Text and references accompanying Nevada Bureau of Mines and Geology Open-File Report 18-6

# Preliminary Geologic Map of the Kelly Creek Area, Humboldt, Elko, and Lander Counties, Nevada

*by*


Joseph A. Laravie

Great Basin GIS, Spring Creek, NV


2018

*Disclaimer: nbmg open-file reports are preliminary. They have not been thoroughly edited or peer reviewed.*

## INTRODUCTION

The geologic map presented here covers much of the area of the Kelly Creek valley, located in eastern Humboldt, western Elko, and extreme northwestern Lander counties, Nevada (fig. 1). The map area is north of Interstate 80, east of the Osgood Mountains and west and southwest of the Snowstorm Mountains. The map covers most of the Dry Hills South, The Knolls, Red House Flat East, and Elevenmile Well 7½' quadrangles, and also extends a few miles onto the Dry Hills North, Kenny Creek, Knight, and Hot Pot quadrangles. Most of the work on the maps was performed in 1988–1991 as part of gold exploration programs of Santa Fe Pacific Mining Inc. (now Newmont Mining Corporation). Additional field work consisting of limited field checks was performed in late 2005.

The quality of mapping varies considerably over the map area, due to exploration priorities and lack of access to much of the area. The Knolls area is the most carefully mapped, with extensive ground mapping, trenching, and drilling information used in the map preparation. Other areas mapped by air photo had only limited field checks, and very sparse drilling, and still others received no ground work whatsoever.

The mapping of the area proceeded in several stages, and resulted in two separate maps, of differing dates (figure 2). Work began in 1988 in the area of plate 1 with limited field work in the Knolls area. Shortly after this, a complete stereo air photo interpretation of the plate 1 area was performed using 1:24,000 scale 1986–87 color air photos, resulting in an early version of plate 1. In 1989, the area of plate 2 was mapped with the same series of air photos with limited field checks, resulting in the map of plate 2. During the period 1989–1991, field checking, mapping and drilling programs continued in the plate 1 area, resulting in significant updates to plate 1, but not to plate 2.

The plates, in essentially their early 1991 form, were first released in 2005 as NBMG Open-File Report 05-1. The only significant modification was the deletion of the Twin Creeks Mine plan of operation area, requested by Newmont as a condition of release. Between late 2005 and 2012 some additional field checks were made, and in 2011–2013 the plates and text were updated. The primary reason for the update was to add geology to the deleted area surrounding the Twin Creeks Mine, but some other updates and corrections were also made. The geology of the area within


**Figure 1.** Map area showing Nevada state outline and counties.

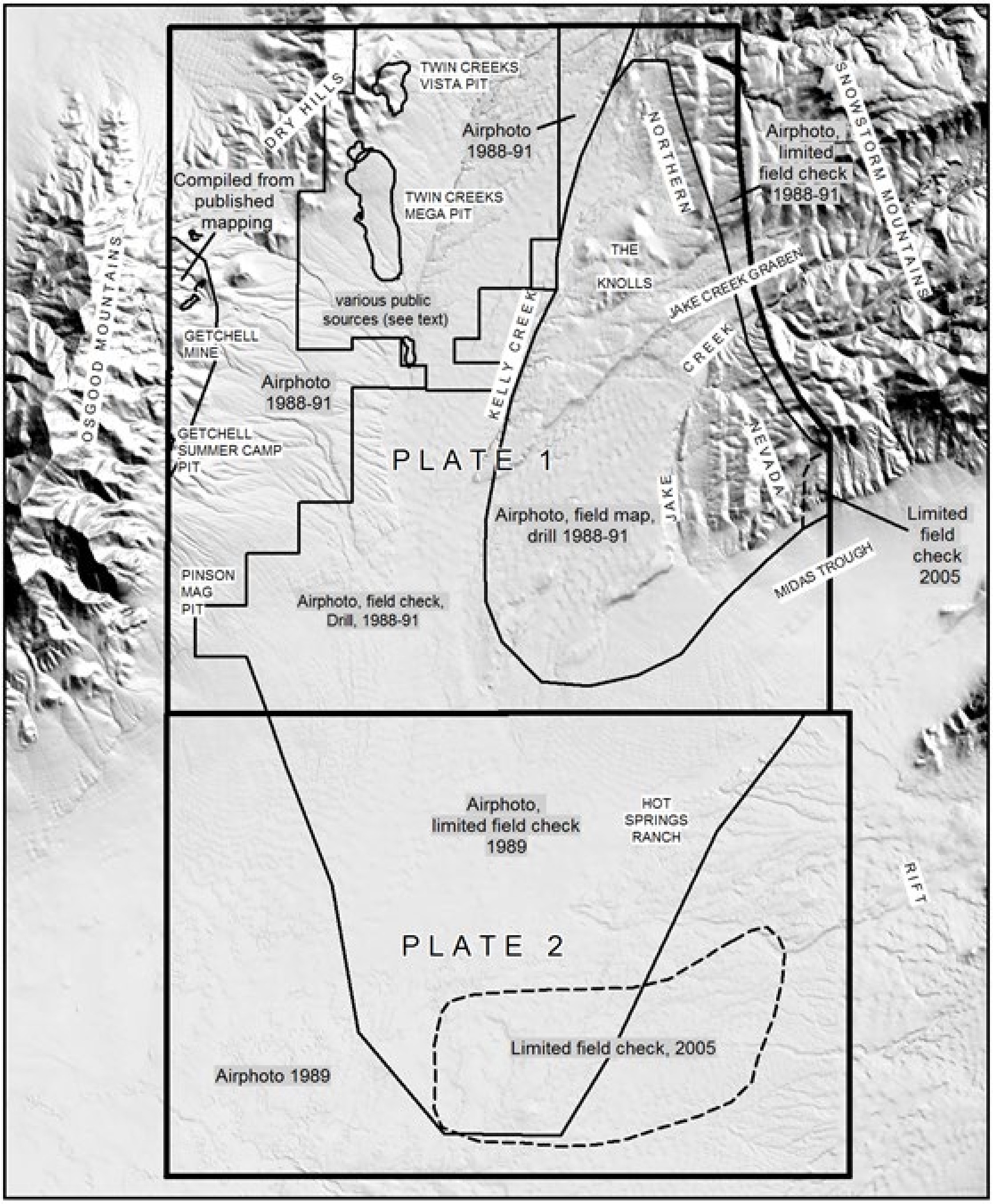


**Figure 2.** Map area showing methods of mapping and localities mentioned in text. All boundaries are approximate. Gold mine open pit outlines circa 2010.

the Twin Creeks plan of operation was completed using a combination of public data sources, including Osterberg 1990, Bureau of Land Management 1996, Simon et al. 1999, Thoreson et al. 2000, Wise et al. 2007, and interpretation of 1981 color infrared stereo air photos, 2006 and 2010 NAIP orthophotos, and other public sources. The overlap area of the 2005 plates was removed by truncating the north edge of plate 2 and making minor edits to both plates.

