Text and references accompanying Nevada Bureau of Mines and Geology Open-File Report 20-2

Reconnaissance Map of the Cenozoic Geology in the Carlin Basin Area, Elko and Eureka Counties, Nevada

by

Alan R. Wallace

U.S. Geological Survey, Emeritus, Reno, NV

2020

Disclaimer: NBMG open-file reports are preliminary. They have not been thoroughly edited or peer reviewed. This geologic map was funded in part by the USGS National Cooperative Geologic Mapping Program under STATEMAP award number G19AC00383.

INTRODUCTION

The middle Miocene Carlin sedimentary basin encompassed a large area between the Adobe Range to the east, the Piñon Range to the south, the southern Independence Mountains and Marys Mountain to the west, and Swales Mountain to the north (figs. 1 and 2). It connected through a low gap in the southern Adobe Range with the Elko basin to the east. Mapping in the Carlin basin from 2003 through 2008, with a small amount of additional mapping in 2010, was undertaken as part of a larger study of the late Cenozoic paleogeographic evolution of north-central Nevada (Wallace et al., 2008b). In the Carlin basin, the focus on the different lithologies and facies of the Miocene sedimentary units helped to define the pre-basin paleogeographic setting, the evolution of the basin, and the events that post-dated sedimentation, including faulting and erosion. A major northwest-trending belt of Eocene-age Carlin-type gold deposits (the Carlin trend) underlies the western part of the basin. These studies also document the events that took place after those Eocene gold deposits formed (Wallace et al., 2008b).

This geologic map presents mapping of parts or all of nine 7.5-minute quadrangles that encompass most of the middle Miocene Carlin sedimentary basin. The original basin extended to the west of the west-northwestern edge of this map towards the top of Welches Canyon. That area was not mapped in detail and is not included on this map, although the limited mapping that area indicate that the geologic history and unit ages are similar to those in this map area (Wallace et al., 2008b).

Prior to this study, the geology of most of the 7.5-minute (1:24,000 scale) quadrangles that cover the current map area had been mapped, with the exception of the Huntsman Ranch quadrangle in the middle of the map area and the Swales Mountain SW quadrangle in the northwestern part of the map area. Those previous mapping efforts largely focused on the pre-Tertiary geology, and few of the Tertiary units and structures were divided. These published maps included, in clockwise order from the northwest (fig. 1), the Schroeder Mountain (Evans and Cress, 1972), Swales Mountain and part of Adobe Summit (Evans and Ketner, 1971, and Hunter (Ketner, 1973) 7.5-minute quadrangles. The smaller-scale (1:62,500) geologic map of the Piñon Range showed the geology of the Grindstone Mountain, Carlin East, and Carlin West quadrangles, which comprise the southeastern, southern, and southwestern quadrangles in the basin area, respectively. In addition, the geology of the Gold Quarry Mine area was compiled by Norby (2002), and limited mapping was done in the Carlin Canyon area by Trexler et al. (2004).

Mapping for this study produced a new geologic map of the Huntsman Ranch quadrangle (Wallace et al., 2008a) and focused on the Tertiary units, especially the Miocene sedimentary rocks, in the previously mapped quadrangles. A progress report on the study was published by Wallace (2005). Mapping in the Huntsman Ranch quadrangle was somewhat more detailed than the mapping for this project in other quadrangles, but the difference is not significant at the scale of this map. Some areas were not examined in detail, such as poorly exposed areas on the northern side of the Piñon Range, or at all, such as in and near the Gold Quarry Mine property, where access was not available. Previous map publications were used to augment the geology of those areas on this map, or the units were generalized if additional data were not available. However, almost all of the contacts that are internal to or bounded the Miocene units, as well as all of the faults that cut or bounded those units, are products of the present study.

With the exception of the Gold Quarry map, all of the previously published maps that were used for this compilation were available only as printed maps or as scans of printed maps. Several of them, such as the

Schroeder Mountain and Piñon Range maps, used topographic bases that were older than the one used for this compilation. Scans of all of printed maps were brought into Adobe Illustrator, their scales were adjusted to fit the current base topography as closely as possible, and the contacts and faults were traced by hand in Adobe Illustrator. The combination of the original paper format, the scanning process, and the differing topographic bases prevented exact reproduction of the contact and fault locations shown on the older maps. Commonly, the position of the original map was adjusted slightly to match the boundaries of a portion of the current map, then adjusted again to match the adjacent portion, and so on. As a result, most of the contact and fault lines on this map that came from the older maps are very close to the locations shown on the original maps, but it was not possible to generate an exact reproduction.

The map of the Gold Quarry area (Norby, 2002), which was available digitally in a PDF format, also used a topographic base that differed from the present base map. It was imported into Illustrator, and its scale was changed to match the current base scale as closely as possible using UTM tick marks. The contacts, faults, and mine workings were then generalized and traced by hand in Illustrator. An exact reproduction was not possible, but, as with the other maps, the line locations are very close.

For the current map, the Paleozoic units shown on all of the previously mapped areas of Paleozoic bedrock were generalized, and most Paleozoic thrust faults and high-angle normal faults cut by those thrusts were not included, in keeping with the Cenozoic theme of the map. The Gold Quarry map includes abundant normal faults of presumably all ages. Not all of those faults are shown on this map for the sake of simplicity, but enough of them are included to illustrate the major strike orientations.

GEOLOGIC UNITS

[All $^{40}Ar/^{39}Ar$ dates and tephra correlations were calculated using the 28.02 Ma standard for Fish Canyon Tuff sanidine (Renne et al., 1998). All of the dates and correlations listed here are from Wallace et al. (2008a, b), unless cited otherwise.]

Qal Alluvium (Quaternary) Unconsolidated, massive to crudely bedded deposits of silt, sand, pebbles, and cobbles along modern streams and related floodplains. Clasts typically are subrounded to subangular and are composed of Paleozoic sedimentary and Tertiary volcanic rocks derived from bedrock exposures in the surrounding highlands; conglomerate beds in the Humboldt Formation and gravel deposits (QTg) also contributed clasts to these deposits. Floodplain deposits have a sparse to dense cover of native and agricultural plants. Modern streams along these drainages are incised 1–2 m into older alluvial deposits (Qoa). The alluvium along the Humboldt River is a composite unit that likely contains multiple alluvial deposits and deposits equivalent to the older alluvial deposits (Qoa), but which were not mapped separately in that area.

