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By EDWARD C. BINGLER

CONTRIBUTIONS TO STRATIGRAPHY

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ABANDONMENT OF THE NAME HARTFORD HILL RHYOLITE TUFF AND ADOPTION OF NEW FORMATION NAMES FOR MIDDLE TERTIARY ASH-FLOW TUFFS IN THE CARSON CITY-SILVER CITY AREA, NEVADA

By EDWARD C. BINGLER[1]

ABSTRACT

The formation name Hartford Hill Rhyolite, first applied to exposures of welded tuff underlying Hartford Hill near Silver City, Nev., and subsequently revised to the Hartford Hill Rhyolite Tuff, has traditionally been applied to all silicic tuffs in western Nevada that form the base of the Tertiary section and underlie andesite flows and breccias of the Alta and Kate Peak Formations. Recent mapping in the Carson City-Silver City area reveals that rocks included within the Hartford Hill Rhyolite Tuff make up a diverse sequence, locally more than 800 m thick, of welded ash-flow tuffs ranging in age from 22 to 28 m.y., erupted from widely separated sources. Several of these tuffs have recently been recognized and named in the Yerington area and mapped in the Gabbs Valley and Gillis Ranges. Four new formations are recognized and named in the Carson City-Silver City area. As it is now clear that rocks previously assigned to the Hartford Hill include genetically and compositionally unrelated ash-flow tuff cooling units of formation rank, no useful purpose is served by continuing the use of this formation name, and it is herein abandoned.

Ash-flow units mapped in the Carson City-Silver City area and described in this report are, from oldest to youngest: Mickey Pass Tuff; Lenihan Canyon Tuff (new name); Nine Hill Tuff (new name); Eureka Canyon Tuff (new name); a thin erosional remnant of biotite dacite crystal tuff tentatively correlated with a similar tuff in the northern Gillis Range; thin and discontinuous erosional remnants of rhyolite and rhyodacite tuff correlated with similar rocks in the Gillis and Gabbs Valley Ranges; and the Santiage Canyon Tuff (new name).

INTRODUCTION

For the past 20 years, it has been common stratigraphic practice to assign all Tertiary silicic ash-flow tuffs (fig. 1) that underlie andesite flows and breccias of the Alta and Kate Peak Formations of central-

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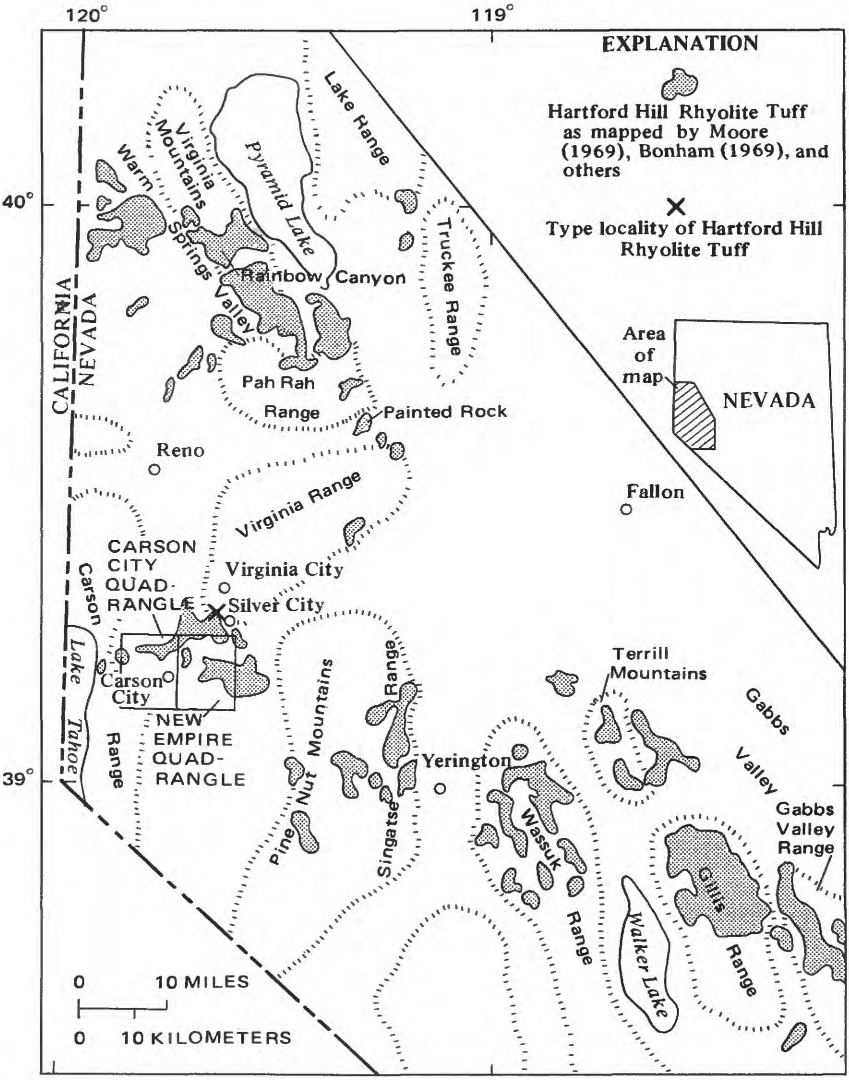

FIGURE 1.—Generalized distribution of 34 to 27-m.y.-old ash-flow tuffs (modified from Stewart and Carlson, 1976) assigned to the Hartford Hill Rhyolite Tuff. Tuffs in the Gillis and Gabbs Valley Ranges are laterally equivalent to tuffs in the Wassuk and Singatse Ranges assigned to the Hartford Hill by Moore (1969).

western Nevada to the Hartford Hill Rhyolite Tuff. Gianella (1936, p. 47) originally coined the name Hartford Hill Rhyolite for exposures of rhyolite in the Silver City mining district. He did not designate a type section but reported that the rhyolite underlies Hartford Hill, a small knoll about 1.6 km northwest of Silver City. Thompson

(1956, p. 50), in mapping the geology of the Virginia City 15-minute quadrangle, designated the hill as the type locality. Recognizing that nearly all of the Hartford Hill Rhyolite was of pyroclastic origin, he modified the formation name to Hartford Hill Rhyolite Tuff to better represent the lithologic types present. Bonham (1969) and Moore (1969) included in the Hartford Hill thick isolated sections of tuff as far north as Pyramid Lake and as far east as the Terrill Mountains (fig. 1).