Previous published mapping that covers the area completely (at 1:250,000 scale) includes the Humboldt County geology map (Willden, 1964) and the geologic map of north central Nevada (Stewart and Carlson, 1984). Hotz and Willden (1964) mapped the two quads abutting to the west. These maps formed the basis for the interpretations in the areas that were mapped by air photos alone. Parts of the area were also mapped by the Southern Pacific Land Company (for example see Olcott, 1959), but this map series was not used in the preparation of the plates in this report.

Several other maps that have been published in the area were not used in the preparation of plates (most were published after the plates were prepared). Wallace (1993) mapped an area that included the entire Kenny Creek and The Knolls quadrangles at 1:50,000 scale. A number of maps have been published in the area of the Twin Creeks Mine, including Atkin (1989), Bloomstein et al. (1991), Osterberg (1990), Osterberg and Guilbert (1991) and Thoreson et al. (2000). The environmental impact statement for the Twin Creeks Mine (Bureau of Land Management, 1996) compiled data (including some data from the original pre-released plate 1) into a 1:250,000 scale geology map with generalized cross sections.

During the time this area was being mapped, a cooperative program was ongoing between the U.S. Geological Survey and the various mining companies in the area (Hoover et al., 1991). Results of this program included airborne magnetic surveys (Grauch and Bankey, 1991, 1994), airborne electromagnetic surveys (Pierce and Hoover 1991, Wojniak et al., 1993), airborne gamma-ray surveys and related calibration rock sampling (Pitkin, 1991, 1994; TerraSense, 1989), chemical and physical studies of alluvium at the Twin Creeks Mine (Detra et al., 1989; Madden-McGuire et al., 1991), age dating of alluvium at the Twin Creeks Mine (Madden-McGuire et al., 1995), regional water geochemistry (Ficklin et al., 1991; Grimes et al., 1995), and regional alluvium geochemistry (Smith et al., 1991a, 1991b; Grimes et al., 1993). Many of the samples used in this program were provided by the mining companies and analyzed by the USGS.

More recently, several authors have described the geology of the mine areas, including Boskie (2001a, 2001b), Breit et al. (2005), and Wise et al. (2007), only small portions of these and other more recent publications were utilized, and the map represents a slightly updated version of the 1989–91 mapping effort.

## GEOLOGY

The map area includes Paleozoic rocks of the lower plate, Roberts Mountains allochthon, Antler sequence, and Golconda allochthon, as well as Tertiary volcanic rocks of Eocene, Miocene, and possibly Pliocene ages. Much of the area is covered by valley-filling alluvial fans, and these are probably Tertiary (Miocene) at depth, and Quaternary at the surface. The southern part of the area was covered by Pleistocene pluvial lakes, and some features on the map may be related to lake shorelines.

The map area is within the Basin and Range Province. In this area, NNE- and N-trending faults of this province are mapped along the base of the Osgood Mountains. Other structural features within the map area include the NNW-trending northern Nevada rift, the westward extension of the ENE-trending Midas trough (graben) and the Jake Creek graben, located 5 miles to the north of the Midas trough along upper Jake Creek. Numerous fault scarps, apparently relating to the Basin and Range and Midas trough trends are mapped in the valley-fill sediments.

Numerous highly economic gold deposits are present in and near the map area. The Twin Creeks Mine is located in the northwest part of plate 1. The Getchell/Turquoise Ridge deposits are located near the west edge of plate 1. The Pinson Mine is located near the SW corner of plate 1. The Ken Snyder (Midas) Mine is located 21 km east of plate 1, and the Lone Tree Mine is located 20 km south of plate 2. All these mines are in large-scale production, except for Lone Tree and Pinson, which closed several years ago. All these gold deposits are Carlin-type and are probably Eocene in age, except for Midas, which is a Miocene low-sulfidation Au-Ag vein system, and Lone Tree, which is probably a distal-disseminated silver-gold deposit with very low silver.

Open pit mine outlines and the limits of mine-related disturbance (dumps, leach pads, tailings ponds and dams) are shown as blue hatched lines. These were traced from 2010 NAIP orthophotos, and in the case of the Twin Creeks Mine West pit outline, 2006 NAIP orthophotos. The geology map represents pre-mining geology, not that exposed in the mine pits.

The map includes one cross section. The basic framework of the section is from the Twin Creeks Mine EIS (Bureau of Land Management 1996), with additions and details interpreted from the geologic map.

## DISCUSSION OF MAJOR ROCK UNITS

### Lower plate (of the Roberts Mountains Thrust)

Lower plate rocks are present along the west edge of plate 1, and were compiled from Berger (1985). The rocks are mapped as Cambrian Preble and Ordovician Comus Formations. This area was not field checked. These rocks were more recently mapped by Boskie (2001a, 2001b). Calcareous siltstone and shale of the Comus Formation is also present in part of the Twin Creeks Mega pit, under the Leviathan thrust (Roberts Mountains thrust), where it was originally covered by alluvium, but is now exposed by mining.

### Roberts Mountains Allochthon

Rocks of the Roberts Mountains allochthon are present in the western, northeastern, and north-central portions of plate 1, and also in the subsurface at the Twin Creeks Mine (on cross section).

The rocks in the western portion, near the Turquoise Ridge Mine, were mapped from air photos, with reference to published small-scale maps and were not field checked.