Qls Landslide deposits (Quaternary) Small areas of unconsolidated, unsorted deposits near Lower Dry Susie Spring, northwest of the Huntsman Ranch site, along Middle Susie Creek, and along the west side of the Humboldt River in the southwestern part of the map area. The Dry Susie Spring deposits are composed of stratigraphically intact beds of andesite (Ta) and the ash-rich member of Humboldt Formation (Tha). The deposits near the Huntsman Ranch site are composed of materials derived from upslope exposures of units Tha, Thm, and QTg. The Middle Susie Creek deposits are composed of Tha and Tt.

Qoa Older alluvial deposits (Quaternary) Unconsolidated silt, sand, and gravel exposed adjacent to and above Susie Creek, Dry Susie Creek, and Maggie Creek. The deposits are poorly exposed and covered by tall, dense sagebrush. The unit also includes narrow alluvial deposits along many ephemeral streams and various local colluvial deposits. Down-slope wash from the gravel deposits (QTg) and the Humboldt Formation has merged with alluvial deposits (Qal, Qoa) to create indistinct and irregular contacts.

QTg Gravel deposits (Quaternary and Pliocene(?)) Unconsolidated deposits of subangular to subrounded pebbles, cobbles, and boulders of Paleozoic sedimentary and Eocene volcanic rocks that were deposited on as many as twelve terrace surfaces at multiple elevations above modern streams (Wallace et al., 2008a). The gravel deposits are overlain and obscured by minor to significant amounts of eolian silt and sand. The thickness of gravel deposits ranges from more than 40 m on a high surface north of the Huntsman Ranch site to <1–3 m on other surfaces. Most commonly, the gravel is present as thin patches of clasts on a pediment surface, and many of these discontinuous areas of gravel are not shown on the map. Clasts in deposits on higher surfaces were derived from the up-gradient highlands, with more mixing towards the center of the map area; the lower surfaces are deeply incised, and clasts were derived only from sources in that particular drainage. Erosion of the underlying Humboldt Formation has significantly redistributed gravel clasts down slope. Shiny, dark Fe-Mn-oxide coatings on many clasts distinguish float of this unit from residual, uncoated clasts in the upper epiclastic member of the Humboldt Formation (Thu), although distinguishing between the two can be impossible.

Tsy Younger sedimentary rocks (Miocene) Light-brown, cream-colored, to white, thin-bedded, fine-grained sedimentary rocks exposed north of Interstate 80 several kilometers northwest of Carlin and also east of Carlin Canyon (fig. 2). The lithologies northwest of Carlin include siltstone and sandstone; thin, discontinuous beds of tan, porous limestone; thin interbeds of granule to pebble conglomerates that increase in number and thickness to the

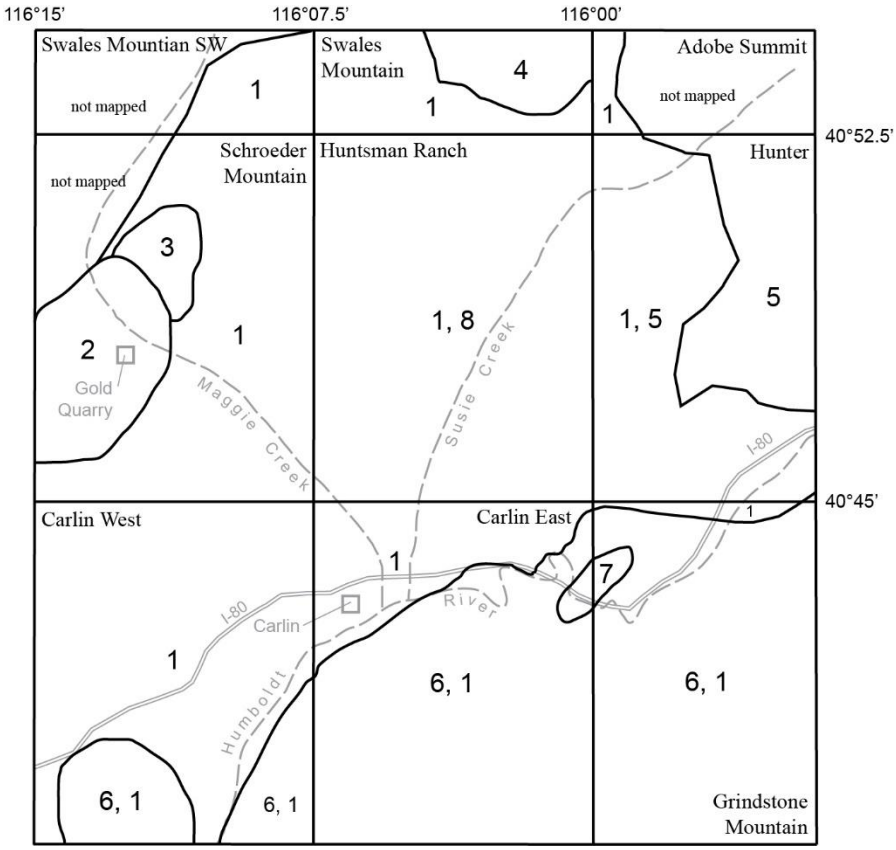

Figure 1. Quadrangle names and sources of geologic mapping for the Carlin basin map. 1, A. Wallace, mapping for this study; 2, Norby (2002); 3, Evans and Cress (1972); 4, Evans and Ketner (1971); 5, Ketner (1973); 6, Smith and Ketner (1978); 7, Trexler et al. (2004); 8, Wallace et al. (2008a).

west; and locally abundant reworked, air-fall ash. Lithic clasts are identical to lithologies exposed in the Marys Mountain (fig. 2) area to the west. The light color reflects significant amounts of carbonate cement, although all of the units are only semiconsolidated and weather easily. The beds are poorly exposed, but bed-related color bands across hillsides indicate that bedding is laterally continuous. The strata are very similar to underlying beds of the ash-rich member of the Humboldt Formation (Tha), which in this area was deposited at about 14.6 Ma (Wallace et al., 2008b) and contain Barstovian (middle Miocene) mammal remains (Regnier, 1960). Hemphillian mammal remains were collected from these younger sedimentary rocks in the northwest quarter of section 29 (R.H. Tedford, American Museum of Natural History, written communication, 2007), indicating a late Miocene age (~10 to ~5 Ma). Due to poor exposures of all strata in the area, contacts between this unit and the very similar ash-rich member of the Humboldt Formation are based on the presence or absence of calcareous cement. Contacts with the upper epiclastic member (Thu) are approximate and based on the tan color and absence of ash beds in Thu. The sediments in this unit likely were deposited in a mixed marsh and shallow lake environment, and clast lithologies indicate fluvial input from sources to the west. The units east of Carlin Canyon were shown on the Smith and Ketner (1978) map as the Hay Ranch Formation, which is Pliocene and Pleistocene in age. They possibly are equivalent to the Pliocene lacustrine sedimentary units related to "Lake Humboldt" that inundated the Elko basin between 2 and 3 million years ago (Wallace et al., 2008b).

