorly sorted, calcareous quartz arenite to sublitharenite are irregularly laminated, poorly indurated and contain up to 3% hematite. The Franson Member is capped by a 10- to 30-foot-thick (3 to 9 m) ledge-forming bryozoan and brachiopod limestone throughout most of the Nephi quadrangle. As in the underlying Grandeur Member, collophane is ubiquitous, though not abundant, as a cement or pore filling.

The contact between the Franson Member and the Triassic Woodside Formation is not well exposed within the Nephi quadrangle. It appears to represent a sharp lithologic change and is marked by a pronounced topographic break. Throughout most of the west-central United States this contact is disconformable (Peterson, 1980).

Park City Formation, undifferentiated (Ppc)

Several outcrops of undifferentiated Park City strata have been mapped in the lower reaches of Quaking Asp Canyon and east of Footes Canyon. Neither of these localities contain strata belonging to the Meade Peak Phosphatic Shale Tongue of the Phosphoria Formation. Considering the close association of the Woodside Formation and Thaynes Limestone, it seems likely that these undifferentiated Park City strata belong to the Franson Member. However, intense deformation, poor exposures, and similarity of the Grandeur and Franson Members precludes subdivision of the Park City Formation at these two localities.

TRIASSIC SYSTEM

Woodside Formation (Ꞧw)

The Early Triassic Woodside Formation (Scythian) is the first of a series of Triassic red beds to blanket north-central Utah. The bulk of the formation was probably deposited in a tide-dominated shallow marine environment. Extensive deformation during emplacement of the Nebo allochthon has resulted in large thickness variations of the Woodside Formation. In the Nephi quadrangle, 200 to 240 feet (60 to 73 m) of Woodside strata are present. The undeformed thickness in the Mt. Nebo area is about 500 feet (152 m)(Witkind and Weiss, 1985).

The Woodside Formation forms very thin to thin even beds of porous, pale-brown to grayish-red-weathering, pale-red to pale-brown, very fine-grained feldsarenite, subfeldsarenite, and similar siltstone. It weathers to form gentle slopes and saddles thinly veneered with colluvium. Microscale planar and trough cross stratification are common, giving weathered surfaces a planar and platy, or rippled and wavy, appearance. Flat-pebble impressions are locally common, as are iron-manganese coatings, although the latter are not so pronounced as those on Thaynes strata. Fossils were not found in the Woodside Formation. The color, lithology, and bedding features of the Woodside are very uniform.

The contact with the overlying Thaynes Limestone is conformable and probably gradational. It marks a subtle break in topography and a distinctive though poorly exposed change in lithology. It corresponds to the first appearance of very thin to thin wavy beds of mottled brown and light-gray silty micrite, and thin-bedded, light-gray limestone.

Thaynes Limestone (Ꞧt)

The Early Triassic Thaynes Limestone (Scythian) is a regressive, cyclic sequence of interbedded fossiliferous limestone, siltstone, shale, and mudstone deposited in open marine to tidal flat environments. About 700 to 800 feet (215 to 250 m) of Thaynes strata are exposed in the Nephi quadrangle although it is 1,300 to 1,400 feet (396 to 427 m) thick in the surrounding area (Black, 1965; Le Vot, 1984; Witkind and Weiss, 1985). Though not as stratigraphically monotonous as the underlying Woodside Formation, the Thaynes Limestone is remarkably uniform. Irregular, argillaceous laminae impart a characteristic, generally coarse, wavy fissility. Iron and manganese stains and calcite stringers are common. Unlike the underlying Woodside Formation, the Thaynes Limestone lacks red hues and contains only traces of mica. It also contains fossiliferous limestone with abundant small pelecypod, crinoid, and echinoderm fragments and traces of ammonoid fragments.

The typical rock type is a slope-forming, very thin- to thin-bedded, mottled light- to medium-brown and light-gray-weathering, brownish- to greenish-gray wackestone (silty micrite and silty biomicrite). The lower portion consists of the wackestone just described, with lesser interbedded calcareous siltstone, fossiliferous wackestone, and grainstone. The siltstone is thin to medium bedded, planar laminated, light brown weathering, spotty or mottled very light gray and light brown with a subfeldsarenite composition. The fossiliferous wackestone and grainstone are thin to medium bedded in well-indurated even beds from 0.5 to 3 feet (0.2-1 m) thick. They make up only a few percent of the section and are usually uniform light gray in color, although the grainstones can be reddish gray. The upper portion of the Thaynes Limestone contains considerably more of this fossiliferous limestone. There is also an upward-increasing proportion of thin- to medium-bedded, brownish-gray to pale-yellowish-brown, very fine-grained, calcareous sandstone and siltstone, locally present as a sedimentary breccia.

The middle red shale unit of the Thaynes Limestone, recognized over much of Utah, including just north of the Nephi quadrangle (Black, 1965), was not observed in the mapped area.

Throughout the region, Lower Triassic marine rocks of the Thaynes Limestone are disconformably overlain by Upper Triassic continental red beds of the Ankareh Formation and its lateral equivalents (Collinson and Hasenmueller, 1978). The contact of the Thaynes Limestone and Ankareh Formation is poorly exposed in the Nephi quadrangle.

Ankareh Formation (T̵Ra)

The Ankareh Formation (late Early and Late Triassic) was probably deposited in relatively low-energy upper tidal flat to fluvial plain environments. It can usually be divided into three members in the Wasatch Range (Hintze, 1988). However, the Ankareh Formation was not divided in this study because no complete section exists and the strata present have been extensively deformed by thrusting. Nevertheless, parts of each member can be recognized.

The lower portion of the Ankareh Formation consists of slope-forming brownish-red or locally brownish-yellow mudstone and siltstone. The top of the lower portion is poorly to very well indurated, thin to massively bedded, fine- to medium-grained sandstone. In decreasing order of abundance the sandstone varieties are sublitharenite, quartz arenite, litharenite, and interbedded siltstone. Each bed locally shows white reduction spots and small, dark-brownish-red mudstone chips. A few beds are decidedly micaceous, and most are cemented by sparry calcite and iron oxides. The siltstone is locally partially replaced by zoned euhedral dolomite. The ledge-forming coarser sandstone exhibits large-scale trough cross stratification. Colors are variable. Common varieties are pale to grayish red purple, white to pale pink, and deep red to dark yellowish orange.

The middle portion is cut by numerous small normal faults and complex mass movements. It consists of a poorly indurated, highly variable sequence of interbedded pebbly sandstone and pebbly conglomerate, coarse sandstone, and mudstone. Color variation is similar to that of the upper part of the lower portion. The pebbly conglomerate contains very well rounded quartzite and black chert clasts. The conglomerate and the sandstone contain ubiquitous, dark brownish-red mudstone chips which commonly account for more than 50% of the rock. Iron-manganese stains are common, and a few pebble-size iron-manganese nodules were found. Pebble-size, greenish-gray siliceous nodules were found weathering out of brownish-yellow mudstone. Although rare, very well indurated, brownish-yellow, silty chert with rounded sand- to granule-size chert intraclasts of the same composition were also found.

The upper portion is composed primarily of variegated red, maroon, and lavender mudstone and siltstone. At the entrance to Red Canyon, the mudstones locally "bleed through" level-2 alluvial fan deposits. Purplish-white to lavender sandstone with large-scale cross stratification, exposed in the creekbed in Red Canyon, marks the top of this formation.

Lithologic and color differences mark the contact between the Ankareh Formation and the overlying Navajo Sandstone. Strata of the Navajo Sandstone are restricted to the "salmon" colors of moderate red orange, moderate orange pink, and pale red brown, although locally they are irregularly or entirely bleached white. Lavender hues dominate the highly variable colors of the Ankareh Formation. The Navajo Sandstone is very fine- to medium-grained, thick to massively cross-bedded quartz arenite. Similar, often coarser grained sandstone, belonging to the Ankareh Formation, is interbedded with brownish-red mudstone and nearly always has evenly dispersed sand- to granule-size brownish-red mudstone chips. The presence of medium- to coarse-grained purplish-white sandstone with large-scale cross bedding at or near the contact with the overlying Navajo Sandstone argues for a conformable, gradational contact.

Triassic strata, undifferentiated (T̵Ru)

There are three locations within the Nephi quadrangle where it has not been possible to differentiate Triassic strata due to poor exposure and structural complexity. These are on the western side of Round Top Hill, a small outcrop about 1,500 feet (457 m) from the mouth of Quaking Asp Canyon, and in the slide complex in the extreme northeastern portion of the quadrangle. Strata involved therein include only portions of the Woodside Formation, Thaynes Limestone, and Ankareh Formation. Most of the questionable exposures are red mudstone and intensely fractured siltstone.

JURASSIC SYSTEM

Navajo Sandstone (Jn)

The Navajo Sandstone (Early Jurassic) was deposited as dunes and interdunes in a vast coastal and inland dune field. A complete section is not exposed in the Nephi quadrangle. Black (1965) estimated the undeformed thickness in the Mt. Nebo area to be at least 600 feet (180 m). Le Vot (1984) estimates the Navajo Sandstone to be nearly 1,000 feet (305 m) thick east of Footes Canyon. In the Nephi 30 x 60-minute quadrangle, Witkind and Weiss (1985) estimate 1,400 to 1,500 feet (427 to 457 m) of Navajo strata.

The bulk of the Navajo Sandstone is very thick to massively cross-bedded, very fine- to medium-grained, well-indurated to extremely friable quartz arenite which often shows a bimodal size and roundness distribution. Subfeldsarenite varieties are present but not abundant. Cementation by silica overgrowths is more common than by sparry calcite, which in turn is more prominent than iron-oxide cement. The generally clean, porous sandstone is everywhere characterized by large-scale trough cross stratification.

The Navajo Sandstone is locally intensely fractured. Large, irregularly bleached areas are concentrated along these fracture systems. Circular to irregularly shaped white reduction spots which are not fracture controlled are also common. They range in size from less than one inch (2.54 cm) to two or three feet (0.6 to 0.9 m) in diameter.

It has not been possible to determine the exact nature of the contact between the Navajo Sandstone and the Twin Creek Limestone in the Nephi quadrangle. It is probably an unconformity.