Recent mapping of pyroclastic rocks in west-central Nevada previously assigned to the Hartford Hill employs the principles and techniques of ash-flow stratigraphy based on the classic studies of Smith (1960a, b) and Ross and Smith (1961). Bingler (1973) described four compositionally and texturally distinct ash-flow tuffs in the Wassuk Range that make up the section of rock assigned by Moore (1969) to the Hartford Hill Rhyolite Tuff. Wallace (1975) recognized siz ash-flow tuff cooling units ranging in age from 28 to 22 m.y. at Rainbow Canyon southwest of Pyramid Lake in tuffs previously mapped as Hartford Hill Rhyolite by Bonham (1969). A thick section of ash-flow tuffs in the Singatse Range, earlier assigned to the Hartford Hill by Moore (1969), was subdivided by Proffett and Proffett (1976) into four compositionally and texturally distinct tuffs ranging in age from 28 to 24 m.y. : the Mickey Pass Tuff, the Singatse Tuff, the Bluestone Mine Tuff, and the tuff and breccia of Gallagher Pass. Ekren and others (E. B. Ekren, written commun., 1976), in mapping five 15-minute quadrangles in the Gillis and Gabbs Valley Ranges, identified a large number of ash-flow cooling units in addition to the Mickey Pass and the Singatse Tuffs.

Direct field evidence for cauldron sources related to any one of the cooling units described is rare. The areal distribution of the principal ash-flow sheets and the distribution of locally thick stratigraphic sections suggest that (1) the Mickey Pass and Singatse Tuffs were erupted from a source region in the Singatse Range-Wassuk Range area and (2) several of the ash-flow tuff sheets mapped by Ekren and others (E. B. Ekren, written commun., 1976) occupy a broad regional depression or source region centered on the southern Gillis-northern Gabbs Valley Range area.

Recently completed mapping by Bingler (1978) and Trexler (1978) near the type locality of the Hartford Hill Rhyolite Tuff reveals that rocks previously assigned to this formation consist of a thick section of Mickey Pass Tuff, thin distal edges of ash-flow tuffs mapped in the Gillis and Gabbs Valley Ranges, and four ash-flows of formation rank named in this report (figs. 2, 3, and 4). Three of the four newly named formations are related to cauldron sources in the Carson City-Silver City area; they range in age from 26 to 22 m.y.

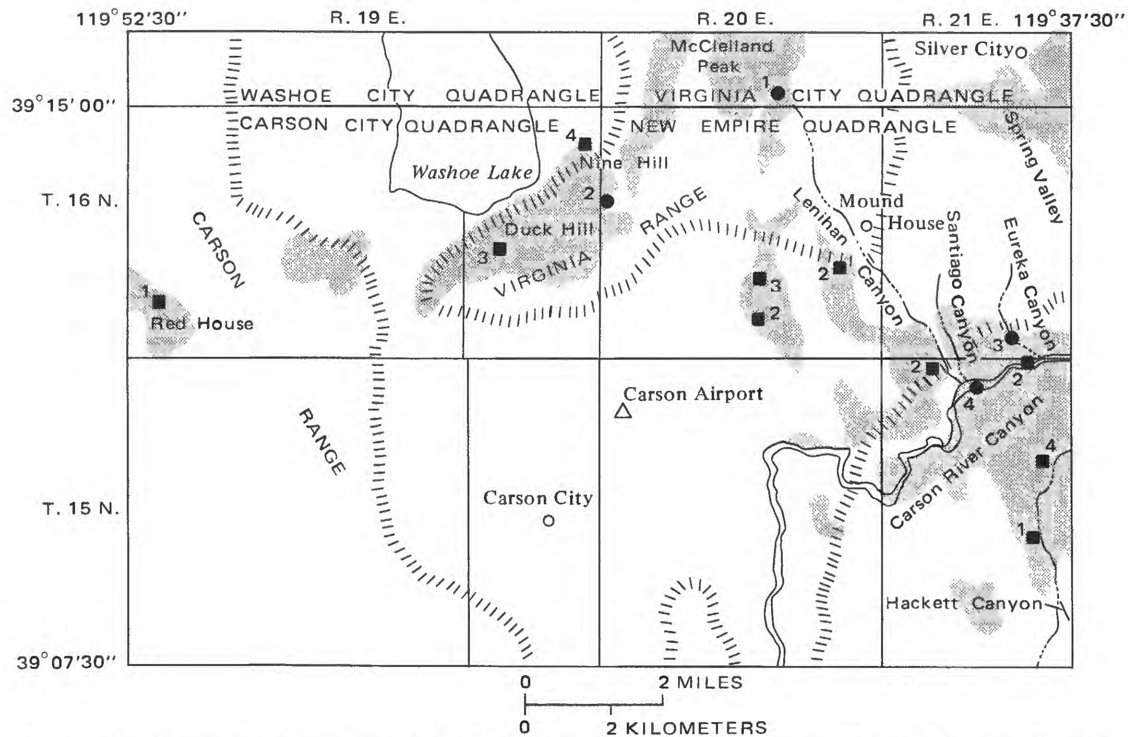

FIGURE 2.—Generalized distribution of ash-flow tuffs (stipple) previously assigned to the Hartford Hill Rhyolite Tuff within parts of the New Empire, Carson City, and Virginia City 7½-minute quadrangles. Type localities (dots) and reference localities (squares) of new formations: 1, Lenihan Canyon Tuff; 2, Nine Hill Tuff; 3, Eureka Canyon Tuff; 4, Santiage Canyon Tuff.

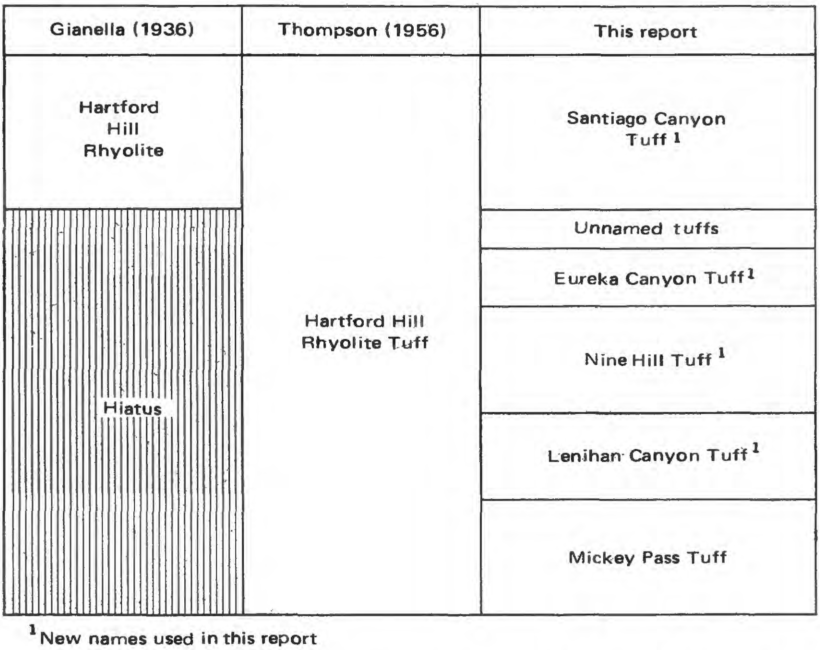

FIGURE 3.—Summary of stratigraphic nomenclature of tuffs in the Carson City-Silver City area.

and are interlayered with ash-flow sheets originating in the Singatse Range-Wassuk Range and Gillis Range-Gabbs Valley regions.