Humboldt Formation (Miocene)

The Humboldt Formation is composed of weakly to moderately consolidated middle Miocene sedimentary rocks that include the informal Carlin formation of Regnier (1960). The sedimentary units are composed variably of epiclastic materials derived from bedrock exposures surrounding the sedimentary basin, and ash derived from distant to more local eruptions. In the Carlin basin, the complex facies architecture of the formation is divided informally into four widespread members: an upper epiclastic member (Thu), an ash-rich member (Tha), a mixed epiclastic and ash-rich member (Thm), and a lower epiclastic member of brown siltstone, sandstone, and conglomerate (Thl) (Wallace et al., 2008a). A fifth

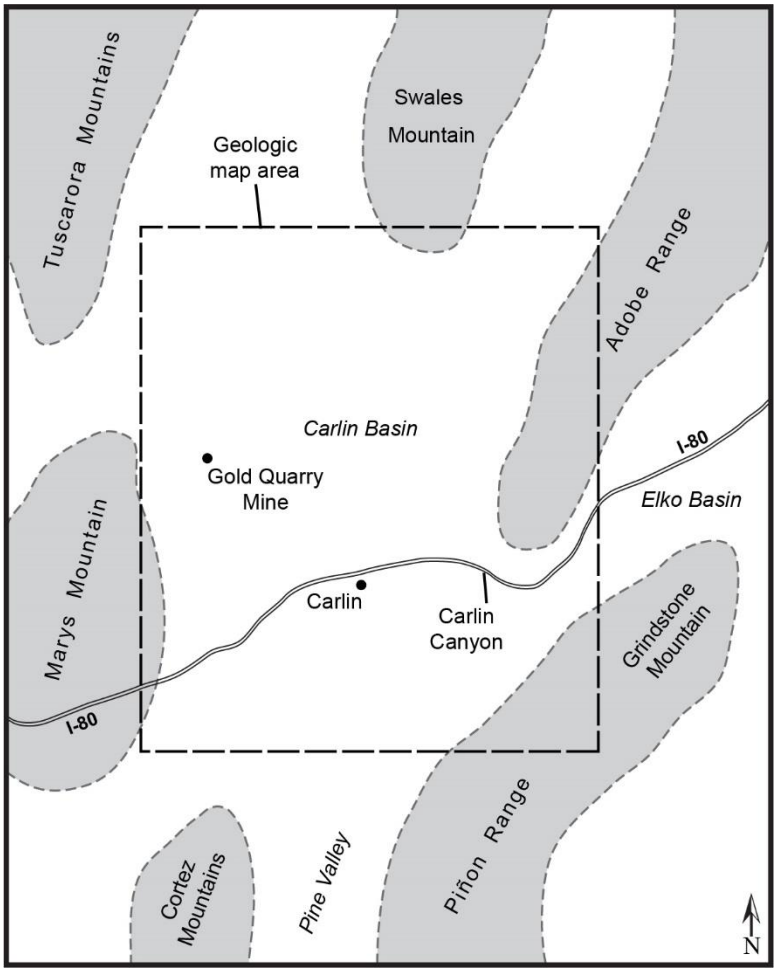

Figure 2. Index map showing the major geographic features surrounding the Carlin basin. The geologic map area is shown with a dashed line, and Interstate 80 is a solid line. Also shown are the Gold Quarry gold mine and the town of Carlin.

member, the ash-rich epiclastic member (Thua), is restricted to an area north-northeast of the Gold Quarry Mine. On the southeast side of the Adobe Range, the Humboldt Formation members have been given different unit designations (Thuc, Thus, Thud) because they differ markedly from those in the Carlin basin. However, they are laterally equivalent to Thu and, in part, Tha. Sedimentary units of the Humboldt Formation on the north side of the Piñon Range are undivided (labeled as unit Thp) but likely equivalent to members Tha and Thu. Depositional environments and unit nomenclature are discussed in Wallace et al. (2008a, b). On the basis of $^{40}Ar/^{39}Ar$ dates and tephra correlations, deposition of Humboldt Formation sediments in the Carlin basin area began shortly before 16.3 Ma and continued until after about 14.6 Ma (Wallace et al., 2008a, b).

Th Humboldt Formation, undivided (Miocene) Exposures of the Humboldt Formation shown on parts of the maps of the Gold Quarry open-pit mine and nearby areas (Evans and Cress, 1972; Norby, 2002). Although Miocene sedimentary rocks were inspected briefly within the Gold Quarry Mine in 2005, the units in the mine and immediately surrounding area were not mapped for the current study. Within the mine, massive to bedded tan sandstone of member Thu overlies massive beds of reworked, locally sandy air-fall ash similar to some beds in member Tha. Member Thu coarsens upward into a conglomerate. As exposed in 2005, Tha overlay the Paleozoic basement, but as much as 120 m of gravel deposits, possibly equivalent to member Thl, locally were exposed beneath Tha in some parts of the open pit during earlier stages of mining (Harlan et al., 2002).

Thu Upper epiclastic member (Miocene) Tan, brown, to light gray-brown, weakly to moderately consolidated sandstone, siltstone, and conglomerate. The unit generally is poorly exposed and forms a surface float of tan sand and scattered pebbles and cobbles. More lithified beds are 10 cm to 2 m thick, and they are massive to very crudely bedded. Strata are weakly to moderately calcareous and contain faint paleosol horizons, rare mudcracks, locally abundant calcareous rhyzoliths, and rare mammal bone fragments. Clast compositions are identical to Paleozoic and Eocene rock types in adjacent

highlands, including the Adobe Range, Swales Mountain, Marys Mountain, and the Piñon Range. The relative percentages of clast lithologies vary widely with location in the map area due to differing source-area lithologies and mixing towards the center of the basin. The sand- to silt-sized matrix is composed of similar materials and minor amounts of reworked ash. Clasts decrease in grain size towards the central part of the map area. The contact between Thu and the underlying members Tha and Thua generally is conformable and is sharp to gradational over <1 to several meters. In the southeastern part of the map area, east of Susie Creek and north of the Humboldt River, the contact zone spans several tens of meters and includes alternating conglomerate (with local boulders) and ash-rich beds; this sequence grades upward into cobble-rich sandstone of Thu. East of Dry Susie Creek, the member is composed of cobble conglomerate and directly overlies Paleozoic sedimentary rocks. In the south-tapering wedge between Dry Gulch and Susie Creek, the member becomes coarser near the top of the exposed section; cobble-rich residual lag along some ridge crests resembles QTg. The exposed thickness of Thu varies from is 10–30 m in the southeastern part of the map area and to at least 400 m between Susie Creek and Dry Gulch. The member overlies 15.2 Ma tephra beds between Susie and Dry Susie creeks, a 14.7 Ma tephra bed in the northern Piñon Range, and a 14.6 Ma tephra bed along Interstate 80 between Carlin and Emigrant Pass. The top of the member is not apparent anywhere in the map area.