Twin Creek Limestone (Jtc)

The Middle Jurassic Twin Creek Limestone (middle to late Bajocian to Callovian) was deposited in warm, shallow marine waters in the south end of a north-trending trough or foreland basin during the first two major Mesozoic transgressive episodes in west-central North America. It is divided into seven members in northern Utah; in ascending order, the Gypsum Spring, Sliderock, Rich, Boundary Ridge, Watton Canyon, Leeds Creek, and Giraffe Creek Members. The lower five members are each lithologically consistent and easily recognizable over a wide area. In central Utah, however, the Leeds Creek and Giraffe Creek Members lose identity and appear to grade into the Arapien Shale (Imlay 1967, 1980; Sprinkel, 1982). Within the Nephi quadrangle, only the Sliderock, Rich, Boundary Ridge, and Watton Canyon Members are present with certainty. In an unpublished section of Miners Ridge strata measured during 1989, D.A. Sprinkel noted red soils and loose rock, similar to Gypsum Spring strata, in the lower part of the north-facing slope in Red Canyon. Based upon this unpublished measured section, the thickness of Twin Creek strata in the Nephi quadrangle is probably on the order of 800 feet (244 m).

Individual members of the Twin Creek Limestone were not mapped because of the scale and poor exposures. Even so, the rock units can be identified. The thick to very thickly bedded oolitic limestone (oosparite and biosparite) of the Sliderock Member is well exposed and easily recognizable in the creekbed of Red Canyon and near the crest of Miners Ridge. It forms a dipslope at the north-facing side of Miners Hill, complicated in part by local faulting and slide blocks. This somewhat sandy, light- to medium-gray limestone often has large lavender patches. White calcite veins are common, and fine fossil hash, including *Pentacrinus asteriscus,* is locally abundant.

The Rich Member is present along the crest of Miners Ridge. It is characterized by laminated to thin-bedded, light-gray, calcareous shale and argillaceous limestone; pencil shale is common. The massive 80-foot-thick (24 m) gypsum bed near the ridge crest belongs to the Boundary Ridge Member. Laminated to thin-bedded, light-gray to greenish-gray, argillaceous limestone and calcareous shale and siltstone of the Watton Canyon Member complete the section on the south side of Miners Ridge.

The nature of the contact between the Twin Creek Limestone and Arapien Shale is uncertain in central Utah, primarily for lack of an unbroken sequence and the extensive deformation of the Arapien Shale. The contact is exposed, however, at Miners Ridge. About 300 feet (90 m) of laminated to thin-bedded, light-gray and brownish-red calcareous shale and siltstone of the basal Arapien Shale conformably overlie the Watton Canyon Member.

Arapien Shale (Ja) and gypsum beds in the Arapien Shale (Jag)

The Arapien Shale (Callovian to Kimmeridgian[?]) was deposited in a north-trending, shallow marine basin in which considerable thicknesses of evaporites accumulated. The nomenclature used in this report follows that of Witkind and Hardy (1984). Throughout central Utah the Arapien Shale has served as a major decollement horizon during Sevier thrusting, so it is everywhere severely deformed. It has also given rise to small-scale, and possibly much larger scale, diapiric structures. In the Nephi quadrangle, the Arapien Shale forms a structurally and stratigraphically complex unit that is probably 3,500 to 4,000 feet (1,060 to 1,220 m) thick. Picard (1980) and Picard and Uygur (1982) pointed out that there is actually very little shale in the Arapien Shale. The bulk of the formation is composed of calcareous claystone, mudstone, and siltstone, and micrite or clayey micrite. Fine-grained sandstone and carbonate rock exclusive of micrite are much less abundant. Gypsum, anhydrite, and salt are also important constituents of the Arapien Shale. Large pods and beds of massive white gypsum and selenite (Jag) were mapped separately because of their potential economic importance and because of their structural and stratigraphic significance.

Hardy (1952) described five highly variable rock units within the Arapien Shale. These units were not mapped because of scale, extreme deformation, and lack of an unbroken section from which positive identifications could be made. Even so, portions of units A, B, C and D are recognizable in the Nephi quadrangle and the upper red saliferous unit E crops out to the east in the Fountain Green North quadrangle (Banks, 1986). I have used numbers to designate the three easily recognizable parts in the Nephi quadrangle, as a definite correlation with Hardy's units A through E has not yet been established.

Part 1, which probably correlates in part with Hardy's (1952) unit A and Black's (1965) unit 1, is composed of yellowish-gray to light-olive-gray calcareous mudstone and siltstone. It usually forms laminated to thin, even beds; rarely it is medium bedded. It contains lesser micrite or clayey micrite and some brownish-red siltstone. The exposed thickness of the basal part of the Arapien Shale is about 300 feet (90 m). It is exposed in Miners Ridge. It may also be present at the entrance to Salt Creek Canyon and underlying Round Top Hill.

Part 2, which may be correlative with Hardy's unit B and Black's unit 2, is the most distinctive Arapien unit due to its red and gray blotched appearance. It contains pod-shaped, coarsely crystalline gypsum (selenite) which weathers in relief next to its host of red siltstone and mudstone and very thin-bedded to laminated yellowish- to light-gray calcareous siltstone. The undeformed thickness of this part of the Arapien Shale probably is not more than a few hundred feet. Part 2 exposures generally are restricted to areas encompassing mapped gypsum deposits, exclusive of those large deposits at Miners Ridge and in the core of the anticline on the south side of the entrance to Salt Creek Canyon.

Part 3, which may be correlative with Hardy's units C and D and Black's units 3, 4, and 5, is composed of yellowish-gray to light-olive-gray, laminated to thin-bedded, even-bedded, calcareous mudstone, siltstone, fine-grained sandstone, and minor gritstone. It is often fissile, thereby giving rise to the common name of "shale." Micrite and clayey micrite are less common. The sandstone, which contains about 2% glauconite, often weathers to a pale yellowish or reddish brown. The gritstone contains chert, quartzite, and abundant reworked calcareous mudstone clasts. Minor flat-pebble conglomerate is also present. Near the crest of anticlines, pencil shale is common. Minor selenite occurs as undeformed lenses. Part 3 may contain minor lenses of strata similar to part 2. The undeformed thickness of this part of the Arapien Shale probably is 2,500 to 3,000 feet (760 to 915 m). It forms the bulk of exposures in Salt Creek Canyon.

The contact of the Arapien Shale and Twist Gulch Formation is not well exposed in the Nephi quadrangle. In some areas, the contact is probably at least in part diapiric or discordant in nature. Elsewhere, the Arapien Shale is unconformably overlain by Tertiary volcaniclastics and the Salt Creek Fanglomerate.

Twist Gulch Formation (Jtg)

The Twist Gulch Formation (Callovian[?] or Neocomian to Aptian[?]) was probably deposited in shallow to marginal marine environments and possibly records the initial, though distal, influences of Sevier orogenic activity to the west. It is largely unfossiliferous throughout its extent in central Utah and has therefore been difficult to date and correlate with the better known Jurassic stratigraphy of northern, southern, and eastern Utah. Approximately 1,200 feet (366 m) of Twist Gulch strata are present in the Nephi quadrangle.

The Twist Gulch Formation consists of a uniform sequence of thin, evenly bedded, soft, light-brown or locally whitish, fine-grained sandstone and siltstone, and lesser interbedded reddish-brown to greenish-gray mudstone and shale and massive gray gritstone. The sandstone is mostly sublitharenite, although subarkose and feldspathic litharenite exist. The generally subangular to subrounded grains are poorly cemented by sparry calcite, microspar, and iron oxides. Roche (1985) found the Twist Gulch Formation of the southeastern Gunnison Plateau to average about 4.5% feldspar, slightly less than the average 7% here. The feldspar grains often weather to a chalky white color and give the sandstone a slight speckled appearance. In contrast, the sandstone of the Cedar Mountain Formation and Indianola Group contains very little feldspar (Roche, 1985).

In its one exposure in the quadrangle east of Rees Flat, the upper contact is conformable and gradational and was chosen as the base of the first appearance of lavender to reddish-brown mudstone. This mudstone contains pebble- to small cobble-size limestone nodules and serves as an easily identifiable mapping horizon. The uppermost sandstone and siltstone horizons of the Twist Gulch Formation tend to be soft and redder in color than those lower in the section, though the color is due in part to staining by iron oxide leached from above. The lowermost Cedar Mountain Formation contains mostly brightly colored variegated mudstone with limestone nodules and gastroliths, and lesser medium-bedded, moderate- to well-indurated sandstone and dolomitic limestone interbeds.

Cretaceous System

Cedar Mountain Formation(Kc)

The Cedar Mountain Formation (Albian to Cenomanian[?]) was deposited in alluvial-fan, braided floodplain, and lacustrine settings and contains the first coarse synorogenic sediments of the Sevier orogenic belt in this part of central Utah. In the Nephi quadrangle, 680 feet (207 m) of Cedar Mountain strata have been identified (figure 1). It consists of a lower mudstone and an upper conglomerate which are not subdivided as map units. That the upper part is Early to possible early Late Cretaceous seems fairly well documented. However, it is not entirely certain whether the lower mudstone part contains strata of Late Jurassic age (Stuecheli, 1984; Witkind and others, 1986; Biek, 1987).

Figure 1. *The hill just right of center, bordering the eastern margin of Rees Flat, is mostly Cedar Mountain strata. The Arapien Shale and Highway 132 are in the foreground and Paleozoic strata of the Nebo allochthon in the background. Note isolated patches of level-2 alluvium in the lower right corner. Looking north from hill 7476, just north of Gravel Spring.*

The lower portion of the Cedar Mountain Formation contains considerable brightly colored reddish-orange, red, and lavender mudstone, often with limestone nodules, and many thin interbeds of dense micritic limestone. Even in heavily vegetated areas, the mudstone and nodules occur as float. Gastroliths and chalcedony are found in these beds as well. Less commonly gastroliths occur in mudstone beds of the upper unit. The upper unit is conglomeratic but contains at least one thin, dense micritic limestone bed. Its composition closely resembles conglomerate of the Indianola Group, though the clast size is smaller.

Most sandstone of the Cedar Mountain Formation is reddish-orange, medium-grained, calcareous quartz arenite with some similar sublitharenite, however, coarse and fine varieties exist. They often show a bimodal size and roundness distribution. Abraded quartz overgrowths are very abundant, and hematite usually makes up 2-3% of the rock. As opposed to Twist Gulch sandstone, they contain only traces of feldspar.

The limestone nodules are mostly structureless micrite, though a single sample composed of angular micritic intraclasts cemented by spar was found. Most are highly fractured and recemented with sparry calcite. Fresh surfaces range from very light gray to grayish pink and weather somewhat lighter in color. Most occur in clusters weathering out of light-gray to lavender mudstone. The chalcedony is white or clear, layered, and occurs in clusters. Very sharp, angular pieces up to one foot (0.3 m) in diameter were observed but most are smaller. Gastroliths are common in association with limestone nodules. They generally are dark-reddish-brown, pale-brown, light-gray, or black chert and quartzite. Their surfaces are highly polished.

