Structure and Stratigraphy of the Nephi NW 7½-Minute Quadrangle, Juab County, Utah*

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ABSTRACT.—The structure and stratigraphy of the Nephi NW 7½-minute Quadrangle record four major phases or geologic events typical of the "hingeline" of central Utah.

The first was a depositional phase which took place from Precambrian through Late Jurassic time and resulted in the accumulation of about 12,735 m of limestone, sandstone, and shale. However, only about 3,200 m of rocks, including the Oquirrh Group, Diamond Creek Sandstone, Park City Formation, Ankareh Shale, and Nugget Sandstone, are exposed in this quadrangle.

The second phase was the Sevier orogeny, during which pre-Jurassic rocks were folded and thrust faulted. Desmoinesian-Missourian rocks of the Oquirrh Group have been thrust over Wolfcampian rocks of the same group in the west central part of this quadrangle. Parts of the Triassic Ankareh Shale also have been thrust over the Jurassic Nugget Sandstone in the southwest quarter of the quadrangle. The eroded debris from these folded and faulted strata accumulated as thick syntectonic conglomerates represented by the Conglomerate of Spring Canyon, the Orme Springs Conglomerate, and the Red Narrows Conglomerate.

The third phase was a period of volcanism during Oligocene time which emanated from a volcanic center in the East Tintic Mountain area. Depositional products of this volcanic episode uncomformably overlie pre-Oligocene rocks in the quadrangle and include volcanic flows and tuffs in the Goldens Ranch Formation, the Fernow Quartz Latite, the Copperopolis Latite, and the Cazier Canyon Agglomerate.

The final phase, beginning in Miocene, resulted from tensional stresses which produced normal faults and associated uplifts within the Basin-and-Range Province.

INTRODUCTION

The Nephi NW 7½-minute Quadrangle lies along the "hingeline" area of central Utah. Paleozoic sedimentary rocks thicken west and thin east of the hingeline, while Mesozoic and Cenozoic sedimentary strata thin westward and thicken eastward. Folds, thrust faults, and tear faults associated with the Sevier orogeny, later Oligocene volcanism and uplift, and still later north-trending normal faults associated with basin-and-range style extension are all a part of the structural scene along this part of the hingeline. Paleozoic and lower Mesozoic rocks deformed by the Sevier orogeny are overlain by upper Mesozoic and Cenozoic strata within the quadrangle.

The purpose of this study is to clarify structural and stratigraphic relationships by detailed mapping. Surface data, coupled with limited subsurface data obtained from the Placid Oil Company #1 Howard well, form the basis for a structural cross section which illustrates subsurface structural and stratigraphic relationships.

The Nephi NW Quadrangle is located in the central part of Long Ridge, directly west of the southern Wasatch Mountains and the town of Nephi, Utah, about 70 km south of Provo, Utah (fig. 1).

Geologic study within the quadrangle was first done by Muessig (1951), who mapped the geology of Long Ridge at a scale of 1:63,360. Black (1965) studied the Nebo thrust, 16 km to the east, where structural and stratigraphic relationships are similar to those in this quadrangle. Morris has worked extensively in surrounding areas (Morris 1964, 1975, 1977; Morris, Douglass, and Kopf 1977; and Morris and Lovering 1961, 1979.)

Geologic mapping was done on aerial photographs, scale 1:20,000. Geologic information was transferred to the Nephi NW Quadrangle map on a scale of 1:24,000. Stratigraphic sections were measured with a Jacob's staff and Abney level. Conglomerate units were differentiated by cobble counts (fig. 5 and appendix 1).

STRATIGRAPHY

General Statement

Rocks of the Nephi NW Quadrangle range in age from Pennsylvanian to Quaternary and are separated by unconformities produced during Early Triassic, Cretaceous, and Tertiary times. The most marked angular unconformity is that below the Tertiary Orme Spring Conglomerate, which buried folded Paleozoic and Mesozoic rocks (fig. 2).

Pennsylvanian-Lower Permian Systems

The oldest formation exposed within the quadrangle is of Pennsylvanian age. Outcrops are limited within this quadrangle, but in the quadrangle to the west (Morris 1977), outcrops of Pennsylvanian-Permian rocks form major ridges.

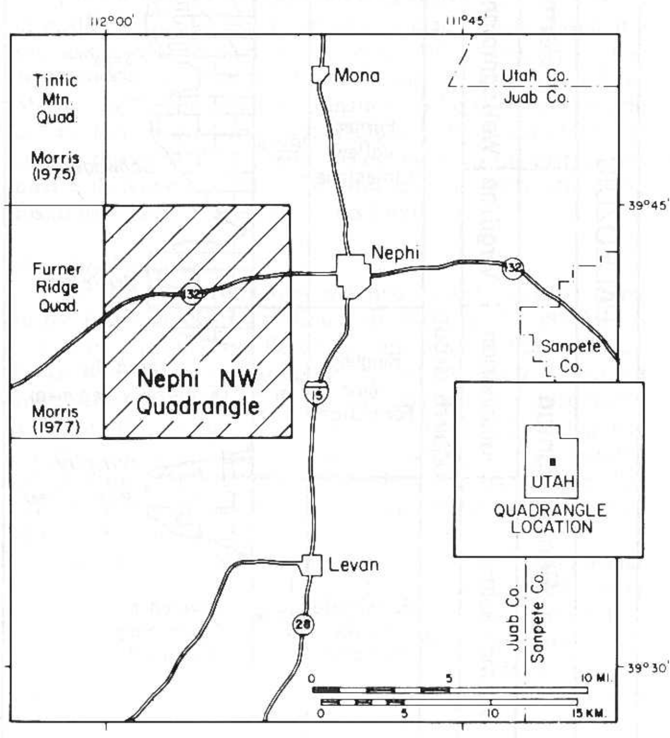

FIGURE 1.—Index map of the Nephi NW 7½-minute Quadrangle, Juab County, Utah.

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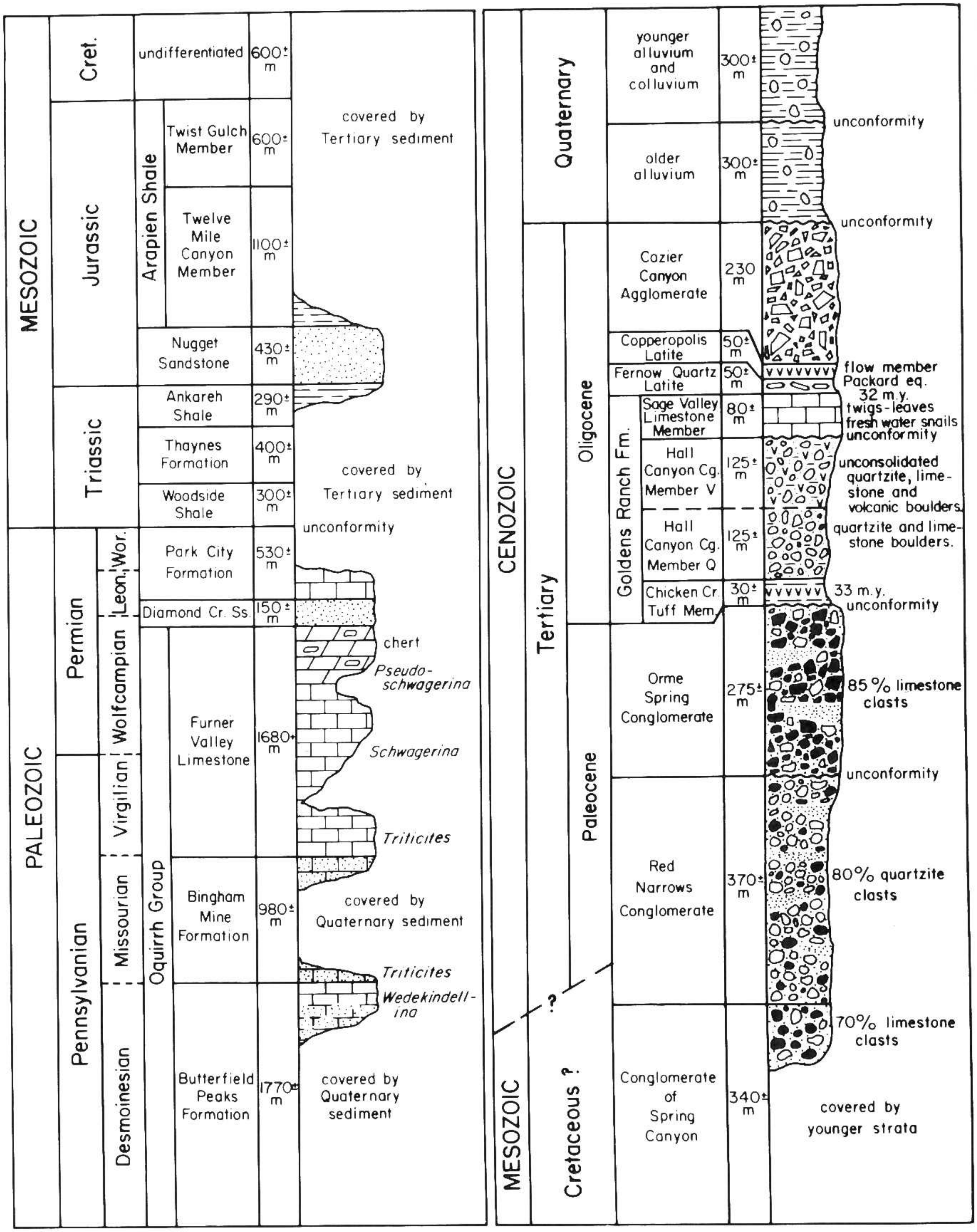

FIGURE 2.—Stratigraphic column of rocks in the Nephi NW Quadrangle. (Thickness of rocks in left column drawn at different scale than those on right column.)

Oquirrh Group

The Oquirrh Formation, first named by Gilluly (1932), was formally raised to group level by Welsh and James (1961). This paper will follow usage proposed by Welsh and James (1961) and followed by Morris and others (1977) in the adjacent Furner Valley Quadrangle. Three formations were included in the Bingham sequence of the Oquirrh Group: the West Canyon Limestone, the Butterfield Peaks Formation, and the Bingham Mine Formation. Morris and others (1977, p. 6–8) added an additional formation to the group in the southern East Tintic Mountains, the Furner Valley Limestone. This formation was added to the upper part of the Oquirrh Group because it was lithologically distinct and dissimilar to the age-equivalent Kirkman Limestone (Morris and others 1977, p. 8).

In the central Dog Valley and Long Ridge areas of this quadrangle, only the upper three formations of the Oquirrh Group are exposed. Of these, the Furner Valley Limestone is most widely exposed. Thickness of the Oquirrh Group in the Furner Valley Quadrangle is given by Morris (1977) to be more than 5,000 m. A similar thickness probably exists in the Nephi NW Quadrangle, but these strata are covered with Tertiary and Quaternary deposits and complete sections are not available.

Butterfield Peaks Formation. Morris (1977) mapped 2,000–2,300 m of Butterfield Peaks Formation in the Furner Valley Quadrangle and determined the formation to be of Desmoinesian age.

Exposures in the Nephi NW Quadrangle are relatively small; outcrops are confined to two small hills in the west central part of the quadrangle (section 7, T. 13 S, R. 1 W). Rocks on the largest hill are mostly medium to dark gray silty limestone with a strong fetid to petroliferous odor. An outcrop near the top of this hill contains a medium gray limestone coquina of bryozoans, brachiopods, and crinoids.

The other small outcrop of the Butterfield Peaks Formation is located in the NW ¼ of section 12, T. 13 S, R. 2 W, and is composed mostly of brown-weathering, fine-grained, highly indurated calcareous sandstone. Small, poorly preserved brachiopods were the only fossils found there.

Bingham Mine Formation. In the Furner Valley Quadrangle, Morris and others (1977, p. 5) reported 975 m of Bingham Mine Formation and state that no other formation of the Oquirrh Group in the southern East Tintic Mountains contains arenaceous units as thick and as prominent as those of the Bingham Mine Formation. Morris and others (1977, p. 14) assign this formation a Missourian age, using fusulinids.

