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Tertiary Geologic History of the Slate Jack Canyon Quadrangle, Juab and Utah Counties, Utah*

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ABSTRACT

During the Cretaceous Sevier orogeny, Precambrian and Paleozoic rocks of the Slate Jack Canyon Quadrangle were folded and thrust eastward. Volcanism from centers in the East Tintic Mountains began in middle Oligocene time with eruption of the Packard Quartz Latite. The edge of a caldera formed by this eruptive episode passes through the northwest corner of the quadrangle. The Copperopolis Latite was then erupted, forming lava flow, tuff, and tuff breccia units; the latter were deposited as a series of lahars. The welded tuff member of the Latite Ridge Latite was then deposited. Following a period of erosion, a lava flow assigned to the Laguna Springs Volcanic Group was emplaced. Basin-and-range normal faulting began after emplacement of the middle Oligocene volcanic rocks and has continued into the Quaternary.

INTRODUCTION

The Tertiary geologic history of the Slate Jack Canyon Quadrangle is dominated by two principal events: eruption and emplacement of Oligocene volcanic rocks, and latest Oligocene or early Miocene (Morris and Lovering 1979) to Recent basin-and-range block faulting. Folding and thrusting of the Sevier orogeny had virtually ceased by the beginning of Tertiary time.

The igneous rocks of the Slate Jack Canyon Quadrangle were first mapped as part of the Laguna Latite Series by Muessig (1951); since that time, this series has been formally subdivided by Morris and Lovering (1979), working in the East Tintic mining district to the northwest (fig. 1). Their subdivisions are here adopted for the Slate Jack Canyon Quadrangle (fig. 2).

The principal contribution of this paper is to document the Tertiary geologic history of the Slate Jack Canyon Quadrangle by correlation of the Oligocene volcanic units, located on the flank of an eroded volcano, with the more complete eruptive sequence exposed in the East Tintic Mountains. Tertiary structural features, earlier sedimentary units, and economic geology of the quadrangle are also described.

Muessig (1951) first mapped part of Long Ridge at a scale of 1:63,360 (figs. 1 and 3). Madsen (1952) and Price (1951b) studied the stratigraphy, structure, and ore deposits of the Precambrian and Paleozoic rocks near the northern edge of the Slate Jack Canyon Quadrangle. Extensive work has been done to the west of this quadrangle in the East Tintic Mountains and East Tintic mining district by Morris (1975, 1977), Morris and Lovering (1979), and earlier workers. The structure and stratigraphy of the adjoining quadrangle to the south has been described by Meibos (1983).

STRATIGRAPHY

Rock units of the Slate Jack Canyon Quadrangle range in age from Precambrian to Quaternary. Most of the quadrangle is underlain by the Oligocene Copperopolis Latite; prevolcanic rocks crop out chiefly near the northern edge of the quadrangle. Pre-Tertiary rocks of this quadrangle have been studied in detail by previous workers (Madsen 1952, Muessig 1951, and Price 1951a, 1951b), so only generalized descriptions of these rocks will be given here.

PRECAMBRIAN SYSTEM

Big Cottonwood Formation

The Precambrian section exposed east of Slate Jack Canyon (in the northwest part of the Slate Jack Canyon Quadrangle) was originally called the "Cottonwood slates" by Muessig (1951). Woodward (1972, p. 2–3) suggested that only the lower 42 m of Muessig's "Cottonwood slates" correlate with the Big Cottonwood Formation, and that the overlying 822 m is correlative with the Mutual

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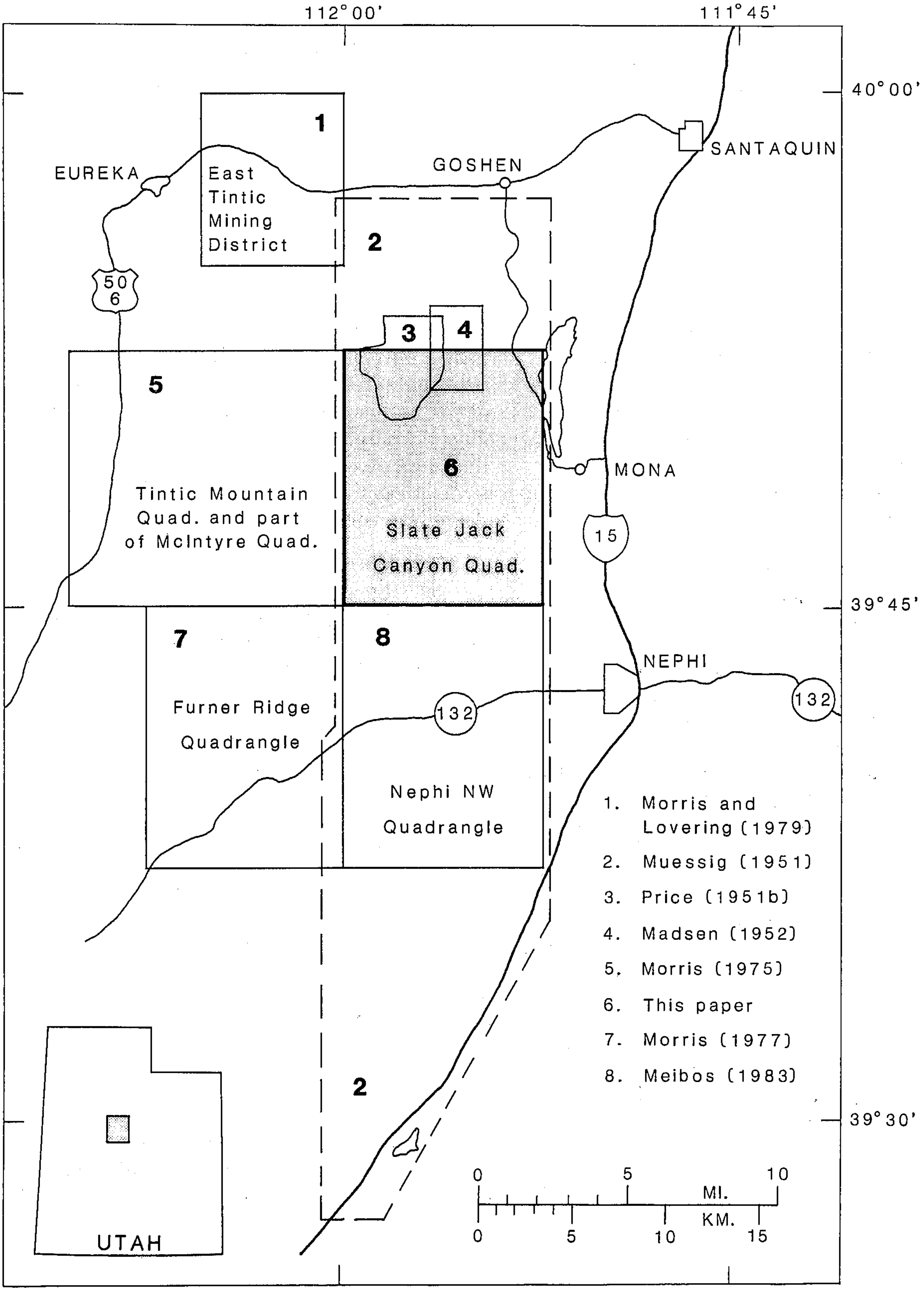

FIGURE 1.—*Index map showing location of the Slate Jack Canyon Quadrangle and other nearby quadrangles.*

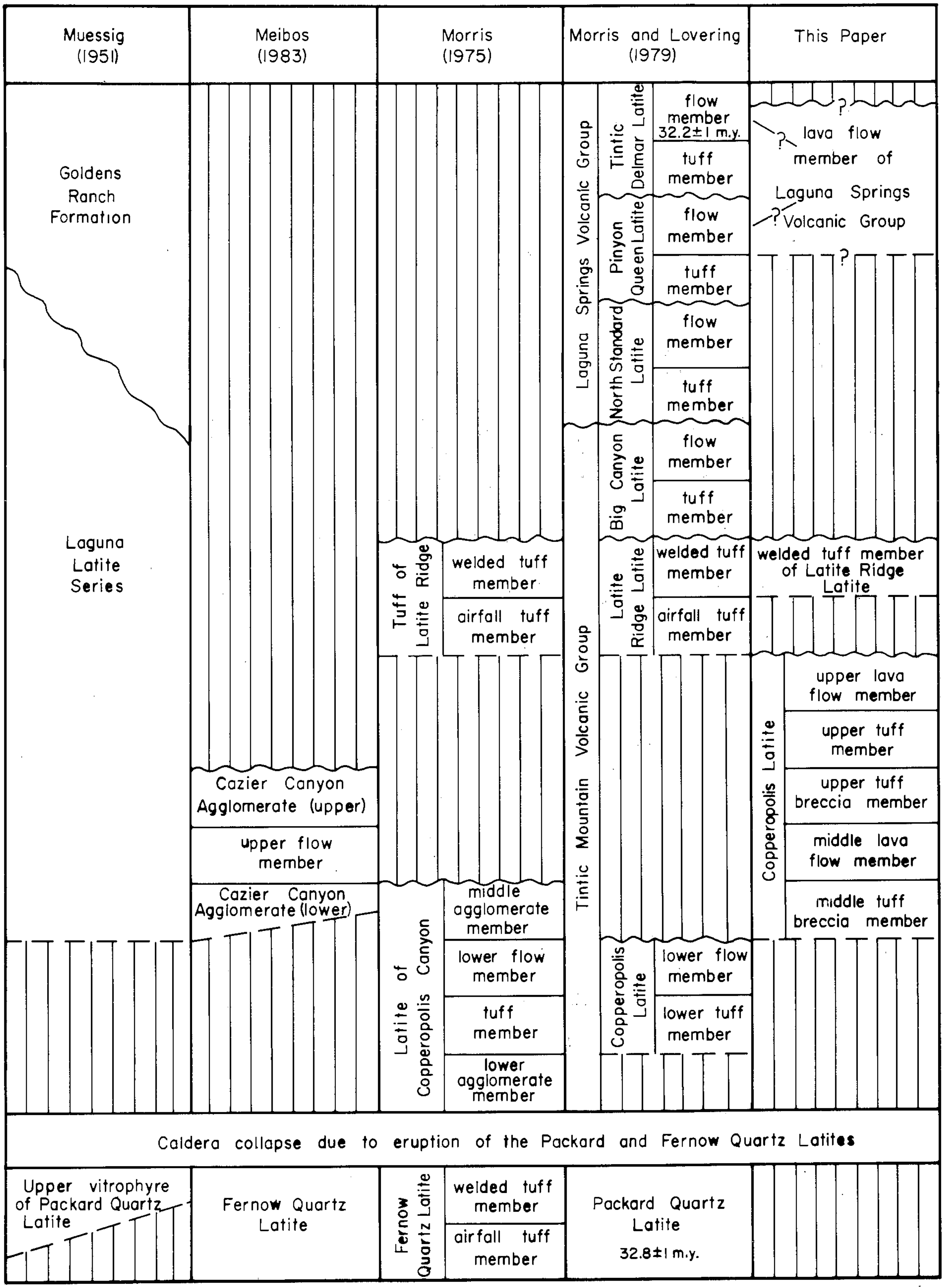

FIGURE 2.—*Correlation chart for Oligocene volcanic rocks of the Slate Jack Canyon area.*