Since the Hartford Hill Rhyolite Tuff as now employed includes a diverse sequence of genetically and compositionally unrelated cooling units of ash-flow tuff of middle Tertiary age from widely separated source regions, and since recent mapping has demonstrated that many of its individual cooling units are also of formational rank, no useful purpose is served by continuing its use, and the formation name Hartford Hill Rhyolite Tuff is herein abandoned.

ACKNOWLEDGMENTS

Ash-flow tuffs in the Carson City-Silver City area were mapped as part of a more comprehensive program of geologic mapping for earthquake hazard reduction supported in part by U.S. Geological Survey Grant 14–08–0001–G–248. H. F. Bonham, Jr., and L. J. Garside, of the Nevada Bureau of Mines and Geology, and J. H. Stewart, M. L. Silberman, and D. H. Whitebread, of the U.S. Geological Survey, made helpful suggestions on the manuscript. I wish to thank H. F. Bonham, Jr., for stimulating discussions on the Cenozoic ash-flow stratigraphy of western Nevada.

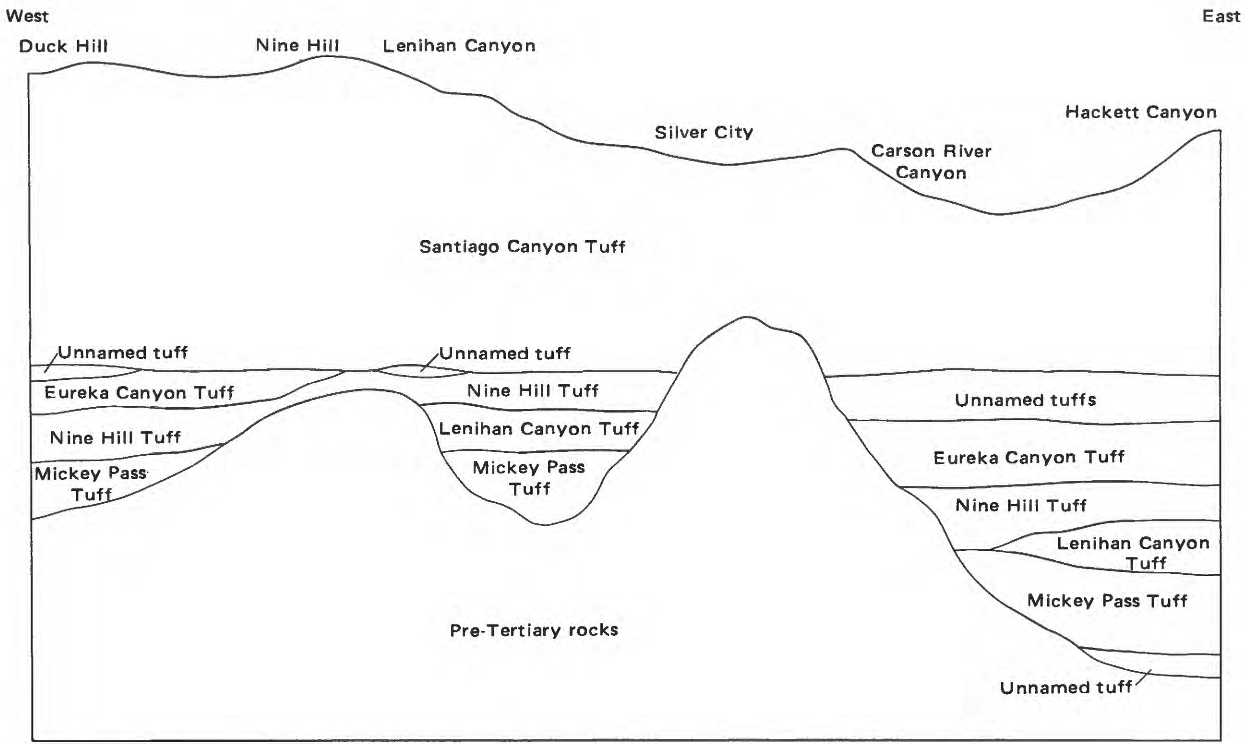

FIGURE 4.—Stratigraphic correlation chart of ash-flow tuffs in the Carson City and New Empire 7½-minute quadrangles. See figure 2 for locations.

ASH-FLOW STRATIGRAPHY IN THE CARSON CITY-SILVER CITY AREA

During the course of geologic mapping in the New Empire and Carson City 7½-minute quadrangles (figs. 1, 2), the sequence of silicic ash-flow cooling units heretofore assigned to the Hartford Hill Rhyolite Tuff (fig. 2) was divided into eight map units distinguished on the basis of composition, phenocryst ratios and abundance, characteristic accessory mineral species, and the stratigraphic parameters of age and bounding disconformities (Bingler, 1978; Trexler, 1978). These eight tuff units, erupted from 28 to 22.5 m.y. ago, are, from oldest to youngest: Mickey Pass Tuff (Proffett and Proffett, 1976), Lenihan Canyon Tuff, Nine Hill Tuff, Eureka Canyon Tuff, an unnamed biotite dacite tuff also recognized in the Gillis Range (R. F. Hardyman, oral commun., 1976), an unnamed rhyolite tuff and an augite rhyodacite tuff also mapped in the Gillis and Gabbs Valley Ranges (E. B. Ekren, written commun., 1976), and the Santiago Canyon Tuff.

MICKEY PASS TUFF

The Mickey Pass Tuff, one of the oldest and most extensive of the widespread ash-flow tuff sheets in western Nevada, was named by Proffett and Proffett (1976, p. 8) for exposures just north of Mickey Pass in the Singatse Range near Yerington, Nev. At the type locality, it includes two members, the Guild Mine and the overlying Weed Heights, and minor amounts of weakly welded tuff and tuffaceous sediment. The Guild Mine Member is a compound cooling unit of as much as 900 m of dense, hard, devitrified, brown to reddish-brown crystal-vitric rhyodacite to rhyolite tuff, strongly to moderately welded throughout. Vapor-phase crystallization is prominent only near the top. The base of the member is commonly marked by black crystal-rich vitrophyre as much as 30 m thick. The Weed Heights Member is a simple cooling unit formed of as much as 200 m of moderately welded crystal-rich quartz latite to rhyolite tuff.