The rocks in the northeastern part of plate 1 (The Knolls) consist of greenstone, quartzite, shale and chert, and are all interpreted to be Valmy Formation based on lithology. This area was carefully mapped and also drilled. The Valmy Formation in this area is part of a west-tilted fault block bounded on the east by the KE fault and on the southeast by the KS fault. The KE fault is parallel to and within the northern Nevada rift, and the KS fault is the north boundary of the Jake Creek graben. Bedding orientation of the Valmy within the fault block is variable. In the SW corner of the block, a nearly horizontal contact separates a large greenstone body from overlying partly silicified chert. Further north and east within the block, the Valmy is composed of disconnected bodies of quartzite within more continuous chert and shale units. Some of the quartzite bodies may be boudins, extended in the WNW-ESE direction, indicating considerable deformation in this area.

In the north-central part of the map, near the north end of the Twin Creeks Mine, greenstone interpreted as Goughs Canyon Formation by Osterberg (1990) (his units Gcm and Gcb) has now been identified as belonging to the Valmy Formation (Thoreson et al., 2000).

A thick unit of greenstone of the Valmy Formation is present in the western part of the Twin Creeks Mine Mega pit area, where it has been exposed by open-pit mining. The Valmy greenstone overlies calcareous siltstone and tuff of the Comus Formation along the Leviathan (Roberts Mountains) thrust (Thoreson et al., 2000).

## Antler Sequence

Rocks of the Antler sequence unconformably overlie the Valmy Formation. In the northwest part of the map area (Dry Hills) these rocks are known as the Etchart Limestone, and consist of sandy limestone and dolomite overlain by fine calcareous sandstones. A few pebbly layers are present in the lower part of the Formation. Except for a thin (10m?) basal conglomerate that was reportedly mined out beneath the alluvium in the northern portion of the Twin Creeks Mega pit (S½ Sec. 18, T39N R43E), there is little or no basal conglomerate. Here, the rocks were mapped from air photos, and were not field checked. Fossils date the Etchart Limestone as Permian at the top, to Pennsylvanian at the base (Johnson, 1990). Additional mapping and rock descriptions for this area can be found in Atkin (1989), Osterberg (1990), Osterberg and Guilbert (1991) and Thoreson et al. (2000).

In The Knolls area, the Antler sequence rocks dip gently NW. The basal unit consists of interbedded conglomerate and sandstone interpreted to be Battle Formation based on lithology and stratigraphic position. A slightly faulted basal contact is exposed near Garret Spring, where the lower few meters of the Battle Formation contains an unusually coarse conglomerate. This lower conglomerate is overlain by a thin unit of medium to coarse grained sandstone, and then by another conglomerate. The Battle Formation is several hundred meters thick. It is overlain by an equally-thick unit of platy siltstone to very fine sandstone. This unit is interpreted as the Edna Mountain Formation, based on stratigraphic position and lithology. No Antler Peak Limestone has been located in The Knolls area.

The lithologies of the Antler sequence rocks differ considerably across the Kelly Creek valley. The only obvious correlation between The Knolls and the Dry Hills is that the Permian upper member of the Etchart Limestone in the Dry Hills correlates with the probable Edna Mountain Formation in The Knolls area based on lithology. The Battle Formation may pinch out or onlap on basement across the valley to the west. Alternatively, there may be- a facies change, where the sandy lower and middle Etchart Limestone in the Dry Hills correlating with the Battle Formation at The Knolls. A small content of conglomerate throughout the lower and middle Etchart Limestone members, as described by Osterberg (1990) suggests that a facies change is more likely, but there are no fossil data from the Battle Formation at The Knolls to confirm this.

## Golconda Allochthon

The Farrel Canyon Formation overlies the Etchart Limestone across the Golconda thrust in the extreme NW corner of plate 1. This area was mapped from air photos, with no ground checking. A couple of miles to the NE, a few miles north of the map area, the Farrel Canyon Formation is well exposed and consists of gently to moderately dipping thick layers of greenstone, bedded chert, sandstone, and shale.

## Cretaceous Granodiorite

One small map unit of the Osgood Mountains stock is present on the west edge of plate 1. This area was not field checked. There are several sills and dikes of similar rock exposed in the vicinity of the Twin Creeks Mine Vista pit (Osterberg, 1990, Atkin, 1989).

## Eocene Volcanic Rocks

One rhyolite map unit (Tbr) is exposed along Kelly Creek in the north part of plate 1. This may represent the southeasternmost exposure of an Eocene volcanic province described by Wallace and McKee (1994). The rock unit is distinctly different from the younger rhyolitic volcanic rocks in its abundance of hydrous mineral phenocrysts (biotite and hornblende). These rocks are approximately coeval with mineralization at the Twin Creeks Mine (Breit et al. 2005).

## Miocene Volcanic Rocks

Lower Miocene andesite (~22 Ma) is exposed in the extreme NW part of plate 1. The unit dips very gently west and lies unconformably on the Farrel Canyon Formation.

In the Snowstorm Mountains to the east, middle and upper Miocene rocks are subdivided into a lower volcanic series and an upper volcanic series (Wallace, 1990, 1993). The lower series is generally older than mineralization in the

Midas district, and hosts the Midas low-sulfidation epithermal mineralization and other prospects in the area. The upper series is mostly post-mineralization.

In the map area, the lower volcanic series is represented by map units Tgs, Twt, Tla, $Tb_1$ and $Tt_1$. These represent a bimodal suite with both mafic and felsic units. The basalt can be traced east a few miles along the north edge of the Midas trough, where it has been dated at 15.2±1.6 Ma (Wallace, 1993). Further east, along the same trend in the Midas mining district, correlative rocks have been more precisely dated at 15.9±0.3 and 16.0±0.2 Ma (Leavitt et al., 2004). Many of the lower volcanic series rocks are very weakly altered to clay and possibly zeolite minerals. This probably reflects their deposition in an area of near-surface water. Lake beds are interbedded with the basalt.

The upper volcanic series is represented by units $Tt_1$, $Trp_1$, $Tt_2$, $Trp_2$, Trp Tkc, $Tt_3$ and Tr. These are all felsic ash-flow tuffs, lava flows, and air-fall tuffs. Except for unit Tr, they coincide with and represent subdivisions of units Tr and Tl of Wallace (1993). Unit Tr correlates with unit Trpo of Wallace (1993). Sawtooth dike, a NNW-trending feeder dike for this unit located several km east of the map area was dated at 15.39±0.02Ma (Leavitt et al. 2004).

Both the upper and lower volcanic series are strongly faulted by the northern Nevada rift faults, and also faults of the Midas trough trend.

## Tertiary-Quaternary Rocks

The above rocks are unconformably overlain by a series of tuffaceous sediments and alluvial fan gravels, with interbedded basalt flows.