In the Nephi NW Quadrangle, only the upper unit of the formation (unit 41 of Morris and others 1977, p. 16) is exposed. This fine-grained, red-brown, calcareous sandstone, though poorly exposed, also contrasts markedly with the younger gray limestones. The Bingham Mine Formation crops out along the eastern portion of section 32, T. 12 S, R. 1 W. Here the exposed Bingham Mine Formation is less than 96 m thick and is unfossiliferous.

Furner Valley Limestone. The Furner Valley Limestone in the Furner Ridge Quadrangle is 1,595 m thick and consists mostly of limestone and dolomite (Morris 1977). Fusulinids noted by Morris and others (1977, p. 14) indicate a Missourian age for the lower 640–700 m, a Virgilian age for the middle 305 m, and a Wolfcampian age for the upper 672–914 m.

The Furner Valley Limestone within the Nephi NW Quadrangle is better exposed than older Oquirrh rocks. The best outcrops are those north of Dog Valley Pass (fig. 3) and in Dog Valley. Good outcrops are limited to the upper half of the formation. The lower part is exposed only in stream gulleys where it happens to be uncovered by erosion. In the Furner Ridge Quadrangle (Morris 1977) most of the upper third of the formation is hydrothermal dolomite and the lower two-thirds is limestone.

Morris and others (1977) collected fusulinids from the Furner Valley Limestone on Long Ridge where some of the dolomite units contain silicified fusulinids. They (1977) report widespread chert nodules in the type section. Fusulinids collected by them (1977) from Long Ridge were correlated to those on Furner Ridge to the west. Photomicrographs of these diagnostic fusulinids were published by Morris and others (1977) because they were better preserved than those of Furner and Jericho Ridges to the west.

Exposed thickness of the Furner Valley Limestone in the Nephi NW Quadrangle is about 1,100 m, but the complete thickness is probably similar to that in the type section (1,500–1,600 m). Morris and others (1977, p. 8) report that the upper portion of the limestone is probably correlative with the lithologically distinct Kirkman Limestone in the southern Wasatch Mountains. Usage of the Kirkman Limestone for the Long Ridge area is not appropriate.

Permian System

Diamond Creek Sandstone

In the Nephi NW Quadrangle the Diamond Creek Sandstone, as Muessig (1951) described it, is a white to grayish pink, medium- to coarse-grained, calcareous, quartz sandstone which crops out in the Dog Valley Pass area (fig. 3), section 9, T. 13 S, R. 1 W, and on the southern end of Sugarloaf in the center of section 18, T. 13 S, R. 1 W.

The Diamond Creek Sandstone is bimodal and composed of medium, rounded quartz grains in a matrix of fine sand and silt, with a calcareous cement. Muessig (1951) reported a thickness of 108 m of Diamond Creek exposed in Dog Valley Pass. Morris (1977) reported the formation to be between 209 and 267 m thick in the Furner Valley Quadrangle. Black (1965) records a thickness of 120 m on Mount Nebo to the east. I have used a thickness of 150 m for cross-section construction. No fossils have been reported from this formation.

Park City Formation

The Park City Formation was first named from exposures in the Park City district by Boutwell (1907, p. 439–58). Morris (1977) reported that the Park City Formation on Furner Ridge, 10 km west of Long Ridge, is about 530 m thick and contains three recognizable members. In the Nephi NW Quadrangle, Park City Formation crops out south of Utah 132 in Dog Valley Pass (fig. 20). The Grandeur Member is the only member of the Park City Formation exposed in this quadrangle. The other members are buried beneath conglomerate of the Tertiary Goldens Ranch Formation.

The Grandeur Member is 290 m thick on Furner Ridge (Morris 1977). On Long Ridge, I computed a thickness of about 304 m. The Park City Formation is regarded as Leonardian–Guadalupian. In this quadrangle, the exposed Park City Formation is composed mostly of grayish pink, medium- to coarse-grained, fossiliferous limestone that has a fetid to petroliferous odor.

Triassic System

General Statement

Only the Ankareh Formation of the Triassic System is exposed in this quadrangle; however, the Woodside Shale and the

FIGURE 3.–Overturned Diamond Creek Sandstone and float-covered Furner Valley Limestone, on the north side of Dog Valley Pass, north ½, section 9, T. 13 S, R. 1 W.

Thaynes Formation will be briefly discussed because these formations likely exist beneath the Tertiary cover.

Woodside Shale

The Woodside Shale, not exposed in this quadrangle, was defined from exposures in Woodside Gulch, Park City district, Utah, by Boutwell (1907, p. 439–58). The nearest exposure is north of Salt Creek Canyon, about 10 km east of the east edge of this quadrangle, where the formation is 305 m thick (Black 1965, p. 64). Black described the Woodside Shale as a red shale with minor red and greenish siltstone and brownish red sandstone that is fine grained and highly cross-bedded.

Thaynes Limestone

The Thaynes Limestone, originally described by Boutwell (1907, p. 439–58) from exposures in Thaynes Canyon, Park City district, Utah, does not crop out in this quadrangle but is concealed beneath Tertiary sediments. Black (1965, p. 64) recorded a thickness of 410 m in excellent exposure north of Salt Creek Canyon, 10 km east of this quadrangle. There the formation is interbedded calcareous red shale, siltstone, calcareous brown sandstone, and gray limestone. Siltstone, sandstone, and shale predominate in the lower half, but gray limestone is most common in the upper half.

Ankareh Shale

The Ankareh Shale was named by Boutwell (1907, p. 439–58) from Ankareh Ridge in the Park City district, Utah. Muessig (1951) measured 175 m of Ankareh Shale south of Stone Quarry Canyon in the Nephi NW Quadrangle. He described the formation as a deep red interbedded shale, siltstone, and sandstone with sandstone and siltstone predominant. One conglomerate unit and two units of white to pink coarse sandstone break the monotony of the red shale and siltstone. Ankareh Shale is exposed in small patches in the northeast ¼ of section 25, T. 13 S, R. 1 W, and the central portion of section 19, T. 13 S, R. 1 W. Only a partial section is exposed because the formation appears to have acted as a glide plane for faulting during both the Sevier orogeny and later basin-and-range extension. No fossils were reported from the formation by Black (1965) or Muessig (1951), and none were found during this study. Reeside and others (1957) designated the Ankareh as Upper Triassic.

D. Sprinkel (personal communication July 1981) reported that the Ankareh Formation was recognized at a depth of 3,658 m in the Placid Oil Company #1 Howard well. Black (1965, p. 65) reported a thickness of 285 m of Ankareh Shale in exposures north of Salt Creek Canyon, 10 km east of this quadrangle.

Jurassic System

Nugget Sandstone

The Nugget Sandstone was named from Nugget station on the Oregon Shortline Railroad in Lincoln County, Wyoming, by Veatch (1907, p. 56).

Muessig (1951, p. 66) described the Nugget rocks on Long Ridge as an orange to brick red, white, and tan, strikingly cross-bedded, medium- to fine-grained, well-cemented, porous

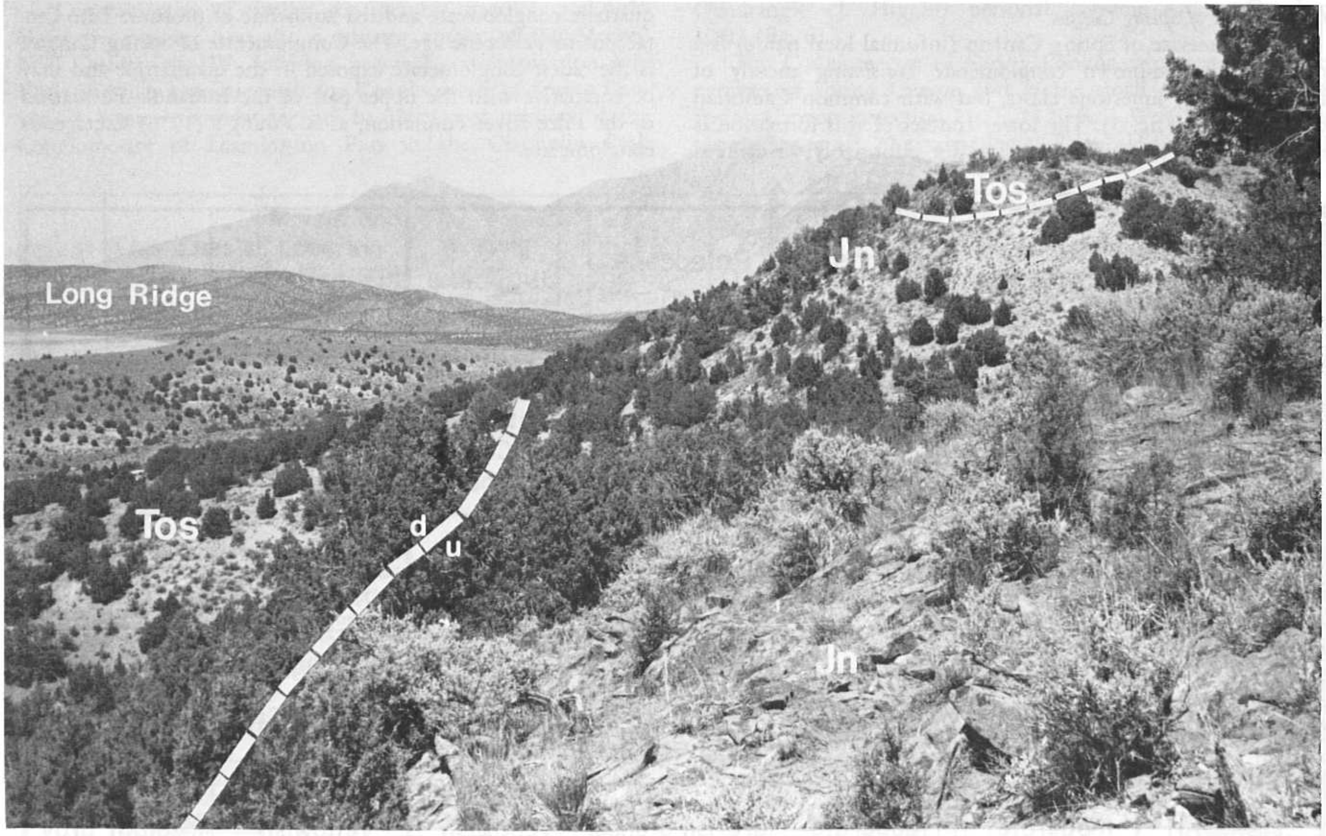

FIGURE 4.–Orme Spring Conglomerate (Tos) downdropped against overturned Nugget Sandstone (Jn). View along strike of the Nugget Sandstone (Jn) is toward the northeast; Mount Nebo in the distance. The fault that places the Orme Spring Conglomerate (Tos) against the Nugget Sandstone (Jn) follows the strike of the Nugget along the northwest side of the cuesta.

sandstone. Muessig also noted that irregular areas of Nugget Sandstone have been bleached white, an observation confirmed by this author. Nugget Sandstone crops out on the southeast side of the northeast-trending lineament (section 19, T. 13 S, R. 1 W, and section 25, T. 13 S, R. 2 W), in the southeast side of the quadrangle (fig. 4). D. Sprinkel (personal communication July 1981) reported that upper Nugget Sandstone cuttings were returned from about 3,100 m in the Placid Oil Company #1 Howard well.

Cross-bed sets in the sandstone are 1–2 m thick. The rocks are pale to moderate reddish brown, except where hydrothermal activity has occurred, and the color is a grayish pink. Most of the sandstone is fine grained. Thickness of exposed Nugget beds in the quadrangle is about 400 m. The Nugget Sandstone is probably of Early Jurassic age, though there is no fossil evidence to substantiate this probability. Fossils found in the overlying Twin Creek Limestone (Arapien equivalent) are Middle Jurassic (Imlay 1967). Black (1965, p. 66) noted well-exposed Nugget Sandstone 15 km east in Salt Creek Canyon, Utah. He described the sandstone as moderately well bedded to massively cross-bedded, porous, friable to compact, and orangish pink to white.