In the Carson City-Silver City area, the Mickey Pass Tuff consists entirely of rock very similar to tuff assigned by Proffett and Proffett (1976, p. 10) to their Guild Mine Member. The formation is a simple cooling unit generally with a few meters of densely welded black crystal-rich vitrophyre at the base that grades rapidly upward into compact tan to red-brown vitric crystal tuff composed of about 10 percent sanidine, 10 percent plagioclase, 5 percent quartz, and a few percent biotite set in a strongly welded matrix of fine ash and sparse pumice. The rock grades upward into weakly to moderately welded lavender tuff that is more crystal rich (30–40 percent) and contains distinctive somewhat rounded bleached white blotches 2 to 3 cm in diameter produced by weak but pervasive vapor-phase alteration in the upper third of the formation. White pumice lapilli increase upward, making up about 10 percent of the rock near the top. Near the top of the formation, quartz phenocrysts that constitute about 15 percent of the total rock are distinctly vermicular and have prominent graphic outlines.

Just southwest of Mound House (fig. 2), approximately 150 m of welded ash-flow tuff typical of the lower part of the Mickey Pass Tuff is disconformably overlain by younger tuff; presumably the crystal-rich lavender blotchy upper part of the formation is eroded. The thick section of Mickey Pass Tuff (120 m) exposed at the head of Lenihan Canyon (figs. 2, 5) differs somewhat from the formation as exposed elsewhere in the mapped area in that weak vapor-phase crystallization has affected the tuff nearly to its base and that the upper part of the formation is marked by a very prominent vapor-phase zone that is strongly oxidized, is orange red from disseminated hematite, and forms bold somewhat cavernous-weathering outcrops. Above the top of the vapor-phase zone, the tuff is white to pale greenish white, weakly welded to nonwelded, and strongly zeolitized.

The Mickey Pass Tuff occurs widely in the New Empire quadrangle and in the northeastern part of the adjacent Carson City quadrangle, where it is exposed as isolated patches resting on pre-Tertiary basement rocks. It is best exposed in sec. 6, T. 15 N., R. 21 E.; sec. 1, T. 15 N., R. 20 E.; sec. 36, T. 16 N., R. 20 E.; and secs. 14 and 23 in T. 16 N., R. 20 E. The exposed thickness is highly variable owing to its mode of deposition; the ash flows first filled valleys and later buried the surrounding hills of a mature topography cut on faulted and deeply eroded pre-Tertiary rocks. Maximum exposed thickness of the member is approximately 300 m. Concordant Oligocene potassium-argon ages of 28.0 ± 0.8 m.y. on biotite and 28.6 ± 0.9 m.y. on plagioclase are reported for vitrophyre at the base of the Mickey Pass in the Carson River canyon (M. L. Silberman, written commun., 1976).

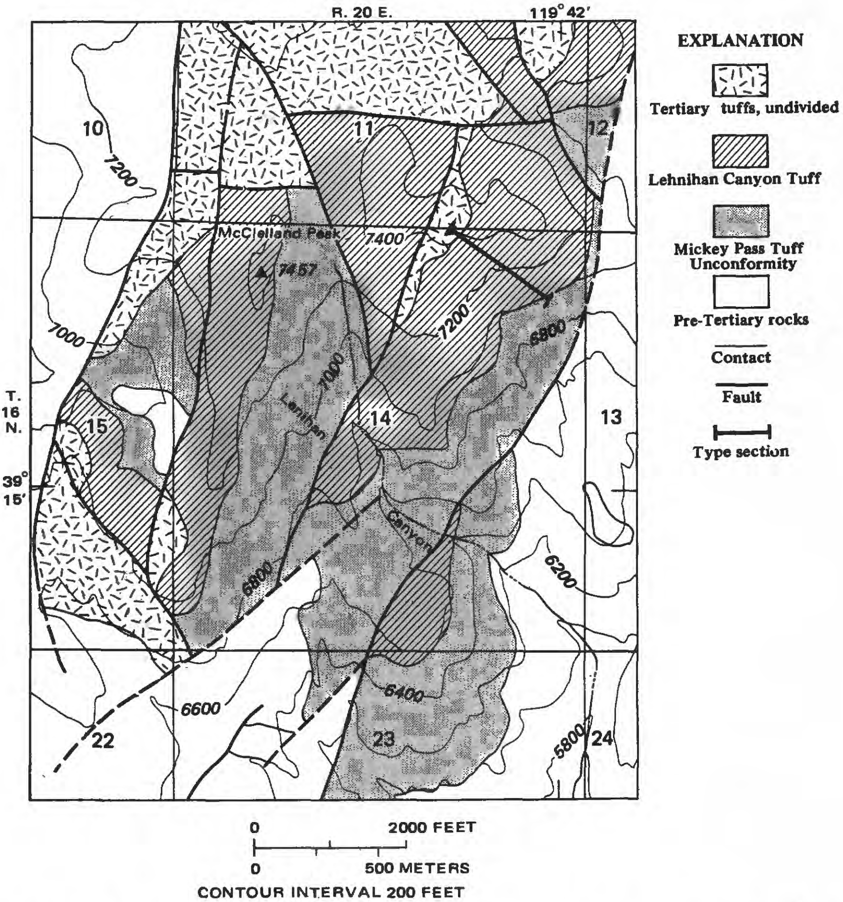

FIGURE 5.—Generalized geologic map showing the distribution of the Lenihan Canyon Tuff in its type locality. Base from U.S. Geological Survey Virginia City and New Empire 7½-minute quadrangles.

LENIHAN CANYON TUFF

The Mickey Pass Tuff is disconformably overlain by as much as 300 m of pale-lavender-brown fine-grained hornblende-biotite quartz latite vitric-crystal tuff, here named the Lenihan Canyon Tuff for its type locality exposures (figs. 2, 5) along the east side of

Lenihan Canyon and in the ridge south of McClelland Peak (secs. 14 and 15, T. 16 N., R. 20 E.). The type section is located in the NE¼ NE¼ sec. 14, T. 16 N., R. 20 E., approximately one-half mile northeast of Lenihan Canyon (fig. 5). Two reference localities are designated. The principal reference locality is along the west side of Hackett Canyon in secs. 16 and 17, T. 15 N., R. 21 E., the second at Red House in sec. 32, T. 16 N., R. 19 E. (fig. 2). The Lenihan Canyon Tuff everywhere rests on the Mickey Pass Tuff except at Red House, in the Carson Range, where it rests unconformably on Cretaceous granodiorite. Where exposed in Hackett Canyon and near McClelland Peak, the tuff overlies the weakly welded to nonwelded top of the Mickey Pass; there appears to have been little erosion between the eruption of the last ash flows of the Mickey Pass and the first ash flows of the Lenihan Canyon. In the Hackett Canyon exposures, a few small pebbles of pre-Tertiary rocks in the float mark the basal disconformity.