Thp Humboldt Formation, northern Piñon Range (Miocene) Boulder- to pebble-rich conglomerate, locally calcareous sandstone and siltstone, and minor interbedded air-fall ash beds are exposed in the northern Piñon Range. New mapping in the northern Piñon Range was very limited, and exposures are rare; many contacts are from Smith and Ketner (1978). In the Woodruff Creek area, a basal conglomerate is composed of pebbles to >1 m boulders derived from Paleozoic rocks exposed to the southeast, and it is overlain by reddish-tan to cream-colored, massive to bedded, sandstone and pebble conglomerate; the grain size generally decreases up section. West of Woodruff Creek, almost all of the Miocene sedimentary units appear to overlie the 15.3 Ma rhyolite of Palisade Canyon, and one air-fall ash bed near the base of the Miocene section just east of Woodruff Creek (in section 14, where the rhyolite is not present) produced a tephra correlation date of 14.74 ± 0.05 Ma (Mike Perkins, written communication, 2010). As such, most of the Humboldt Formation in the northern Piñon Range is temporally equivalent to member Thu in the main part of the basin to the north, and to Thu and Tha in the southwestern part of the basin. Exposures along NV 278 show that some ash-rich sedimentary units underlie the rhyolite, but the base of the Miocene section is not exposed. Between NV 278 and Woodruff Creek, limited float of brown dirt and pebbles suggest the presence of a thin (<10 m) interval of Miocene sandstone between the rhyolite and the underlying Paleozoic rocks. Beds west of Woodruff Creek generally dip to the west-northwest, similar to that of the underlying rhyolite. Strata east of Woodruff Creek have inconsistent dips that possibly reflect the presence of unexposed faults in that area.

Thua Ash-rich epiclastic member (Miocene) Grayish-tan, non-calcareous ash-rich sandstone is exposed northeast of the Gold Quarry Mine and Maggie Creek. Some of the sandstone beds form 1- to 2-m-thick, massive, resistant outcrops that extend for hundreds of meters along strike. The strata are similar to those in the upper epiclastic member (Thu), but they contain far greater amounts of reworked, fine-grained ash, similar to what comprises the ash-rich member (Tha). Discrete ash beds are absent, and clasts larger than sand and grit are very uncommon. The ash content produces a glittery appearance to the outcrops and residual soil. Tha is not present in this area, and this facies takes its place between Thu and Thm or locally Thl where Thm is absent. This facies may reflect an area where the lacustrine environment received a major influx of fluvial sediments along with abundant ash.

Tha Ash-rich member (Miocene) Light-gray to white, less commonly light-green, yellow, and tan, to rarely orange and reddish, fine-grained, thinly bedded to massive ash, locally abundant diatomite, and thin beds of limestone, ash-rich sandstone, and chert. The member usually is poorly exposed. Ash beds are composed of fine-grained ash with minor feldspar phenocrysts; beds are a few centimeters to more than a meter thick, have uniform thicknesses, and are laterally continuous. Weak to pronounced fluvial and eolian cross bedding, ripple marks, thinly bedded algal mats, and gypsum- and calcite-cemented concretions locally are common. Diatomite, denoted by red circles on the geologic map, is white and massive to thinly bedded, <1 m to >4 m thick, with 1–20-cm-thick interbeds of light-gray ash. Diatomite is most common near the top of the member, but it also forms 5–30-cm-thick beds throughout the member; it was mined in the southeastern part of the basin. Limestone beds are finely to coarsely crystalline, light tan to dark gray, and usually less than 10 cm thick. Massive gray limestone forms small outcrops near Lower Dry Susie Spring; these could be slide blocks derived from exposures of similar Paleozoic rocks just to the northeast. In sec. 26, T. 34 N., R. 52 E., limestone forms thin tufa-like beds; enclosing ash beds were replaced by secondary zeolites and chert. In the eastern part of the map area, Tha contains thin beds of siltstone to coarse-grained sandstone composed of reworked ash, phenocrysts, subrounded grains of black

vitric material, and small, subrounded platy siltstone clasts derived from the Paleozoic Webb and Vinini Formations. Sparse clast imbrications indicate a westerly to northwesterly transport direction. The ash-rich member is distinguished from the underlying mixed epiclastic and ash-rich member (Thm) by the dominance of air-fall ash and diatomite and greatly subordinate amounts of epiclastic materials. East of Susie Creek and in some areas to the west, a persistent green chert horizon, denoted by green lines and circles on the geologic map, generally occurs near the contact between these two members; sediments beneath this horizon in the upper Dry Susie Creek area are composed mostly of ash but are included in Thm on the map. The member is about 80 m thick west of Dry Gulch and in the north-central part of the map area. The member directly overlies Paleozoic sedimentary rocks in the southeastern part of the map area, Eocene rhyolite porphyry (Trp) along the eastern edge of the map area, and the 15.3 Ma Palisade Canyon rhyolite in the southwestern part of the map area; there, an ash bed directly above the rhyolite was dated at 14.6 Ma. In the southeastern part of the map area, the member ranges in age from about 16 to 15.2 Ma. In the northern and northeastern parts of the map area, the top of the member is about 15.6 Ma.