Arapien Shale

The Arapien Shale is not exposed in this quadrangle, nor is it exposed to the west. However, about 1,500 m of diapiric Arapien Shale is present in Salt Creek Canyon east of Nephi, Utah (Black 1965). Thickness of the Arapien Shale is questionable in the Nephi NW Quadrangle.

I have followed Spieker's (1946, p. 122–25) usage and have designated the upper Arapien Shale as the Twist Gulch Member (600 ± m thick) and the lower part as the Twelve Mile Canyon Member (1,100 m thick).

D. Sprinkel reported (personal communication July 1981) that about 1,700 m of interbedded limestone, shale, and evaporites (gypsum and salt) of the formation were encountered in the Placid Oil Company #1 Howard well.

Cretaceous System

General Statement

Strata of possible Cretaceous age in this quadrangle have been correlated by previous workers with the Price River and Indianola Formations. The Indianola Formation was originally described by Schoff (1938, p. 378) as a thick sequence of conglomerate, sandstone, shale, coal, and limestone exposed near Indianola, Utah. The Indianola Formation is overlain by the Price River Formation, which has been described as a series of interbedded sandstone, shale, and coal in its type section (Spieker 1946).

Young (1976) noted that the Cretaceous conglomerate in the Billies Mountain Quadrangle near Thistle, Utah, is quite different from rocks of the Indianola and Price River Formations and left the Cretaceous conglomerate undifferentiated there.

In the Nephi NW Quadrangle, rocks of probable Cretaceous age are also unlike the Indianola and Price River Formations, and so the conglomerate of probable Cretaceous age will be informally called here Conglomerate of Spring Canyon.

Conglomerate of Spring Canyon

Conglomerate of Spring Canyon (informal local name) is a cliff-forming, red-brown conglomerate consisting mostly of lower Paleozoic limestone clasts, but with common Cambrian quartzite clasts (fig. 5). The lower contact of this formation is not exposed. This formation lies disconformably below red quartzite conglomerate and red sandstone of probable Late Cretaceous to Paleocene age. The Conglomerate of Spring Canyon is the oldest conglomerate exposed in the quadrangle and may be correlative with the upper part of the Indianola Formation or the Price River Formation, as is Young's (1976) Cretaceous conglomerate.

Rock Features \ Age	Upper K - Paleocene (?)	Paleocene (?)	Paleocene (?)	Oligocene	Oligocene	Oligocene
Conglomerate	Conglomerate of Spring Canyon	Red Narrows Conglomerate	Orme Spring Conglomerate	Goldens Ranch Unit Q of Hall Canyon Member	Goldens Ranch Unit V of Hall Canyon Member	Cazier Canyon Agglomerate
Clast/Matrix Ratio	80%/20%	65%/35%	85%/15%	80%/20%	80%/20%	60%/40%
Degree of Lithification	highly consolidated	moderately consolidated	moderately to highly consolidated	poorly to unconsolidated	poorly to unconsolidated	moderately consolidated
General Color	moderate orange brown	moderate redish orange brown	grayish orange to dusky yellow	yellowish gray	yellowish gray	medium gray to red gray
Quartzite Clast %	30-35%	75-80%	15-30%	60-75%	55-60%	0-10%
Limestone Clast %	65-70%	20-25%	70-85%	35-40%	10-15%	0-1%
Volcanic Clast %	θ	θ	θ	θ	25-30%	90-100%
Eocambrian Quartzite Clasts	rare	common	rare	present	present	absent
Topographic Expression	small cliffs and ledges	slopes, ledges, and small cliffs	rounded knobs and some ledges	slopes	slopes	slopes, ledges, and cliffs
% Boulders greater than 25 cm.	1.49%	2.65%	1.14%	3.05%	5.45%	< 1%

FIGURE 5.—Conglomerate characteristic comparison chart that illustrates the differences between the conglomerates exposed in the Nephi NW Quadrangle.

Conglomerates of similar stratigraphic position and lithology are exposed near the northwest corner of the Moroni NW Quadrangle (W. Jefferson personal communication July 1981) and may correlate with the Conglomerate of Spring Canyon. A western correlative may be the lower portion of the Conglomerate of Leamington Pass in the Champlin Peak Quadrangle (J. Higgins personal communication October 1981) (fig. 6).

The Conglomerate of Spring Canyon occurs only in the narrows of Spring Canyon and in the small canyon north of Spring Canyon in section 21, T. 13 S, R. 1 W. Clasts from this conglomerate are 70 percent lower Paleozoic limestone and 30

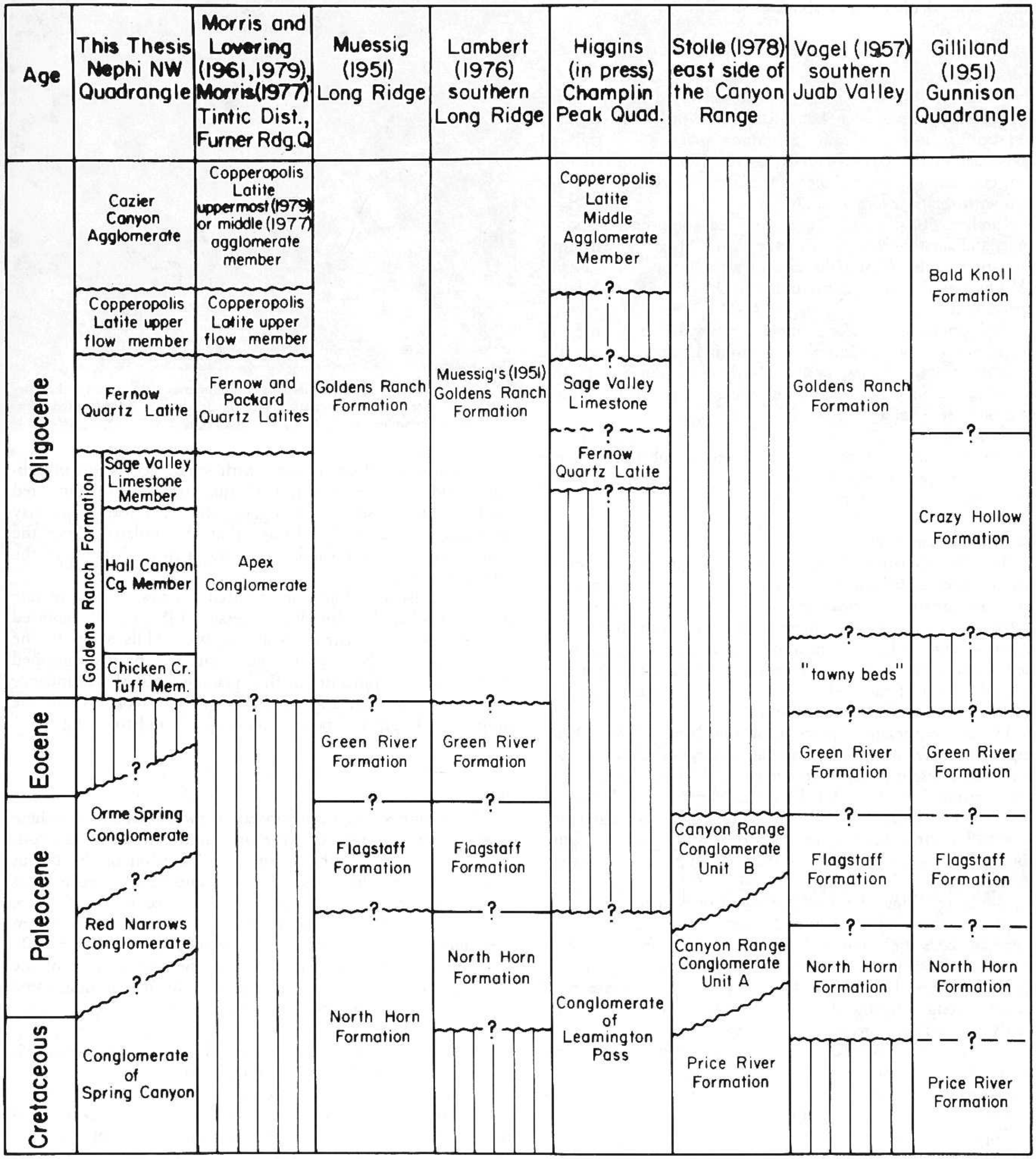

FIGURE 6.–Conglomerate correlation chart which illustrates how conglomerates from the Nephi NW Quadrangle may correlate with units of similar rocks reported by previous workers.

percent Cambrian quartzite. Clasts make up 80 to 85 percent of the conglomerate, and the rest is sandy matrix that is pale brown, fine- to coarse-grained, rounded to subrounded quartz and quartzite grains. No sandstone lenses were noted within the unit. The Conglomerate of Spring Canyon erodes to subdued rounded cliffs but is distinguishable from other conglomerates by differences in clast composition (fig. 5). Exposed thickness is calculated to be about 45 m.

Upper Cretaceous-Tertiary (Paleocene) System

General Statement

Muessig (1951, p. 71) described the dark red conglomerate and sandstone exposed on Long Ridge as North Horn Formation because it had become "common practice" to call red sandstones in the Upper Cretaceous the North Horn Formation, even though the sediments are "not everywhere synchronous with the type formation."

Lambert (1976, p. 13) noted that red conglomerate, sandstone, and siltstone mapped by Muessig (1951) as North Horn Formation in the West Hills, east of Sage Valley in the Nephi SW Quadrangle, are certainly unlike rocks of the North Horn type section.

Red sandstone and conglomerate exposed mostly on Long Ridge, east of Spring Canyon in this quadrangle, are not like those of the type section of the North Horn Formation, and should not be included there (J. R. Bushman personal communication September 1981).

Stolle (1977, p. 125) reported that the conglomerate he differentiated as unit A in the Canyon Range is probably the same as those mapped as the North Horn Formation by Muessig (1951) on the basis of lithology and color (fig. 6).

Red Narrows Conglomerate

The Red Narrows Conglomerate was named from exposures of interbedded quartzite-boulder conglomerate, red sandstone, and siltstone in Spanish Fork Canyon by Young (1976, p. 220–26). He noted that these rocks unconformably overlie folded Middle to Upper Cretaceous units that correlate with the Indianola and Price River Formations. Young thought that the middle part of the Red Narrows Conglomerate is probably equivalent to the North Horn Formation.

In the southeastern portion of the Nephi NW Quadrangle, exposures of red siltstone, sandstone, and conglomerate dominate. These exposures were mapped by Muessig (1951) as North Horn Formation. I believe that, because of the difference in composition of these rocks and the type North Horn beds and their similarity to Young's Red Narrows Conglomerate, these rocks should be included in the Red Narrows Conglomerate.

On Long Ridge, the Red Narrows Conglomerate is about 50 percent conglomerate and 50 percent sandstone. Conglomerate beds are composed mostly of quartzite clasts that range from small pebbles to boulders (0.9–1.2 m) (fig. 7). Figure 5 illustrates clast comparisons of this conglomerate with the other conglomerates of the quadrangle. Quartzite clasts are mostly Cambrian; however, Precambrian clasts are also common. About 80 to 85 percent of the clasts are quartzite. Combined upper and lower Paleozoic limestone clasts make up 15 to 20 percent of the clasts. Sandstone cobbles were not observed in the Red Narrows Conglomerate.