The Lenihan Canyon Tuff is a simple cooling unit of moderately to strongly welded hornblende biotite quartz latite. At Hackett Canyon and Red House, the basal few meters consist of white to gray-white weakly welded vitric-crystal tuff that grades rapidly upward into gray to gray-black densely welded phenocryst-rich vitrophyre, generally less than 5 m thick. The bulk of the formation is devitrified pale-lavender to purplish-tan fine-grained crystal-vitric tuff. Phenocrysts make up about 25 percent of the rock: about 5 percent are quartz, 3 percent sanidine, 12 percent plagioclase (Ca-oligoclase), 3 percent biotite, 2 percent hornblende, and a trace of opaque oxides. Pumice and lithic fragments are sparse to very rare. Features characteristic of this tuff are (1) fresh black biotite flakes 1–3 mm in diameter that are well alined in the foliation plane, imparting a prominent speckled appearance to fracture surfaces parallel to the foliation; (2) abundant small (average 0.5 mm) plagioclase phenocrysts, inconspicuous in hand specimen; (3) sparse distinctively large quartz (slightly vermicular and rounded) and subhedral sanidine phenocrysts about 0.5 cm in diameter; and (4) hornblende phenocrysts. Despite these distinguishing features, it may be difficult to distinguish Lenihan Canyon Tuff from isolated outcrops of the devitrified lower part of the Mickey Pass Tuff. In thin section, however, the Mickey Pass (except for the basal vitrophyre) is not seen to contain the fine-grained plagioclase phenocrysts ubiquitous in the Lenihan Canyon, nor does it contain hornblende phenocrysts. And in much of the Mickey Pass Tuff, quartz tends to occur as subhedral bipyramids that contain vermicular inclusions of glass.

Biotite and sanidine separated from samples of the Lenihan Canyon Tuff south of McClelland Peak and radiometrically dated by potassium-argon techniques yielded slightly discordant Oligocene dates of 26.7 ± 0.8 m.y. on biotite and 25.1 ± 0.8 m.y. on sanidine (M. L. Silberman, written commun., 1976).

The source area of the Lenihan Canyon Tuff is not known with certainty, but exposures of this tuff at Red House may be very near a cauldron source. Here a dike-shaped mass of black vitrophyre with vertical foliation trends approximately east-west and appears to intrude nearly flat-lying devitrified prominently zoned Lenihan Canyon Tuff. Along the south contact of the dike-shaped mass, devitrified Lenihan Canyon Tuff is brecciated and oxidized to reddish brown; these textures disappear a few meters away from the contact. Owing to extensive colluvial cover, this apparent intrusive relation could not be traced in the field except where the contact is exposed along an aqueduct.

NINE HILL TUFF

The Nine Hill Tuff is here named for a distinctive and lithologically diverse compound cooling unit of pumiceous, in part densely welded and stretched, vitric tuff and tuff-breccia exposed in and around Nine Hill in secs. 20, 21, and 29, T. 16 N., R. 20 E. (figs. 2, 6). The type section (fig. 6) is in NE¼ sec. 29, T. 16 N., R. 20 E. Other reference localities (fig. 2) are designated near the mouth of Santiago Canyon (NE¼ sec. 6, T. 15 N., R. 21 E.) (the principal reference locality), in Eureka Canyon (SW¼ sec. 33, T. 16 N., R. 21 E.), in the hills 1 mile north-northeast of the Carson Airport (SW¼ sec. 34, T. 16 N., R. 20 E.), and in an unnamed south-draining canyon in secs. 26 and 35, T. 16 N., R. 20 E.

At the type locality, the Nine Hill Tuff unconformably overlies pre-Tertiary basement rocks and scattered thin erosional remnants of Mickey Pass Tuff and is disconformably overlain by Eureka Canyon Tuff and late Tertiary basaltic andesite flows. In the type section, the Nine Hill unconformably overlies Mesozoic granodiorite. Here it is nearly 250 m thick; its lower 130 m is densely welded and lineated, whereas its top is deeply eroded. Throughout much of the New Empire and Carson City quadrangles (fig. 2), the base of the Nine Hill Tuff includes several meters of cobble to boulder gravel made up of rounded clasts of older tuffs and basement rocks. At the reference locality in the mouth of Eureka Canyon, the base of the Nine Hill contains large boulders (average diameter 1–2 m; maximum diameter 5m) of Singatse(?) Tuff, Lenihan Canyon Tuff, and Triassic meta-andesite in a nonwelded matrix of vitric tuff-breccia.

The Nine Hill Tuff includes four principal rock types distinguished by pumice content, degree of welding and secondary flowage, and phenocryst content. At the type locality, in the hills