Thm Mixed epiclastic and ash-rich member (Miocene) Commonly poorly exposed gray, white, to tan, fine-grained ash; tan, gray, to black siltstone and sandstone; and minor pebble conglomerate. The proportions of each lithology vary widely with location; the percentage of ash-rich sediments increases up section and to the south and southwest. Ash-rich beds are gray to off-white, thin- to thick-bedded, and massive to cross-bedded, similar to those in the ash-rich member (Tha); 5–20-cm-thick diatomite beds are present locally. Sandstone beds are grayish tan to brown, fine-grained, and several centimeters thick; they increase in thickness, coarseness, and abundance to the north and northwest. Sandstone contains a mixture of quartz and feldspar sand and reworked dark ash. Dark-gray to black tuffaceous to pumiceous sandstone forms distinctive beds that alternate with tan to brown sandstone; the thickness and percentage of the dark pumiceous beds increases to the northwest. Planar-bedded to reworked and cross-bedded black pumice also is present. Clasts in local pebble conglomerate lenses are composed primarily of Paleozoic sedimentary rocks and less-common Eocene volcanic rocks. Poorly exposed beds with 10–50-cm-diameter clasts of Tertiary and Paleozoic rocks are interbedded with sandstones south of Dry Gulch; these beds may be continuous along strike with debris flow deposits in member Thl, indicating interfingering with Thl. Along Susie Creek and upper Dry Gulch, the base of the member contains pistachio-green to tan, planar-bedded shale, siltstone, white ash, and minor chert, with increasing numbers of small-pebble to granule-conglomerate beds higher in the section; conglomerate beds in these areas contain only clasts of Paleozoic rocks and, at Susie Creek, large round quartz grains that possibly were derived from weathered and eroded Eocene rhyolite porphyry outcrops. Diagenetic to post-diagenetic erionite and clinoptilolite are common in these areas. Some strata in both areas also contain abundant secondary chalcedony and quartz and are extensively bleached. The age range of the member in the upper Dry Gulch area is about 16 to 15.7 Ma; three tephra beds near the Huntsman Ranch site were dated at 16.3 to 16.2 Ma.

Thl Lower epiclastic member (Miocene) The lower epiclastic member is composed of epiclastic sandstone and conglomerate, with some boulder-rich beds. In the northwestern part of the map, primarily north of Cottonwood Creek but also extending southeast towards Dry Gulch, the basal part of the member is predominantly tan to grayish-tan, massive, thick-bedded layers composed of epiclastic sand and gray ash and small pumice; some beds contain abundant matrix-supported to matrix-poor pebbles to boulders of Paleozoic and Eocene rocks derived from Swales Mountain just to the northeast. These units may be debris flows induced by the sudden deposition of ash and pumice, which created gravitational instability. Planar-bedded beds of fine-grained, silver-colored ash similar to those in units Thm and Tha are rare to absent except in the northwestern most part of the map area, although the quartz-feldspar sand matrix contains variable amounts of reworked ash. Coarser clasts are subangular to subrounded, 5–100 cm in size, and composed of Eocene rhyodacite, Paleozoic (Vinini) chert and quartzite, and variable amounts of Eocene rhyolite porphyry. Conglomerates exposed in the upper Dry Gulch drainage near the Elko-Eureka county line contain minor clasts derived from altered plutonic rocks in the Tuscarora Mountains to the west. Many planar-bedded pebble conglomerates are composed entirely of small, platy clasts of Vinini siltstone with clear silica cement and little or no matrix. In the northeastern part of the map area near Susie Creek, Thl includes poorly exposed tan sandstone with variable amounts of pebbles and cobbles of Eocene rhyodacite and lesser amounts of Paleozoic chert. The contact with the overlying mixed epiclastic and ash-rich member (Thm) generally is defined by the first appearance of laterally persistent beds composed only of fine-grained ash. In the lower part of the Dry Susie Creek drainage, the basal 10–20 m of the Humboldt Formation is composed of angular to subangular clasts, 1–30 cm in diameter that were derived from nearby Paleozoic rocks and likely represent a colluvial deposit along the early margin of the basin. In sections 29 and 32, T.34N., R.53E. east of Susie Creek, a >200-m-thick stratigraphic section of massive conglomerate forms massive, 1–3-m-thick, sheet-like beds with lesser tan, massive, 10–m-thick ash-bearing sandstone

interbeds. The top of this thick conglomerate sequence grades upward into member Tha. The conglomerate-rich zone thins to the northeast into a kilometer-wide, 10−m-thick conglomerate horizon both vertically and laterally contained within finer-grained, ash-rich and epiclastic beds of member Thm. The lower epiclastic member was not dated; tephra near the base of the overlying Thm member north of Dry Gulch was dated at 16.03±0.05. Along Susie Creek near the Huntsman Ranch site, the conglomerate sequence underlies tephra dated at 16.3 to 16.2 Ma.

Humboldt Formation, southeast side of the Adobe Range

The Humboldt Formation on the southeastern side of the Adobe Range includes members Thu and Tha, as well as three units found only in this area: a basal debris flow unit (Thd), a middle sandstone unit (Ths), and an upper conglomerate unit (Thc). This area was part of the Elko sedimentary basin (Wallace et al., 2008b). Units Thu and Tha of the Carlin basin area, along with the interbedded andesite flow unit (Ta), are continuous across what is now the southern Adobe Range and indicate that the Carlin and Elko basins were connected at the time of their deposition. Thd and Ths appear to be laterally continuous and conformable with the general contact between the upper epiclastic member (Thu) and the ash-rich member (Tha). Local debris flows are present at this contact in the southeastern part of the Carlin basin. Here, the Thd deposits are much coarser, with megablocks derived from Paleozoic rocks (Thd (Pz)) that were exposed just to the north. This initially high-energy environment moderated into a low-energy environment represented by Thus, and the depositional energy increased somewhat to form unit Thc, which is very similar to the coarser parts of unit Thu. Contacts between the underlying Paleozoic rocks and the bases of Ths and Thc are locally steep and angular, and those sediments may have filled steep-sided channels cut into the Paleozoic bedrock. The northwest bulge of Thc in the southwestern part of section 31 appears to reflect a southeast-trending paleovalley that was filled with >100 m of Thc.

Thc Conglomerate (Miocene) Poorly to locally well-exposed conglomerate. The conglomerate is composed of subangular limestone and quartzite pebbles and small cobbles, with some larger (20–40 cm) clasts, in a matrix of calcareous sandstone. These lithologies are identical to bedrock north of the conglomerate exposures. Despite poor exposures, the conglomerate appears to become coarser-grained up section. The total thickness varies but may exceed 100 m in a southwest-trending paleovalley (see above).