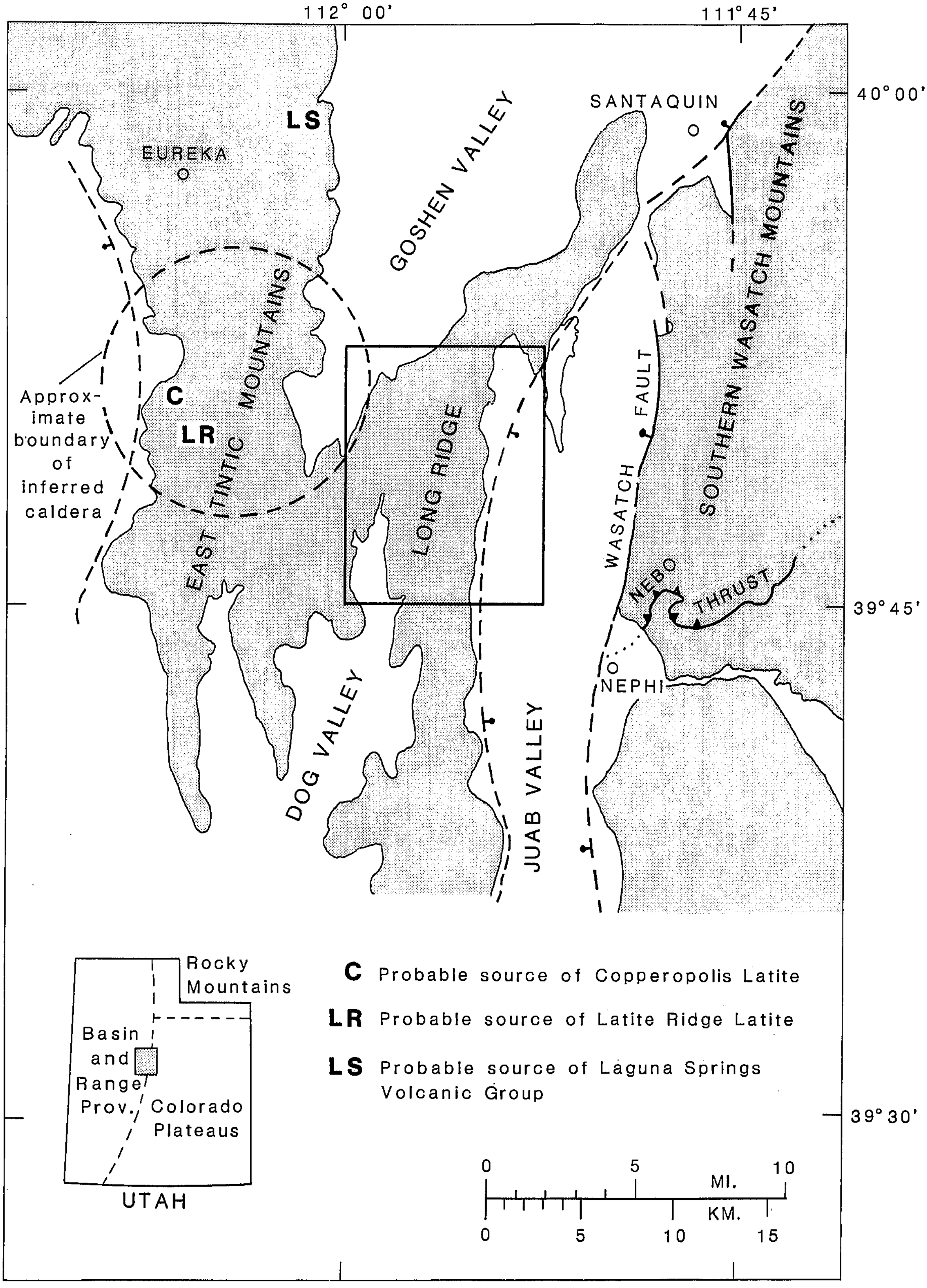

FIGURE 3.—*Relationship of the Slate Jack Canyon Quadrangle to major topographic and structural features (adapted from Morris 1975 and 1977, and Morris and Lovering 1979).*

Formation. The exposed portion of the Big Cottonwood Formation in Slate Jack Canyon is grayish pink, cliff-forming quartzite in which the grains are rounded and very fine to fine.

The absence of a stratigraphic unit between the Big Cottonwood Formation and the overlying Mutual Formation of the Slate Jack Canyon area creates a problem with correlation of the Big Cottonwood Formation (H. T. Morris written communication 1984). Correlation of the Big Cottonwood Formation of the Slate Jack Canyon Quadrangle with its type section in Big Cottonwood Canyon was based on lithologic similarities (Woodward 1972); but the Big Cottonwood and Mutual are commonly separated by the Mineral Fork Tillite (Crittenden and others 1952), which does not crop out within this quadrangle. The Caddy Canyon Quartzite of the Sheeprock Mountains is separated from the Mutual by the Inkom Formation (Christie-Blick 1982), and the Caddy Canyon is also lithologically similar to the Big Cottonwood Formation; but the Inkom does not crop out in the Slate Jack Canyon area either. This paper follows the correlation of Woodward (1972) and uses the name Big Cottonwood Formation, but it must be kept in mind that these strata may actually correlate with the Caddy Canyon Quartzite.

Mutual Formation

The Mutual Formation forms the east side of Slate Jack Canyon, and also crops out on the east side of Cottonwood Canyon (southwest corner of section 29, T. 11 S, R. 1 W). It consists of grayish red purple and pale pink, banded and mottled slate and silty argillite (after usage in Pettijohn 1975, p. 262), the argillite being more common. Interbedded with the argillite and slate is pale orange to pink quartzite. The slate is micaceous along some bedding planes, and contains sandy layers and lenses that are up to coarse grained. The quartzite is very fine to medium grained, cross-bedded, and forms prominent cliffs. Muessig (1951, p. 193) measured 822 m of Mutual eastward from Slate Jack Canyon.

CAMBRIAN SYSTEM

Tintic Quartzite

The Tintic Quartzite is dominantly light pinkish gray to pinkish orange, medium- to coarse-grained quartzite in which the grains are well sorted and subrounded to rounded. Also present are lenses of quartzitic conglomerate. The basal unit is a conglomerate in which the light-colored quartzite clasts are set in a purplish matrix. Near the top of the Tintic Quartzite, both in the outcrops in the north part of the quadrangle and in the left fork of Old Canyon, the quartzite is dark reddish brown because of a higher iron content (see Lindgren and Loughlin 1919, p. 24). Total thickness of the Tintic within the Slate Jack Canyon Quadrangle is approximately 492 m (Price 1951b, p. 26).

An amygdaloidal basalt flow crops out 49 m above the base of the Tintic and is 14 m thick (Price 1951a, p. 26). The flow is dark grayish red to dark gray, very finely phaneritic to aphanitic, and includes xenoliths of quartzite up to 0.8 m long near the base. This flow is described in more detail by Abbott (1951).

No identifiable fossils have been found in the Tintic Quartzite (Hintze 1962, p. 11). However, *Skolithos* ichnofossils are present in layers or lenses within the upper 12 m of the Tintic, both in the larger outcrop in Crooked Canyon (SE 1/4, section 9, T. 11 S, R. 1 W) and the isolated outcrop in the left fork of Old Canyon. Presence of *Skolithos* ichnofossils indicates a littoral environment (Pettijohn 1975, p. 131).

Ophir Formation

The Ophir Formation consists mostly of banded moderate orange pink and pale olive shale. The basal unit is interbedded phyllite and slate, which contains ripple marks and small horizontal burrows. Limestone occurs near the middle and top of the formation; the middle limestone unit is pisolitic, and the upper limestone unit is oolitic and contains silty stringers and lenses. The lower contact is gradational. Thickness of the Ophir on Long Ridge is about 90 m (Madsen 1952, p. 15).

Fossils collected from the Ophir Formation on Long Ridge include faunas from the *Glossopleura* and *Ehmaniella* zones (fossils identified by R. A. Robison, written communication 1983), and date the Ophir as Middle Cambrian (Hintze 1962, p. 11; Moore and others, 1952, p. 499).

Teutonic Limestone

The Teutonic Limestone consists of dark gray, very fine-grained limestone with medium to dark gray dolomite near the top, and is mottled with argillaceous material that weathers reddish orange and grayish red. It is pisolitic in some parts, and contains minor cross-bedding. This formation weathers to a reddish orange soil in the Crooked Canyon area. Madsen (1952, p. 20–22) measured 89 m of Teutonic near the north end of this quadrangle.