Topographic expression of this formation is principally rounded hills and gullies. Rare exposures of channel-fill sandstone and conglomerate occur irregularly throughout the mapped exposures (fig. 8). Most of the formation makes either

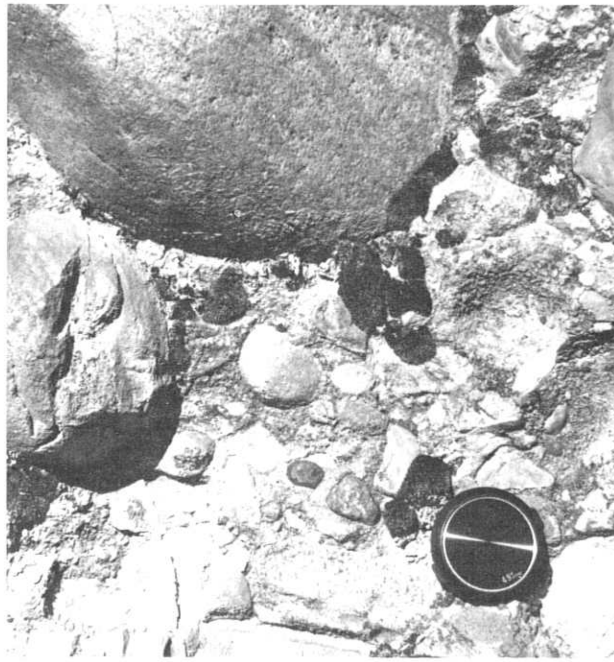

FIGURE 7.–Closeup of Red Narrows Conglomerate illustrating the predominance of quartzite clasts, degree of rounding, and the limited number of limestone clasts in section 34, T. 13 S, R. 1 W.

bright red sandy slopes covered with sparse vegetation or subdued reddish slopes strewn with quartzite boulders and red sand. Limited observations suggest that this formation may represent an alluvial fan deposit that accumulated along the foot of the Sevier highland, which was a short distance to the west or northwest.

No fossils were found in the Red Narrows Conglomerate in this quadrangle. However, Muessig (1951, p. 73) reported the occurrence of gastropods in the West Hills 8 km to the south. The Red Narrows Conglomerate can be distinguished from other conglomerates in this quadrangle by the abundance of both Precambrian and Cambrian quartzite cobbles and the deep red to bright red, poorly consolidated sandstone (fig. 7).

Upper Paleocene (?) Series

Orme Spring Conglomerate

The Orme Spring Conglomerate (new formal name) is here named from exposures of a predominately limestone-clast conglomerate exposed in the south central portion of the Nephi NW Quadrangle, Juab County, Utah. The type section for this formation is in the northeastern corner of section 31, T. 13 S, R. 2 W. A cobble count at the type locality was made 244 m west and 152 m south of the northwest corner of section 6, T. 14 S, R. 1 W. Exposures are poor, so the southeast ¼ of the southeast ¼ of section 31, T. 13 S, R. 1 W, is here designated as the type area. Reference localities for the Orme Spring Conglomerate include NW ¼ SW ¼ of section 33, T. 13 S, R. 1 W (near Orme Spring), and SE ¼ NE ¼ NW ¼ section 35, T. 13 S, R. 1 W (cobble count done here).

In the type area (fig. 9) the Orme Spring Conglomerate is composed of 75 to 90 percent conglomerate and typically forms rounded knobs (fig. 9). Coarse sandstone lenses crop out here and there within the formation and form low ledges. The Orme Spring Conglomerate can be distinguished from other conglomerate units in the Nephi NW Quadrangle by com-

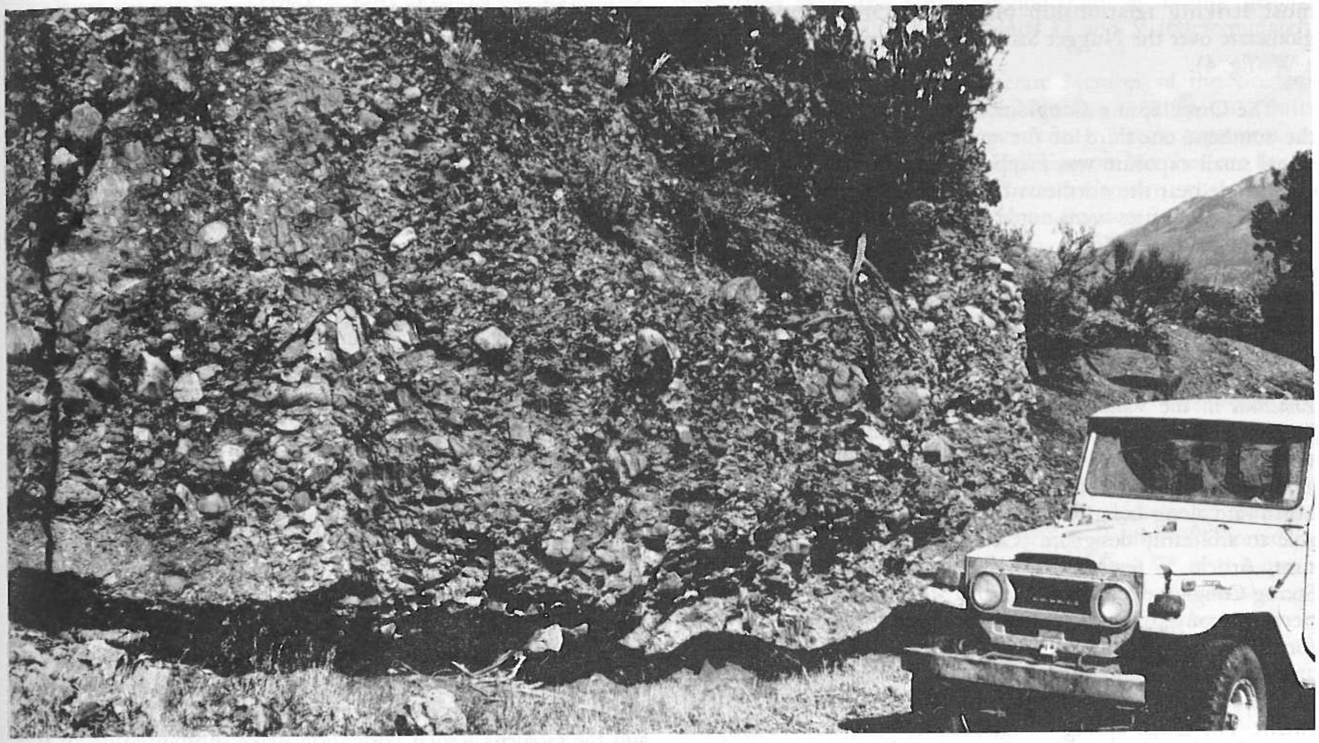

FIGURE 8.–Conglomerates lens in the Red Narrows Conglomerate on the east side of Long Ridge (section 34, T. 13 S, R. 1 W). The mountain in the distance is the northern end of Mount Nebo.

paring the following: percentage ratios of matrix to clasts; composition and percentage of clasts; stratigraphic position; topographic expression; and shape and size of clasts. Of these criteria, some are better than others for distinguishing certain conglomerates within the quadrangle. All of these criteria, however, work well in characterizing the Orme Spring Conglomerate.

As figure 5 indicates, the Orme Spring Conglomerate consists of 10 to 15 percent matrix and 85 to 90 percent clasts. Sorting generally is poor to fair, and bedding surfaces are rare. The matrix generally consists of medium- to coarse-grained, subangular to subrounded grains of mostly quartz, quartzite, chert, and lesser amounts of limestone. Matrix in the type area is grayish orange to dusky yellow.

Clast composition is the most readily apparent characteristic. Cobble counts from two widely separated parts of the quadrangle (appendix 1) indicate that 65 to 75 percent of the clasts are upper Paleozoic limestones, many of which are fossiliferous. Of these, some contain fusulinids, an indication that they are probably from the Oquirrh Group. Quartzose clasts make up 25 to 35 percent and include both metamorphic quartzite (70 percent) and very hard calcareous sandstone (30 percent). Clasts are mostly subangular to subrounded in the type area. The degree of rounding varies locally, as do the size and composition of clast. The reasons for this variance are discussed below.

The upper formation boundary is not preserved in the type section but is exposed in nearby areas. The Orme Spring Conglomerate is overlain near the type area by quartzite-rich, tuffaceous conglomerate and limestone of the Goldens Ranch Formation. Elsewhere, near outcrops of the overturned Nugget Sandstone, in section 17, T. 13 S, R. 1 W, the Orme Spring Conglomerate is overlain by lacustrine limestone. A small lens of a biotite ash-flow tuff also appears to overlie the Orme Spring Conglomerate in a small canyon west of Spring Canyon in section 21, T. 13 S, R. 1 W. These different units overlying the Orme Spring Conglomerate denote an erosional disconformity with younger strata. The basal stratigraphic boundary, likewise, is not exposed in the type area, but the Orme Spring Conglomerate unconformably to disconformably overlies several formations in various parts of the quadrangle. The

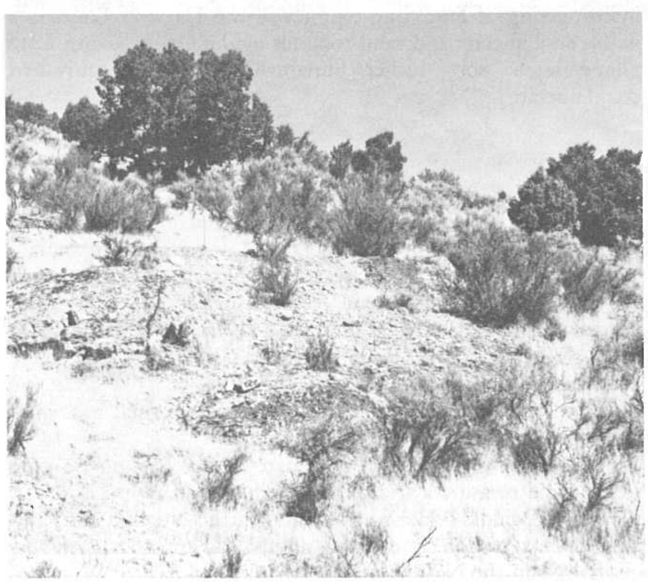

FIGURE 9.–Topographic expression of the Orme Spring Conglomerate in its type area; SE ¼, section 31, T. 13 S, R. 1 W.

and stem fragments, which Roland Brown identified as follows:

Equisetum sp. (horsetail)
Sabalities sp. (palm)
Koelreuteria nigricans
fragments of other dicotyledons

Brown (in a letter quoted by Muessig 1951, p. 99) also noted some freshwater mollusks.

Common leaf, twig, and rare branch impressions were also found at various locations throughout the quadrangle during my study, but no generic identification of these fossils has been made. Representative samples of some of the leaves and reeds collected are shown in figure 11.

Muessig (1951) noted only the mollusks mentioned in Brown's letter concerning his leaves. No other mention is made of mollusks from the Sage Valley Limestone by him or previous workers.

Several specimens of different species of freshwater gastropods (fig. 11E) were collected during the present study. They have been examined by John Hanley (personal communication September 1981). He tentatively identified three of the specimens as *Lymnaea*, species indeterminate; Lymnaeidae, genus and species indeterminate; and Gastropoda, genus and species indeterminate. Hanley suggested that these gastropods were probably from deposits of a shallow, freshwater pond or small lake. The limited areal exposures of the Sage Valley Limestone Member, as well as its lenslike nature, supports this possibility.