Unit Ttl and Ttlp are tuffaceous sediments and represent the lower part of this sequence. Ttlp is the basal unit, and contains sand grains to boulders of the underlying Paleozoic units. It is thin and discontinuous, but widespread in the basin, apparently extending even 15 km south of the map area to the Lone Tree Mine (Panhorst, 1996, p. 39).

Unit Ttl is the first unit to be discussed that is also present on plate 2, where it is exposed in the center of the valley. Here it is very devitrified, clay-altered and wet, and is onlapped on both the north and east by alluvial fan gravels. Further north, on the south edge of plate 1, it is present along low hills in the center of the valley just north of the Midas road fault. Still further north, in The Knolls area, it is less clay-altered, and locally contains fresh glass. The regional variation in clay alteration probably reflects a higher groundwater level, and perhaps a higher percentage of deposition in a lacustrine environment to the south. The unit is not dated directly, but its date can be inferred from a number of indirect relationships. Unit $Tt_l$ underlies a basalt flow north of the Midas road fault that correlates with basalt flows nearby dated at 4.3 to 6.4 Ma., and it overlies the Miocene (14.3 Ma) volcanic rocks discussed above, thus its age is probably between about 6 and 14 Ma. Within unit $Tt_l$, a thin bed of unaltered pumice agglomerate is exposed in the stream bank west of The Knolls, in the W1/2 SW1/4 Section 26.

Units QTap, QTag, QTar, and QTal represent a suite of alluvial-fan gravel of varied provenance derived from the surrounding mountain ranges. In some places near the margins of the valley the gravel forms a very thin capping. This is visible along gullies in the SW part of The Knolls area, in the Jake Creek graben, and in the center of the valley 1 mile north of the Midas road fault. However, it is much thicker in other places (it is some 200 m thick in the Twin Creek Mine Mega pit area) (Bloomstein et al., 1991). Unit QTal is primarily derived from the Etchart Limestone. Unit QTag is primarily derived from the Osgood Mountains granodiorite. Unit QTar is derived primarily from the Miocene volcanic rocks to the east, and unit QTap is derived primarily from the Cambrian and Ordovician formations exposed along the west edge of the map area.

These units have many vertical offsets in their surface. Most appear to be stream terrace boundaries or boundaries at the edges of individual alluvial fans. Although in some respects they resemble fault scarps, they are interpreted to result from sedimentary processes. These features are marked on the plates by thin lines, with the lower elevation side noted. Some may represent strath surface boundaries.

McGuire (1995) obtained some dates from unit QTal in the Twin Creeks Mine area. Interbedded volcanic ash at 30 m depth yielded zircon fission-track ages of 2.7±1.0 and 2.8±0.8 Ma, and another interbedded ash at 70 m depth yielded Ar-Ar sanidine ages of 13.5±0.1, 13.9±0.2, and 14.1±0.1 Ma.

Detra et al. (1989) described the chemistry and physical characteristics of core samples of unit QTal (and possibly QTap in the lower portion) from a single hole within the Twin Creeks Mine area in incredible detail. Madden-McGuire et al. (1991) presented a more readable summary of the same data.

Thin basalt flows are interbedded in the Quaternary-Tertiary alluvial-fan units near the Midas Road fault, and in one case, have flowed out on the surface of unit Ttl, before being covered by alluvial-fan gravels. A small basalt shield volcano and an area of basalt subcrop ½ mile to its northwest are mapped in the south part of plate 2. Possibly correlative basalts 10 km to the northeast were dated by Wallace (1993) as 6.4±2.3 Ma and thin basalt flows near Iron Point, 20 km SW, were dated as 4.22±0.58 Ma (Hart et al., 1984).

## Quaternary Sediments

Youngest Quaternary map units include younger alluvium confined to smaller stream valleys, low-lying distal portions of alluvial fans and the Humboldt River floodplain. Localized stream terrace deposits occur along small stream valleys along Jake Creek and Kelly Creek and cover lower portions of alluvial fans in the central part of the map. Levee deposits occur along west-flowing stream valleys in the east 1/2 of plate 2. Other Quaternary units include spring-related deposits north of The Knolls, eolian sand dunes covering large areas within plate 2, and small playas.

The younger alluvium and terrace deposits have many vertical offsets in their surface. Most appear to be stream terrace boundaries. These features are marked on the plates by thin lines, with the lower elevation side noted.

Several units appear to be related to Pleistocene pluvial lakes. The shoreline of this lake generally extended from the SW corner of plate 1 to the ENE, following the general trace of the Midas Road fault, and then extended south in the east half of plate 2 (Reheis, 1999). The gaps in the westward-flowing valleys in the east half of plate 2 (south of the Hot Springs Ranch) may be due to beach wave sediment redistribution along the N-S trending lake shoreline. The levee(?) deposits (unit Qal) may be incipient deltas related to streamflow into the pluvial lake. A field check of these levee features in late 2005 revealed them to be aeolian sand deposits, at least at the surface. Sand of pluvial shoreline origin apparently was blown out of the thinly-vegetated channels and accumulated in the more thickly vegetated overbank area.

## STRUCTURE

Two major thrust faults are present in the map area. The Roberts Mountains thrust separates the Comus Formation from the overlying Valmy Formation in the Twin Creeks and Getchell Mine areas. In the Twin Creeks area, the Leviathan thrust is the local name for the Roberts Mountains thrust. Strong folding in the lower plate and shearing in the upper plate is apparently associated with this thrusting event. On plate 1 and the cross section, the Leviathan thrust, and other faults in the Twin Creeks area are shown in their pre-mining setting, as covered by alluvium. Northwest of the Twin Creeks Mine, the Farrel Canyon Formation is thrust over the Etchart Limestone along the Golconda thrust.

Three regional high-angle fault sets are present in the map area. The oldest is probably NNE- to N-trending basin and range faults. These faults are most prominent along the west edge of plate 1, where they are exposed in the Getchell Mine and parallel the range front of the Osgood Mountains, 2–3 miles east of the range front, where they offset the alluvial-fan surface and thus also have a very young displacement. NNE-trending faults cutting unit Tts in the southwest part of plate 2 mostly show down-to-the-west displacement of the surface and are probably related to movement at the east edge of the deeper portion of the basin, which is located between these faults and the Osgood Mountains, based on gravity data (Erwin et al., 1985).