Dagmar Dolomite

The Dagmar Dolomite is characteristically light colored on weathered surfaces and stands out as a distinctive marker bed in the Cambrian sequence of this area (Morris and Lovering 1979). This formation consists of very fine-grained dolomite that weathers yellowish gray to medium light brown. The dolomite is abundantly laminated. It conformably overlies the Teutonic Limestone and is 13 m thick in Crooked Canyon (Madsen 1952, p. 26–27).

Herkimer Limestone

The Herkimer Limestone consists of interbedded limestone and dolomite. The limestone is dark gray and is banded and mottled with silty to argillaceous material that weathers pale yellowish brown. The dolomite is dark gray and contains oolitic beds up to 0.5 m thick. Muessig (1951, p. 26) found many *Lingulella* in the upper part of the formation. An aggregate thickness of 72 m was measured by Muessig (1951, p. 194 and 200) in two incomplete sections.

Bluebird Dolomite

The Bluebird Dolomite consists of very finely crystalline grayish black dolomite that commonly weathers to a rough surface. A distinctive feature of this unit is the abundance of white dolomite rods, which appear to be of organic origin (Morris and Lovering 1979). These rods are present throughout the formation, appear to have a completely random orientation, and are about 1 cm in length. Muessig (1951, p. 199–200) measured 38 m of Bluebird near the north end of the quadrangle.

Cole Canyon Dolomite

The Cole Canyon Dolomite crops out not only in the east fork of Crooked Canyon but also along the west side of Dog Valley (sections 12 and 13, T. 12 S, R. 2 W), where the middle tuff breccia member of the Copperopolis Latite has been eroded away to expose scattered outcrops of Cole Canyon Dolomite. The Cole Canyon Dolomite consists of interbedded light and dark gray-weathering dolomites. The lighter beds are medium gray, very fine grained, and contain thin laminations and rare banded chert. The darker beds are medium dark gray, and contain clasts of dolomite, sandy layers up to 20 cm thick, and some white rods as found in the Bluebird Dolomite. Muessig (1951, p. 198–199) measured 163 m of Cole Canyon Dolomite.

Opex Formation

The Opex Dolomite consists principally of medium to coarsely crystalline, medium gray dolomite that is mottled with darker dolomite and rounded clasts of light gray argillaceous material, and weathers to a sandy surface. Sandstone lenses within the Opex are yellowish gray, very fine to coarse grained, and cemented with calcite. Sandstone and pebble conglomerates are present throughout the unit (Muessig 1951, p. 34). A total thickness of 55 m was reported by Madsen (1952, p. 40–41). No identifiable fossils have been found in the Opex within the Slate Jack Canyon Quadrangle.

Ajax Dolomite

The Ajax Dolomite consists mostly of medium light gray to light olive gray, fine to coarsely crystalline dolomite. It contains crinoid stem fragments (Muessig 1951, p. 37) and weathers to a rough surface. The middle section is fine- to coarse-grained dolomite, and weathers light gray (Madsen 1952, p. 45). The upper part is very fine grained and medium light gray, with layers, stringers, and nodules of chert. Muessig (1951, p. 37) reported a sandstone bed in the lower part of the formation, and a basal shale bed in which a *Lingulella* was found. A thickness of at least 67 m was measured by Muessig (1951, p. 196–197).

ORDOVICIAN SYSTEM

Opohonga Limestone

The outcrop identified as Opohonga by Madsen (1952) is highly altered for the most part, but the unaltered portions are medium light to medium dark gray, finely crystalline dolomitic limestone with about 5% pale grayish red and dark yellowish orange chert as irregular masses and layers. Where altered, the rock is dark yellowish orange and very siliceous. There is only one small exposure within the Slate Jack Canyon Quadrangle; at this outcrop the Opohonga Limestone is overlain unconformably by the upper tuff breccia member of the Copperopolis Latite.

TERTIARY-CRETACEOUS SYSTEM

North Horn Formation

The North Horn Formation unconformably overlies Paleozoic units and consists of moderate reddish brown and grayish orange conglomerate with sandstone lenses. Conglomerate clasts are 60% quartzite and 40% carbonate rock, very poorly sorted, and as large as cobble size. The formation contains sandstone lenses 10 to 15 cm thick composed of about 85% quartz and 15% feldspar; the grains are poorly sorted and subrounded to rounded. Due to incomplete exposures, no sections of the North Horn have been measured within the Slate Jack Canyon Quadrangle; however, I estimate a thickness of more than 35 m.

TERTIARY SYSTEM

All of the extrusive igneous rocks of the East Tintic Mountains that overlie the Packard Quartz Latite were previously called the Laguna Latite Series (Muessig 1951). The Laguna Latite Series of the East Tintic mining district has been formally subdivided by Morris and Lovering (1979) into the Oligocene Tintic Mountain and Laguna Springs Volcanic Groups (fig. 2), and the Miocene Silver Shield Quartz Latite. The Tintic Mountain Volcanic Group consists of three formations (in ascending order): Copperopolis Latite, Latite Ridge Latite, and Big Canyon Latite. The younger Laguna Springs Volcanic Group also consists of three formations: North Standard Latite, Pinyon Queen Latite, and Tintic Delmar Latite. In the East Tintic mining district, each of these six formations consists of two informal members: a lower airfall tuff member and an upper lava flow member (except the Latite Ridge Latite, in which the upper member is welded tuff) (Morris and Lovering 1979).

The stratigraphic terminology for the Oligocene volcanic rocks of the East Tintic Mountains is here adopted for the Slate Jack Canyon Quadrangle. That terminology is based on a more complete volcanic section than is exposed in the Slate Jack Canyon Quadrangle. Even though additional lava flow, tuff, and tuff breccia units of the Copperopolis Latite crop out in the Slate Jack Canyon Quadrangle that are not present in the East Tintic Mountains, no new formal member or formation names are here introduced, as the introduction of new stratigraphic names may confuse relationships with the volcano-stratigraphic terminology established in the East Tintic Mountains.

The Copperopolis Latite of the Slate Jack Canyon Quadrangle consists of six units that are stratigraphically higher than the two members recognized in the East Tintic mining district (figs. 2 and 4). Also present in the Slate Jack Canyon Quadrangle are the welded tuff member of the Latite Ridge Latite and a lava flow that is believed to be a member of the Laguna Springs Volcanic Group.

The Slate Jack Canyon Quadrangle is situated on the southeast flank of an eroded volcano built primarily by eruptions of the Copperopolis Latite. Rocks of the Copperopolis and Latite Ridge Latites show lithologic features indicative of emplacement in the proximal facies of Williams and McBirney (1979). This facies includes "rocks laid down at increasing distances on the slopes and outer flanks of a large volcanic complex" (Williams and McBirney 1979, p. 312), and generally extends as far as 5 to 15 km from the central vents.

The Tintic Mountain Volcanic Group overlies the Packard Quartz Latite (fig. 2). The Packard Quartz Latite has a K-Ar age of 32.8 ± 1.0 m.y. on biotite from a sample collected near the Central Standard shaft in the East Tintic mining district (Laughlin and others 1969). The youngest extrusive unit of the Laguna Springs Volcanic Group, the Tintic Delmar Latite, has a K-Ar age of 32.2 ± 1 m.y. from biotite and 32.3 ± 1 m.y. from hornblende of the lava flow member 1.6 km north of the East Tintic mining district (Morris and Lovering 1979), indicating that all of the volcanic rocks of the Slate Jack Canyon Quadrangle are essentially 32 to 33 m.y. old and came from eruptions during middle Oligocene time.

Tintic Mountain Volcanic Group

Copperopolis Latite. The Copperopolis Latite within the Slate Jack Canyon Quadrangle consists of latite lava flows, airfall tuff, and laharic tuff breccia units (fig. 4). Three older members of this formation that do not crop out in this quadrangle are present to the west in the Tintic Mountain and McIntyre Quadrangles; these are the lower agglomerate, tuff, and lower flow members of Morris (1975) (see fig. 2). After the collapse of the caldera caused by eruption of the Packard Quartz Latite, eruption of early units of the Copperopolis Latite built a volcano centered about 12 km to the west of Long Ridge (fig. 3); further extrusions apparently filled and buried the caldera (Morris 1975) and covered the prevolcanic rocks of the Slate Jack Canyon Quadrangle.

Middle tuff breccia member. The oldest member of the Copperopolis Latite in the Slate Jack Canyon Quadrangle is the middle tuff breccia member, which appears to have been deposited as a series of lahars. Within the Slate Jack Canyon Quadrangle, this member crops out only along the west side of Dog Valley, where it ranges in thickness from 0 to 63 m. This unit is exposed more extensively in the adjoining Tintic Mountain Quadrangle to the west, where Morris (1975) estimates a maximum thickness of more than 1200 m.

The rock is light gray, poorly stratified to nonstratified, and poorly sorted. Graded bedding is present in some outcrops in Young Canyon but is not observed elsewhere. Clasts constitute up to 60% of the rock, and are mostly grayish black, aphanitic porphyritic latite, which is similar to that of the overlying lava flow member. Five to ten percent of the clasts are reddish brown latite; pumice fragments are rare. Some of the clasts are as large as 2 m in diameter, and some lapilli clasts consist of tuff.

The groundmass is a heterogeneous mixture of ash-size subangular to rounded crystal, lithic, and rare vitric fragments. The crystal fragments include plagioclase, pyroxenes, Fe-Ti oxides, biotite, and quartz. The lithic fragments are the same lithology as larger clasts.

The middle tuff breccia member is similar to the upper tuff breccia member that is extensively exposed on Long Ridge. Because of their similarity, and the sparse outcrops, the contact relationship between these two units is unclear except where the middle lava flow member is present between them, as in the central part of Young Canyon (S 1/2, section 36, T. 11 S, R. 2 W, Tintic Mountain Quadrangle) just to the west of the Slate Jack Canyon Quadrangle.

Middle lava flow member. The middle lava flow member is thickest and best exposed along the eastern edge of Goshen Valley from Slate Jack Canyon southwest to Young Canyon. Smaller exposures occur east of Slate Jack Canyon and along the west side of Dog Valley.