Thickness of the Sage Valley Limestone Member is somewhat irregular throughout the quadrangle. Muessig (1951, p. 186) reported an unbounded thickness of 45 m in its type section, and in the type area for the Goldens Ranch Formation he reported an unbounded thickness of only 30 m for the Sage Valley Limestone Member. My reference section 1 includes 80 m of Sage Valley Limestone, buried by alluvium at the base,

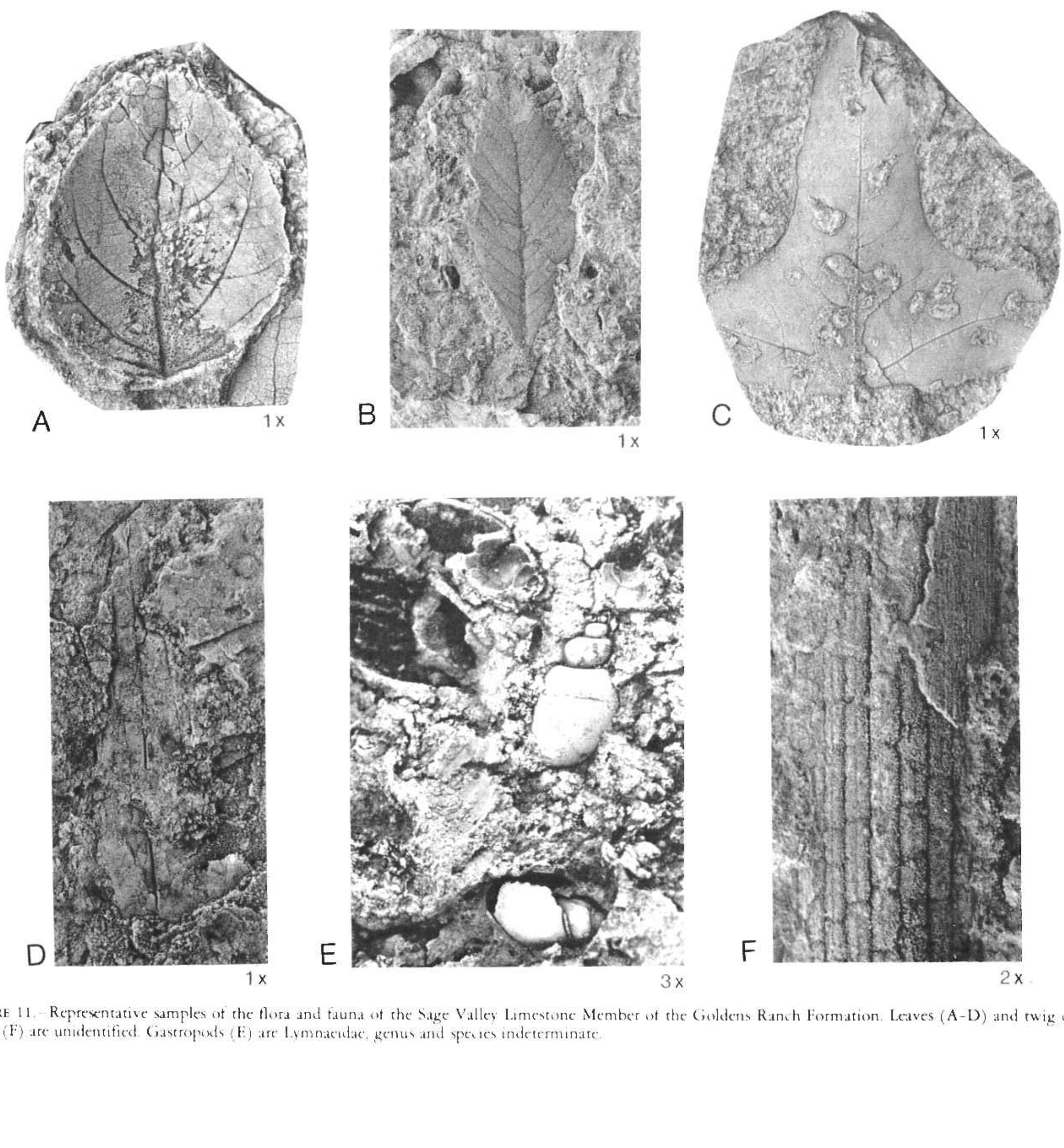

FIGURE 11.—Representative samples of the flora and fauna of the Sage Valley Limestone Member of the Goldens Ranch Formation. Leaves (A–D) and twig or reed (F) are unidentified. Gastropods (E) are Lymnaeidae, genus and species indeterminate.

with a volcanic agglomerate at the top (section 24, T. 13 S, R. 2 W). In reference section 2, however, the limestone is only 30 m thick, lies on unit Q of the Hall Canyon Conglomerate Member, and is overlain above by volcanic agglomerate (section 29, T. 13 S, R. 1 W). Several small exposures of this limestone differentiated on the geologic map are beds only 5 to 8 m thick. Some additional limestone exposures were not mapped because they are too small. The Sage Valley Limestone Member of the Goldens Ranch Formation ranges between 0 and 80 m thick in this quadrangle.

The Sage Valley Limestone Member overlies several lithologic units with erosional unconformity. In the SW ¼ of the SE ¼ of section 17, T. 13 S, R. 1 W, the limestone overlies the Orme Spring Conglomerate. On Sugarloaf, in the middle of Dog Valley, Sage Valley Limestone angularly overlies folded Furner Valley Limestone. In the type area, Sage Valley Limestone overlies units Q and V of the Hall Canyon Conglomerate Member.

The Sage Valley Limestone Member generally forms ledgy slopes but some of the thicker, more massive sections of the limestone form small (5-m-high) cliffs, which cap several hills throughout the quadrangle. Where thinner portions of this limestone are eroded, only small chunks of limestone lie irregularly scattered over the slope.

In the SE ¼ of the SE ¼ of section 24, T. 13 S, R. 2 W, the Sage Valley Limestone Member is overlain by a lens of ash-flow tuff (fig. 12) that contains doubly terminated quartz crystals. This tuff fits the description and looks the same as the Fernow Quartz Latite mapped in the Tintic Mountain and Furner Ridge Quadrangles by Morris (1975, 1977). Morris (1975) concluded that the Fernow and Packard Quartz Latites are temporally equivalent. Morris and Lovering (1979, p. 34) later reported that the Packard Quartz Latite yielded isotopic ages between 32.8 m.y. ± 1 m.y. and 32.07 m.y. ± 1 m.y. This finding suggests that the Sage Valley Limestone Member is no younger than Packard or Fernow Quartz Latites. Because the Sage Valley Limestone Member overlies the Chicken Creek Tuff Member, which Evernden and James (1964) dated at 33.2 m.y., the limestone should also be no older than 33.2 m.y. (middle to upper Chadronian).

Fernow Quartz Latite

The Fernow Quartz Latite was first described as the Fernow Rhyolite by Tower and Smith (1899), from exposures in Fernow Canyon in the southern part of the Tintic district. Morris (1957) later identified it as a quartz latite.

Hand samples of the unit from both the Nephi NW and the Furner Ridge Quadrangles appear to be rhyolitic, but no detailed chemical or petrographic analysis were undertaken.

The Fernow Quartz Latite crops out in only one small area in the quadrangle (fig. 12), where it overlies the Sage Valley Limestone Member of the Goldens Ranch Formation. This preserved lens of Fernow Quartz Latite is small and only about 20 m thick. Modal analysis suggest the ash flow consists of 20 percent doubly terminated quartz phenocrysts, 10 percent sanidine phenocrysts, up to 5 percent lithic fragments, and 1 to 2 percent biotite phenocrysts. The lower part of the flow, above the Sage Valley Limestone Member, contains angular dark andesitic fragments, 5 to 8 cm in diameter, surrounded by flow material described above. These andesitic cobbles and boulders are probably from flows older than either the Fernow Quartz Latite or the Chicken Creek Tuff.

The Fernow Quartz Latite is thought to be equivalent to the Packard Quartz Latite of the Tintic district (Morris 1975) and is probably the same age (32.8 to 32.07 m.y.).

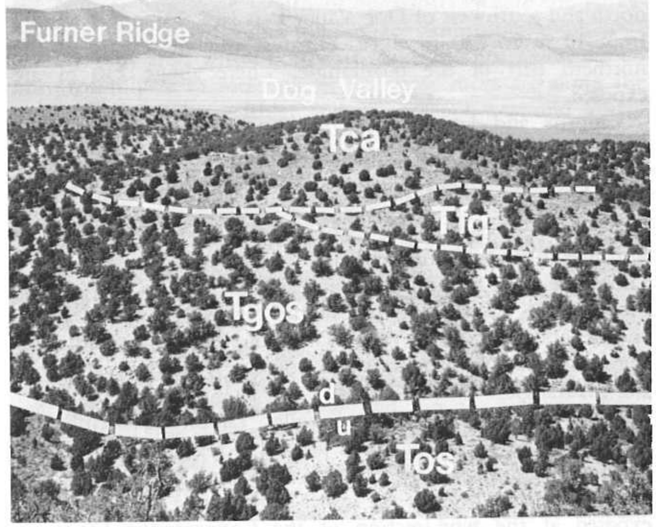

FIGURE 12.—The Sage Valley Limestone Member (Tgos) of the Goldens Ranch Formation is overlain by the Fernow Quartz Latite (Tfg) and the Cazier Canyon Agglomerate (Tca) in section 24, T. 13 S, R. 2 W; Dog Valley, Furner Ridge, and the Tintic Mountains can be seen in the distance.

Morris and Lovering (1979, p. 34) reported that rare fossils of aquatic plants occur in basal tuffs of the Packard Quartz Latite in the Tintic district. These tuffs may correlate with upper beds of the Sage Valley Limestone Member of the Goldens Ranch Formation, which also contain plants from a marshlike environment.

The sequence of ash-flow tuff overlying sedimentary rocks containing aquatic plants in this quadrangle, as well as in the Tintic district, may additionally support the conclusion that the Fernow and Packard Quartz Latites are temporally equivalent.

The Fernow Quartz Latite is overlain by the upper agglomerate member (after Morris and Lovering 1979) of the Copperopolis Latite, named the Cazier Canyon Agglomerate in a following section.

Copperopolis Latite of the Tintic Mountain Volcanic Group

The Copperopolis Latite is the oldest of three formations that belong to the Tintic Mountain Volcanic Group (Morris and Lovering 1979). The Copperopolis Latite was named from exposures in Copperopolis Canyon, in the west central part of the East Tintic Mountains. Morris (1975) initially informally referred to the Copperopolis Latite and four informal members. In the type area, three informal members are recognized: (1) a lower agglomerate and spatter breccia, (2) a middle tuff member, and (3) an upper flow member (Morris and Lovering 1979, p. 36). The three listed above are exposed in the type section, but the fourth, called the middle agglomerate member by Morris (1975, 1977) and also called the uppermost agglomerate by Morris and Lovering (1979), does not occur in the type area in the Tintic Mountain Quadrangle.

This uppermost Copperopolis Latite agglomerate unit of Morris and Lovering (1979) and the underlying flow member are both exposed in the Nephi NW Quadrangle, but lower members are not exposed. Only small outcrops of the upper flow member were identified (fig. 20). The upper flow member crops out in small lenses in the northern part of the quadrangle, where it is aphanitic (almost glassy) and reddish brown.

The upper agglomerate unconformably overlies older rocks north and southwest of Dog Valley Pass (fig. 20), and it ranges from 10 m to 230 m thick. Greatest thicknesses are in the northern part of the quadrangle, where about 230 m are exposed.

Morris and Lovering (1979) concluded that uppermost Copperopolis rocks interfinger with the lacustrine Sage Valley Limestone toward the south, apparently including the Nephi NW Quadrangle.

The upper part of the Copperopolis Latite probably does not interfinger with the lacustrine sediments of the Sage Valley Limestone. Firstly, the intervening Fernow Quartz Latite overlies the Sage Valley Limestone in the Nephi NW Quadrangle, and, secondly, the Sage Valley Limestone does not overlie the upper agglomerate of Morris and Lovering (1979) anywhere in the quadrangle.

However, where the Sage Valley Limestone Member is overlain by a rock stratigraphic unit, it is generally overlain by the upper agglomerate of Morris and Lovering (1979).

I think that, because the upper agglomerate member is not exposed at the type section of the Copperopolis Latite, it should not be included as part of the Copperopolis Latite. It should be given status of its own in spite of genetic relationships which it may have with members of the Copperopolis Latite. Rather, I suggest that the Copperopolis Latite be restricted to the three members in the type locality described by Morris and Lovering (1979). I also propose that the upper agglomerate of Morris and Lovering (1979) be given formation status.