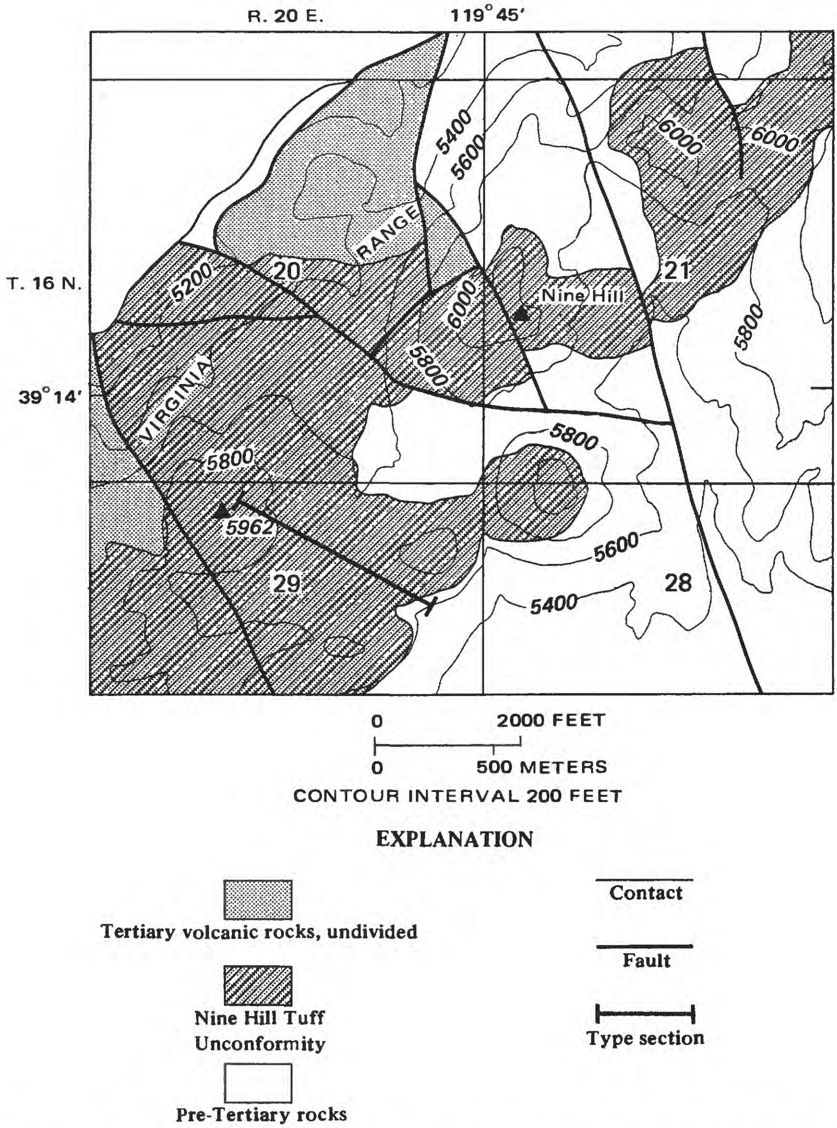

FIGURE 6.—Generalized geologic map showing the distribution of the Nine Hill Tuff in its type locality. Base from U.S. Geological Survey Carson City and New Empire 7½-minute quadrangles.

northeast of the Carson Airport, and in the Santiago Canyon drainage, the Nine Hill is made up of a densely welded and prominently eutaxitic pumice-rich lower part a few to more than 400 m thick and a pumice-poor weakly welded to nonwelded upper part a few tens to several hundred meters thick. The contact between these two principal rock types in the Nine Hill Tuff is everwhere gradational. The lower part of the Nine Hill consists of devitrified densely welded to stretched (length-to-thickness ratio of pumice lapilli greater than 20:1) pale-orange-red to pale-green to reddish-purple pumiceous vitric tuff. This rock typically is about 3–4 percent phenocrysts (sanidine:plagioclase:quartz approximately 4:2:1 plus a trace of biotite), 10–15 percent strongly flattened to stretched pumice lapilli generally 2–3 cm in longest dimension, and 2–5 percent small felsitic lithic fragments, all set in a matrix of devitrified fine-grained shards and ash. The upper part of the Nine Hill Tuff is pale-brown to purplish-brown vitric tuff containing less than 5 percent undeformed to slightly flattened pumice lapilli, a trace of very small felsitic lithic fragments, and about 5 percent small equant phenocrysts of sanidine, plagioclase, and quartz set in a fine-grained devitrified matrix of undeformed glass shards and submicroscopic ash. Where exposed 2.4 km west of Mound House, densely welded and lineated tuff typical of the lower part of the Nine Hill grades into fluidal crystal-rich vitric tuff. These fluidal rocks contain less than 2 percent pumice and somewhat more than 10 percent phenocrysts of sanidine (9 percent) and quartz (2 percent). The rock appears flow banded in hand specimen and contains numerous wispy lens-shaped vugs where pockets of vapor-phase crystallization products have disaggregated and weathered from the rock. Similar fluidal vitric tuff is not exposed elsewhere in the mapped area, but I have seen identical tuff in Warm Springs Valley south of the Virginia Range and at Painted Rock (fig. 1). In both these localities, the fluidal tuff lies on densely welded and lineated tuff in the lower part of the Nine Hill Tuff with no indication of a cooling break. In Eureka Canyon, the Nine Hill Tuff consists entirely of pale-pinkish-brown nonwelded pumiceous vitric tuff that disconformably overlies the Lenihan Canyon Tuff in Hackett Canyon or the Mickey Pass Tuff in Eureka Canyon and is separated from the overlying Eureka Canyon Tuff by a disconformity. The tuff in these two localities contains about 8 percent pumice lapilli ranging in maximum diameter from less than 1 to more than 4 cm; 2–5 percent small phenocrysts of plagioclase, sanidine, and quartz (2:2:1) plus a trace of biotite; a few percent of angular felsitic lithic fragments about 1 cm or less in diameter; and fine-to medium-grained shard-rich ash.

Locally within the Nine Hill Tuff, very densely welded and stretched tuff forms near-vertical dikes and pluglike masses that intrude brecciated and in part hydrothermally altered vitric tuff typical of the upper part of the unit. The dikelike masses are surrounded by an envelope of brecciated tuff a few meters to 10 m thick. Discontinuous patches of bleached and hydrothermally altered breccia within the envelope were formed by upward-streaming volatiles that accompanied the brecciation. These features strongly suggest that the plugs and dikes of tuff fill pyroclastic vents developed in the Nine Hill as it accumulated. It is possible that the densely welded and very hot lower part of the unit locally flowed and was diapirically forced upward through a thick intracaldera accumulation of vitric tuff. These unusual intrusive phases and the locally very thick accumulation of densely welded tuff suggest that much of the Nine Hill in the study area is in or near its cauldron source.

The Nine Hill Tuff is an areally extensive ash-flow sheet. Known equivalents occur in Warm Springs Valley as noted, in the Gillis Range (R. F. Hardyman, oral commun., 1976), and in the Singatse and Wassuk Ranges. The Nine Hill intertongues with the tuff of Gabbs Valley (E. B. Ekren, written commun., 1976) and is younger than the Lenihan Canyon Tuff. These stratigraphic relations indicate that the Nine Hill Tuff was erupted during the Oligocene about 25 m.y. ago.

EUREKA CANYON TUFF

The Nine Hill Tuff is overlain disconformably by a compound cooling unit as much as 150 m thick of white to pale-gray, lavender, and tan rhyolite vitric tuff here named the Eureka Canyon Tuff for exposures at its type locality in secs 32 and 33, T. 16 N., R. 21 E. (figs. 2, 7). The type section (fig. 7) is at the common boundary between secs. 32 and 33, T. 16 N., R. 21 E. Reference sections (fig. 2) are designated 2.25 km northeast of the Carson Airport in NE¼NW¼ sec. 34, T. 16 N., R. 20 E., and at Duck Hill in sec. 30, T. 16 N., R. 20 E.

In Eureka Canyon, the formation is about 130 m thick and displays a distinct cooling zonation. Pale-green zeolitized poorly welded to nonwelded tuff a few meters thick grades upward into moderately welded gray vitrophyre with a maximum thickness of about 5 meters. Above the vitrophyre, the tuff is devitrified and displays weak vapor-phase alteration. Above the vapor-phase zone, the rock is a gray-white glassy shard tuff 5–10 m thick to the top of the cooling unit. Elsewhere in the study area, most of the Eureka Canyon is white to pale-yellowish-white bleached devitrified weakly welded tuff. North of the airport and at Duck Hill, the Eureka Canyon includes several thin gray zones (1–3 m) of glassy vitrophyre, and it is probable that the boundary where these glassy zones overlie weak vapor-phase rock represents a partial cooling break.