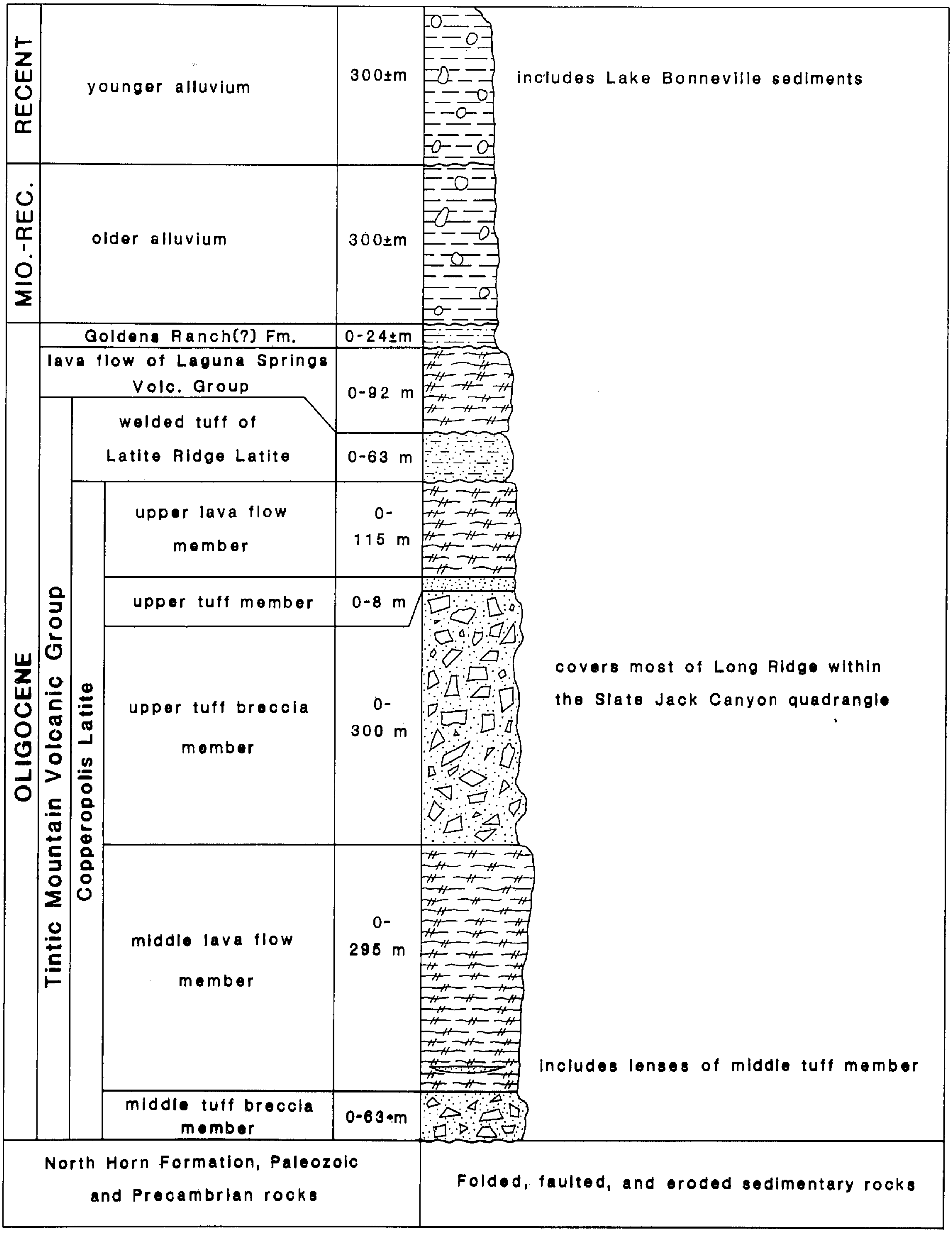

FIGURE 4.—*Columnar section of the Cenozoic rocks of the Slate Jack Canyon Quadrangle.*

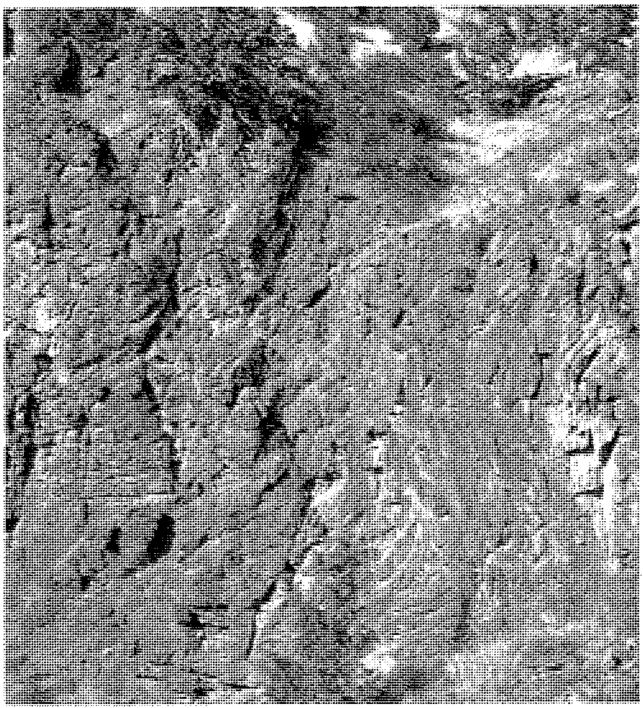

FIGURE 5.—*Flow folding within the middle lava flow member of the Copperopolis Latite (1 km northeast of the mouth of Cottonwood Canyon, south of center of N 1/2 section 19, T. 11 S, R. 1 W).*

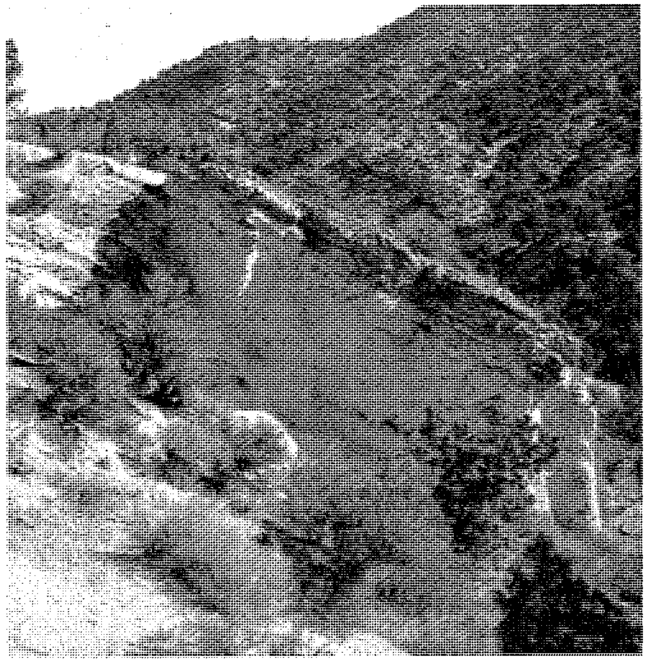

FIGURE 6.—*Exposure of the middle tuff member within the middle lava flow member of the Copperopolis Latite (NW 1/4, section 30, T. 11 S, R. 1 W).*

Thickness ranges from 0 to 295 m. The rock is very dark gray to black latite with phenocrysts (0.2–3 mm) of plagioclase and pyroxene in an aphanitic matrix. The lava flow weathers slablike and is flow folded (fig 5).

About 70% to 75% of the rock is aphanitic groundmass with pilotaxitic texture and flow layering. The groundmass consists of feldspar, magnetite, pyroxene microlites, and local glassy material.

Plagioclase constitutes up to 80% of the phenocrysts, and occurs as resorbed and broken crystals, sometimes in glomeroporphyritic clots with pyroxene and magnetite. The plagioclase crystals are concentrically zoned, with an average An content of 68% (determined optically). Augite makes up 10% to 15% of the phenocrysts, with smaller amounts of hypersthene and magnetite. Sphene and apatite are present as accessory minerals.

Airfall crystal-rich tuff and tuff breccia lenses occur locally within this unit. The tuff is up to 30 m thick, gray to very pale green, moderately bedded (fig. 6), and has angular fragments of plagioclase, pyroxene, Fe-Ti oxides, glass, sanidine (?), and quartz. Lithic and vitric fragments from ash to lapilli size constitute up to 10% of the rock in some outcrops. The lithic fragments are aphanitic porphyritic rocks similar to the associated latite lava flows, and some tuff. A distinctive tuff breccia, in which both the subangular clasts and matrix are reddish orange to orange pink, crops out in several places within the middle lava flow member. These lenses of tuff and tuff breccia indicate that the middle lava flow member was not erupted as a single unit, but rather as a series of eruptions.

Upper tuff breccia member. The upper tuff breccia member is the most extensive of any rock unit within the Slate Jack Canyon Quadrangle, covering much of Long Ridge, and is up to 300 m thick. It was emplaced as a series of lahars that moved down the flanks of the volcano built by eruptions of the Copperopolis Latite (fig. 3).

The member is poorly stratified, poorly sorted, and heterolithologic. Crude stratification is present in some outcrops where more than one individual mudflow unit is exposed; however, many outcrops are nonstratified. Graded bedding is found at several localities, the graded sequences being about 0.6 m or more thick and occurring in the same outcrop with ungraded layers (fig. 7).

Clasts constitute 50% to 75% of the rock and are dominantly dark gray, aphanitic porphyritic rocks (with phenocrysts up to 5 mm) similar to the associated latite lava flows (fig. 8). Distinctive reddish brown glassy clasts are common; vesicular clasts are present locally. Phenocrysts within the clasts seem to be slightly larger on the north end of the quadrangle than on the south end. The clasts are angular to subrounded, and commonly range up to 45 cm in diameter, with some clasts over 1.2 m.