Cazier Canyon Agglomerate

The Cazier Canyon Agglomerate is here named from thick exposures of volcanic agglomerate (fig. 13) that are lithologically distinct from other rocks in this quadrangle and mappable at a scale of 1:24,000. It is 230 m thick in the type section in Cazier Canyon, located mostly in the NE ¼ of section 23, T. 12 S, R. 1 W, Nephi NW Quadrangle, Juab County, Utah. The section begins in the bottom of Cazier Canyon, near the southeast corner of the NW ¼ of section 28, and extends to the top of the ridge in the SW ¼, SW ¼, SE ¼ of section 21, all in T. 12 S, R. 1 W.

This volcanic agglomerate (fig. 13) consists mostly of dark red and light to grayish pink volcanic clasts. The composition of the clasts is quite varied; however, clasts of dark red andesite seem to predominate. Lesser amounts of aphanitic, grayish latite (?) are also common. A cobble count made about 800 m south of the type section verified that the agglomerate contains 100 percent volcanic clasts. Most of the clasts are angular to subangular. The agglomerate is about 60 percent clasts and 40 percent matrix. Most of the formation is poorly sorted and not well bedded. No depositional structures were observed. The Cazier Canyon Agglomerate near the type area is homogenous as to the size, shape, and composition of the clasts, and the clasts to matrix ratio is about the same throughout the quadrangle.

In the type area, the Cazier Canyon Agglomerate is well consolidated and is exposed as steep ledges and cliffs. However, south of the type area the agglomerate becomes semi- to poorly consolidated and thins away from its source. South of section 33, T. 12 S, R. 1 W, the agglomerate is so poorly lithified and thin (4 to 8 m thick) that quartzite boulders from underlying Goldens Ranch Formation are occasionally seen mixed with the volcanics. Although quartzite clasts are locally present, volcanic clasts still account for at least 90 percent of the fragments throughout the areal extent of the formation.

FIGURE 13.—Closeup of the Cazier Canyon Agglomerate illustrating angularity, size of volcanic clasts, and character of the matrix in section 28, T. 12 S, R. 1 W.

The Cazier Canyon Agglomerate unconformably overlies older rocks in the northern and southwestern parts of the quadrangle. No exposures occur east of Sage Valley or in Dog Valley Pass.

The Cazier Canyon Agglomerate is the uppermost Tertiary unit in the Nephi NW Quadrangle and is locally covered only by Quaternary alluvium or colluvium. Younger Tertiary formations are exposed in the Tintic Mountain Quadrangle and the Eureka Quadrangle to the northwest.

Summary of Tertiary History

This paper supports the proposal by Morris (1975) and Morris and Lovering (1979) that a caldera existed northwest of this study area during Tertiary time. Volcanic material in the Nephi NW Quadrangle probably came from eruptions in the Tintic district.

Quaternary Deposits

Older Alluvium

Older alluvium as mapped in this quadrangle consists mostly of unconsolidated alluvial fan sediments deposited during basin-and-range extension. Most of these fan sediments are now covered by more recent alluvium and colluvium. Older alluvium is exposed only in areas where recurrent uplift along basin-and-range faults has exposed the older, unconsolidated sediments. These older fans are composed mostly of poorly sorted, unconsolidated sand, silt, clays, and local pebble- to boulder-size clasts of adjacent outcropping units. The best exposure of this older alluvial fan material is on the west side of Dog Valley Pass in roadcuts along Utah 132. The deposits exposed are about 10 m thick.

Younger Alluvium, Colluvium, and Landslide Debris

Younger alluvium was mapped separately from colluvium and landslide material, but no attempt was made to differentiate the colluvium from landslide debris. Younger alluvium consists mostly of fan sediments from the mountains and hills of Long Ridge that were shed eastward into Juab Valley and westward into Dog Valley. These deposits accumulated following the last major basin-and-range uplift. Colluvium and landslide debris are generally seen on steeper slopes.

Stratigraphy Conclusions

Rock units in the Nephi NW Quadrangle can be divided into five groups that reflect different depositional environments. Paleozoic sediments were deposited within a marine environment. Mesozoic rocks generally reflect mixed marine and nonmarine continental margin deposition. Tertiary and Quaternary rocks represent terrigenous deposition of three different kinds. First are the conglomerates deposited in association with the Sevier orogeny. Second is volcanic material deposited in association with volcanism of the Tintic area. Third and last are deposits of sediments along the mountain ranges formed by basin-and-range extension.

STRUCTURE

General Statement

Structural relationships within the Nephi NW Quadrangle are represented by four different phases of regional structural development. The first phase is represented by Pennsylvanian through Jurassic sedimentary rocks which indicate that a structurally stable setting predominated, uninterrupted by major structural deformation or uplift throughout that time interval. The second phase of structural involvement is represented by the major thrusts and folds of the Sevier orogeny, which affected the area in late Mesozoic time. Cretaceous sediments shed from the Sevier highlands and deposited in this quadrangle are mostly conglomerate, with lesser amounts of sandstone and siltstone. Highlands formed during the Sevier orogeny continued to shed sediments during the time when Laramide uplifts were developing in eastern Utah. The third structural phase is associated with Oligocene volcanic activity in and around the Tintic district. Poorly exposed, east-trending normal faults may be part of this phase. The fourth and final phase is characterized by the north-trending normal faults of basin-and-range affinity. Of these four phases of structural involvement, only the last three will be discussed in detail.

Sevier Orogenic Phase

The Sevier orogeny deformed lower Cretaceous rocks (proven by lower Cretaceous pollen found in sandstone cuttings immediately below synorogenic conglomerates in the #1 Howard well [D. Sprinkel personal communication 1981]) and all older rocks in western Utah and formed folds and thrust faults in this area. Overturned fold relationships are easily documented in the Dog Valley Pass area (fig. 20), where younger Permian Park City Formation is apparently overlain by the older Permian Diamond Creek Sandstone and the Pennsylvanian-Permian Furner Valley Limestone. Additional overturned relationships are shown at the south end of Sugarloaf, where the Furner Valley Limestone apparently overlies the Diamond Creek Sandstone, and along the northwest-facing exposure of the Nugget Sandstone (south of Sugarloaf), where the Ankareh shale apparently overlies the Nugget Sandstone.

The only areas where northeast strike and northwest dip do not predominate in Mesozoic or Paleozoic rocks are along the western edge of Long Ridge and in outcrops west and northwest of Sugarloaf (fig. 20). Along the western edge of Long Ridge, the strike changes gradually from N 65° E near Dog Valley Pass to N 10° E in the NE ¼ of section 32, T. 12 S, R. 1 W. The dip also changes from 55° NW to 25° WNW. This change in attitude may represent a change in orientation of a major fold axis buried beneath Mesozoic-Cenozoic conglomerates and/or Juab Valley alluvium. The change may also represent a secondary structure on a larger fold. No additional evidence was gathered to support either relationship.

West and directly northwest of Sugarloaf (fig. 20) Paleozoic sediments strike N 68° W and dip an average of 45° southwest. These rocks and two additional small outcrops west of Sugarloaf appear to be lying in normal stratigraphic order (not overturned).

Placid Oil encountered moderately dipping beds of Arapien Shale, Nugget Sandstone, and Ankareh Shale in the #1 Howard well (NW ¼ of section 5, T. 14 S, R. 1 W). These rocks dip to the northwest and are not overturned. The top of the Nugget Sandstone was encountered in the Placid Oil #1 Howard Well at a depth of 3,250 m (D. Sprinkel personal communication July 1981).

Stratigraphic and structural information from the Placid Oil Company #1 and #2 Howard wells was combined with surface data to construct a cross section (fig. 20), which shows that the overturned rocks at the surface and those found in the well are part of the same fold (figs. 14, 20). This interpretation is substantiated by drill stem test data of the Nugget Sandstone in the #2 Howard well. The drill stem test recovered a "flush of fresh water" from the Nugget at a depth of 3,130 m (D. Sprinkel personal communication September 1981).

The cross section (fig. 20) portrays the nature of Sevier

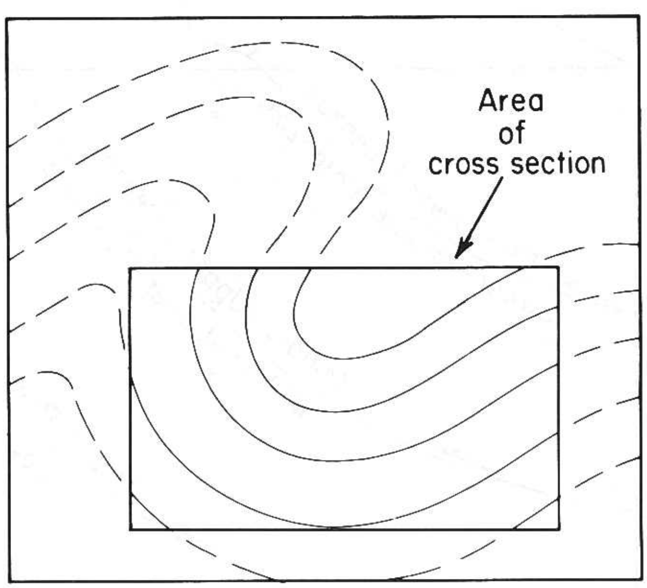

FIGURE 14.–The lower part of an overturned fold that generally represents Sevier fold relationships in the Nephi NW Quadrangle.

style folding and thrusting within this quadrangle. Of the two thrusts shown in the cross section, only one is exposed at the surface. It reaches the surface (fig. 20) between Sugarloaf and the hill immediately northwest of Sugarloaf in section 7, T. 13 S, R. 1 W. Rocks on Sugarloaf are overturned, strike 65° northeast, and dip 55° to 65° northwest. Rocks on the hill northwest of Sugarloaf are probably not overturned, strike 65° northwest, and dip 45° southwest. Dips on this hill, as well as on the other small outcrops noted above, indicate a significant structural break between this hill and Sugarloaf.

Muessig (1951) mapped the relationship between these two hills as a normal fault. However, the structure illustrated in the cross section (fig. 20) better fits the observed data. Both the dip directions described above and the lithologic character of the small hill in the alluvium north of Utah 132 (fig. 20) verify the proposed conclusion.

Dip directions and lithology are not the only evidence used to establish existence of a thrust northwest of Sugarloaf. Fusulinids from the hill northwest of Sugarloaf and south of Utah 132 date rocks there as Desmoinesian–Missourian. Rocks on Sugarloaf, however, are overturned and include Wolfcampian-age Diamond Creek Sandstone on the south end of the hill (fig. 20). The Sugarloaf thrust places upper Desmoinesian–Missourian rocks over Wolfcampian rocks, as illustrated in the cross section. This thrust may be part of an imbricate secondary sheet associated with a larger thrust, or it may be a regional thrust in and of itself.

A second thrust fault is shown on the cross section (fig. 20) near the base of the Nugget Sandstone in the Ankareh Shale (section 19, T. 13 S, R. 1 W). This fault trace is covered by Tertiary sedimentary rocks within the quadrangle. However, the thrust is inferred by stratigraphic relationships. The Diamond Creek, Park City, Thaynes, Woodside, and Ankareh Formations have a local combined thickness of 1,700 m (Black 1965, Morris 1977, and Muessig 1951). The horizontal distance between the bottom of the Diamond Creek Sandstone outcrop on the south end of Sugarloaf and the bottom of the Nugget Sandstone in the NW ¼ of section 20 (T. 13 S, R. 1 W) is only 1,450 to 1,500 m. This distance is not enough to account for the combined thickness of Permian and Triassic rocks that should be present in the subsurface. A thrust fault whose trace is buried beneath the Tertiary rocks would account for the distance-thickness discrepancy.

Occurrence of such a fault below the surface is also suggested by the relationships of the normal faults which are parallel to the strike of the Nugget Sandstone. The trace of the main fault near the Nugget outcrop is evident on both the topographic map and in aerial photos of the quadrangle. The Quaternary normal faults paralleling the Nugget outcrop have apparently moved in recurrent fashion along a thrust plane. Sevier-style folds and thrusts in this quadrangle may be related to, or are a continuation of, the Nebo thrust (mapped by Black 1965). Faults in this quadrangle may also represent small imbricate sheets of a larger thrust concealed at depths greater than 4,000 m.