In the Nephi quadrangle, the contact with the overlying Indianola Group has been placed at the base of a laterally persistent 50-foot-thick (15 m) massive conglomerate bed, as chosen by Witkind and Weiss (1985). As such, it is conformable and gradational. Along the western flank of the Gunnison Plateau, this bed can be traced south at least 10 miles (16 km) from just north of Salt Creek Canyon. It marks a sharp break in topography and is composed of medium to large boulders, in sharp contrast to the pebbly and cobbly conglomerate of the upper Cedar Mountain Formation. The basel Indianola contains no limestone or micrite beds or nodules, and no gastroliths. The character of mass movements derived from these formations is also different. Those of the basal Indianola are very shallow debris flows, whereas deep rotational slumps characterize the Cedar Mountain Formation.

Indianola Group (Ki)

The Indianola Group (Cenomanian [?] to Campanian) is an eastward-thinning heterogeneous assemblage of generally coarse, non-marine and marine strata shed east and southeast off the Sevier orogenic belt. It intertongues eastward with distal, fine-grained clastic and marine strata. Standlee (1982) reported late Albian palynomorphs obtained 120 feet (37 m) above the base of the Indianola in the Gunnison Plateau. Auby (1987), Banks (1986), and Lawton (1985) obtained similar results, suggesting relatively continuous sedimentation across the Cedar Mountain-Indianola contact.

Rapid facies changes make regional subdivision of the Indianola Group difficult. Exposures in the Sanpete Valley can be subdivided into the Sanpete, Allen Valley, Funk Valley, and Sixmile Canyon Formations. In the Nephi quadrangle the four-part division of Thomas (1960) is used in which members are named from base to top, I, II, III, and IV. Only the lower part of member I, about 3,450 feet (1,050 m), crops out in the Nephi quadrangle. Most of the upper part of member I, about 3,700 feet (1,128 m), is exposed immediately to the east in the Fountain Green North quadrangle (Banks, 1986).

Indianola strata within the Nephi quadrangle can be divided into two informal parts which represent different modes of deposition. The lower part consists primarily of very thick to massive, lenticularly bedded, bimictic, polymodal, clast-supported, pale-red to reddish-brown to moderate-orangish-pink conglomerate. It is distinctly redder than the upper part. Separating these conglomerate beds are relatively thin, similarly colored, sandstone, siltstone, and mudstone interbeds. These finer grained clastic sediments give rise to many shallow debris flows which further distinguish the two parts. These fine-grained interbeds pinch out to the south, and east of Levan they are replaced almost entirely by massive reddish-brown conglomerate (Auby, 1987; Biek, 1987).

The upper part forms sheer cliffs of massive, pale-red to brownish-gray conglomerate similar to that of the lower part. However, it lacks the fine-grained interbeds and associated debris flows of the lower parts. The base of the upper part marks a sharp break in topography corresponding to the north-trending line of saddles along the extreme northeastern margin of the quadrangle.

The overall quartzite-to-limestone clast ratio of the Indianola Group in the Nephi quadrangle is about 60:40. Even so, beds occur that nearly lack limestone clasts and others have over 80% clasts. These bimictic, polymodal, clast-supported conglomerate beds frequently contain clasts of medium boulder size. Most clasts are rounded to subrounded. Medium to thick, lenticularly bedded, trough cross-stratified sandstone interbeds are common. No matrix-supported conglomerate was observed in the Nephi quadrangle. Because the conglomerate is generally well indurated, fractures tend to cut across the clasts.

The upper contact of the Indianola Group is not exposed in the Nephi quadrangle. A regional unconformity of middle Campanian age caps the Indianola Group throughout central Utah (Spieker, 1946; Fouch and others, 1983).

CRETACEOUS AND PALEOCENE SYSTEMS
North Horn Formation (TKnh)

The North Horn Formation contains variegated shale and mudstone, sandstone, conglomerate, and freshwater limestone deposited in the foreland basin of central Utah. Deposition under continental and lacustrine conditions within many smaller sub-basins resulted in rapid facies changes, widely variable thicknesses, and numerous local source areas for the North Horn Formation. Insufficient fossil evidence has precluded resolution of the age of the North Horn. Fouch and others (1983) recovered early Eocene palynomorphs from Flagstaff Limestone beds just above the intertonguing North Horn/Flagstaff contact, leading them to assign an Eocene age to upper North Horn strata. A tentative Maastrichtian to late Paleocene age is accepted.

In the Nephi quadrangle, strata belonging to the North Horn Formation crop out in two small down-faulted blocks along the western flank of the Gunnison Plateau. The northern exposure near Salt Creek contains subequal amounts of orangish-red pebble-to-cobble conglomerate and sandstone, and orangish-red to light-grayish-purple mudstone. The bimictic, polymodal, clast-supported conglomerate has a sandy to gritty calcareous matrix. It contains subequal amounts of well-rounded, light- to dark-gray limestone and quartzite clasts. The southern block, at Suttons Canyon, contains similar conglomerate and lesser sandstone; mudstone interbeds are rare.

Neither the upper or lower contacts of the North Horn Formation are exposed in the Nephi quadrangle. Spieker (1946) noted that North Horn strata gradationally overlie the Price River Formation in east-central Utah, but that to the west it lies unconformably over older strata.Throughout much of central Utah, the Flagstaff Limestone conformably and often gradationally overlies the North Horn Formation.

TERTIARY SYSTEM

Tertiary volcaniclastic deposits (Tv)

Volcaniclastic strata in the Nephi quadrangle are mostly fluvial in origin and were probably deposited as valley fill in old channels, and in alluvial-fan and braidplain environments. They consist of a lower clayey-to-pebbly tuffaceous part overlain by coarse pebble-to-cobble volcanic conglomerate interbedded with tuffaceous lenses similar to the lower part. The top of the lower tuffaceous part is completely covered. Each part is poorly consolidated and forms float-covered hillsides.

Correlation of volcanic and volcaniclastic strata in central Utah continues to be problematic, primarily because of discontinuous exposures and lack of readily datable materials. Witkind and Marvin (1989) suggest that such strata west of Juab Valley be referred to as the Goldens Ranch Formation and that the Moroni Formation be used for exposures east of Juab Valley. They believe that these formations represent one and the same volcanic-sedimentary complex and, based on K-Ar dates, are very probably late Eocene to middle Oligocene in age. However, physical continuity has not been demonstrated between the two formations, nor is it known if they had the same source (Cooper, 1956; Witkind and Marvin, 1989). Additionally, geomorphic evidence suggests that volcaniclastic strata in the Nephi quadrangle were derived from the west, indicating correlation with the Goldens Ranch Formation of Long Ridge (Biek, 1987). Because of these uncertainties, the generic term "Tertiary volcaniclastics" is used.

Unnamed Tertiary volcaniclastic strata are exposed along the northwestern flank of the Gunnison Plateau, from Salt Creek Canyon south to Cedar Point. The unit ranges from 0 to at least 500 feet (0 to 152 m) thick and was deposited over a surface of considerable relief. Bedding orientations are difficult to obtain. However, strata south of Miller Canyon strike uniformly northwest and dip 10 to 15 degrees northeast. They also thin eastward toward the plateau, although this may result partly from erosion prior to the deposition of the Salt Creek Fanglomerate.

Exposures immediately southeast of Nephi and north of the Biglows Canyon retaining pond are whitish, tuffaceous, clayey, sandy, and pebbly water-lain deposits containing a few thin interbedded lenses of volcanic conglomerate. Channelized contacts, graded bedding, and vague trough cross stratification occur. South of Biglows Canyon these deposits may be concealed by normal faulting or they may grade laterally into volcanic conglomerate.

Exposures south of Biglows Canyon consist almost entirely of poorly consolidated, slope-forming, grayish, pebble-to-boulder volcanic conglomerate. Thin lenses of white to light-brown, sandy to pebbly, tuffaceous sandstone are exposed in Broad Canyon. Clasts are generally subrounded and range in diameter up to three feet (0.9 m). Most of the clasts are light to dark gray andesite and light-gray-weathering basalt; some are vesicular. However, a wide variety of extrusive igneous rock types are present, including dark-brownish-red rhyolite and rhyolitic lithic-welded tuff with abundant bronze-colored biotite flakes, light-brown welded tuff with black fiamme, and black porphyritic igneous rock with a glassy groundmass like obsidian. The unit contains up to about 5% quartzite and limestone clasts.

In Biglows Canyon, and the canyon immediately to its north, the base of these volcaniclastic strata is marked by a poorly consolidated to somewhat blocky red siltstone of variable thickness, also described by Hunt (1950). It lacks volcanic debris and contains scattered small reddish gypsum crystals; it probably represents an old weathering horizon developed upon the Arapien Shale.

The volcaniclastic strata in the Nephi quadrangle are overlain by the Salt Creek Fanglomerate. Because of the poorly consolidated nature of both units, their contact is not well exposed. The contact was chosen to coincide with the topographically highest level of abundant volcanic clasts. This gradational interval is generally less than 10 feet thick.

Altered sills (Tis)

Black (1965) and R. Steele (personal communication, 1985) noted a few poorly exposed, dark-green lamprophyre sills up to six inches (15 cm) thick in Permian strata northeast of Round Top Hill. They intrude the Kirkman Limestone, but no alteration of the host limestone was observed. Their presence is revealed by traces of soft, green, chloritic float which lead uphill to the inconspicuous sills. Individual sills are not shown on the map but their general location is labeled.

The highly altered intrusions contain about 50% biotite/chlorite, 1% quartz and plagioclase, and traces of magnetite, commonly euhedral and partly altered to hematite. The remainder of the rock is replaced by sparry calcite. Both the biotite/chlorite and calcite contain abundant, apparently well-preserved, needle-like apatite inclusions. The biotite/chlorite combination has strong light-yellowish-brown and very dark-green pleochroism. Chlorite incompletely replaces most of the biotite, yet the structure of the original biotite is well preserved. These flakes are rimmed with a rusty reddish-brown reaction rim and often a rind of similarly colored unaltered biotite.

The relict mineralogy of the sills just described is suggestive of derivation from a volatile-rich basic magma. These sills may be related to the lamprophyre dikes northeast of Mona, along the western flank of the southern Wasatch Range, described by Phillips (1940) and Phillips (1962). Witkind and Marvin (1989) sampled a dark-grayish-green minette near the head of Birch Creek, just north of the Nephi quadrangle, and determined an age of 23 Ma.