Ths Sandstone (Miocene) Light-gray, moderately calcareous, ash-rich sandstone. The sandstone forms massive, thick (3–4 m) beds with no internal bedding; subtle color and weathering breaks may indicate bed tops; some exposures show extensive burrow structures. The massive sandstone beds do not contain any coarse clasts, although some beds in the unit contain pebbles of limestone; sparse clast imbrications indicate a southeasterly transport direction. Thin beds of light-gray ash are interbedded with the sandstone beds. One bed in the middle of the unit produced a tephra age of <15.28 Ma, and a second bed near the contact with unit Thc produced a tephra age of ~15.1 Ma (Wallace et al., 2008b). These ages are equivalent to the age of the Thu-Tha contact in the southeastern part of the Carlin basin. The unit is gradational upward over several tens of meters into clast-rich Thc, although the transition zone is very poorly exposed. The unit may be about 50 m thick.

Thd, Thd (Pz) Debris flow and breccia (Miocene) A generally tan-colored megabreccia unit that contains abundant clasts ranging in size from a few centimeters to many meters; rare megablocks are half a kilometer long. Exposures are rare, and most of the unit has weathered to a tan surficial deposit littered with small to very coarse clasts. Rare exposures show both white, matrix-poor, very calcareous, clast-supported conglomerate and calcareous tan sandstone with more than 50 percent clasts. Clasts are composed primarily of Permian and Pennsylvanian limestone and lesser Mississippian conglomerate, identical to rocks exposed just north of the debris-flow deposits (Ketner, 1973). The largest clasts and the megablocks are composed of limestone; larger blocks are labeled as Thd (Pz) to denote that they are one single block within Thd, and the orientation of bedding within some megablocks is shown on the map. The clasts that are meters to tens of meters in size project well above the ground surface. Exposures labeled Thd (Pz) in the gully in the northern part of section 12 (near the pond) contain abundant, close-spaced, 1- to 20-meter limestone blocks that, in aggregate, resemble bedrock but have locally differing orientations and include scattered blocks of Mississippian conglomerate. The megablocks elsewhere resemble bedrock but are entirely surrounded by finer-grained conglomerate. Overall, the unit may be about 100 m thick. The western margin of this unit appears to be laterally conformable with the Thu-Tha contact (see above).

Tar Andesite and rhyolite, undivided (Miocene) Andesite and underlying rhyolite flow units that are poorly exposed east of Susie Creek just north of Interstate 80. The two lithologies resemble those found in units Ta and Tpr. The flow units underlie both Thu and Tha, and they overlie the Ordovician Vinini Formation (shown as Pzu).

Ta Andesite (Miocene) Dark-brown to black andesite flow units exposed in a linear zone from Susie Creek to east of the Adobe Range crest, and in a smaller area just east of Maggie Creek north of Carlin. This unit is present at the horizon between members Tha and Thu of the

Humboldt Formation. The andesite contains abundant, tabular, 0.5−2-cm-long plagioclase phenocrysts in a black, fine-grained groundmass; phenocrysts are highly visible on fresh surfaces but indistinct on weathered surfaces. One sample contains 58.1 wt. percent SiO_2 and 5.3 wt. percent Na_2O+K_2O. Flow-unit thickness varies from 1 m to >3 m; units contain a basal platy, weakly to non-vesicular zone and an upper, massive to very vesicular zone. The eastern exposures locally have two flow units, but most exposures show only one flow unit; east of the Adobe Range crest, the single flow unit thins to the east. The exposures near Maggie Creek include one massive, vesicular to aphyric and glassy flow; a possible feeder vent is exposed in the rock quarry in this area. Geophysical and drilling data indicate that these flow units extend in the subsurface southwestward beneath Maggie Creek (Plume, 1995). Attempts to obtain a date on the unit were unsuccessful. An estimated age of about 15.1 Ma is based upon the 15.2 Ma age of the youngest tephra in the underlying Tha and the apparent depositional continuity between Tha and overlying Thu.

Tpr Rhyolite of Palisade Canyon (Miocene) Dark-brown to black, flow-folded, weakly porphyritic, fine-grained to vitric rhyolite flow units that are exposed extensively in the southwestern part of the map area, in a small area beneath the andesite (Ta) east of Maggie Creek, and in an isolated, small area beneath unit Tha east of Susie Creek and north of Interstate 80. The rhyolite contains 0.5–1-mm-diameter phenocrysts of sanidine, plagioclase, quartz, biotite, and hornblende in a massive to porous aphanitic groundmass. The rhyolite variably overlies parts of the Humboldt Formation, as well as Eocene volcanic rocks and Paleozoic rocks; it underlies member Tha of the Humboldt Formation, which was dated just above the contact west of Carlin at 14.6 Ma. Just south of the southwestern edge of the map area, the rhyolite overlies Jurassic volcanic rocks (Smith and Ketner, 1978). The rhyolite is several hundred meters thick at the southern edge of the map near the Humboldt River; in more distant areas to the west, northwest and east, the rhyolite is thinner and has fewer flow units. The rhyolite speculatively may be continuous to the northeast beneath younger units to the small outcrops east of Maggie Creek. Quarry and river-cut exposures just south of the map area near the Humboldt River show multiple thick flow units and small dome-like bodies with vitric, rubbly carapaces that are overlain by later flow units. These relations indicate that the eruptive center was in and just south of the southwestern part of the map area, and that flows emanated outward from that source area. The base of the rhyolite along the Humboldt River just south of the map area was dated at 15.26±0.03 Ma (Wallace et al., 2008b), and a flow unit near Marys Mountain, just west of the map area, was dated at 15.32±0.04 Ma (Henry and Faulds, 1999).

Tea Hornblende andesite (Eocene) Dark-brown andesite flows with small hornblende phenocrysts are exposed in the southwestern most corner of the map area. The flows underlie the Humboldt Formation and the rhyolite of Palisade Canyon. Just west of the map area, they are more extensive, overlie the Eocene Elko Formation, and were dated at 37.61±0.24 Ma (Henry and Faulds, 1999).

Trd Rhyodacite (Eocene) Dark-brown rhyodacite flow units and breccias are exposed in the northern parts of the map area on the flanks of Swales Mountain. The rhyodacite is brittle, massive to locally flow foliated or vesicular, glassy to aphyric, and contains small plagioclase, sanidine, biotite, and hornblende phenocrysts. Flow tops, especially the uppermost flow, are brecciated. The rhyodacite typically overlies Eocene tuff (Tt) or rhyolite porphyry (Trp) and is overlain by the lower epiclastic member of the Humboldt Formation (Thl); in the northwestern part of the map area near Cottonwood Creek, the rhyodacite is between the Vinini Formation and the Humboldt Formation. In the northeastern most part of the map area, Trd and Tt are both exposed, but they were not divided; those areas are labeled as Trd + Tt. The rhyodacite is equivalent to the latite in the "Volcanic rocks" unit mapped in the Swales Mountain quadrangle, where it overlies the equivalent of unit Trp (Evans and Ketner, 1971). Intrusive equivalents of the latite were dated at ~38.8 Ma in that area (Henry and Ressel, 2000).