The groundmass consists of randomly oriented lithic and crystal fragments that are angular to rounded, and

FIGURE 7.—*Crude grading and stratification in the upper tuff breccia member of the Copperopolis Latite (near center of S 1/2, section 20, T. 11 S, R. 1 W).*

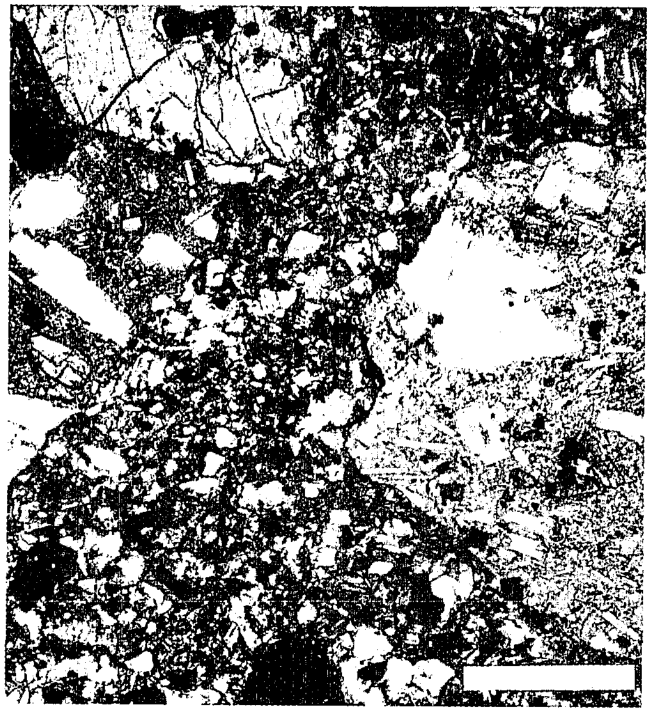

FIGURE 8.—*Small clasts and groundmass in the upper tuff breccia member of the Copperopolis Latite. Bar is 0.5 mm long.*

fine ash. The smaller particles are more rounded than the lapilli- and block-size clasts. The crystal fragments are broken plagioclase, pyroxenes, Fe-Ti oxides, glass, and rare biotite and sphene; hornblende and oxyhornblende are present in some outcrops near the top of the unit, both in clasts and matrix.

An epiclastic volcanic sandstone lies at the top of this unit, beneath the upper lava flow member 1.1 km north of the mouth of Old Canyon. The sandstone is poorly consolidated and poorly bedded, and the grains are mostly rounded to well-rounded plagioclase and quartz, with lesser amounts of pyroxene, hornblende, rare potassium feldspar, and sphene. This sandstone appears to have been deposited in a small canyon cut into the upper tuff breccia member, with part of the upper lava flow member later being emplaced over the sandstone.

Upper tuff member. The upper tuff member is recognized at only one location near the northern edge of the quadrangle (E 1/2, section 10, T. 11 S, R. 1 W), where it is poorly exposed directly beneath the upper lava flow member. The rock is a light grayish pink crystal tuff. Phenocrysts include plagioclase, pyroxenes, biotite, Fe-Ti oxides, and minor sphene. Plagioclase makes up about 90% of the phenocrysts, and the centers of the plagioclase phenocrysts are highly corroded, more so than the edges. The pyroxenes are also corroded, and are commonly replaced by chlorite. The biotite crystals appear broken and have opaque rims. The groundmass consists of tiny microlites of feldspar and pyroxene in a dusty-looking finer matrix.

Upper lava flow member. The upper lava flow member is exposed in scattered outcrops along the east side and top of Long Ridge. It consists of porphyritic aphanitic to porphyritic vitric latite lava flows, which range up to 115 m thick. The generally reddish brown matrix (70% of the rock) is glassy to pilotaxitic, with microlites of plagioclase, pyroxene, Fe-Ti oxides, and apatite.

Subhedral to euhedral plagioclase (average An content is 57% to 65%) constitutes 85% of the phenocrysts and is up to 5 mm in length in the large flow of Old Canyon. The plagioclase in this member is noticeably more resorbed than in the older middle lava flow member, displaying a sievelike texture (fig. 9). Other phenocrysts include augite, hypersthene, and Fe-Ti oxides; sphene and apatite are rare. Augite, hypersthene, and Fe-Ti oxides often occur in glomeroporphyritic clots. Biotite appears locally; the crystals are about 1 mm in length, have broken

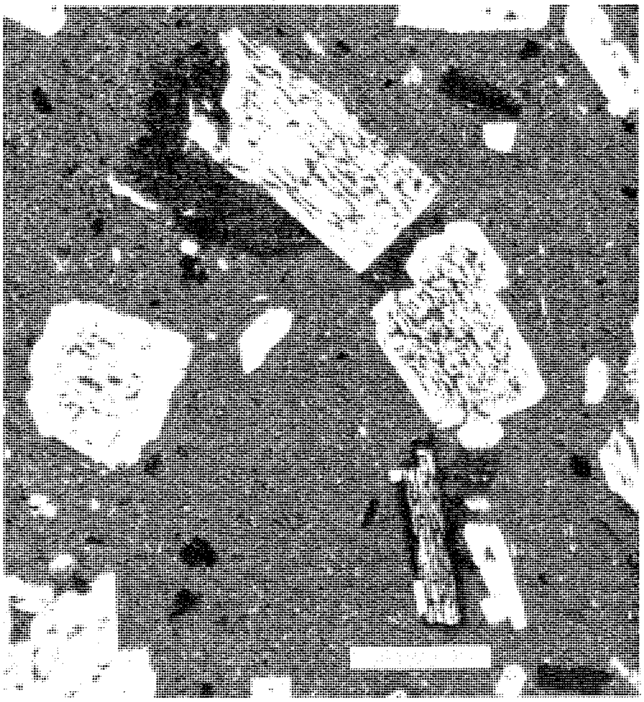

FIGURE 9.—*Plagioclase in the upper lava flow member of the Copperopolis Latite showing resorption of centers of crystals. Bar is 1 mm long.*

and frayed ends, and have an alteration rim of fine Fe-Ti oxides.

Latite Ridge Latite welded tuff member. The welded tuff member of the Latite Ridge Latite occurs along the east side of Long Ridge in patchy outcrops as much as 63 m thick. Muessig (1951) showed the two small outcrops in Juab Valley (W 1/2, SE 1/4, section 11, T. 11 S, R. 1 W) as "xenocrystic-xenolithic flow rock" on his map of Long Ridge. A lower airfall tuff member recognized in adjoining areas by Morris (1975) and Morris and Lovering (1979) does not crop out within the Slate Jack Canyon Quadrangle.

The rock displays eutaxitic texture and is moderately to densely welded. Compressed pumice fragments with frayed ends are especially abundant in the northern outcrops, where they are readily seen both in weathered outcrops and in thin section (figs. 10 and 11). Outcrops in the southern end of the Slate Jack Canyon Quadrangle are generally darker in color and more devitrified than those of the north. The groundmass makes up 70% to 75% of the rock and is moderate brown where devitrified.

Most of the phenocrysts (60%–65%) are plagioclase, are up to 3 mm in length, and are about An43. Broken crystals of biotite up to 4 mm long make up about 20% of the phenocrysts. Other phenocrysts present are augite,

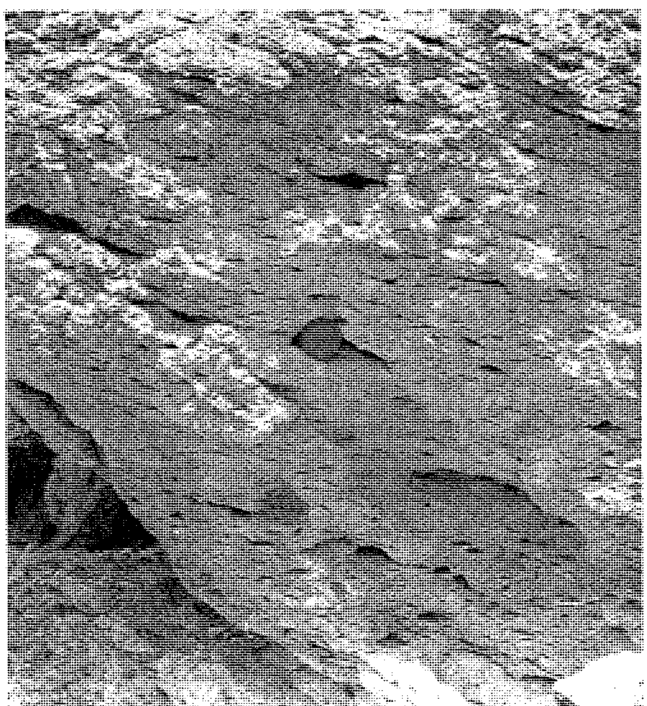

FIGURE 10.—*Outcrop of the welded tuff member of the Latite Ridge Latite showing voids left from the weathering of flattened pumice lapilli, along the eastern edge of Long Ridge (SW 1/4, SE 1/4, section 14, T. 11 S, R. 1 W).*

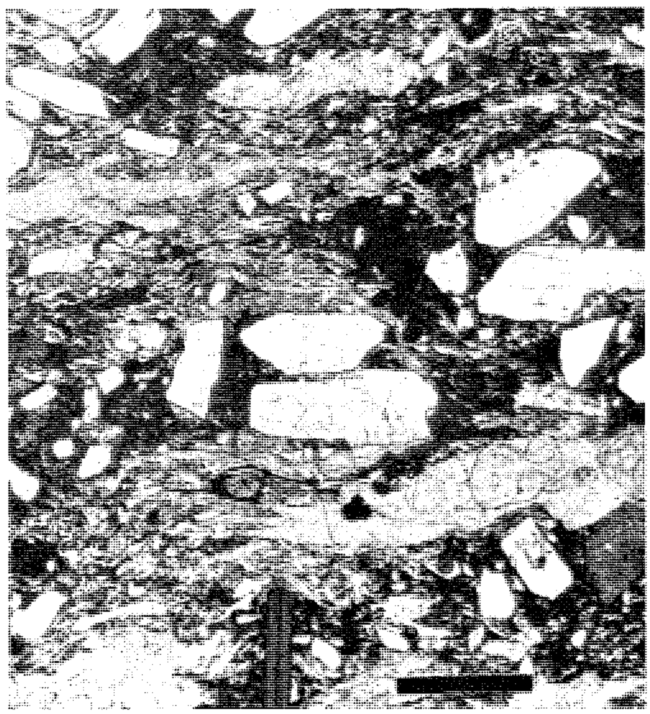

FIGURE 11.—*Flattened pumice fragments with frayed ends in the welded tuff member of the Latite Ridge Latite. Bar is 1 mm long.*

FIGURE 12.—*Hornblende crystal with opaque rim, from the lava flow unit of the Laguna Springs Volcanic Group. Bar is 0.5 mm long.*

sanidine, hypersthene, resorbed quartz, and Fe-Ti oxides. Secondary calcite and chlorite are also present. Rare small crystals of dark yellowish orange amphibole are found in one outcrop.