The western margin of the northern Nevada rift, one of a number of NNW-trending magnetic anomalies, extends through the eastern portion of the map area (Zoback and Thompson, 1978). Within plate 2, It is largely covered with younger sediment, with little evidence of recent activity. Within plate 1 numerous N- to NNW-trending down-to-the-east faults are mapped within the Miocene volcanic rocks. The rift structure in this area is highly asymmetrical, with numerous west-tilted fault blocks. These faults cut Paleozoic, Eocene, and Miocene rocks, but the younger rocks, including the alluvial units and youngest basalt appear to post-date the faulting. No dikes are mapped on plate 1, but Sawtooth dike, a NNW-trending rhyolite dike located 6 km east of plate 1, is probably related to the rift and was dated at 15.39±0.02 Ma (Leavitt et al. 2004).

The youngest fault set is the ENE-trending horst and graben structures of the Midas trough and Jake Creek graben. The youngest basalt ($Tb_2$) appears to have erupted along faults of this trend, especially along the northern margin of the Midas trough. A great number of fault scarps with this trend cut alluvial fans throughout the Kelly Creek valley. In a few localities, the faults appear to cut even the youngest alluvial deposits along Kelly Creek and Summer Camp Creek. Scattered faults with this trend also cut the Miocene volcanic rocks in the Snowstorm Mountains, especially between the Midas trough and Jake Creek graben. Some early basin and range faults were reactivated at this time. The NNE faults along the Osgood Mountains range front show a tendency to curve to the ENE, cut across the valley and join the Midas trough fault trend. The Osgood Mountains apparently formed a buttress that the youngest ENE faults did not penetrate.

## GEOLOGIC UNITS

## Quaternary Deposits

**Qp Playa and modern lake deposits** Sand, silt, and clay.

**Qae Eolian silt and sand** Barchan dune field in southwestern part of map area. Transverse (?) dune field east of Hot Springs ranch. In addition to these mapped areas, most of the surface of the alluvial fans is covered by a 0.3 to 3m thick layer of silty loess, usually containing pebbles of underlying units brought up by burrowing animals. The thickness of this layer generally decreases to the north over the area of plate 1. The “clay pit” at the Twin Creeks Mine is in this silty loess unit.

**Qls Landslide deposits** Includes both slump block and debris flows.

**Qay Active and recent alluvial deposits** Dominantly gravel and sand in narrow valleys and along intermittent streams. Commonly covered in eolian silt. Provenance generally reflects rock types in present-day drainage areas.

**Qal Levee deposits** Medium grained sand-covered levees along east-west channels in the eastern half of the map area. The sand surface layer appears to be eolian, but their restricted distribution suggests a relation to the Pleistocene Lake Lahontan shoreline, possibly as incipient delta deposits, later covered by wind-blown sand.

**Qat Inactive fluvial terrace and distal alluvial-fan deposits** Dominantly gravel and sand. May include Quaternary shoreline deposits at Lower Clover Ranch and along the Midas Road.

**QTs Spring-related deposits** Mostly calcareous mud and travertine.

**QTar Older alluvial-fan deposits of rhyolitic provenance** Dominantly gravel and sand in dissected alluvial fans. Generally coarsens upward and northeastward. Provenance reflects volcanic rocks exposed in Snowstorm Mountains and other nearby volcanic areas. Mostly aphyric rhyolitic provenance at top, grading down to porphyritic rhyolitic provenance at base.

**QTag Older alluvial-fan deposits of granitic provenance** Dominantly gravel and sand in weakly dissected alluvial fans. Gravel with boulders at higher elevations on fans and sand at lower, more distal areas. Provenance mostly Osgood Mountain granodiorite.

**QTap Older alluvial-fan deposits of Paleozoic sedimentary provenance** Dominantly gravel and sand in dissected alluvial fans. Includes chert, siltstone, shale, and greenstone clasts (from Comus, Preble, Valmy and Farrel Canyon Formations).

**QTal Older alluvial-fan deposits of limestone provenance** Dominantly gravel in dissected alluvial fans. Mostly limestone clasts with small proportion of basalt clasts, increasing to 10–30% basalt near the north edge of the map. Cemented with caliche in many areas.

## Tertiary Volcanic and Sedimentary Rocks

**Tb$_2$ Basalt** Fresh black basalt. Coarser grained than Tb$_1$, with trace small olivine and plagioclase phenocrysts. Mostly located near base of unit QTar. Individual flows up to 50 ft (15.24 m) thick, but most are much thinner. Weathers to large blocks and outcrops on ridges. Also includes a small shield volcano and associated area of basalt subcrop on plate 2. Probably correlates with unit Tb (6.3 Ma) of Wallace (1990) in the Midas trough. May also correlate with basalt flows at Iron Point (unit Tb of Erikson and Marsh, 1974).

**Tar Older alluvial-fan deposits** Gravel, sand, silt, and clay. Strongly dissected by gullies up to 8 m deep. Overlain by thin reddish sand of rhyolitic provenance. Mapped in Elko County as unit Ts$_3$ by Coats (1987) (possibly equivalent to the Humboldt or Carlin Formation).

**Ttl Tuffaceous sand, silt, and clay** Fluvial volcanic sandstone devitrified to clay with rare thin tuffaceous clay/silt flood plain or lacustrine beds and fresh glassy agglomerate. Usually greenish-gray where fresh, olive where weathered. Generally less-altered and coarser northward.

**Ttc Gravel and sand** Fine gravel containing subrounded white to light gray biotite rhyolite porphyry clasts. Clasts appear to be derived from unit Tbr. Found only in small area at The Knolls.

**Ttlp Tuffaceous-matrix pebbly sand and conglomerate** Pebbly sand and conglomerate. Chert, quartzite, greenstone, and siltstone grains and clasts in a tuffaceous, devitrified, and partially oxidized soft sand matrix. Rare clasts up to several meters diameter. Usually brown, or reddish-brown, and more oxidized than overlying beds. Forms a discontinuous layer between unit Ttl and underlying Paleozoic rocks.

**Tr Rhyolite porphyry** Gray, highly porphyritic (30–40% K-spar and quartz phenocrysts 2–3mm diameter). Forms ridges in the SE edge of the map area and the highest units of the Snowstorm Mountains to the east of the map area. Strongly columnar jointed. Probably lava flows and domes. Correlates with unit Trpo (14.3 Ma) or possibly unit Trp (13.4 Ma) of Wallace, (1990) in the southern Snowstorm Mountains.