Tt Tuff (Eocene) Light-tan to off-white, nonwelded tuff forms small to extensive exposures in the northeastern part of the map area. The tuff is pumice rich and contains moderate amounts of angular lithic fragments, including dark, aphyric, 1–5-cm-diameter volcanic clasts and 1–10-cm-diameter, white to tan pumice clasts. Weakly consolidated epiclastic beds composed of sand and pebbles are interbedded with the tuff along Middle Susie Creek. The tuff overlies Paleozoic and Eocene sedimentary rocks and is overlain by rhyodacite flow units (Trd). The tuff is equivalent to pyroclastic rocks within the late Eocene "Quartz porphyry" unit mapped in the Swales Mountain quadrangle (Evans and Ketner, 1971), which underlies ~38.8 Ma latite flow units (unit Trd in this quadrangle) (Henry and Ressel, 2000).

Trp Rhyolite porphyry (Eocene) Light-tan to reddish-tan rhyolite flow units of rhyolite porphyry are exposed along Dry Susie Creek and in the northern part of the map area near Swales Mountain; the latter exposures are more extensive to the north and northeast (Evans and Ketner, 1971). The rhyolite has a fine-grained, light-tan to light-gray groundmass with abundant 1–5-mm quartz, sanidine, and lesser plagioclase, biotite, and hornblende phenocrysts; clear quartz phenocrysts are distinctive on reddish-tan weathered surfaces. The flows are massive and weather to coarse grus. Local internal, black, vitric zones suggest contacts between multiple flow units, and isoclinal flow folds are visible in the northern exposures. The phenocryst assemblage in the rhyolite is identical to that of the intrusive rhyolite (Trpi) along the western side of the Adobe Range. Many of the exposures mapped in the

Swales Mountain area (Evans and Ketner, 1971) were not examined for this study, but the published descriptions indicate that those rhyolites are similar to the rhyolite porphyries that were examined elsewhere. In that northern area, they are part of the "Quartz porphyry" unit (Evans and Ketner, 1971) and underlie ~38.8 Ma latite (rhyodacite) flows.

Trpi Intrusive rocks (Eocene) Slightly porphyritic to equigranular, fine- to medium-grained, rhyolite to minor dacite intrusive rocks that form a north-trending, elongate body along the western side of the Adobe Range. The southern part of this intrusive body is shown on the Hunter quadrangle geologic map (Ketner, 1973). The eastern margin of the body is finer grained and contains vertical flow banding adjacent to contacts with Paleozoic rocks. The rocks contain quartz, plagioclase, sanidine, biotite, and hornblende in varying proportions. The rhyolite porphyry is light reddish tan on weathered surfaces, contains primarily small quartz phenocrysts, sanidine, and minor biotite, and comprises the majority of the exposed rocks. The rhyolite is very similar to flow units in unit Trp; in small outcrop areas just west of the main intrusive body, the distinction between a flow or intrusive origin is unclear. In the Swales Mountain area, Evans and Ketner (1971) included both intrusive and extrusive units in the same rhyolite porphyry unit. The dacite phase is dark colored, weakly porphyritic to very fine grained, and contains plagioclase, hornblende, biotite, and lesser sanidine and quartz. Exposures of this lithology are limited to the very southwestern end of the large area of exposure in the Adobe Range, where this unit appears to be gradational into the rhyolite porphyry unit, and to two small outlying areas in the northern part of section 35 and southern part of section 26; the phase was not divided on the map. The rhyolite is unaltered, but a dense stockwork of black quartz veins cuts the small exposure shown in the east-southeastern part of section 26.

Tse Elko Formation (Eocene) Pre-Miocene sedimentary rocks are exposed in the southeastern, northeastern, and southwestern parts of the map area. Exposures in the southeastern area were shown as part of the "Eocene(?) limestone and limestone-clast conglomerate" unit by Smith and Ketner (1978) and identified by Haynes (2003) as part of the Eocene Elko Formation. The rocks are composed largely of tan, moderately cemented limestone-clast conglomerate with strong to weak bedding. Exposures along Interstate 80 have weathered into tall, narrow spires. Near the Susie Creek-Middle Susie Creek confluence in the northeastern part of the map area, strongly cemented, moderately sorted, light-tan sandstone is exposed in a small area. The sandstone has subangular to angular, <0.5- to >1-mm grains of quartz and plagioclase and lesser sanidine and hornblende; sparse lithics are small and include altered pumice and siltstone. Nearly vertical, north-striking small fractures cut the rocks and largely obscure the westerly dip of the bedding. The sandstone is overlain by tuff (Tt); the base is not exposed. The unit may be related to the Eocene Elko Formation, based on its stratigraphic position and the presence of minor volcanic material. Along the southwestern edge of the map area, tan, bedded, sandstone is exposed only as scattered float in a small area. That area of float is continuous with more extensive and better exposures just to the west, where it underlies Eocene volcanic rocks and was mapped as the Elko Formation (Henry and Faulds, 1999). Rocks exposed just to the east of these Tse exposures were mapped as undivided Upper Paleozoic rocks (?) (Smith and Ketner, 1978). Just south of the map area, these rocks appear to overlie Jurassic volcanic units (Smith and Ketner, 1978) and thus may be younger. They are shown on this map as Tse(?).

Pzu Paleozoic sedimentary rocks, undivided (Ordovician to Permian) Limestone, sandstone, siltstone, shale, chert, and conglomerate in various Paleozoic formations ranging in age from Ordovician to Permian. Published maps that cover most of the areas that have extensive exposures of pre-Tertiary rocks provide detailed information on the formations (Evans and Ketner, 1971; Evans and Cress, 1972; Ketner, 1973; Smith and Ketner, 1978; Henry and Faulds, 1999; Wallace et al., 2008a). In general, Lower Paleozoic rocks are exposed in the western and southern parts of the map area, and Upper Paleozoic rocks are exposed in the Adobe Range and in the northeastern Piñon Range. The Paleozoic rocks near Cottonwood Creek, in the northwestern most part of the map area, are not shown on any larger-scale map. Rocks in that area include chert and shale, with minor limestone, and they exhibit varying amounts of folding and deformation. Those units are similar to rocks mapped as the Ordovician Vinini Formation to the northeast (Evans and Ketner, 1971; Wallace et al., 2008a), but other formations may be present in these exposures. A small area of Vinini Formation (shown as Pzu) also was identified east of Susie Creek and north of Interstate 80; it is not shown on the Smith and Ketner (1978) map, which covers the same area.