TERTIARY AND QUATERNARY SYSTEMS

Salt Creek Fanglomerate

The Salt Creek Fanglomerate is a poorly sorted, rarely consolidated, red to reddish-brown, coarse rubble sheet ranging from 0 to about 500 feet (0 to 150 m) thick. It was deposited as a large alluvial-fan complex. It can be divided into two broadly contemporaneous units, a limestone-rich unit containing angular clasts derived from the Nebo allochthon, and a quartzite-rich unit containing rounded clasts of both quartzite and limestone recycled from the Indianola Group of the Gunnison Plateau. Both units are deeply dissected. Relative uplift along the Wasatch fault zone and concomitant erosion have left many exposures in excess of 600 feet (180 m) above present drainages. The quartzite-rich unit is cut by numerous high-angle normal faults.

Inconclusive geomorphic evidence suggests a late Tertiary age for the Salt Creek Fanglomerate. However, an early Pleistocene age cannot be ruled out for the upper part of the unit. Its base may contain strata that record the initial uplift of the Gunnison Plateau. The limestone- and quartzite-rich units are probably contemporaneous in age, based upon their similar stratigraphic position and morphology. Just north of the mouth of Salt Creek Canyon, the quartzite-rich unit overlies the limestone-rich unit, indicating overlapping alluvial-fan deposits from separate sources.

Limestone-rich unit (QTsl) — The limestone-rich unit is overall brownish in color. It is distinguished from the other unit by the angular nature of its clasts and the conspicuous lack of quartzite. Most clasts are cobble size, but clasts six feet (1.8 m) in diameter were noted; Oquirrh, Diamond Creek, Park City, Woodside, and Thaynes cobbles are distinguishable. On the northern wall of Quaking Asp Canyon, there is a small consolidated exposure of this unit cemented by calcite.

Quartzite-rich unit (QTsq) — The quartzite-rich unit of the Salt Creek Fanglomerate also contains limestone clasts, but these are subrounded to rounded, recycled clasts from the Indianola Group of the Gunnison Plateau. Quartzite is generally dominant, though the quartzite:limestone clast ratio can differ considerably from one exposure to another. The quartzite is identical to that of the Indianola Group. It is rounded, mostly cobble sized, but boulders are locally present. It displays a wide variety of colors, including white, purple, ochre, red, and laminated white and purple. Clast size does not vary appreciably over the Nephi quadrangle, except closer to the Indianola cliffs where large conglomeratic blocks up to 10 feet (3 m) in diameter occur. The matrix of this unit is everywhere calcareous and consists of poorly sorted silt- to pebble-size material. It is distinctly reddish and less often brown. Near springs and seeps a white caliche crust usually develops. The unit is medium to thick, lenticularly bedded, with minor lenticular sandstone and pebbly sandstone interbeds.

The quartzite-rich unit is nearly always unconsolidated and develops a boulder-strewn surface. Where consolidated it appears identical to conglomerates of the Indianola Group; only its distribution and anomalous attitudes serve to distinguish it from Indianola strata. Where unconsolidated, it can appear identical to level-2 alluvium; however, it can be distinguished on the basis of morphology and elevation.

QUATERNARY SYSTEM

Lake Bonneville

The Bonneville shoreline has been extended into the northwestern part of the Nephi quadrangle by Currey (1982, Plate 1). The proposed extent of Lake Bonneville follows the 5,090-foot (1,551 m) contour line, thereby encompassing nearly eight square miles (20 km^2) of the quadrangle. However, exposures of Lake Bonneville sediments or erosional features were not observed. Additionally, post-Bonneville movement along the Wasatch fault zone has dropped the valley floor 23 feet (7 m) since the mid-Holocene (Schwartz and Coppersmith, 1984). Additional post-Bonneville offset is uncertain, but a series of faulting events northeast of Nephi has produced a single well-preserved fault scarp up to 105 feet (32 m) high. The areal extent of possible Lake Bonneville deposits or erosional features is thus reduced. However, the area in question has been cultivated or otherwise disturbed and instructive exposures are poor. If Bonneville sediments are present in the extreme northwest corner of the Nephi quadrangle, they are covered by younger, fine, alluvial-fan sediments from Salt Creek Canyon.

Mass-movement deposits

Using the definitions of Varnes (1978), most mass movements of the Nephi quadrangle are debris-flow or avalanche deposits, although debris and rock slumps, and large, complex mass movements are also present. Those that have involved Cedar Mountain strata are designated by Qmsc, while others are mapped as Qms.

East of Footes Canyon, in the northeastern portion of the Nephi quadrangle, there is a jumbled mass of Paleozoic and early Mesozoic strata overlying the Arapien Shale. Black (1965) mapped this hill as a series of imbricate thrust splays caught beneath the sole of the Nebo overthrust. Le Vot (1984) believed it represents an ancient landslide complex. I concur with Le Vot. I indicate the boundaries of the landslide complex on the map, however, because the mass is composed of large coherent blocks, the material is labeled by its bedrock name.

Pleistocene and Holocene mass-movement deposits (Qmsc and Qms) — A series of complex, overlapping mass-movement deposits involving Cedar Mountain strata occur along the Twist Gulch and Cedar Mountain strike zones. Those south of Old Pinery Canyon are suggestive of the slow periodic creep of toreva blocks active since late Pleistocene time, rather than individual slope failures. Each probably is still active on a large scale, and their surfaces are marred by recent small debris slumps. Narrow, north-trending depressions mark the locations of major scarps and are partially filled with slope wash. However, three well-developed mass movements are present. In Rocky Ridge Canyon, a long, narrow debris-flow deposit fills the canyon to an estimated depth of 100 feet (30 m). The other two are near the head of Biglows Canyon at the base of the Indianola cliffs, and in Suttons Canyon immediately south of Death Hollow Spring.

Based upon their blunted morphology, three other mass-movement deposits are probably late Pleistocene in age. The largest, in Andrews Spring Canyon, probably moved as a rock and debris avalanche. It consists almost entirely of unconsolidated quartzite and limestone pebbles, cobbles, and boulders, and minor blocks of conglomerate up to 10 feet (3 m) in diameter derived from the quartzite-rich unit of the Salt Creek Fanglomerate and the basal Indianola Group. It is deeply incised and locally has a deep, densely vegetated regolith. It issues from a narrow graben at Gravel Spring, suggesting that rupture along the faults may have triggered the slope failure. At one time this mass-movement deposit blocked Andrews Spring Canyon. Old alluvium occurs in an incision cut along the northern flank of the slide.

Just to the southwest in Miller Canyon, sediment derived from the Twist Gulch Formation forms a well-developed earth flow composed entirely of light-brown, porous, sandy soil. It has a classic lobate front and hummocky surface considerably modified by stream incision. Southeast of Nephi, a deeply dissected rock slump involves unconsolidated gravels from the quartzite-rich unit of the Salt Creek Fanglomerate. The material is poorly sorted, unconsolidated, and well vegetated. None of these three mass-movement deposits show evidence of recent large-scale movement.

Based upon their youthful morphology, most mass-movement deposits in the Nephi quadrangle are Holocene in age. Most were formed or reactivated during 1982 and the spring of 1983, a season of higher than average rainfall. Calcareous mudstone strata of the Arapien Shale, the Twist Gulch Formation, the Cedar Mountain Formation, and the lower portion of the Indianola Group are the units most susceptible to slope failure. Except for the northernmost block, which contains mudstone, the conglomeratic North Horn blocks are not susceptible. Few mass movements have occurred in strata of the Nebo allochthon, except in the Ankareh Formation in Red Canyon.

The most conspicuous mass-movement deposits within the Nephi quadrangle are shallow debris flows. Sources are marked by avalanche scars eroded into the lower Indianola cliffs along the northwestern flank of the Gunnison Plateau. They are found only south of Biglows Canyon where they occur in shallow, colluvial-filled ravines. To the north, strata especially susceptible to slope failure have been concealed by faulting and the Salt Creek Fanglomerate, and perhaps in part replaced by a northward coarsening facies change across this fault. These shallow debris flows usually extend slightly past the major break in slope.

Associated with these shallow debris flows and avalanche scars are debris and rock slumps that cut into the Indianola hillside up to 20 feet (6 m) or more. They are rotational, with the upper generally coherent block moving down an average of 20 to 30 feet (6 to 9 m). Their toes, however, often are broken up into many smaller debris-flow and avalanche deposits. Though intact, the blocks are usually fractured by a myriad of subsidiary scarps. At the crown of each large slump is a massive conglomerate bed. Small seeps usually occur in the mudstone and sandstone interbeds directly below the conglomerate.

Immediately north of the Nephi quadrangle, on the north-facing flank of Round Top Hill, is a large rock and debris slump. Upslope from the main scarp, and reaching into the Nephi quadrangle, are numerous small subsidiary fractures which were not mapped. Other important Holocene mass movements occur in Old Pinery Canyon, near the heads of Salt Spring and Rocky Ridge Canyons, The Elk Pasture, and along outcrops of Indianola Group on the west flank of the Gunnison Plateau (Biek, 1987). Several mass movements have damaged roads and trails, and threaten streams and man-made facilities.

Alluvial-fan deposits

Three levels of alluvial-fan deposits have been mapped in the Nephi quadrangle. The oldest are the large coalesced alluvial fans of Juab Valley, upon which younger and smaller inactive and active fans overlap. The large coalesced alluvial fans likely contain late Tertiary strata beneath the surface; however, only Quaternary sediments are exposed.

Coalesced alluvial-fan deposits (Qafc) — One large coalesced alluvial fan of Juab Valley emanates from Salt Creek Canyon, and the other from Old Pinery and Fourmile Canyons. Both slope gently westward and continue beyond the western border of the Nephi quadrangle. A distinctive down-fan fining is present with the finer middle and distal portions being cultivated. Coarser materials, restricted to the apices of these fans, are poorly sorted, subangular to subrounded pebbles and cobbles with a few boulders. Both fans contain mostly quartzite and limestone clasts derived primarily from the Indianola Group. The northern fan also contains substantial sediments derived from the Nebo allochthon. Wells in Juab Valley bottom in alluvial deposits and have not reached bedrock. Based upon interpretation of gravity data and a seismic-reflection profile, Zoback (1987) indicates that Juab Valley just west of Nephi contains a maximum of about 5,200 feet (1,585 m) of valley fill.