Relationships of Sevier faults throughout the central Utah overthrust region (fig. 15) were summarized by Burchfiel and Hickcox (1972). Precambrian to lower Paleozoic rocks are thrust over lower to middle Paleozoic rocks, Cambrian to middle Paleozoic rocks are thrust over upper Paleozoic rocks, and upper Paleozoic rocks are thrust over lower to middle Mesozoic rocks. These relationships are not seen everywhere; however, most of the thrust relationships reported in this region come close to these general relationships. Figure 16 is a region-

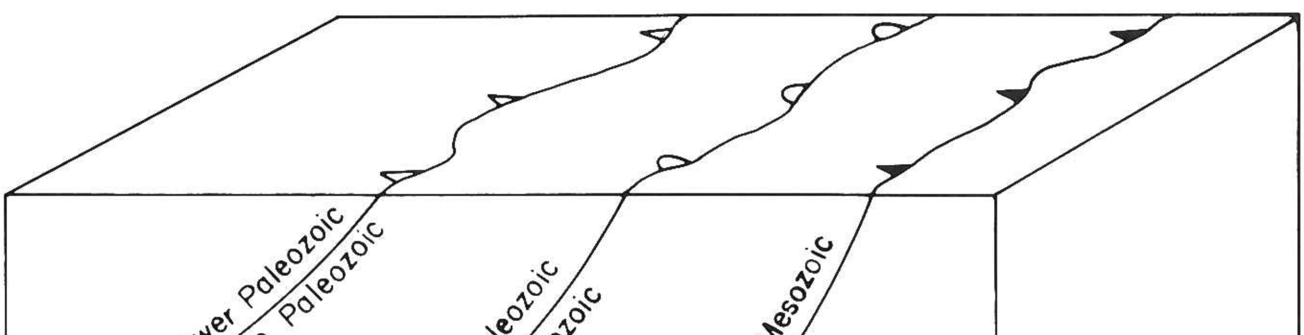

FIGURE 15. Generalized regional thrust relationships exposed in the "hingeline" area of central Utah (after Burchfiel and Hickcox 1972).

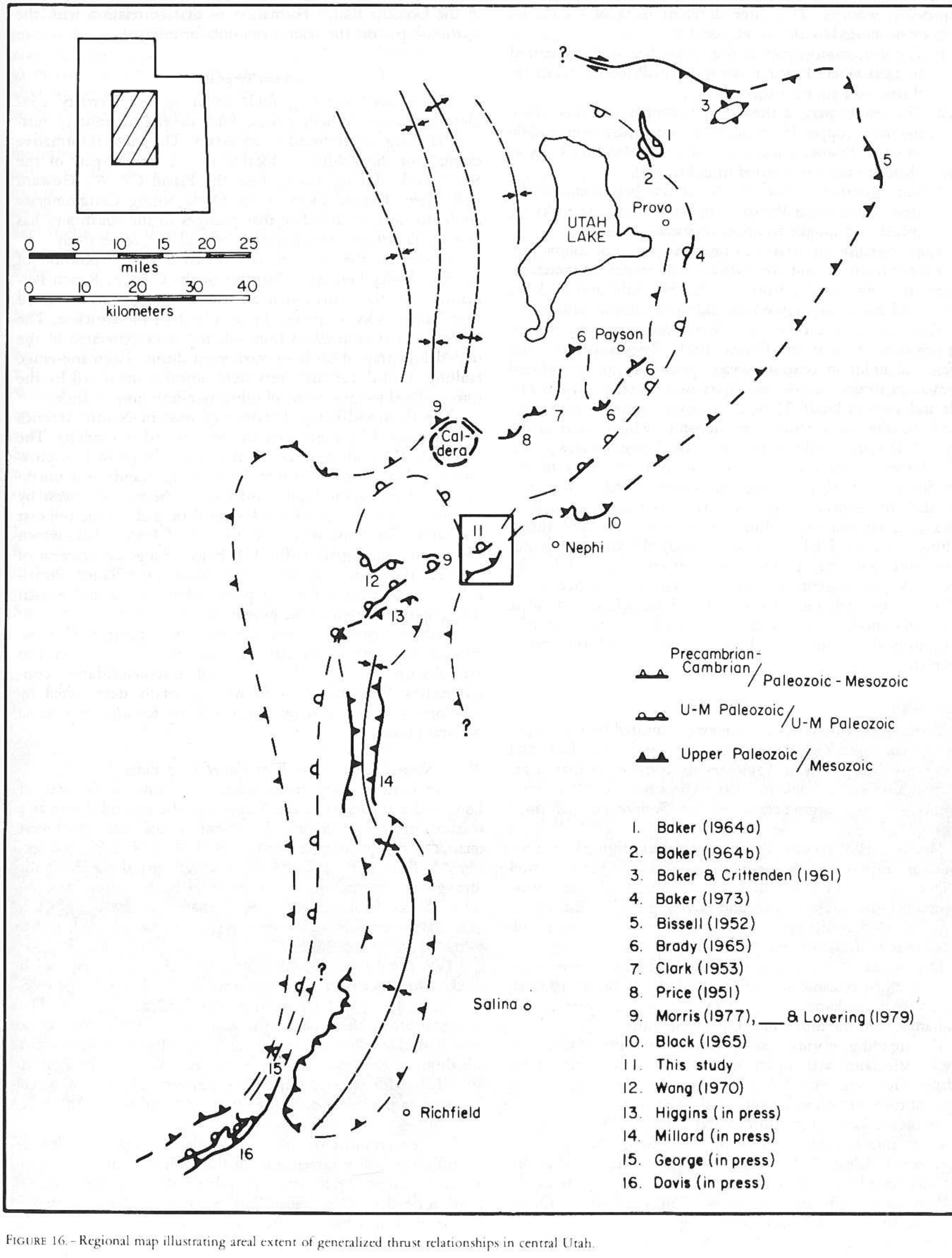

FIGURE 16. – Regional map illustrating areal extent of generalized thrust relationships in central Utah.

al map which shows similarities in these Sevier faults reported by previous workers. The three different belts of connected faults are delineated by thrust relationships:

1. The westernmost part of the thrust belt is characterized by areas where Precambrian to lower Paleozoic rocks are thrust over younger rocks.
2. The central part of the thrust belt includes areas where middle to upper Paleozoic rocks are thrust over middle to upper Paleozoic rocks or where the Manning Canyon Shale has been attenuated or obliterated.
3. The easternmost part of the thrust belt includes the areas where upper Paleozoic to lower Mesozoic rocks are thrust over middle to upper Mesozoic rocks.

The correlation illustrated in figure 16 does not follow previous interpretations and correlations. The reader is, therefore, referred to work done by Morris (1979), Burchfiel and Hickcox (1972), and Armstrong (1968) for additional interpretations.

The most recent model for Sevier orogenic deformation was proposed by Hose and Danes (1973). They suggested that differential uplift in central Nevada produced gravity-induced attenuation thrusts of younger strata over older in eastern Nevada and western Utah. These attenuation faults, in turn, produced the older over younger relationships which occur in the Nephi NW Quadrangle, as well as in the hingeline area generally. Hintze (1978) discussed attenuation phenomena in the Fish Springs and House Ranges in western Utah and thinks that the areal separation of these two contrasting structural styles (i.e., attenuation faulting in western Utah and thrust faulting in central Utah) of approximately the same age is not mere coincidence but probably two effects produced by the same cause. He suggests that more analysis of both overthrust and attenuation relationships should be done before a complete satisfactory model is obtained. Sevier orogeny structural relationships in this quadrangle add little additional information to the recent model.

Tertiary Volcanic Phase

Tertiary volcanic rocks are somewhat limited in the Nephi NW Quadrangle. The most extensive unit is the thick and widespread Cazier Canyon Agglomerate. It indicates that large-scale volcanic events took place at some time after the Sevier orogeny, for the agglomerate overlies Sevier-style deformed rocks.

Morris (1975) reported that a large caldera formed after voluminous eruptions of the Fernow and Packard Quartz Latites (Oligocene, 32 m.y.) in the central portion of the Tintic Mountain Quadrangle. Morris and Lovering (1979) also pointed out that, after its formation, at least two composite volcanoes were built up around the caldera.

Deposition of the Cazier Canyon Agglomerate was probably a result of volcanic activity in the Tintic Mountain Quadrangle. Thick agglomerate occurs in the northern part of this quadrangle, and the unit thins toward the south.

East-trending normal faults throughout the quadrangle may be associated with uplift before eruption or with caldera collapse. However, critical data on timing are wanting, and the origin of these east-west faults remains somewhat obscure.

Moderate local relief during Oligocene time is inferred because of large boulders of Cambrian Tintic Quartzite in the Oligocene Goldens Ranch Formation. The nearest outcrops that may have been the source for the clasts of quartzite in the Goldens Ranch Formation are in the Tintic Mountain Quadrangle northwest of this quadrangle (fig. 1). These outcrops lie near the inferred edge of the caldera as mapped by Morris (1975). Again, however, consolidated deposits were not found in the Goldens Ranch Formation so that correlation with the relationships near the caldera can only be inferred.

Basin-and-Range Phase

Minor north-trending folds occur in the Tertiary conglomerate units. Whether these folds developed prior to east-west faulting or afterward is uncertain. The most informative example of this folding is located in the eastern part of the South Fork of Dog Valley, near the Placid Oil #1 Howard well. Here, Tertiary rocks of the Orme Spring Conglomerate are folded into an anticline that plunges to the south and has dips on its east and west limbs of 25° and 15°, respectively.

Folding of the conglomerate occurred after deposition of the Sage Valley Limestone Member of the Goldens Ranch Formation (32 m.y.), inasmuch as one small exposure of tilted Sage Valley rocks occurs on the west limb of the anticline. The folding may have resulted from salt tectonics generated in the underlying Arapien Shale or movement during basin-and-range faulting. Folded Tertiary units were probably deformed by the forces related to movement of north-trending normal faults.

The Basin-and-Range Province of western North America is characterized by north-trending valleys and mountains. The Nephi NW Quadrangle lies at the eastern edge of this province and shows similar trends. Long Ridge stands as a north-trending topographic high, bordered on the east and west by valleys. Long Ridge is a horst bounded by grabens on the east and west. The Nebo massif occurs east of Juab Valley, which lies in the eastern graben (fig. 17); Furner Ridge occurs west of (fig. 12) the western graben, which forms Dog Valley. Principally, dip-slip normal faulting produced the horst and graben topography throughout the province.

Basin-and-range-style faults within this quadrangle, however, are far from spectacular. Most normal fault relationships are obscured by an abundance of unconsolidated conglomerates. Fault relationships were generally determined by lithologic contrasts and by obvious linear features observable on areal photos.

Major Normal Faults on the West Side of Long Ridge

The most striking basin-and-range normal fault west of Long Ridge is parallel to the Nugget Sandstone and shows as a marked northeast-trending lineament across the southwest quarter of the quadrangle (section 19, T. 13 S, R. 1 W, and section 25, T. 13 S, R. 2 W). Reverse movement along this fault during the Miocene apparently occurred on a previously established Sevier fault surface. The Tertiary Orme Spring Conglomerate overlying the Nugget Sandstone has been offset between 30 and 100 m (fig. 4).

Two parallel normal faults are exposed immediately north of the Dog Valley Pass, on the west side of Long Ridge (section 5, T. 13 S, R. 1 W, section 32, T. 12 S, R. 1 W). The westernmost of these places Paleozoic and Tertiary sediments, as well as older alluvium, on the upthrown block against recent alluvium on the downthrown block (section 5, T. 13 S, R. 1 W). This fault trace is buried beneath recent alluvium when followed to the north or south (sections 5 and 8, T. 13 S, R. 1 W).

The easternmost of the two parallel normal faults juxtaposes Furner Valley Limestone, on the upthrown block, against Tertiary conglomerate on the downthrown block. About 1,600 m north of Dog Valley Pass, Paleozoic rocks are exposed on the upthrown block faulted against recent alluvium on the downthrown block.