The Eureka Canyon Tuff is very uniform in primary texture and composition. Most of the tuff contains about 3–8 percent phenocrysts set in a matrix of partially welded to nonwelded glass shards

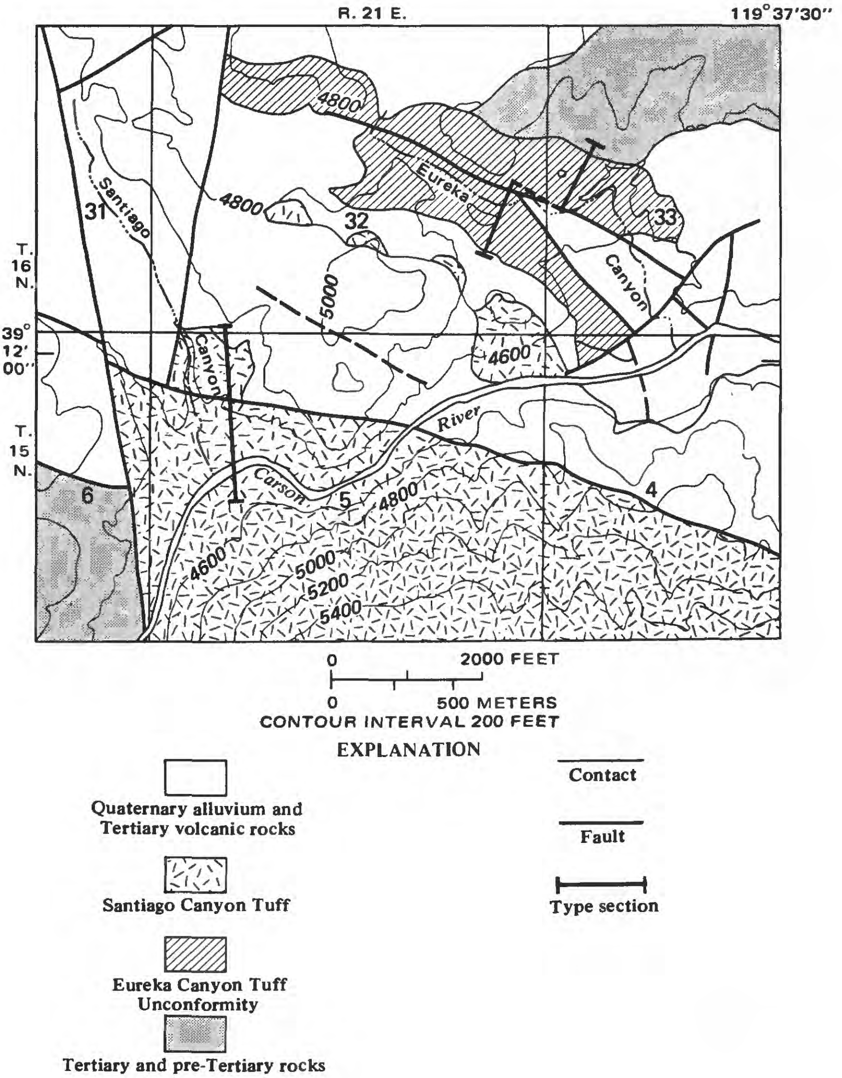

FIGURE 7.—Generalized geologic map showing the distribution of Eureka Canyon Tuff and Santiago Canyon Tuff in their type localities. Base from U.S. Geological Survey New Empire 7½-minute quadrangle.

(0.2 mm) and about 5–10 percent lenticular weakly compacted white pumice fragments. Phenocrysts comprise 50–60 percent quartz, 40–50 percent sanidine, a few percent to 10 percent plagioclase, and a few small ragged flakes of biotite per thin section.

The Eureka Canyon Tuff correlates with the upper part of the Bluestone Mine Tuff of Proffett and Proffett (1976) and with one of the thin cooling units in the tuff of Gabbs Valley (E. B. Ekren, written commun., 1976), where potassium-argon determinations on two sanidine separates yielded Oligocene ages of 25.0 ± 1.0 and 26.1 ± 0.8 m.y. In the Carson City-Silver City area, the Eureka Canyon is locally separated from the underlying Nine Hill Tuff by beds of bouldery gravel a few meters thick that contain rounded cobble- to boulder-size clasts of Mickey Pass Tuff, Nine Hill Tuff, Lenihan Canyon Tuff, and basement rocks. The occurrence of this gravel indicates that considerable erosion and alluviation took place after the Nine Hill eruptive episode and before emplacement of the first ash flows of the Eureka Canyon Tuff.

DACITE TUFF

Southwest of McClelland Peak (fig. 2) in sec. 15, T. 16 N., R. 20 E., the Lenihan Canyon Tuff is disconformably overlain by a thin erosional remnant (10 m) of biotite-plagioclase crystal vitric dacite tuff reported by Hardyman to correlate with one of the tuffs of Gabbs Valley exposed in the northern Gillis Range (R. F. Hardyman, oral commun., 1976); the correlation is made principally by the distinctive petrography of the unit and the position of the tuff in the stratigraphic section. The tuff rests in part on the Lenihan Canyon Tuff and in part on intraformational boulder-to-cobble gravel that fills a channel cut nearly through the Lenihan Canyon Tuff to just above the top of the Mickey Pass Tuff. Clasts in the gravel include boulders of Lenihan Canyon Tuff, Nine Hill Tuff, and Eureka Canyon Tuff.

The dacite tuff is a devitrified remnant of a moderately welded simple cooling unit. Pumice fragments are very small and sparse; lithic fragments are rare. In thin section the phenocryst fraction includes 30 percent fresh broken phenocrysts of zoned plagioclase (andesine) ranging in size from less than 0.1 mm to 3 mm, 5 percent red-brown biotite, 4 percent magnetite, and a trace of quartz. The rock generally is a distinct reddish brown due to disseminated fine-grained hematite in the matrix.

RHYOLITE TUFF AND AUGITE RHYODACITE TUFF

Rhyolite tuff and augite rhyodacite tuff are exposed in the Hackett Canyon-Carson River canyon area, where they overlie the Eureka Canyon Tuff and are overlain by the Santiago Canyon Tuff. Both units are thin distal edges of much thicker and more complex eruptive sequences exposed in the Singatse Range (Proffett and Proffett, 1976, p. 21), Wassuk Range (Bingler, 1973, p. 12), and east of Walker Lake in the Gillis Range (R. F. Hardyman, oral commun., 1976).