**Tt$_3$ Unwelded tuffs and tuffaceous sediments** Medium gray color, fresh, with 2–8% small crystals. Poorly exposed.

**Tkc Welded tuff** Brown-weathering porphyritic welded ash-flow tuff. 10–12% K-spar phenocrysts 1–3 mm diameter. Forms columnar-jointed cliffs.

**Trp$_2$ Rhyolite porphyry and welded ash-flow tuff** Gray, red-weathering porphyritic welded ash-flow tuff. Usually forms well defined, sharp-edge ridges. Extremely welded, with re-melted texture and platy jointing. 0 to 8% K-spar and/or plagioclase phenocrysts <1 mm diameter. Less than 1% pyroxene phenocrysts.

**Tt$_2$ Poorly welded to non-welded tuff and sediments** Between units Trp$_1$ and Trp$_2$. Variable in color with brown, olive, green, gray, and orange intervals.

**Trp$_1$ Rhyolite porphyry** Gray to red, red-weathering porphyritic welded ash-flow tuff. A sequence of thin flows and interbeds forming hillslopes and less well-defined, more rounded ridges, than unit Trp$_2$. Strongly welded, with visible flattened fragments and no granophyric or re-melted texture. Blocky jointed. 2 to 12% K-spar phenocrysts <1 mm diameter. Less than 1% pyroxene phenocrysts.

**Trp Rhyolite porphyry** Units Trp$_1$ and Trp$_2$ combined as unit Trp in The Knolls area. May correlate with units Tl and/or Tr of Wallace (1990) in the Snowstorm Mountains.

**Tt$_1$ Unwelded tuff and tuffaceous sediments** Between Trp$_1$ and Tb$_1$. Thin and poorly exposed.

**Tb$_1$ Vesicular basalt flows** A sequence of thin highly vesicular (amygdaloidal) basalt flows exposed along the east side of plate 1. Gray to reddish brown and finer grained than unit Tb$_2$. Weathers to soft clayey sand and forms recessive, limonite stained outcrops where altered. Contains minor interbedded rhyolitic tuffaceous sands and lake beds. Correlates with unit Tba (15.1 Ma) of Wallace (1990).

**Tla Lake beds** White to light brownish gray platy silt and sand.

**Twt Coarse rhyolite welded tuffs** Agglomerate and possibly conglomerate. Contains coarse blocks locally, but overall texture is difficult to see and describe. Mostly strongly leached and limonite stained. Forms ridges.

**Tgs Tuffaceous sandstone and siltstone** Sandstsone and siltstone, with possible interbeds of weakly welded rhyolitic tuff. Olive brown to green in color, with 0–10% white altered K-spar(?) phenocrysts <1 mm diameter.

**Tb$_0$ Basalt of Dry Hills** A sequence of thin flows of fine grained basalt (and basaltic andesite?). Dips very gently west and lies unconformably on the Farrel Canyon Formation. Dated at 22.1±0.7 Ma by Wallace and McKee (1994).

**Tbr Biotite rhyolite** Light brownish gray rhyolite with 20–40% phenocrysts of plagioclase, quartz, biotite, hornblende, and K-spar 1–2 mm diameter. Exposed along Kelly Creek about 2 miles north of The Knolls. A surface sample from this outcrop area at the top of a small hill approximately ¼ mile east of Kelly Creek was dated (K-Ar-biotite) at 41.1±1.0 Ma.

## Paleozoic Sedimentary Rocks

**PPf Farrel Canyon Formation** Mostly sandstone, shale, and chert. As mapped by Berger (1985), Hotz and Willden (1964), and Osterberg (1990). Not field checked.

**Peu Etchart Limestone, upper member of Osterberg (1990)** Dolomitic siltstone, argillite, and calcareous siltstone., mostly thin-bedded. Some thin biomicrite. Contains Permian conodonts (Osterberg, 1990)

**PPe Etchart Limestone, middle and lower members of Osterberg (1990)** Limestone, limy sandstone, dolomite, conglomerate, and thin beds of pebbly limestone. Sericite, kaolinite, dickite, alunite, natroalunite, and probably some dolomite are hydrothermal alteration products (Osterberg, 1990). This unit is the main host for the gold mineralization in the Vista Pit of the Twin Creeks Mine.

**Ps Siltstone and very fine-grained sandstone** Poorly sorted. Angular to subangular grains of quartz, muscovite, chert, and dolomite in fine muddy matrix. Weathers recessively to thin plates. Similar to some lithologies of the upper member of the Etchart Limestone in the Dry Hills and possibly correlative to it. Probably equivalent to Edna Mountain Formation.

**Pbs Battle Formation sandstone** Coarse to medium grained sandstones interbedded with Battle Formation conglomerate. Weathers recessively.

**Pbc Battle Formation conglomerate** Sand-matrix conglomerate. Clasts dominated by chert and quartzite similar to that found in units Ovc and Ovq. Clasts up to ~1m diameter, but mostly < 20 cm. Forms ridges and large outcrops.

**Ovg Valmy Formation greenstone** Greenstone and related basaltic tuffs and volcaniclastic rocks. Contains massive (equigranular), pillow, fragmental and tuffaceous textures. Occasional irregular masses and veins of calcite. Basalt and lesser chert within the Twin Creeks Mine area (Breit et al. 2005).

**Ovc Valmy Formation chert** Bedded chert with thin shale or phyllite partings. Usually black or gray.

**Ovs Valmy Formation siltstone and shale** Siltstone and shale, usually gray.

**Ovq Valmy Formation quartzite** Strongly cemented quartz arenite. Fine grained and very well sorted. Highly rounded grains of quartz, with very little accessory or heavy minerals. Distinctive inclusion trains extend across grain boundaries. Mapped only in The Knolls area where it occurs as disconnected WNW-ESE elongate lens-shaped and irregular bodies surrounded by variably sheared shale and chert. Weathers to smooth-surfaced rounded outcrops.

**Oc Comus Formation** Shale, limestone, and tuff. as mapped by Berger (1985). Black shale, siltstone, silty to sandy limestone, mafic tuff/debris flows and intrusions in the Twin Creeks Mine Mega pit. (Breit et al., 2005). This unit is the main host for gold mineralization in the Twin Creeks Mine Mega pit and West pit, as well as the Turquoise Ridge Mine.