The xenoliths consist of rare quartzite and subangular to rounded fragments similar to lava flows of the underlying Copperopolis Latite and are up to 4 cm in diameter. A basal black vitrophyre is present in some places around the base of the southernmost outcrops.

Laguna Springs Volcanic Group

Lava flow member. The lava flow member assigned to the Laguna Springs Volcanic Group crops out in three places within the Slate Jack Canyon Quadrangle. It is best preserved in the outcrop approximately 0.8 km east of Slate Jack Canyon. The stratigraphic relationships are unclear at this locality, but are better seen at the two smaller outcrops capping ridges on the east and west sides of the northern tip of Dog Valley where it clearly overlies the upper tuff breccia member of the Copperopolis Latite.

The groundmass is aphanitic, has a pilotaxitic to hyalopilitic texture, makes up about 65% of the rock, and consists of plagioclase, hornblende, augite, magnetite, some glass, and sanidine(?). Biotite is present locally. Plagioclase (An55–An60) constitutes 60% of the phenocrysts; they are euhedral to subhedral, somewhat resorbed, and many have inclusion-filled compositional zones.

The abundance of hornblende identifies this unit as part of the Laguna Springs Volcanic Group; but with the data available, it is not possible to say with which one of the three formations of the Laguna Springs Volcanic Group this unit correlates. The hornblende, as much as 7 mm in length, is seen in thin section as subhedral and euhedral hexagonal cross sections and elongated laths. Many crystals show opaque rims around the edges (fig. 12). The hornblende laths are somewhat aligned both on fresh and weathered surfaces.

Goldens Ranch(?) Formation. The Goldens Ranch(?) Formation is exposed only along the eastern edge of Long Ridge, near the southeast corner of the quadrangle (section 15 and SE 1/4, section 10, T. 12 S, R. 1 W). It consists of dark reddish orange silty claystone and pale grayish orange sandy siltstone. It is calcareous and, for the most part, poorly bedded and poorly consolidated. This unit appears to overlie the upper tuff breccia member of the Copperopolis Latite and underlies alluvium of Miocene to Recent age. The outcrops described here appear to correlate with part of the Goldens Ranch Formation as described by Muessig (1951).

QUATERNARY-TERTIARY SYSTEM

Older Alluvium

The older alluvium in the Slate Jack Canyon Quadrangle crops out on both the east and west sides of Long Ridge in the southern half of the quadrangle. These deposits are a product of Miocene to Recent block faulting, and are now covered by Quaternary alluvium except where exposed by Recent block faulting. The outcrops are located near the mouths of canyons as alluvial fan deposits. The alluvium consists of subrounded to rounded, poorly sorted sand to cobble clasts with occasional boulders. It locally contains limestone clasts. Caliche layers are seen in the top few meters of the outcrops.

QUATERNARY SYSTEM

Younger Alluvium and Lake Bonneville Deposits

Quaternary alluvium fills the valleys surrounding Long Ridge and has been deposited primarily as coalescing alluvial fans (Muessig 1951). It consists of clay to pebble-size clasts that are poorly sorted. Also included in this unit are Lake Bonneville sediments in Juab and Goshen Valleys that include both erosional and depositional features. A well-preserved wave-built terrace is present just east of the mouth of Goosenest Canyon. Well-stratified, fine-grained Lake Bonneville deposits are found in the small gravel pit in the northeast corner of the quadrangle where several freshwater gastropods were found. Eardley (1933) reports that the total thickness of alluvium in the Mount Nebo area (probably Juab Valley) is over 600 m in some places.

PETROCHEMISTRY

Representative samples of the three lava flow units and one welded tuff unit were analyzed in duplicate for major and minor elements (except Na) by X-ray fluorescence spectrometry using the method of Norrish and Hutton (1969). Pressed pellets of pulverized rock were analyzed for Na and trace elements. Standards used were NIM-G, G-2, GSP-1, and VSN. Total iron is shown as Fe_2O_3.

All of the units analyzed are best described chemically as latite (LeMaitre 1976, Cox and others 1979); the ratio K_2O/Na_2O varies from 1.01 to 1.89, and SiO_2 varies from 55 to 62 weight percent (table 1).

The middle and upper lava flow members of the Copperopolis Latite are similar in chemical composition, and both members yield analyses similar to those published by Morris and Lovering (1979) for the lower lava flow member in the East Tintic mining district. Analyses for the welded tuff member of the Latite Ridge Latite and the lava flow unit of the Laguna Springs Volcanic Group are also similar to those published by Morris and Lovering (1979) for the respective units in the East Tintic mining district.

The volcanic rocks that crop out within the Slate Jack Canyon Quadrangle show many of the same chemical changes with time that were noted by Morris and Lovering (1979). These similar chemical patterns aid in correlation of rocks in the Slate Jack Canyon Quadrangle with those that crop out in the East Tintic mining district. The Latite Ridge Latite contains less CaO, more K_2O, and slightly more SiO_2 than units of the Copperopolis Latite, and the Laguna Springs lava flow contains less K_2O than that of the Tintic Mountain Volcanic Group, but the lowered CaO and total Fe noted in their samples of the Tintic Mountain Volcanic Group is not exhibited here.

Two of the trace elements, Sr and Zr, show the same chemical changes with time that are shown in analyses of the correlative units in the East Tintic mining district (analyses of rock units in the East Tintic mining district are found in Morris and Lovering 1979). There is an increase in Zr from the Copperopolis rocks to the Latite Ridge welded tuff, and a decrease from the Latite Ridge to the Laguna Springs lava flow. The Sr content decreases from the Copperopolis to the Latite Ridge, but increases again in the Laguna Springs Group.

LAHARIC TUFF BRECCIAS

The most widespread rock type within the Slate Jack Canyon Quadrangle is tuff breccia, which was deposited as a series of lahars, or volcanic mudflows, to form very thick and extensive deposits. Parsons (1969) listed nine characteristics of tuff breccia deposited by lahars, all of which are exhibited within the two tuff breccia members of the Slate Jack Canyon Quadrangle:

1. Heterolithologic tuff breccia.
2. Poor stratification.
3. Poor sorting.
4. Fragments angular to subrounded.
5. Not in recognizable cone structure.
6. Great lateral extent (for the upper tuff breccia member: 21 km north–south along Long Ridge, 10 km east–west across Long Ridge plus what is covered by alluvium in Juab Valley).
7. Fragments extremely heterogeneous in size.
8. Interbedded with stream deposits and volcanic rocks (epiclastic sandstone near Old Canyon, and lava flow members of the Copperopolis Latite).
9. Crude vertical grading.

Parsons (1969) indicates that lahars locally may contain thin lenses of water-sorted and water-deposited material with cross-bedding, which distinguishes laharic deposits from pyroclastic deposits. Only one occurrence of cross-bedding within the tuff breccia members of Long Ridge has been noted, located in the left fork of Old Canyon (N 1/2, SE 1/4, section 33, T. 12 S, R. 1 W). Laharic tuff breccias also have few if any glass shards or pumice clasts, and the matrix contains both coarse and fine ash-sized particles.

Lahars can be emplaced either during the actual eruption or long after eruption. Hot lahars may char wood or show signs of fumarolic activity (Williams and McBirney 1979). No indications of a high temperature of emplacement were found in the tuff breccia units of the Slate Jack Canyon Quadrangle.

STRUCTURE

PREVOLCANIC STRUCTURAL FEATURES

The Slate Jack Canyon Quadrangle is located near the eastern edge of the Sevier orogenic belt. Precambrian and Paleozoic strata of western Utah, including the rocks underlying Long Ridge, were folded and thrust eastward between Late Jurassic and early Cenozoic time (Hintze 1973). Thrusts exposed within the Slate Jack Canyon Quadrangle are the Slate Jack Canyon thrust fault near the northern edge of the quadrangle, and a newly mapped thrust in the left fork of Old Canyon.