Level-2 alluvial-fan deposits (Qaf_2) — Level-2 fans are cut by younger alluvium and level-1 alluvial fans. Deposits north and northeast of Nephi are isolated and are offset by relatively recent movement along the Wasatch fault zone. Level-2 fans to the south may be related to a similar, though poorly expressed movement along the inferred trace of the Wasatch fault zone, and/or perhaps to movement resulting from rotation along faults dissecting the ridge crest immediately to the east. They are assumed to be generally contemporaneous with their northern counterparts due to their similar morphology and stratigraphic position. The relationship of level-2 alluvial fans and level-2 alluvium is uncertain, but they are probably contemporaneous.

Level-2 fans at the entrances to Gardner Creek and Red Canyon consist of angular to subangular, poorly sorted, pebble- to cobble-size clasts derived from the Nebo allochthon. Light- to medium-gray limestone is the dominant rock type. Thicknesses range from 0 to about 50 feet (0 to 15 m).

Level-2 fans south of Nephi overlap unnamed volcaniclastic strata, but they contain few volcanic clasts. Most are subrounded, pebble- to cobble-size quartzite and limestone clasts derived from the quartzite-rich unit of the Salt Creek Fanglomerate.

Level-1 alluvial-fan deposits (Qaf_1) — Level-1 alluvial fans include the small, actively forming alluvial fans of the Nephi quadrangle. Recent movement along the Wasatch fault zone has produced scarps in these fans northeast of Nephi. The contact of these deposits with the large alluvial fans of Juab Valley and canyon bottom alluvium is generally gradational. The contact with upstream alluvium is even more gradational. All contacts are based primarily upon morphological differences. The fans are composed of locally derived materials. The largest level-1 alluvial fans are those prograding and coalescing out into Juab Valley.

Alluvial deposits

Both young and old alluvial deposits have been mapped in the Nephi quadrangle. Young (level-1) alluvium is restricted to canyon or valley bottoms. Older (level-2) alluvium is also restricted to modern drainages, but it has been deeply incised and thus isolated from active streams. Because it lies above modern streams, it has often been mistaken for the Salt Creek Fanglomerate.

Level-2 alluvial deposits (Qal_2) — Numerous, evidently contemporaneous, elevated alluvial deposits have been mapped in the Nephi quadrangle (figure 2). Because of the lithologic similarity, prior workers (Eardley, 1933a; Johnson, 1959; Black, 1965; LeVot, 1984) mapped parts of them as Salt Creek Fanglomerate. They can be distinguished, however, by morphology and elevation. The surfaces of this alluvium are everywhere planar and slope gently away from the Nebo allochthon or Gunnison Plateau, in sharp contrast to the deeply dissected topography of the Salt Creek Fanglomerate. Margins are incised up to 280 feet (85 m), though most average 160 to 200 feet (50-60 m). Incision decreases upstream in accord with greater down-cutting expected closer to the Wasatch fault zone. Although their margins are deeply incised, these old alluvial deposits clearly are restricted to modern drainages.

North of and in Biglows Canyon, thicknesses range from 0 to about 120 feet (0 to 36 m). The extensive deposits south of Biglows Canyon are probably thicker. Over the extent of their grassy, generally unfaulted surfaces, there is usually no appreciable variation in clast size. Level-2 alluvial deposits north of Salt Creek consist of thick- to massively bedded, poorly sorted, clast-supported, angular to subangular pebbles, cobbles, and rare small to medium boulders of recognizable overthrust strata set in a brown, poorly sorted matrix. South of Salt Creek these deposits appear redder because they have been derived from strata of the Gunnison Plateau, including the quartzite-rich unit of the Salt Creek Fanglomerate. They consist of poorly sorted, subrounded quartzite and limestone pebbles, cobbles, and minor small to medium boulders set in a poorly sorted brownish-red matrix. These deposits are unconsolidated nearly everywhere.

The extensive exposure of level-2 alluvium in the south-central portion of the Nephi quadrangle is cut by numerous recent normal faults along the Wasatch fault zone. Though of different morphology and faulted, it is continuous with the large coalesced alluvial fan immediately to the west.

Level-1 alluvial deposits (Qal_1) — Level-1 alluvium has been mapped in most major drainages except Biglows Canyon where its small size precludes placement on a map of this scale. Its thickness is widely variable; it is probably greatest at Little Valley where it may be in excess of 50 feet (15 m) thick. Its composition everywhere reflects that of local headland sources. All level-1 alluvial deposits are unconsolidated. Most are poorly sorted and coarse. However, near the center of Little Valley they consist of well-sorted sand and silt, with a locally developed soil profile. Modern channels associated with these deposits cut older alluvial fans and are distinguished from active alluvial fans by morphology. Additionally, the streambed of most deposits is entrenched, often as much as 10 feet (3 m). East and northeast of Nephi, these deposits are locally offset by recent movement along the Wasatch fault zone.

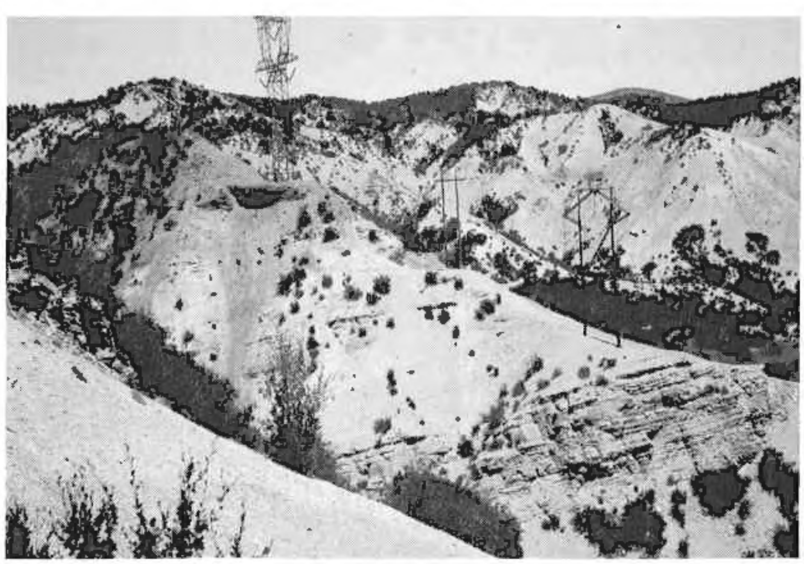

Figure 2. Remnant of level-2 alluvium unconformably overlying the Arapien Shale, just west of the entrance to Footes Canyon. View to the northeast.

Colluvial deposits

Several small exposures of colluvium have been mapped in the Nephi quadrangle. Most are distinctly gravelly, but fine-grained colluvium was mapped at one locality. All contain unconsolidated, poorly sorted, locally derived, gravitationally deposited material.

Fine-grained colluvial deposits (Qcf)

A single exposure of fine-grained colluvium just north of Suttons Canyon may be in part modified by slope wash processes. It consists entirely of redeposited sand and silt from the Twist Gulch Formation and has developed a deep regolith. It nearly obscures a small west-dipping exposure of down-faulted North Horn conglomerate.

Gravelly Colluvial Deposits (Qcg) — Small, coarse colluvial patches of gravel have been mapped in a few places in the quadrangle.

Slope-wash deposits (Qac)

Numerous, though small, deposits of slope wash have been mapped in the Nephi quadrangle. They consist of generally fine colluvial debris modified by fluvial processes. Most often this slope wash is restricted to closed, grass-covered depressions which receive diffuse, locally derived, clastic input from all directions, unlike alluvial deposits which have a definite unidirectional source and transport. Where surrounded by steeper hills, the deposits tend to be coarser. Narrow, north-trending deposits in the southeastern portion of the quadrangle mark the scarps of large toreva blocks.

Calcareous spring tufa (Qst)

A small deposit of calcareous spring tufa is located at the southern toe of Round Top Hill. It originates from a spring located at the intersection of thrust and normal faults in Red Canyon. This light- to medium-gray tufa is lightweight, porous, and contains a sponge-like network of vesicles. Although likely still forming, most of this tufa is probably older than old alluvium which appears to lap up against it.

Artificial-fill deposits (Qfl)

Four small areas of artificial fill have been mapped within the Nephi quadrangle. The many small stock-pond dams were not mapped, but most are shown on the topographic base. Artificial fill along Interstate 15 was not mapped, but it forms a long curvilinear belt along its length. Most of the fill has come from a gravel pit located in level-1 alluvial fans at the mouth of Broad Canyon, approximately two miles (3.2 km) south of Nephi.

STRUCTURE

The geology of the Nephi quadrangle records results of at least two major crustal disturbances: the Sevier orogeny (Late Cretaceous to Paleocene [?]) and basin and range extension (early-middle Miocene to present). Salt diapirism has also disturbed the rocks on a smaller scale.

NEBO ALLOCHTHON

The Nebo allochthon consists of a mostly Paleozoic to early Mesozoic sedimentary assemblage exposed in the southern Wasatch Range and thrust 12 to 40 miles (19 to 64 km) eastward during the Late Cretaceous Sevier orogeny along the Charleston-Nebo overthrust (Hintze, 1960; Crittenden, 1961; Royse and others, 1975; Dixon, 1982; Morris, 1983; Tooker, 1983; LeVot, 1984; Jordan, 1985). I use the name "Nebo overthrust" when referring to that segment of the Charleston-Nebo overthrust bounding the southern Wasatch Range.

Most workers suggest that emplacement of the Nebo allochthon was accompanied by compressional forces directed towards the east or northeast (Black, 1965; Le Vot, 1984). However, the northeast trend of the Nebo anticline and large doubly plunging Arapien anticline on Salt Creek Canyon, together with smaller superimposed folds and faults, indicate a component of southeast-directed compression in the Nephi quadrangle (Biek, 1987). This apparent contradiction results from the quadrangle's location at the southern terminus of a large northeast-trending ramp anticline. At the margin of such a structure, a component of southeast-directed compression would accompany the allochthon's relative northeast movement and northeast rotation of the northern end of the Gunnison Plateau during final emplacement of the Nebo allochthon.

Le Vot (1984) indicates that the Nebo allochthon was emplaced during the late Cretaceous (Campanian), before deposition of an overlap assemblage of North Horn strata (Maastrichtian[?] to Paleocene). Dating of underlying blind thrusts inferred by Jefferson (1982) and Le Vot (1984) is more problematic; Lawton (1985) believes they are no older than early Maastrichtian, while Villien and Kligfield (1986) prefer a late Paleocene age for final foreland thrusting in central Utah.

Thrust plates

Within the Nephi quadrangle, the base of the Nebo allochthon is marked by a series of imbricate plates. Each was sheared from the base of the upper plate and lagged behind as the sheet advanced eastward (Black, 1965). These splays are present in incompetent rocks of the Ankareh Formation and Arapien Shale. The main thrust plate (herein referred to as thrust plate I), which forms the bulk of the southern Wasatch Range, includes strata from the upper Oquirrh Group through the middle Ankareh Formation.