**Єp Preble Formation** Phyllite and limestone as mapped by Berger (1985). Carbonaceous, laminated, locally phyllitic silty mudstone at (below) the Twin Creeks Mine Mega pit. (Breit et al. 2005)

## Intrusive Rocks

**Kg Granodiorite of Osgood Mountains** Stock and associated dikes. As mapped by Berger (1985). Equigranular medium-grained light-gray to very light gray rock composed of white feldspar and gray quartz, with biotite, hornblende, and a little magnetite (Hotz and Willden, 1964).

# ACKNOWLEDGMENTS

I thank Newmont Mining Corp. for releasing the data in the earlier version of plates 1 and 2. I also thank the exploration managers at Santa Fe Pacific Mining, Inc., Ken Sageser, Ron Parratt, and Roy Owen, who allowed me to explore this high-priority and interesting area with little interference and considerable assistance. I also thank the numerous employees and contractors of Santa Fe Pacific Mining who helped in drafting, permitting, logging, discussions, advice and otherwise contributing to the exploration and mapping in this area. Geological Society of Nevada Foundation contributed funds to Nevada Bureau of Mines and Geology in order to finalize this version of the maps.

# REFERENCES

Atkin, S., 1989, The geology of the North Pit, Chimney Creek Mine, Humboldt County, Nevada *in* Buffa, R., Klessig, P., and Scgafer, R., editors, 1989 Fall field trip guidebook—geology and gold deposits of the Osgood Mountains, Nevada: Geological Society of Nevada Special Publication 10, 13p.

Berger, B. R., 1985, Geology and geochemical relationships at the Getchell Mine and vicinity, Humboldt County, Nevada *in* Hollister, V.F., editor, Case histories of mineral discoveries vol.1 discoveries of valuable minerals and precious metals deposits related to intrusions and faults: Society for Mining, Metallurgy, and Exploration, Littleton, CO, USA, p.51–59

Bloomstein, E.I., Massingill, G.L., Parratt, R.L., and Peltonen, D.R., 1991, Discovery, geology, and mineralization of the rabbit creek gold deposit, Humboldt County, Nevada *in* Raines, G., Lisle, R., Schafer, R., and Wilkinson, W., editors, Geology and ore deposits of the Great Basin, Symposium Proceedings April 1–5 1990: Geological Society of Nevada, p. 821–843.

Breit, F.J.Jr., Ressel, M.W., Anderson, S.D., and Muirhead, E.M.M., 2005, Geology and gold deposits of the Twin Creeks Mine, Humboldt County, Nevada *in* Rhoden, H.N., Steininger, R.C., and Vikre, P.G., editors, Geological Society of Nevada Symposium 2005: Window to the World Proceedings, Reno, Nevada, May 2005, p. 431–451.

Bureau of Land Management, 1996, Final environmental ompact statement, Twin Creeks Mine: U.S. Bureau of Land Management, Winnemucca District Office, Winnemucca, Nevada.

Boskie, R.M., 2001a, Detailed structure and stratigraphy of Lower Paleozoic rocks of the Getchell trend, Osgood Mountains, Humboldt County, Nevada: University of Nevada, Reno, M.S. thesis.

Boskie, R.M., 2001b, Structure and stratigraphy of Lower Paleozoic rocks of the Getchell trend, Osgood Mountains, Humboldt County, Nevada *in* Regional tectonics and structural control of ore—the major gold trends of northern Nevada: Geological Society of Nevada Special Publication 33. p.263–293.

Coats, R.R., 1987, Geology of Elko County, Nevada: Nevada Bureau of Mines and Geology Bulletin 101, 112 p.

Detra, D.E., Madden-McGuire. D.J., Smith, S.M., Silberman, M.L., Botinelly, T., Grimes, D.J., Ficklin, W.H., McHugh, J.B., O'Leary, R.M., and Hinkle, ME., 1989, Chemical and physical characteristics of alluvium from drill core near the Rabbit Creek gold deposit, Getchell mining district, Humboldt County, Nevada: U.S. Geological Survey Open-File Report 89-455, 88 p.

Erickson, R.L., and S.P. Marsh, 1974, Geologic map of the Iron Point quadrangle, Humboldt County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-1175, scale 1:24,000.

Erwin, J.W., Ponce, D.A., and Wagini, A., 1985, Bouguer gravity map of Nevada, McDermitt sheet: Nevada Bureau of Mines and Geology Map 86.

Ficklin, W.H., Meier, A.L., and Grimes, D.J., 1991, Arsenic, antimony, and tungsten distribution in surface water and groundwater near and away from concealed gold deposits in the Kelly Creek valley, Nevada *in* Thorman, C.H. editor, 1991, Some current research in eastern Nevada and western Utah by the U.S. Geological Survey: U.S. Geological Survey Open-File Report 91-386, 26 p.

Grauch, V.J.S., and Bankey, V., 1991, Preliminary results of aeromagnetic studies of the Getchell disseminated gold deposit trend, Osgood Mountains, north-central Nevada *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., editors, Geology and ore deposits of the Great Basin: Symposium Proceedings: Geological Society of Nevada, Reno, Nevada, p. 781–791.

Grauch, V.J.S., and Bankey, V., 1994, Aeromagnetic and Rrelated maps of the Getchell gold trend, Osgood Mountains, north-central Nevada: U.S. Geological Survey Geophysical Investigations Map GP-1003-B.

Grimes, D.J., McHugh, J.B., Ficklin, W.H., and Meier, A.L., 1993, Anomalous gold, antimony, arsenic and tungsten in ground water and alluvium around disseminated gold deposits along the Getchell trend, Humboldt County, Nevada *in* Romberger, S.B., and Fletcher, D.I., editors, 1993, Integrated methods in exploration and discovery: Conference Program and Abstracts, Denver, USA, Society of Exploration Geologists, p. AB-42.

Grimes, D.J., McHugh, J.B., and Meier, A.L., 1995, Chemical analyses of major, minor, and trace elements including gold and the arsenic species, As(III) and As(V) in water samples collected along the Getchell trend, Humboldt County, Nevada: U.S. Geological Survey Open-File Report 95-636.