The Slate Jack Canyon thrust fault was recognized by both Muessig (1951) and Price (1951b). At the surface, the fault dips approximately 60 degrees to the west. Presence of the fault is shown by folded and overturned beds, brecciation, and a change of dip across the fault (see map

Table 1. Chemical Composition of Oligocene Volcanic Rocks of the Slate Jack Canyon Quadrangle

SAMPLE	1	2	3	4	5	6	7	8	9
SI02	59.26	58.29	59.72	55.12	61.12	59.96	61.44	61.98	61.53
TI02	0.99	1.05	0.92	1.13	0.74	0.89	0.75	0.81	0.64
AL203	17.06	16.91	16.78	16.24	17.39	16.98	16.18	16.43	16.38
FE203	5.85	5.12	5.48	6.42	3.99	5.87	4.21	4.49	4.99
MNO	0.08	0.13	0.08	0.12	0.06	0.04	0.09	0.09	0.10
MGO	3.09	2.94	3.16	2.23	2.40	2.00	1.66	1.85	2.41
CAO	5.31	6.08	5.42	7.09	5.03	4.93	3.13	2.85	4.53
NA20	2.61	2.61	2.50	2.23	2.72	3.02	3.35	3.28	3.55
K20	3.93	3.80	4.08	3.68	4.44	3.55	6.28	6.19	3.57
P205	0.44	0.49	0.37	0.56	0.22	0.40	0.24	0.25	0.27
TOTAL	98.62	97.42	98.51	94.82	98.11	97.64	97.33	98.22	97.97
Rb	128	121	138	123	137	96	239	234	101
Sr	762	778	759	756	731	596	417	445	579
Zr	252	224	251	199	274	325	447	446	228
Ba	1286	1209	1320	1222	1255	1304	1445	1463	1386
CIPW NORMS	Fe203/FeO ratio: 1.58 (from LeMaitre 1976)								
Q	14.35	13.35	14.71	12.88	14.87	16.39	10.15	11.20	15.15
C	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00
OR	23.20	22.43	24.08	21.72	26.21	20.95	37.07	36.54	21.07
AB	22.07	22.07	21.14	18.85	23.00	25.53	28.32	27.73	30.01
AN	23.21	23.18	22.50	23.42	22.11	21.83	10.55	11.82	18.20
DI	0.19	2.93	1.53	6.30	1.08	0.00	2.65	0.53	1.95
HY	7.58	5.94	7.14	2.63	5.46	4.96	2.90	4.35	5.23
OL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MT	4.71	3.78	4.45	5.15	3.04	4.89	3.39	3.56	4.44
IL	1.88	2.00	1.75	2.15	1.41	1.69	1.43	1.54	1.22
HM	0.34	0.53	0.29	0.39	0.35	0.23	0.25	0.30	0.00
AP	0.96	1.07	0.81	1.22	0.48	0.87	0.52	0.55	0.59
TOTAL	98.49	97.29	98.39	94.71	98.01	97.52	97.23	98.11	97.87
AN/AN+AB	0.51	0.51	0.52	0.55	0.49	0.46	0.27	0.30	0.38

SAMPLE DESCRIPTIONS AND LOCATIONS

TINTIC MOUNTAIN VOLCANIC GROUP

Copperopolis Latite

Middle lava flow member

1. 0.9 km south of mouth of Cottonwood Canyon (101).
2. 100 m east of Cottonwood Spring (102).
3. Near top of Young Canyon (103).
4. 500 m east of Cottonwood Spring (104).

Upper lava flow member

5. Just west of mouth of Old Canyon (122).
6. North of Pass Canyon, on peak marked 5940 feet (125).

Latite Ridge Latite

Welded tuff member

7. 1 km north of mouth of Pass Canyon (123).
8. 2.6 km southeast of Top triangulation station (124).

LAGUNA SPRINGS VOLCANIC GROUP

Lava flow member

9. East fork of Slate Jack Canyon (140).

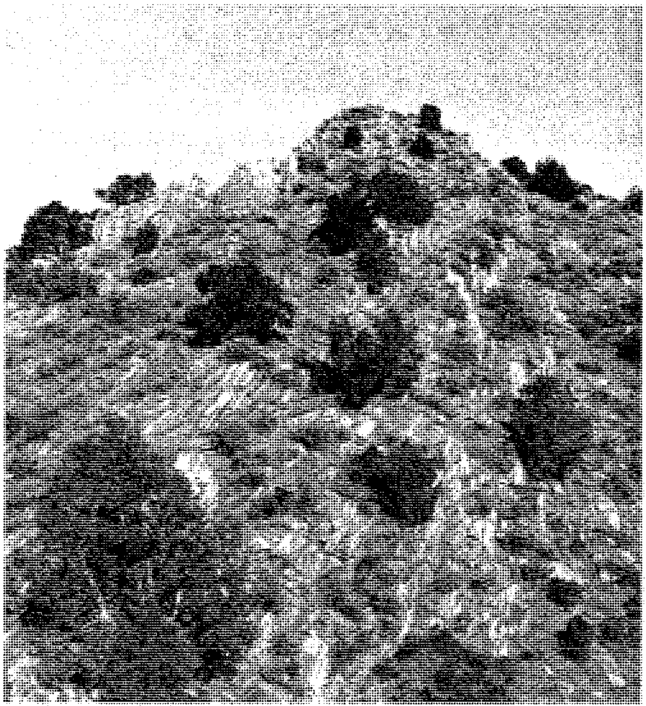

FIGURE 13.—*Overturned allochthonous beds along the thrust fault in the left fork of Old Canyon (E 1/2, SW 1/4, section 33, T. 11 S, R. 1 W). Beds dip steeply to the west.*

of Price 1951b). Displacement along the Slate Jack Canyon thrust fault appears to be small, as the upper and lower plates of the thrust are both Tintic Quartzite. Normal faults of small displacement are present in the allochthonous Mutual Formation, and may be related to the thrusting and folding.

The thrust fault exposed in the left fork of Old Canyon appears to be completely within the Teutonic and Herkimer Limestones, and dips steeply to the west (fig. 13). The Dagmar Dolomite, which helps to distinguish the Teutonic Limestone from the Herkimer Limestone, does not crop out at this location. The amount of displacement has not been determined, but it appears to be small; the beds are overturned and slickensides are present, but there is little brecciation. There is not enough evidence to say with certainty if this is a part of the Slate Jack Canyon thrust fault, or if this is a separate minor thrust fault.

Relationships of the major regional thrust faults are discussed by Meibos (1983) and Morris (1977).

Both Muessig (1951) and Madsen (1952) recognized small outcrops of the North Horn Formation near the north edge of the quadrangle that overlie normally faulted Paleozoic rocks, but the North Horn itself is not offset. This relationship indicates there was minor normal faulting in this area prior to Tertiary time.

TERTIARY VOLCANIC AND STRUCTURAL FEATURES

Volcanic activity in the East Tintic Mountains was initiated during middle Oligocene time; early eruptions laid down the thick and extensive Packard and Fernow Quartz Latites (Morris and Lovering 1979). Morris (1975) presents evidence indicating that, following eruption of the initial quartz latites, a caldera was formed in the central East Tintic Mountains. The inferred rim of this caldera passes through the northeast corner of the Slate Jack Canyon Quadrangle (plate 1, in pocket). Presence of the caldera is indicated by (Morris 1975):

1. Absence of exposures of Paleozoic rocks and Packard or Fernow Quartz Latite in a roughly circular area of the central East Tintic Mountains.
2. More than 900 m of post-Packard volcanic rocks in the central part of the East Tintic Mountains (known from exploration drill holes).
3. Occurrence of a large positive magnetic anomaly approximately centered over the inferred caldera, the characteristics of which suggest a steep-sided cylindrical feature (Mabey and Morris 1967).

Evidence found through mapping in the Slate Jack Canyon Quadrangle that supports the presence of the inferred caldera is:

1. Absence of Precambrian and Paleozoic rocks within the inferred boundary.
2. Presence of the thick middle lava flow member of the Copperopolis Latite, which could have covered the actual caldera rim.

Emplacement of the last volcanic unit (lava flow member of Laguna Springs Volcanic Group) took place in middle Oligocene time. Basin-and-range block faulting in this area apparently began in latest Oligocene or early Miocene time (Morris and Lovering 1979) and is still active.

Long Ridge itself is a horst, bounded on the east and west by normal faults except for the southwest-trending ridge that connects it with the East Tintic Mountains. Direct evidence for the fault on the east side of Long Ridge was not found, but existence of this fault is inferred in a regional gravity study by Cook and Berg (1961). Their data also seem to indicate that Juab Valley is a long narrow graben (Cook and Berg 1961).

Long Ridge is bounded on the west by normal faults that overlap in en echelon fashion. The northwestern fault is the southward extension of the Goshen fault. The two southwestern faults form the eastern edge of Dog Valley (plate 1). Numerous small normal faults offset the middle lava flow member of the Copperopolis Latite along the eastern edge of Goshen Valley; their maximum displacement is about 30 m.

Price (1951b) studied the structure and stratigraphy of the Precambrian and Cambrian rocks from Slate Jack Canyon east to Crooked Canyon, and Madsen (1952) studied the geology and ore deposits of the Crooked Canyon area. Their maps were carefully checked in the field, and the geology remapped on aerial photographs. I agree with most of their work, differing only in a few details.

In Slate Jack Canyon, fault breccia is exposed along the north–south fault; the breccia dips 51 degrees to the west, and the fault offsets the volcanic rocks at its southern end. Slickensides exposed at one location along this fault indicate only dip-slip movement. Price (1951a) estimated displacement exceeding 600 m along this fault.

Cambrian and Ordovician strata of the Crooked Canyon area dip generally to the east. Several normal faults in the Crooked Canyon area offset volcanic rocks of the Copperopolis Latite; but not all of the faults can be seen to offset the volcanic rocks, indicating that some of the normal faulting in the northern part of Long Ridge may have taken place before Oligocene time, and could possibly be part of the pre-North Horn faulting mentioned previously. Near the mouth of Crooked Canyon, boulders and cobbles of the North Horn Formation are fractured at an angle to the locally northeast-trending normal faults.

Many of the normal faults of the Crooked Canyon area appear to be quite low-angle. Madsen (1952) theorized that these faults were originally steeper, and that Long Ridge has been tilted to make these appear as low-angle faults.

TERTIARY GEOLOGIC HISTORY OF THE SLATE JACK CANYON QUADRANGLE

During latest Jurassic to early Cenozoic time, Precambrian and Paleozoic rocks of central Utah were thrust eastward and folded as part of the Sevier orogeny (Hintze 1973). Minor normal faulting within the allochthon of the Slate Jack Canyon thrust fault also may have taken place during this time. Sometime before deposition of the North Horn conglomerate, there was minor normal faulting, at least in the northern part of this quadrangle; Muessig (1951) believed that this faulting took place after the Sevier orogenic phase.

At the beginning of Tertiary time, erosional debris that formed the North Horn Formation was being shed eastward from nearby highlands of the Sevier Orogenic Belt, and deposited in the Long Ridge area as alluvial fans (Muessig 1951). These deposits are some of the westernmost known; so the Sevier highlands were quite close to the west. To the south and east of this quadrangle, the North Horn Formation grades upward into the lacustrine and fluvial facies of the Flagstaff Formation (Muessig 1951) and its lateral equivalent, the Orme Spring Conglomerate (Meibos 1983).