ACKNOWLEDGMENTS

The Neogene and Quaternary geology, as well as some previously unmapped areas of older rocks, were mapped by A.R. Wallace in 2003–2008 and briefly in 2010. The geology of the Huntsman Ranch quadrangle was published in Wallace et al. (2008a). The pre-Tertiary and Paleogene units and structures in other quadrangles were generalized from Evans and Ketner (1971), Evans and Cress (1972), Ketner (1973), and Smith and Ketner (1978). Geologic features in the Gold Quarry Mine area were generalized from Norby (2002), and minor additions in the Carlin Canyon area were derived from Figure 4 in Trexler et al. (2004). Most of the geochronological data for Miocene units are available in Wallace et al. (2008a, b); one additional tephra correlations date from the Woodruff Creek area in the northern Piñon Range was provided by

Mike Perkins at the University of Utah after that paper was completed.

The Maggie Creek Ranch, through ranch manager Jon Griggs, granted access to the privately owned parts of the map area. Mike Perkins (University of Utah) and Bob Fleck (U.S. Geological Survey) provided the new tephra correlation ages and $^{40}Ar/^{39}Ar$ dates that are cited here and published in Wallace et al. (2008a, b). Peter Vikre and Jim Faulds reviewed the manuscript and map and provided helpful suggestions for improvements. Irene Edgerton did all of the cartography and layout.

The research and mapping for this project were done while the author was employed by the U.S. Geological Survey. The current map publication was supported by the USGS National Cooperative Geologic Mapping Program under STATEMAP award number G19AC00383 .

REFERENCES

Evans, J.G., and Cress, L.D., 1972, Preliminary geologic map of the Schroeder Mountain quadrangle, Nevada: U.S. Geological Survey Miscellaneous Field Studies Map MF-342, scale 1:24,000.

Evans, J.G., and Ketner, K.B., 1971, Geologic map of the Swales Mountain quadrangle and part of the Adobe Summit quadrangle, Elko County, Nevada: U.S. Geological Survey Miscellaneous Investigations Series Map I-667, scale 1:24,000.

Harlan, J.B., Harris, D.A., Mallette, P.M., Norby, J.W., Rota, J.C., and Sagar, J.J., 2002, Geology and mineralization of the Maggie Creek district, *in* Thompson, T.B., Teal, L., and Meeuwig, R.O., editors, Gold deposits of the Carlin trend: Nevada Bureau of Mines and Geology Bulletin 111, p. 115–142.

Haynes, S.R., 2003, Development of the Eocene Elko basin, northeastern Nevada—implications for paleogeography and regional tectonism: Vancouver, British Columbia, Canada, unpublished Master's thesis, University of British Columbia, 156 p.

Henry, C.D., and Faulds, J.E., 1999, Geologic map of the Emigrant Pass quadrangle, Nevada: Nevada Bureau of Mines and Geology Open-File Report 99-9, scale 1:24,000.

Henry, C.D., and Ressel, M.W., 2000, Eocene magmatism of northeastern Nevada—the smoking gun for Carlin-type gold deposits, *in* Cluer, J.K., Price, J.G., Struhsacker, E.M., Hardyman, R.F., and Morris, C.L., editors, Geology and ore deposits 2000—the Great Basin and beyond: Geological Society of Nevada Symposium Proceedings, Reno/Sparks, May 15–18, 2000, p. 365–388.

Ketner, K.B., 1973, Preliminary geologic map of the Hunt quadrangle, Elko County, Nevada: U.S. Geological Survey Miscellaneous Field Studies Map MF-539, scale 1:24,000.

Norby, J.W., compiler, 2002, Geology of the Maggie Creek district, Carlin trend, Eureka County, Nevada *in* Thompson, T.B., Teal, L., and Meeuwig, R.O., editors, Gold deposits of the Carlin trend: Nevada Bureau of Mines and Geology Bulleting 111, scale 1:18,000.

Plume, R.W., 1995, Water resources and potential effects of ground-water development in Maggie, Marys, and Susie Creek basins, Elko and Eureka counties, Nevada: U.S. Geological Survey Water-Resources Investigations Report 94-4222, 87 p.

Regnier, J., 1960, Cenozoic geology in the vicinity of Carlin, Nevada: Geological Society of America Bulletin, v. 71, p. 1189–1210.

Renne, P.R., Swisher, C.C., Deino, A.L., Karner, D.B., Owens, T.L., and DePaolo, D.J., 1998, Intercalibration of standards, absolute ages and uncertainties in $^{40}Ar/^{39}Ar$ dating: Chemical Geology, v. 145, p. 117–152.

Smith, J.F., Jr., and Ketner, K.B., 1978, Geologic map of the Carlin-Piñon Range area, Elko and Eureka counties, Nevada: U.S. Geological Survey Miscellaneous Investigations Series Map I-1028, scale 1:62,500.

Trexler, J.H., Jr., Cashman, P.H., Snyder, W.S., and Davydov, V.I., 2004, Late Paleozoic tectonism in Nevada—timing, kinematics, and tectonic significance: Geological Society of America Bulletin, v. 116, no. 5/6, p. 525–538.

Wallace, A.R., 2005, Sedimentation, faulting, and erosion in the Carlin basin, northeastern Nevada, and implications for mineral exploration and ground water resources, *in* Rhoden, H.N., Steininger, R.C, and Vikre, P.G., editors, Window to the World: Geological Society of Nevada, Symposium Proceedings, p. 147–159.

Wallace, A.R., Perkins, M.E., and Fleck, R.J., 2008a, Geologic map of the Huntsman Ranch quadrangle, Elko and Eureka Counties, Nevada: Nevada Bureau of Mines and Geology Map 163, scale 1:24,000.

Wallace, A.R., Perkins, M.E., and Fleck, R.J., 2008b, Late Cenozoic paleogeographic evolution of northeastern Nevada: Evidence from the sedimentary basins: Geosphere, v. 4, no. 1, p. 36–74.

Suggested Citation:

Wallace, A.R., 2020, Reconnaissance map of the Cenozoic geology in the Carlin basin area, Elko and Eureka counties, Nevada: Nevada Bureau of Mines and Geology Open-File Report 20-2, scale 1:50,000, 10 p.

© Copyright 2020 The University of Nevada, Reno. All Rights Reserved.