These strata are overturned, generally dipping to the north-northwest. The thrust-bounding thrust plate I cuts successively younger strata as it is traced east, ramping up out of the Nebo anticline. East of Round Top Hill, this thrust is nearly horizontal, while to the west it dips gently west. It is locally deformed in the vicinity of Round Top Hill (figure 3).

At Red Canyon, and north in the Mona quadrangle, a window in thrust plate I exposes at least two other major thrust sheets: thrust plates II and III. The upper one (thrust plate II) is repeatedly sliced by nearly horizontal or slightly east-dipping thrusts. It contains incomplete sections of the Woodside Formation, Thaynes Limestone, Ankareh Formation, and incompetent, undifferentiable Triassic red beds. Thrust plate II contains an incomplete north-dipping section of Thaynes strata thrust over an overturned northwest-dipping sequence of middle and lower Ankareh beds. The mudstones of the Ankareh appear to have been smeared out along bedding planes and are very poorly exposed. Small isoclinal folds were observed in mudstone float, but none were found in place.

Thrust plate III includes a complete, though deformed, section of Twin Creek Limestone that is enclosed by portions of the Navajo Sandstone and Arapien Shale. It makes up the whole of Miners Ridge and the lower depths of Red Canyon. The thrust fault bounding the lower surface of this plate, exposed on the north wall of Quaking Asp Canyon, has 200 to 300 feet (60-90 m) of relief. In the Red Canyon creekbed, Navajo and Twin Creek strata are fully overturned. There, the Sliderock Member of the Twin Creek Limestone has been gently folded into a doubly plunging synformal anticline which trends slightly north of east. To the south, strata bend upwards and form a dipslope such that at the crest of Miners Ridge they are nearly vertical. A down-faulted block of west-dipping Sliderock strata is present in Red Canyon; its northeastern corner is marked by a brecciated zone of white-colored Navajo Sandstone several feet thick. Aside from a small central fault with an offset of about 10 feet (3 m), the displacement on these faults is unknown. Twin Creek strata are in fault contact on the east with Navajo Sandstone, suggesting a displacement less than 200 feet (60 m). On the west, the block is in fault contact with the Ankareh Formation, suggesting a greater displacement, perhaps 1,000 feet (305 m). Because these faults do not appear to cut thrust plate I, they are likely contemporaneous with its emplacement.

The structurally lowest plate of the Nebo allochthon (thrust plate IV) crops out in the lower reaches of Quaking Asp Canyon. However, it is poorly exposed and consists mostly of undifferentiated Park City strata with uncertain attitudes. Map patterns on the south side of the entrance to Quaking Asp Canyon suggest that Thaynes, Woodside, and undifferentiated Park City strata are folded in this thrust sheet. Across the canyon, several thin slices of these same units crop out, bounded by apparently warped thrusts.

The sequence of events leading to the emplacement of thrust plates I-IV of the Nebo allochthon is unclear. Steeper dips on the east side of the south-plunging asymmetric anticline underlying Round Top Hill (discussed below) suggest that it formed during the late stages of emplacement of the Nebo allochthon. The irregularity in the thrust surface may have contributed to shearing off of slivers of thrust plate I as suggested by Black (1965). Folding of the thrust surface of plate I in Red Canyon would thus be contemporaneous with thrusting. Alternatively, it is possible that thrust plates II, III, and IV were emplaced subsequent to plate I, thus folding its thrust plane. Under this scenario, the window in plate I at Red Canyon reveals a stacked sequence of small-scale duplexes. Apparently horizontal or gently east-dipping, closely spaced thrusts on the southwest side of Round Top Hill may represent back thrusts rising out of a wedge of gypsiferous Arapien Shale pushed up in front of these plates.

Folds

The overturned strata of the Nebo allochthon form the southern end of a large anticline that extends about 18 miles (29 km) to the north. Studies by Eardley (1934), Jefferson (1982), Le Vot (1984), and Smith and Bruhn (1984) indicate that it is a ramp anticline. Gentle, north-to-northwest dips of the Nebo overthrust may indicate that this thrust is not a tear fault but a ramp thrust which reaches the surface. If this interpretation is correct, then the Leamington transcurrent fault of Morris (1983) must flatten and merge with the Nebo overthrust before reaching the southern Wasatch Range.

Underlying Round Top Hill is the southern end of a gypsum-cored anticline that plunges about 15 degrees south. Map patterns indicate that the eastern flank of this fold dips more steeply than its western flank (70-80 degrees versus 30-40 degrees). Permian and Triassic strata overlying this fold dip moderately to the north at such an angle that they do not appear to be refolded. A shallow graben has accommodated extension of these beds.

At the head of Rees Flat, overturned Park City and early Triassic strata have been folded into northeast-trending asymmetric folds superimposed upon the Nebo anticline. Poor outcrops preclude their detailed description, but this synformal anticline and antiformal syncline do plunge gently northeast. A poorly expressed, asymmetric antiformal syncline, parallel to the others, may lie immediately to the north in strata of the Franson Member of the Park City Formation and the Meade Peak Phosphatic Shale Tongue of the Phosphoria Formation. The western end of this fold is truncated by a small southeast-trending tear fault, with right lateral displacement up to 1,000 feet (304 m).

Normal faults

Aside from truncation by the Wasatch fault zone which has produced faceted spurs on plate I strata northwest of the J-Hill, normal faulting associated with basin and range extension has not modified structural relationships of the Nebo allochthon in the Nephi quadrangle. Normal faulting has, however, had considerable effect in the area immediately north of the quadrangle (Black, 1965; Le Vot, 1984).

GUNNISON PLATEAU

The Gunnison Plateau is plateau-like in its center but is bounded east and west by high-angle normal faults; it loses its table-top character to the north (Weiss, 1982). The eastern margin contains steeply dipping to overturned strata. The western flank is characterized in the north by Arapien foothills, in the middle portion by a west-dipping monoclinal belt, and in the south by a complicated graben system. Weiss (1982) notes that the Gunnison Plateau contains a parallel pair of superimposed synclines which plunge gently south. The older, centrally located syncline contains strata of the Twist Gulch through the South Flat Formations, while the younger, less tightly folded syncline consists of Price River through Green River strata with its axis close to the eastern margin of the Gunnison Plateau.

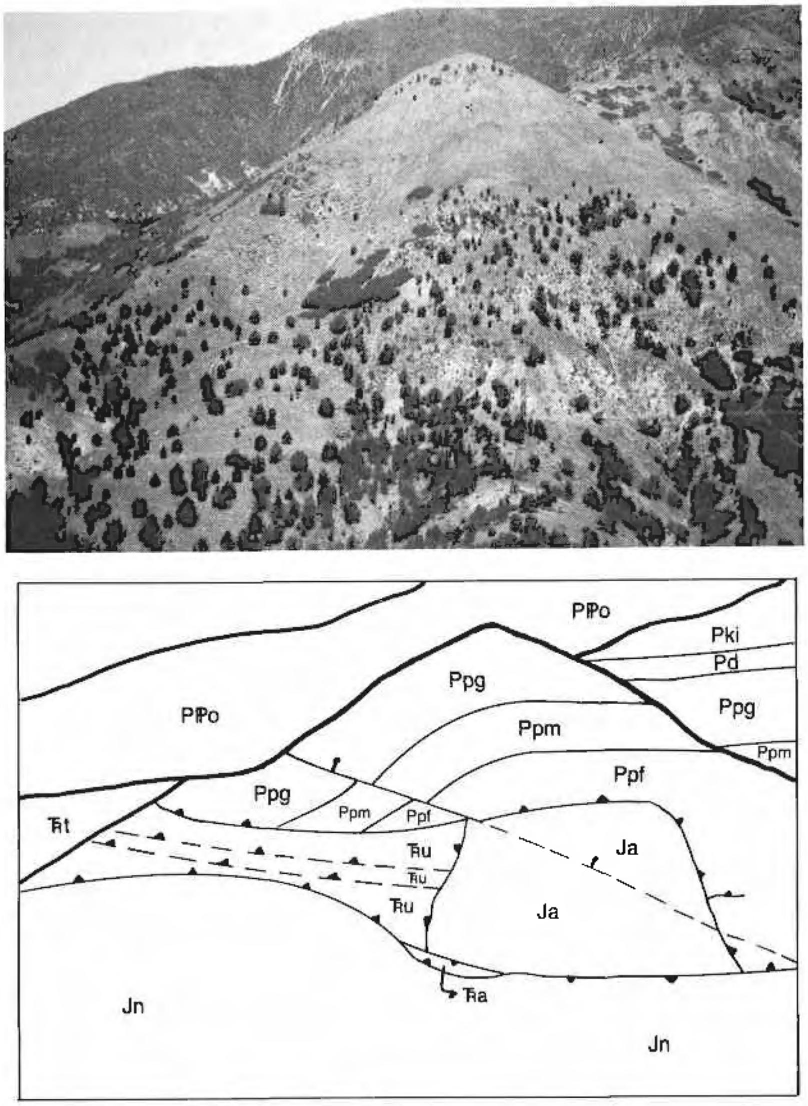

***Figure 3.** The south side of Round Top Hill as seen from Miners Ridge. Three main thrust plates are visible, with strata in each generally overturned and dipping to the north-northwest. Here, thrust plate I strata include the Oquirrh Group (PIPo), Kirkman Limestone (Pki), Diamond Creek Sandstone (Pd), and the Park City Formation (Ppg, Ppm, Ppf). Thrust plate II strata include the Thaynes Limestone Ŧt), Ankareh Formation (Ŧa), and undifferentiated Triassic beds(Ŧu) sandwiched between thrust faults in the left-center of the photograph. Thrust plate III contains only the Navajo Sandstone (Jn). The Arapien Shale (Ja) marks the southern end of a gypsum-cored antiform that plunges about 15 degrees south. A shallow graben follows the axis of this fold and accommodates extension of beds in their strike plane.*

Folds

Only the moderately east-dipping northwestern flank of the older syncline lies in the Nephi quadrangle. Attitudes of the Arapien Shale and Twist Gulch Formation show that this flank gradually swings to the northeast such that it is on strike with correlative beds in the Cedar Hills. Attitudes within the Indianola Group, near Gravel Spring, reflect a more abrupt change, probably influenced in part by faulting.