In at least two places within the Slate Jack Canyon Quadrangle the middle tuff breccia member of the Copperopolis Latite unconformably overlies the North Horn. Eardley (1934) reported that in the southern Wasatch Mountains, the North Horn conglomerate and older rocks were eroded to form a topography of considerable relief. Morris and Lovering (1979) have reported that in the East Tintic Mountains a youthful erosion surface with relief of at least 1219 m was formed before eruption of the Oligocene volcanic rocks. This indicates that the volcanic rocks of the Long Ridge area were also laid down on an eroded surface of considerable relief.

Volcanism in the East Tintic Mountains began in early middle Oligocene, and the first unit erupted was the Packard Quartz Latite and its correlative units (Morris 1975). Evidence indicates that a caldera was formed as a consequence of the voluminous eruptions of the Packard (Morris 1975). After collapse of the caldera, eruptions of the Copperopolis Latite took place from one or more vents near Volcano Ridge, about 12 km west of Long Ridge (fig. 3) (Morris and Lovering 1979). Eruptions of the Copperopolis Latite, along with the lahars of the middle and upper tuff breccia members, eventually filled and buried the caldera. The lower agglomerate, tuff, and lava flow members were erupted first, and crop out in the Tintic Mountain and McIntyre Quadrangles to the west (figs. 2 and 3) (Morris 1975). The middle tuff breccia member was then deposited, probably as a series of lahars.

Lava flows of the thick middle lava flow member were then erupted, and covered part of the middle tuff breccia member and much of the pre-Tertiary strata. Interbedded tuff and lenses of tuff breccia within this unit indicate that this member was emplaced during several periods of eruption. A period of erosion followed the eruptions; during this period of erosion the upper tuff breccia member was deposited, covering Long Ridge with a series of lahars.

The upper tuff breccia member of the Copperopolis Latite, in turn, was somewhat eroded before eruption of the upper tuff and lava flow members. Evidence for this is the presence of the epiclastic sandstone near Old Canyon and the fact that the upper lava flow member near Old Canyon seems to have been deposited in a small canyon within the upper tuff breccia member.

The welded tuff member of the Latite Ridge Latite was emplaced as an ash-flow tuff, probably from a vent about 10 km to the west in the East Tintic Mountains (fig. 3) (Morris and Lovering 1979). Some of the tuff both in this quadrangle and the one to the west seem to have been deposited in small canyons cut into previously emplaced units. Morris and Lovering (1979) noted that after eruption of the Copperopolis Latite, but before eruption of the Latite Ridge Latite, the magma chamber that served as the source for these units had experienced some differentiation.

Rocks of the Tintic Mountain Volcanic Group were extensively eroded before eruption of the lava flow member of the Laguna Springs Volcanic Group. The lava flow member was probably erupted from vents in the northeastern part of the East Tintic mining district (fig. 3) (Morris and Lovering 1979). Tertiary volcanic rocks of the Slate Jack Canyon Quadrangle were emplaced on the southeast flank of the volcano built mostly by units of the Copperopolis Latite.

The youngest unit of the Laguna Springs Volcanic Group (Tintic Delmar Latite) yields a K-Ar age of 32.2 ± 1 m.y., less than one million years after the first eruptive unit of the East Tintic Mountains (Packard Quartz Latite), showing the Oligocene volcanic activity in the East Tintic Mountains probably took place in less than one million years (Morris and Lovering 1979). Minor volcanism took place in the East Tintic Mountains during middle Miocene time (Morris and Lovering 1979), but no evidence of this is seen in the Slate Jack Canyon Quadrangle.

After the Oligocene volcanic activity, but probably before the beginning of basin-and-range block faulting, rocks of Long Ridge were eroded to form deposits of orange and tan claystone and siltstone of the Goldens Ranch(?) Formation that crop out near the southeast corner of this quadrangle.

Basin-and-range block faulting began in this area at least in early Miocene time (Morris and Lovering 1979) and continues to the present. North to northeast-trending normal faults bound Long Ridge on the east and west. Early faulting caused deposition of the older alluvium along both sides of Long Ridge. The older alluvial deposits are largely covered by Lake Bonneville sediments and alluvium of Quaternary age.

ECONOMIC GEOLOGY

MINERALS

In the spring of 1928, the Crooked Canyon area of northern Long Ridge (N 1/2, section 9, T. 11 S, R. 1 W) was being promoted as a promising section of the famous Tintic mining district; in the headline article of The Mining Review of April 15, 1928, the editor gives "a brief description of the location of what is likely to develop into a new camp—and maybe carry a name of its own" (Camomile 1928). Three shafts were sunk in the area of interest, two of the shafts are located within the Slate Jack Canyon Quadrangle: the Tintic Eagle shaft (SE 1/4, NW 1/4, section 9, T. 11 S, R. 1 W) and the Tintic Lead shaft (SE 1/4, NE 1/4, section 9, T. 11 S, R. 1 W) (Camomile 1928). The Tintic Giant shaft is located just north of the Slate Jack Canyon Quadrangle (N 1/2, NE 1/4, section 9, T. 11 S, R. 1 W, Goshen quadrangle) (Camomile 1928), and was reportedly sunk to a depth of 213 to 244 m (Madsen 1952). Despite the promise that was held by the Crooked Canyon area, no recorded production was noted from these three mine shafts, and all of their surface buildings and equipment are now gone.

Most of the ore actually produced from the Slate Jack Canyon Quadrangle was manganese ore, and all of the recorded production was from mines located within the outcrop area of the Precambrian and Paleozoic rocks near the northern edge of the quadrangle. The first recorded production from this quadrangle was in 1924, the ore being shipped from the Trotter mine (SE 1/4, NW 1/4, section 9, T. 11 S, R. 1 W); however, mining activity may have taken place earlier, as the Queen of the West claim (just west of the center of W 1/2, section 10, T. 11 S, R. 1 W) was leased to S. D. Trotter in 1917 and 1918 (Crittenden 1951). Mining activity occurred intermittently until 1950; other manganese mines developed during this period were the Post-War claim (W 1/2, section 9, T. 11 S, R. 1 W), Lucky Boy mine (SW 1/4, SW 1/4, section 10, T. 11 S, R. 1 W), Alpha claim (SW 1/4, NW 1/4, section 10, T. 11 S, R. 1 W) (Madsen 1952), and two open pits near the mouth of Slate Jack Canyon (S 1/2, section 8, T. 11 S, R. 1 W) (Price 1951a). Total recorded production from the Crooked Canyon area (sections 9 and 10, T. 11 S, R. 1 W) was 2108.5 tons of ore containing an average of 11.2 percent manganese (Crittenden 1951, and Madsen 1952). About 600 tons of ore were shipped from the open pits near the mouth of Slate Jack Canyon (S 1/2, section 8, T. 11 S, R. 1 W) before 1950 (Price 1951a).

The manganese ore deposits of the Crooked Canyon area have been studied in detail by Madsen (1952), and this paragraph is a review of work done by him. The ore deposits are epigenetic, and are associated with the northeast–southwest-trending normal faults. Ore-bearing fluids moved up along the faults, depositing jasper, rhodochrosite, and/or manganiferous calcite, and pyrite(?). The primary minerals were oxidized to form psilomelane, pyrolusite, "wad," hematite, and limonite; these secondary minerals have been further concentrated by supergene enrichment. The faults, fault gouge, and wall rock lithology all acted as localizing agents for the ore-bearing fluids; in one mine, beds of favorable lithology have been replaced by ore for a distance of 0.3 to 0.6 m. Exposures of the ore are restricted in size, and the ore occurs as stringers and irregular masses within and near the faults.

Silicification has taken place along normal faults in the Crooked Canyon area and along the north–south-trending normal fault in Slate Jack Canyon. The silicification is present along veins as jasper (Madsen 1952), as "sanded" limestone (Crittenden 1951), and as large masses of jasper near many faults. Madsen (1952) indicated that silicification in the Crooked Canyon area took place before or penecontemporaneously with formation of the primary manganese minerals. Argillic alteration is present in many of the mines (Madsen 1952), and is also noted near the mouth of Cottonwood Canyon, immediately west of the mouth of the east fork of Slate Jack Canyon, and in the east fork of Slate Jack Canyon (SE 1/4, section 17, T. 11 S, R. 1 W).

Numerous prospects are located near the west side of the Slate Jack Canyon Quadrangle, in the upper part of Young Canyon, and in and near Cottonwood Canyon (sections 29–32, T. 11 S, R. 1 W; sections 25 and 36, T. 11 S, R. 2 W; and section 1, T. 12 S, R. 2 W); most of these prospects were opened between 1953 and 1965. Many of the prospects are located in lenses of tuff, with local Precambrian and Paleozoic rocks. Muessig (1951) reported an adit in the SE 1/4 of section 8, T. 11 S, R. 1 W, and several adits along a quartz vein in Slate Jack Canyon, but no economic mineralization was reported from these adits. There is also a mine in Pass Canyon (SW 1/4, SW 1/4, SE 1/4, section 10, T. 11 S, R. 1 W) from which no reported production was noted.

PETROLEUM

No drilling has been undertaken in the Slate Jack Canyon Quadrangle for oil or gas. Two wells have recently been drilled by Placid Oil in the Nephi Northwest 7 1/2-Minute Quadrangle (Meibos 1983), directly to the south of the Slate Jack Canyon Quadrangle. Detailed information for these wells was not obtained.

SUGGESTED RESEARCH

The upper members of the Copperopolis Latite cover most of the Slate Jack Canyon Quadrangle, and Morris and Lovering (1979) believe that volcanic-boulder conglomerate of the Moroni Formation that crops out north of Moroni, Utah (about 45 km southeast of the Slate Jack Canyon Quadrangle), is part of the uppermost Copperopolis. A detailed study of the stratigraphic relationships between these rock units may add to our understanding of the volcanic history of the Tintic area. Another problem is correlation of the Big Cottonwood strata of the Slate Jack Canyon area. H. T. Morris (written communication 1984) suggested that these strata may correlate with the Caddy Canyon Quartzite, or possibly with part of the Sheeprock Formation.

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