Major Normal Faults on the East Side of Long Ridge

Normal faults associated with basin-and-range-style deformation along the east side of Long Ridge are difficult to recognize because they cut poorly consolidated Tertiary conglomerates or are buried by alluvium. Only minor offset is observed (6 to 12 m) where the traces of these north-trending faults are exposed at the surface.

Cook and Berg (1961, p. 82) indicate that gravity gradients measured in Juab Valley suggest that a normal fault(s) may be buried in the alluvium of Juab Valley. The two normal faults exposed on the west side of Dog Valley Pass indicate, to a small degree, that the basin-and-range-style faults may be steplike. If this is so, then other normal faults may be present beneath alluvium east of those mapped on the east side of Long Ridge.

Spring Canyon Graben

Spring Canyon is located in the south central part of the Nephi NW Quadrangle in sections 21, 28, and 33, T. 13 S, R. 1 W (fig. 18). It is bounded on the west by the here named West Spring Canyon Fault. This fault is mappable from the center of the quadrangle, near the east side of Dog Valley Pass, southward for 9 km into the Nephi SW Quadrangle. Orme Spring Conglomerate and part of the Goldens Ranch Formation have been downdropped between 5 to 20 m against rocks of the same formations on the west.

Spring Canyon is bounded on the east by the (here named) East Spring Canyon Fault. This fault can be traced southward from where it truncates against the West Spring Canyon fault, in the northern end of Spring Canyon, to the southwestern part of the Nephi SW Quadrangle. Muessig (1951) mapped the Sage Valley Fault as having displaced the North Horn and Flagstaff Formations on the upthrown eastern block against mostly alluvium on the downthrown western block. Muessig mapped the Flagstaff Formation in the downthrown block against the North Horn Formation in the upthrown block near the west edge of section 12, T. 15 S, R. 2 W. Similar relationships are exposed in Spring Canyon in this quadrangle.

The East Spring Canyon fault displaces Red Narrows Conglomerate (North Horn equivalent) in the eastern upthrown block against the Orme Spring Conglomerate (Flagstaff Formation equivalent) in the downthrown block (fig. 19) in section 27, T. 13 S, R. 1 W.

Spring Canyon (fig. 18) is in a graben because rocks of the valley have been dropped relative to those to the east and west. Continuity of the Sage Valley fault, from the Nephi SW Quadrangle into Spring Valley, is inferred.

Conclusions concerning Basin-and-Range Faulting

The basin-and-range faulting is the youngest structural feature of the quadrangle. Movement has occurred so recently that uplifted alluvial fan material has been only partially eroded since displacement. Movement along basin-and-range faults near the quadrangle has occurred as recently as 1980, when a small earthquake occurred near Elberta, Utah, and future movement should be anticipated.

ECONOMIC GEOLOGY

Economically significant deposits developed within the Nephi NW Quadrangle in the past include aragonite vein-fillings and limited pyritic alteration products of limonite and hematite along basin-and-range normal faults in Tertiary deposits. Blocks of the aragonite have been polished and sold to tourists in Nephi, Utah.

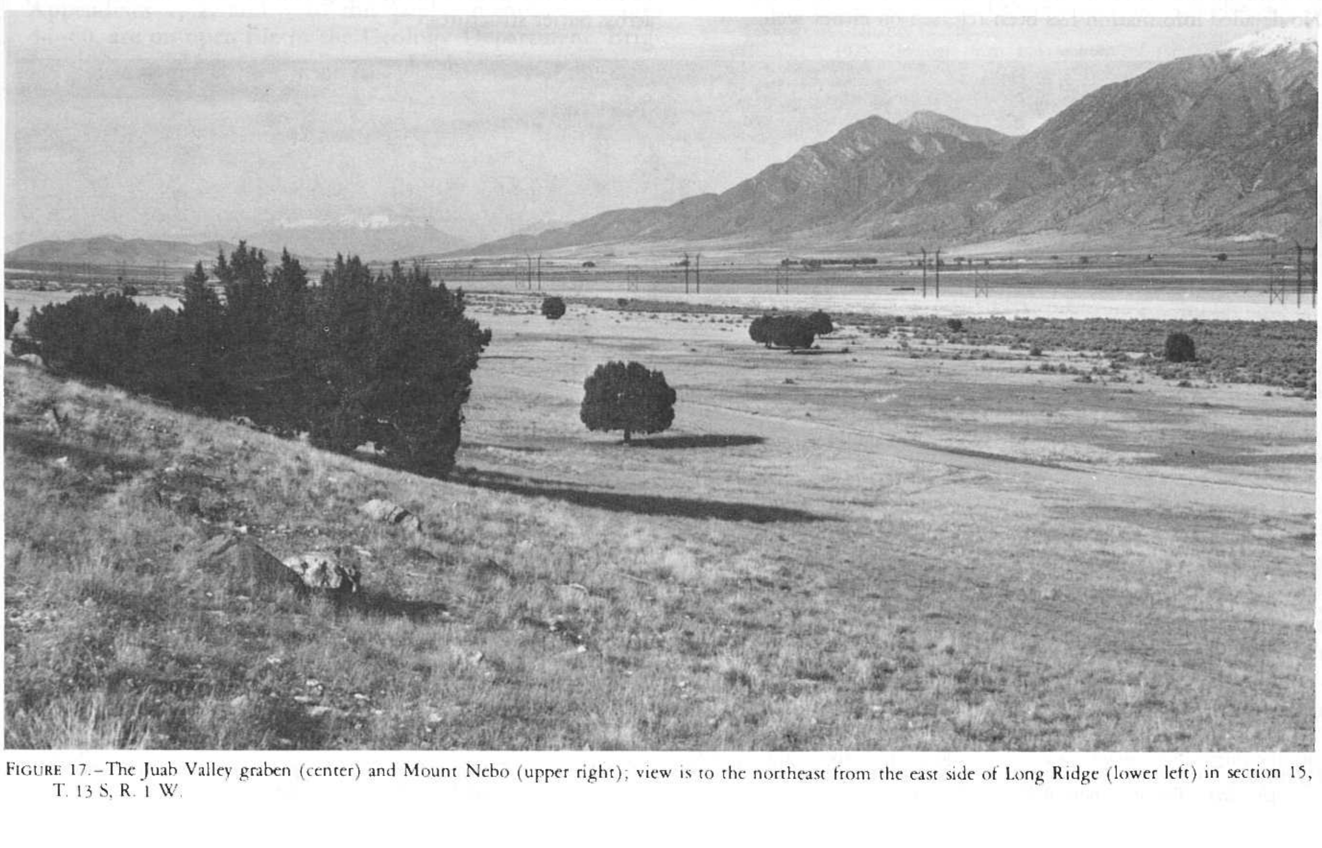

FIGURE 17.–The Juab Valley graben (center) and Mount Nebo (upper right); view is to the northeast from the east side of Long Ridge (lower left) in section 15, T. 13 S, R. 1 W.

FIGURE 18.–The central part of the Spring Canyon graben in sections 21, 28, 33, T. 12 S, R. 1 W; view is to the northeast.

Recent oil exploration in the Overthrust Belt of Wyoming and northeastern Utah has generated interest in similar geologic relationships in the central Utah thrust belt, including this quadrangle.

Placid Oil Company has recently drilled two wells in the south central part of this quadrangle: Placid Oil #1 Howard in the NW ¼, section 5, T. 14 S, R. 1 W; and Placid Oil #2 Howard in the center of NE ¼, section 5, T. 14 S, R. 1 W. No detailed information has been released on either well.

CONCLUSIONS

Structural relationships in the Nephi NW Quadrangle represent several phases of deformation, the most prominent being Sevier folds and thrust faults and normal faults of basin-and-range affinity. Sevier folds and thrust faults deformed pre-Cretaceous rocks and are a continuation of similar structures observed on Mount Nebo 15 km to the east. In this quadrangle Paleocene (?) Orme Spring Conglomerate rests unconformably across Sevier structures.

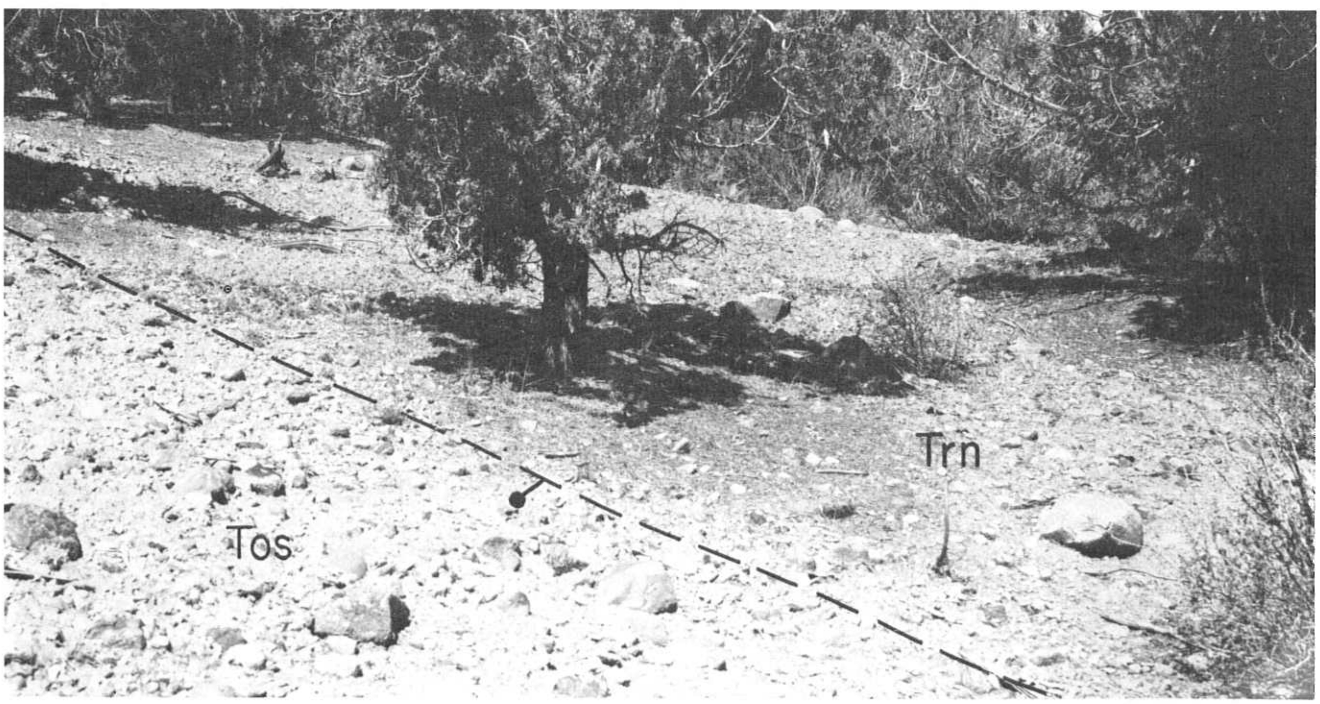

FIGURE 19.–Trace of the East Spring Canyon Fault where rocks of the Orme Spring Conglomerate (Tos) have been downdropped against the Red Narrows Conglomerate (Trn) in section 28, T. 13 S, R. 1 W.

Long Ridge is bounded and dissected by north-trending normal faults of basin-and-range affinity that cut all stratigraphic units but youngest alluvium. Juab Valley on the east and Dog Valley on the west of the Long Ridge horst lie in grabens generated by continuous movement along the normal faults bordering Long Ridge.

Clarification of stratigraphic relationships of conglomerates related to the Cretaceous Sevier orogeny and Oligocene volcanism were necessary so that structural relationships could be understood. Differentiation of somewhat similar-appearing Tertiary units made this possible.

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My final thanks go to my wife who has supported me through this study and my schooling.

Appendixes 1, 2, and 3 to this paper, manuscript pages 44–60, are on open file in the Geology Department, Brigham Young University, Provo, Utah 84602, where a Xerox copy may be obtained.

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