Normal faults

The thick, structurally coherent slab of Indianola conglomerate capping the plateau is generally uncut by faults, but adjacent foothills are heavily faulted. The main feature of these western foothills is a large down-faulted block defined by a fault striking southeast up Biglows Canyon, and a complex fault zone striking due south along the Twist Gulch strike zone. Outcrop patterns along the Biglows Canyon fault indicate that it is a high-angle normal fault with a scissor-like displacement. Displacement, likely no more than 700 feet (213 m), is greatest upstream and appears to be slight at the canyon's entrance. Displacement at the southern margin of the south-striking fault zone is accommodated by rotation along large toreva blocks that are stepped down sequentially to the west. In the vicinity of Gardners Fork and Suttons Canyon, several down-to-the-west high-angle normal faults bound and cut blocks of west-dipping conglomeratic North Horn strata. At Suttons Canyon, fault drag on these blocks has increased dips from about 25 degrees to 55 degrees. The minimum displacement along the master western fault at Suttons Canyon is probably about 400 to 500 feet (122 to 152 m). Relations between the Arapien Shale and Twist Gulch Formation one mile (1.6 km) to the north seem to require a displacement approaching 700 feet (213 m).

This large, down-faulted block is itself cut by numerous high-angle normal faults, most of which are stepped down to the west. The north-striking fault scarps just north of the mouth of Fourmile Creek have subdued morphologies, suggesting that they are older, perhaps late Pleistocene to early Holocene in age. They form a series of down-to-the-west blocks and minor grabens which together take up some displacement along the Wasatch fault zone. These scarps are not traceable with certainty north across unconsolidated Salt Creek Fanglomerate deposits at Cedar Point, but they are likely present, curving slightly to the northwest and stepping down Tertiary volcaniclastic and Salt Creek Fanglomerate deposits in what would otherwise appear to be a normal unconformable stratigraphic contact.

Northeast of Cedar Point, the Salt Creek Fanglomerate is cut by an anastomosing network of north-striking, high-angle, normal faults that bound blocks generally stepped down to the west. Displacement on these faults is unknown but is probably less than 200 feet (60 m) total.

Forming the southern margin of Little Valley, an anomalous triplet of down-to-the-north high-angle normal faults strikes almost east-west. Though densely vegetated, the north-facing slopes of the southern two scarps are well preserved, up to 50 feet (15 m) high. The northern fault scarp is much smaller and more subdued. These faults are in part antithetic to a larger and older fault bounding the eastern side of Little Valley and are probably late Pleistocene to early Holocene in age.

SALT CREEK CANYON

Folds

Salt Creek Canyon is carved into a great dome-like mass of Arapien Shale that is host to a vast array of smaller, complex structures. Several independent lines of evidence suggest that the dome is a northeast-trending, doubly plunging anticline roughly four miles (6.4 km) long. First, from atop a high vantage point it has a dome-like appearance. Second, southeast-dipping strata at the northwest edge of the Gunnison Plateau form its southeastern limb, while identical strata just east of Rees Flat dip north and northeast and form its northwestern limb. Third, the distribution of stratigraphic units of the Arapien Shale suggest a grossly anticlinal structure plunging more steeply to the northeast than to the southwest. On the west it is truncated by the Wasatch fault zone and subsidiary faults at the mountain front, on the south by a fault trending up Biglows Canyon, and to the northeast in the Fountain Green North quadrangle it is concealed by the Moroni Formation.

Well-exposed subsidiary folds of large size in Salt Creek Canyon have been described by Baer (1976), Standlee (1982), Witkind (1982), and Witkind and Hardy (1984). The largest is the gypsum-cored anticline currently being mined at the entrance to Salt Creek Canyon. It trends north-south and plunges steeply north; it may plunge south as well. Directly across Salt Creek the nose of this anticline, composed of light-greenish-gray calcareous mudstone, is deflected sharply to the northeast. Flowage of massive white gypsum into the core of this structure is clearly revealed in the quarry walls. There, the contact of the gypsum and overlying light-greenish-gray calcareous mudstone and clayey micrite is marked by a shear zone roughly one foot (0.3 m) thick that incorporates pieces of each rock type.

To the northeast, on the north side of Salt Creek Canyon, is the overturned northern limb of an east-west-trending fold that plunges 20 degrees east. It is cored by red and gray gypsiferous siltstone and mudstone. This diapiric fold trends nearly perpendicular to most folds in the Arapien Shale.

Faults

Faults within the Arapien Shale are extremely difficult to trace along strike. Nevertheless, most deformation within Arapien strata appears to be taken up through folding. Black (1965) mentions several small thrust faults within the Arapien Shale of Salt Creek Canyon. Some of these are reinterpreted as diapiric contacts related to the diapir described above. Displacement along normal faults bounding a block of North Horn strata near the mouth of Salt Creek Canyon is probably less than several hundred feet.

A single large reverse fault was observed in the Arapien Shale. It is located in Salt Spring Canyon, dips 70 degrees north and has a displacement of about 50 feet (15 m). A similar, though smaller, fault is present immediately to the south. Both strike just north of east, parallel to an inferred thrust fault of Banks (1986) in the North Fork of Salt Creek Canyon.

DIAPIRISM

Relatively small-scale diapiric structures up to one mile (1.6 km) long are present in the Nephi quadrangle. At the entrance to Salt Creek Canyon, a gypsum-cored anticline is currently being mined. The exposed gypsum core is about 475 feet (144 m) high by 230 to 300 feet (70-90 m) wide. Vertical movement of gypsum into the core of this structure is clearly revealed by shear zones in the quarry walls. Additionally, the structure at Round Top Hill may have resulted in part from vertical movement of gypsiferous Arapien Shale during emplacement of the Nebo allochthon.

Much larger scale diapiric structures (of the order of tens of miles in length) have been interpreted in central Utah. Witkind (1982, 1983) and Witkind and Weiss (1985) suggest that a 24-mile-long (38 km) late(?) Oligocene or Miocene diapiric fold forms the northwestern margin of the Gunnison Plateau. Witkind believes that this structure, the Levan diapiric fold, branches into three splays just east of Nephi, each deforming the Nebo overthrust. While surface geology and available subsurface data do not uniquely constrain structural interpretations of the northwestern Gunnison Plateau, this mapping and a recent seismic reflection profile through Salt Creek Canyon do conflict with certain aspects of Witkind's model.

The western branch of the Levan *diapiric* fold is based in part on misidentified strata at Miners Ridge and Red Canyon. As previously discussed, this mapping suggests that structural complexities at Round Top Hill formed during emplacement of the Nebo allochthon. Additionally, strata at Miners Ridge and Quaking Asp Canyon reveal no evidence of lying along the axis of an existing or collapsed diapiric structure.

The central branch of Witkind's Levan diapiric fold is based on the asymmetric syncline just east of Rees Flat. He correctly defines the asymmetry of this structure but misidentifies its strata. He believes that the basin is underlain by diapiric Arapien Shale which bowed up the beds and Nebo overthrust. However, this syncline is composed primarily of Cedar Mountain strata. Conformably underlying Twist Gulch beds can be projected underneath the toe of the thrust, effectively sealing off passage for such a diapir. The asymmetry of this syncline is attributable to emplacement of the Nebo allochthon (Black, 1965; Le Vot, 1984; Biek, 1987).

The eastern branch of the Levan diapiric fold is based on the gentle northwest dip of the Nebo overthrust in the upper reaches of Salt Creek Canyon, wide variation in axial trends of folds in Salt Creek Canyon, and the northwest strike of strata in the northernmost Gunnison Plateau. However, these observations are most simply explained by eastward-directed compression during the Sevier orogeny (Black, 1965; Banks, 1986; Villien and Kligfield, 1986; Biek, 1987). Additionally, a seismic reflection profile through Salt Creek Canyon revealed prominent subhorizontal reflectors roughly 1 to 1.5 miles (1.6 to 2.4 m) below the Gunnison Plateau, arguing against large-scale salt diapirism (Zoback, 1987). The shallowest reflectors are slightly upwarped and consistent with localized diapirism observed in Salt Creek Canyon.

WASATCH FAULT ZONE

The Wasatch fault zone is a major mid-Miocene to Holocene normal fault bounding the eastern margin of the Great Basin. Relative uplift of 9,500 to 16,000 feet (2,895 to 4,877 m) created the imposing western flank of the Wasatch Range; adjacent basin fill is up to 13,000 feet (3,960 m) thick (Zoback, 1983).

Schwartz and Coppersmith (1984) divide the Wasatch fault zone into six segments. The Nephi quadrangle includes parts of the Nephi and Levan segments. Their boundary, near Nephi, marks a major change in front range physiography and geology (Crone and Harding, 1984) and coincides with the boundary between the Middle Rocky Mountains and Colorado Plateau provinces. Smith and Bruhn (1984) point out that the segment boundary is also coincident with a major, northeast-trending displacement transfer zone between the Charleston and Pavant thrust systems that is marked by the Leamington fold.

Nephi and Levan segments of the Wasatch fault zone are believed to be separated by a gap of 9 to 10.5 miles (14.4-16.8 km) long in Holocene and late Pleistocene scarps, although there is evidence of older Quaternary scarps (Machette, 1984; Schwartz and Coppersmith, 1984). The Nephi segment is characterized by relatively large Holocene scarps, while the Levan segment has smaller ones (Crone and Harding, 1984). Paleoseismic studies indicate that three surface-faulting events have occurred since the mid-Holocene, with a combined displacement of about 23 feet (7 m) along the Nephi segment (Machette, 1984; Schwartz and Coppersmith, 1984; Jackson and Ruzicka, 1988). The most recent event occurred within the past 1100 years, and perhaps as recently as 300 to 500 years ago. A series of faulting events northeast of Nephi has created a single scarp up to 105 feet (32 m) high.

Seismic reflection and gravity data indicate Juab Valley is an asymmetric graben, bounded on the east by the west-dipping Wasatch fault zone and on the west by numerous buried, antithetic step faults (Zoback, 1983, 1987). Zoback (1983, 1987) estimates a maximum of about 5,200 feet (1,585 m) of valley fill and a minimum vertical offset of 8,500 feet (2,591 m) in this region. Data further suggest that the Wasatch fault zone at Nephi is characterized by a steeply dipping planar normal fault which may extend into crystalline basement, cutting older thrust faults (Zoback, 1983, 1987). In contrast, to the south at Levan, this fault is believed to merge with the Pavant thrust (Standlee, 1982; Smith and Bruhn, 1984). Crone and Harding (1984) suggest that the Wasatch fault does not hug the mountain front at Nephi but runs through the center of town. However, it has not recently broken through to the surface. They documented subsidiary faults which hug the mountain front east of Nephi, creating a bedrock bench about 400 feet (122 m) below the surface.