Along the west side of Eureka Canyon in sec. 32, T. 16 N., R. 21 E., the Eureka Canyon Tuff is disconformably overlain by gray-white to yellowish-gray sparsely porphyritic pumiceous fine-grained glassy rhyolite vitric-crystal tuff as much as 30–40 m thick. The tuff is weakly welded to nonwelded and is about 10–15 percent undeformed shards and fine ash. Phenocrysts comprise 9 percent plagioclase, 7 percent quartz, 2 percent sanidine, 2 percent biotite, and traces of hornblende and anorthoclase. Most phenocrysts are fragments of larger cognate crystals, but ovoid and vermicular grains of quartz and anorthoclase as much as 1 cm in diameter are scattered throughout the tuff. The distinctive quartz grains greatly aid in identifying the rhyolite tuff in isolated outcrops.

The rhyolite tuff is disconformably overlain by a very distinctive pale-greenish-gray augite-biotite-plagioclase pumice- and lithic-rich crystal-lithic tuff of rhyodacitic composition. In Eureka Canyon this tuff fills a channel cut several tens of meters into the top of the underlying rhyolite tuff. At Hackett Canyon the tuff is disconformable on the Eureka Canyon Tuff, but there is little relief on the erosion surface, and no pebble beds mark the disconformity. The pyroxene-bearing tuff is distinctive in its mineralogy and clearly related to the thick succession of augite rhyodacite tuff, breccia, and lava flows in the Walker Lake area.

The augite rhyodacite tuff is very thin north of the Carson River but reaches a maximum thickness of about 170 m in and east of Hackett Canyon (fig. 2) (sec. 16, T. 15 N., R. 21 E.). The tuff is uniform in texture and mineralogy and displays no distinct cooling zonation. The rock consists of about 5–10 percent cognate lithic fragments composed of pale-brownish-lavender augite rhyodacite lava, approximately 20 percent undeformed white pumice (average diameter 1–1.5 cm), and 30–50 percent medium-sized phenocrysts, all set in a matrix of fine-grained ash. The phenocrysts include about 30 percent plagioclase, 15 percent fresh black biotite, and 5 percent or less apple-green diopsidic augite. In many exposures the pyroxene is altered and weathered from the rock, leaving characteristic small cavities marking the former presence of the stubby pyroxene crystals. Radiometric dates obtained (E. B. Ekren and others, written commun., 1976) on biotite from augite rhyodacite tuff in the Gillis Range are 23.2 ± 0.8 m.y., and on plagioclase 21.6 ± 0.6 m.y.

SANTIAGO CANYON TUFF

The youngest ash-flow tuff in the Carson City-Silver City area is a simple cooling unit of sphene-bearing hornblende-biotite quartz latite crystal-vitric tuff here named the Santiago Canyon Tuff for its type-section exposures at the mouth of Santiago Canyon in NW¼ sec. 5, T. 15 N., R. 21 E. Reference localities are designated at Hackett Canyon (fig. 2) in sec. 9, T. 15 N., R. 21 E., and at the hill 1.5 km northwest of Nine Hill (fig. 2) in W ½ NE ¼ sec. 20, T. 16 N., R. 20 E. The Santiago Canyon Tuff rests disconformably on older Tertiary ash flows and unconformably on Mesozoic basement rocks; it is more than 300 m thick south of the Carson River near Santiago Canyon and is unconformably overlain by flows and breccias of the Alta Formation (Bingler, 1977). The great thickness of this tuff, together with the simple and uniform cooling zonation, suggests that its source lies within or just east of the Santiago Canyon-Hackett Canyon area (fig. 2).

The Santiago Canyon Tuff typically includes a basal few meters of gray-white weakly welded tuff that grades upward into gray glassy densely welded vitrophyre a few meters to about 10 m thick. Above the vitrophyre, the cooling unit is strongly welded and devitrified tuff exhibiting only weak and local vapor-phase effects. Outcrops are blocky, somewhat rounded, and gray to pale lavender or brownish gray. The tuff contains about 10 percent pumice lapilli, in general considerably flattened as a result of uniformly strong welding. The foliation defined by these flattened pumice fragments is weak and difficult to discern because the fragments are nearly the same color as the rock and only 1–2 cm long. In thin section, the rock contains slightly less than 10 percent quartz, 5–10 percent sanidine, about 20 percent plagioclase (Ca-oligoclase), and 5 percent each of hornblende and biotite. Euhedral prisms of sphene, commonly 5–10 grains per thin section, are present in fresh rock. This accessory mineral, not found in any of the other ash-flow tuffs described, is critical in distinguishing the Santiago Canyon from the older, but texturally and mineralogically similar, Singatse Tuff of Proffett and Proffett (1976).

In the Spring Valley area (fig. 2), the Santiago Canyon Tuff is moderately to intensely propylitized and silicified. Much of the rock is bleached by acid leaching related to oxidation of disseminated pyrite that occurs in the tuff as part of regional alteration related to the Comstock Lode. Where the tuff is propylitically altered, the overall color of the rock is lavender or purple, and feldspar and pumice fragments are chalky white aggregates that stand out against the darker matrix; the pumice lapilli, in particular, become clearly visible as 1–2-cm rounded or nearly circular white blotches on foliation planes. The general appearance of these pumice lapilli is a diagnostic feature useful for recognizing the Santiago Canyon Tuff in propylitized areas. Where the tuff is bleached and(or) silicified, it weathers pale yellowish tan to orange brown and is very light tan to white on fresh surfaces. Feldspar alters to chalky white remnants that are difficult to distinguish from the matrix; only the quartz phenocrysts (slightly vermicular and equant) help distinguish the Santiago Canyon Tuff from other older tuffs.

The Santiago Canyon Tuff is of latest Oligocene or earliest Miocene age. Sanidine and biotite from vitrophyre near the base of the tuff yielded potassium-argon dates of 20.5 and 21.8 m.y., respectively (determination by Geochron Laboratories determination; Nevada Bureau of Mines and Geology sample AD 49). Whitebread (1976, table 1) reports a potassium-argon date of 22.7 m.y. on biotite from a tuff sample (Hartford Hill Rhyolite Tuff) apparently collected from rock here included in the Santiago Canyon Tuff.

Sphene-bearing ash-flow tuff similar to the Santiago Canyon Tuff is recognized by E. B. Ekren (written commun., 1976) as underlying Copper Mountain in the Gabbs Valley area and by J. M. Proffett, Jr. (oral commun., 1976) as cropping out in the Terrill Mountains north of Schurz, Nev. Reconnaissance mapping by Bingler (unpub. mapping, 1976) at Hartford Hill, the type locality of the Hartford Hill Rhyolite Tuff, revealed that all of the rock assigned to the Hartford Hill Rhyolite by Gianella (1936) is now part of the Santiago Canyon Tuff.

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