ECONOMIC GEOLOGY

OIL AND GAS

The Nephi quadrangle is located in the Utah hingeline-thrust belt region, which has been the subject of considerable oil and gas exploration. No exploration wells have been drilled in the Nephi quadrangle. However, several wells have been drilled in adjacent quadrangles and shows have been reported. Potential source beds include Pennsylvanian and Permian strata, the Triassic Thaynes Limestone, the Jurassic Twin Creek Limestone and Arapien Shale, and possibly Cretaceous strata. Many potential reservoir rocks occur in the quadrangle (Britt and Howard, 1982; Stark and Gordon, 1982).

URANIUM AND VANADIUM

Immediately north of the Nephi quadrangle, on the western flank of Mt. Nebo, uraninite and tyuyamunite (calcium uranium vanadate) mineralization occurs in oolitic limestone of the Sliderock Member of the Twin Creek Limestone, although preliminary studies suggest no economic reserves (R. Steel, personal communication, August 1985).

GYPSUM

Massive rock-gypsum has been mined in the Nephi quadrangle intermittently since the late 1880s (Bullock, 1962; Hintze, 1988). The mine at the south side of the entrance to Salt Creek Canyon is contained within the core of a steeply north-plunging anticline. The exposed ore body is about 500 feet (152 m) high, 240 to 320 feet (73 to 97 m) wide, and 700 feet (213 m) long. It has been considerably thickened due to gypsum flowage into the core. Reserves of about one million tons are estimated to be recoverable without digging further south into the core of the anticline (R. Steele, personal communication, August, 1985). The gypsum is primarily used in cement production with a minor amount used as fertilizer. Assays indicate that the gypsum is 98-100% pure, contaminated by only minor amounts of Arapien mudstones.

Prior to 1959, gypsum was mined on Miners Ridge. The 80-foot-thick (24 m) gypsum bed stands vertical and was mined by a drift tunneled into the gypsum from the western spur of the ridge. The drift was stoped, leaving pits along the ridge. The attitude of the stratum and the enclosing incompetent Arapien mudstones make mining of the remaining gypsum difficult.

Pods of gypsum in Salt Creek Canyon have been prospected. Most, however, are contaminated by red and greenish-gray mudstone. Most are small. A large pod, located in the north part of section 2, T. 13 S., R. 1 E., may be sizable enough to warrant further consideration.

Gypsum on the northern flank of Round Top Hill has not been mined but is a favorable target. Sorenson and Korzeb (1984, p. 982) document additional gypsum nearby in Gardner Creek Canyon.

SAND AND GRAVEL

Alluvial fans along the eastern margin of Juab Valley contain large reserves of sand and gravel. However, most deposits are poorly sorted. Deposits south of Salt Creek Canyon tend to contain more rounded clasts than those to the north. One large sand, gravel and road-fill pit located in an alluvial fan about two miles (3.2 km) south of Nephi was used for construction of Interstate 15. Small borrow pits are scattered throughout the Nephi quadrangle and have provided fill for nearby stock and retaining ponds. The large expanse of alluvium in the south-central portion of the Nephi quadrangle could serve as a good source of rounded, generally cobble-sized gravel.

Well-sorted pebble-sized fill is found in talus cones at the bases of Arapien hills, especially in Salt Creek Canyon. It is well sorted because of the evenly bedded and fractured nature of its source and therefore does not require processing for most uses.

PHOSPHATE

The base of the Meade Peak Phosphatic Shale Tongue of the Phosphoria Formation is marked by a laterally continuous 8- to 12-inch-thick (20 to 30 cm) oolitic phosphorite bed throughout the Mt. Nebo area. This bed contains 35-40% collophane. Exposures at the head of Rees Flat in Quaking Asp Canyon are accessible. The soft, porous, fetid, black bed could yield small quantities of rock phosphate for fertilizer.

OTHER PROSPECTS

A small prospect pit occurs at the mouth of Quaking Asp Canyon in the SW NE NE ¼ section 34, T. 12 S., R. 1 E. Minor mineralization of a thin, thrusted slice of undifferentiated Park City strata, including iron oxide stains and veins of limonite and euhedral quartz crystals, is exposed, but offers little evidence of valuable base metals. Robert Steele (personal communication, August 1985) reported traces of gold in the gravel pit south of Nephi that may have been concentrated by reworking of old alluvial gravels derived from the Indianola Group.

A prospect, probably for salt, is shown on the topographic base map in Salt Spring Canyon, near the Arapien Shale/Twist Gulch contact. It has been obscured by dense vegetation and, perhaps, covered by mass-movement debris.

WATER RESOURCES
SURFACE WATER AND SPRINGS

The Nephi quadrangle is located in the Northern Juab Valley hydrogeologic area and is part of the Jordan River drainage basin. Salt Creek is the only perennial stream in the quadrangle. Small quantities of surface water are found in many smaller canyons, especially the upper reaches of Footes and Red Canyons, but normally disappears into alluvium downstream.

Because 1985 (when this field work was completed) marked the third year of an unusually wet cycle, more ground-water discharge points were observed than normally might be expected. Their locations are shown on the map and their estimated discharges are on file at the UGS. Many of these springs, particularly those shown on the topographic base, have been impounded for livestock.

GROUND WATER

Gates (1982) provided a general synthesis of shallow ground water, less than 500 feet (152 m) deep, of the Nephi area. Generalized directions of ground-water movement are from uplands to Juab Valley. Ground water also flows north from the ground-water divide located about two miles (3.2 km) south of Levan Ridge, the topographic divide which separates Juab Valley into northern and southern portions. Artesian conditions are common in the center of Juab Valley. Smaller reserves of water likely exist in the large level-2 alluvial deposit in the south-central portion of the quadrangle and in the Twist Gulch Formation.

GEOLOGIC HAZARDS
EARTHQUAKES

The Nephi quadrangle lies within the Intermountain seismic belt, a north-trending zone of diffuse, shallow seismicity approximately encompassing the transition zone between the Basin and Range and Colorado Plateau physiographic provinces (McKee and Arabasz, 1982). The Wasatch fault zone transects the Nephi quadrangle and poses the greatest potential for large earthquakes.

Although surface rupture has not occurred along the Nephi segment of the Wasatch fault zone in the past 137 years, abundant geologic evidence indicates that the fault is active and is capable of producing large-magnitude (M_L 6.5-7.5) earthquakes. Three such surface-faulting events have occurred along the Nephi segment during the late Pleistocene to early Holocene, dropping the valley floor about 23 feet (7 m) relative to the adjacent southern Wasatch Range. At the mouth of Gardner Creek, these plus earlier Pleistocene movements have produced a single scarp 92 to 105 feet (28 to 32 m) high (Machette, 1984; Schwartz and Coppersmith, 1984).

No surface ruptures have been identified in the town of Nephi even though Crone and Harding (1984) and Zoback (1987) document that the Wasatch fault zone continues south through Nephi at depth. Faults hugging the mountain front east of Nephi show relatively fresh fault scarps and should be considered active. The greatest earthquake hazards are ground shaking and the rupture of unconsolidated alluvial-fan sediments of Juab Valley. Old, unreinforced masonry houses in Nephi present a serious potential for personal injury and property damage in the event of an earthquake.

Normal faults cut older unconsolidated gravels in the ridge crest from Cedar Point to Biglows Canyon, but they show no evidence of late Pleistocene or Holocene movement. Normal faults showing evidence of Quaternary activity also occur in Little Valley and in level-2 alluvial deposits due south of Cedar Point (Biek, 1987). All of these faults are within the footwall of the Wasatch fault zone and they all cut older Quaternary deposits. Thus, all of these faults are likely related to the Wasatch fault zone and might be reactivated.

MASS MOVEMENTS

Mass movements cause considerable concern in the Nephi quadrangle (Biek, 1987). Stratigraphic units especially susceptible to slope failure are the Ankareh Formation, Arapien Shale, Twist Gulch and Cedar Mountain Formations, and basal Indianola Group. The Cedar Mountain Formation is host to a particularly large number of debris-flow deposits, slumps, and very large complex Pleistocene mass movements. Along with the basal Indianola Group, the Cedar Mountain Formation is capable of producing the largest mass movements in the quadrangle.

Mass movements of immediate concern exist in the upper reaches of Old Pinery and Footes Canyons. Mass movements at the Elk Pasture in Footes Canyon occur in level-2 alluvium and (probably basal) Arapien Shale. Of significant concern in this area, the large, densely vegetated bowl immediately to the east (in the NE SW and SE NW ¼ section 30 T. 12 S. R. 1 E.) is dissected by 1- to 3-foot-high (0.3-0.9 m) scarps, and mass-movement deposits could bury the upper reaches of Footes Canyon. The campground at Old Pinery Canyon is ringed on the east and south by similar debris slumps in displaced Cedar Mountain strata.

FLASH FLOODS

Price (1984) records the general locations of flash floods resulting from cloudbursts in the Nephi 30 x 60-minute quadrangle since 1850. Such floods have occurred just west of the entrance of Footes Canyon, in the town of Nephi, and in Old Pinery Canyon just south of Little Valley. Because Nephi is located at the discharge point of a 95.6-square-mile (248 km^2) basin, future floods must be anticipated. The seriousness of this problem is brought out in the peak flow of 49,920 gpm (832 cfs) measured on Salt Creek during a 1968 summer thunderstorm; it is 35 times greater than the average annual flow of 1,620 gpm (27 cfs).

SUBSIDENCE

Subsidence has occurred in the large coalesced alluvial fan at Salt Creek and in the distal edges of overlapping level-1 alluvial fans in the southeast and, to a lesser extent, northeast, portions of Nephi. Geomorphic evidence indicates that up to 20 feet (6 m) of subsidence has occurred (Bruce Kaliser, personal communication, May 30, 1985). Most of the disturbed area underlies farmland, although there remains a very real potential for damage to Interstate 15 and other public and private properties. Deep cracks have been reported southeast of Nephi (Bruce Kaliser, personal communication, May 30, 1985).

It is unknown whether this subsidence results from 1) dissolution of the Arapien Shale at depth, 2) hydrocompaction, 3) excessive ground-water pumping, or 4) tectonic creep. Kaliser, who has made preliminary observations of the problem, prefers options 1 and 2. I prefer option 3. Even though excessive withdrawal of ground water is apparently not taking place in Nephi, Salt Creek, the principal source of its recharge, is mostly diverted for irrigation. With less water available for recharge, subsidence may occur.

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