Hart, W.K., Aronson, J.L., and Mertzman, S.A., 1984, Areal distribution and age of Low-K, high-alumina olivine tholeiite magmatism in the northwestern Great Basin: Geological Society of America Bulletin, v. 95, p. 186–195.

Hoover, D.B., Grauch, V.J.S, Pitkin, J.A., Krohn, D., and Pierce, H.A., 1991, Getchell trend airborne geophysics—an integrated airborne geophysical study along the Getchell trend of gold deposits, north central Nevada *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., editors, Geology and ore deposits of the Great Basin, Symposium Proceedings: Geological Society of Nevada, Reno, Nevada, p.739–758

Hotz, P.E., and Willden, R., 1964, Geology and mineral deposits of the Osgood Mountains quadrangle, Humboldt County, Nevada: U.S. Geological Survey Professional Paper 431, 128 p., scale 1:62,500.

Johnson, W.J., 1990, Conodont biostratigraphy, sedimentology, and depositional environments of the Etchart Limestone, north-central Nevada: University of Wisconsin-Madison, M.S. thesis, 100 p.

Leavitt, E.D, Spell, T.L, Goldstrand, P.M., and Arehart, G.B., 2004, Geochronology of the Midas low-sulfidation epithermal gold-silver deposit, Elko County, Nevada: Economic Geology v. 99, p. 1665–1686.

Madden-McGuire, D.J., Smith, S.M., Botinelly, T., Silberman, M.L., Detra, D.E., and Staff of Santa Fe Pacific Mining, Inc., 1991, Nature and origin of alluvium above the Rabbit Creek gold deposit, Getchell gold belt, Humboldt County, Nevada *in* Raines, G., Lisle, R., Schafer, R., and Wilkinson, W., editors, Geology and ore deposits of the Great Basin: Symposium Proceedings April 1–5 1990, Geological Society of Nevada p. 895–911.

McGuire, D.J., 1995, Late Pliocene and Miocene ages from basin fill volcanic ash above the Rabbit Creek (Twin Creeks) gold deposit, Humboldt County, Nevada *in* Geology and ore deposits of the American cordillera: Program with Abstracts, Geological Society of Nevada April 10–13, 1995 p. A53.

Olcott, G.W., 1959, Areal economic geology T39N R43E: Southern Pacific-Mineral Survey unpublished map, scale 1:24,000.

Osterberg. Mark W., 1990, Geology and geochemistry of the Chimney Creek gold deposit, Humboldt County, Nevada: University of Arizona, Tucson, Ph.D. dissertation, 173 p.

Osterberg, M.W., and Guilbert, J.M., 1991, Geology, wall-rock alteration, and new exploration techniques at the Chimney Creek sediment-hosted gold deposit, Humboldt County, Nevada *in* Raines, G., Lisle, R., Schafer, R., and Wilkinson, W., editors, 1991, Geology and ore deposits of the Great Basin: Symposium Proceedings April 1–5, 1990, Geological Society of Nevada, p. 805.

Panhorst, T.L, 1996, Structural control and mineralization at the Lone Tree Mine, Humboldt County, Nevada with implications on sampling protocol: University of Nevada, Reno Ph.D. dissertation, 263 p.

Pierce, H.A., and Hoover, D.B., 1991, Airborne electromagnetic applications—mapping structure and electrical boundaries beneath cover along the Getchell trend, Nevada *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., editors, Geology and ore deposits of the Great Basin: Symposium Proceedings: Geological Society of Nevada, Reno, Nevada, p.771–780.

Pitkin, 1991, Radioelement data of the Getchell trend, Humboldt County, Nevada—geologic discussion and possible significance for gold exploration *in* Raines, G.,.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., editors, 1991, Geology and ore deposits of the Great Basin: Symposium Proceedings April 1–5, 1990; Geological Society of Nevada, Reno, Nevada, p. 759–769.

Pitkin, J.A., 1994, Analytical results and sample locality map of rock-and-soil samples from aerial gamma-ray anomalies, Getchell gold trend, Humboldt County, Nevada: U.S. Geological Survey Open-File Report 94-202.

Reheis, M, 1999, Extent of Pleistocene lakes in the western Great Basin, U.S. Geological Survey Map MF-2323, scale 1:800,000.

Simon, G., Kesler, S.E., and Chryssoulis, S., 1999, Geochemistry and textures of gold-bearing arsenian pyrite, Twin Creeks, Nevada—implications for deposition of gold in Carlin-type deposits: Economic Geology V 94 No.3 p. 405–522.

Smith, S.M., D.E., Detra, P.K., Theobald, and P.M., Theodorakos, 1991a, Element dispersion in alluvium covering gold deposits east of the Osgood Mountains, Getchell trend, Humboldt County, Nevada—slides and ext of a talk given at the Association of Exploration Geochemists' 15th International Geochemical Exploration Symposium, Reno, Nevada: U.S. Geological Survey Open-File Report 91-599.

Smith, S.M., Detra, D.E., Theobald, P.K., and Theodorakos, P.M., 1991b, Element distribution in alluvium covering gold deposits east of the Osgood Mountains, Getchell trend, Humboldt County, Nevada: 15th International Geochemical Exploration Symposium, Reno Nevada Abstracts with Program, p. 30.

Stewart, J.H., and Carlson, J.E., 1984, Geologic map of north-central Nevada: Nevada Bureau of Mines and Geology Map 50, scale 1:250,000.

TerraSense, 1989, Uranium, potassium, and thorium contour maps derived from a helicopter gamma-ray spectrometer survey of the Getchell trend, Humboldt County, Nevada: U.S. Geological Survey Open-File Report 89-287, scale 1:24,000.

Thoreson, R. F., Jones, M.E., Breit, F.J., Doyle-Kunkel, M.A., and Clarke, L.J., 2000, The geology and gold mineralization of the Twin Creeks gold deposits, Humboldt County, Nevada *in* Crafford, A.E.J., editor, 2000, Geology and ore deposits 2000: The Great Basin and Beyond, Field Trip 9 Guidebook, p. 85–111.

Wallace, A.R., 1990, Geologic map of the Jake Creek Mountain quadrangle, Elko County, Nevada: U.S. Geological Survey Map GQ-1672.

Wallace, A.R., 1993, Geologic map of the Snowstorm Mountains and vicinity, Elko and Humboldt counties, Nevada: U.S. Geological Survey Map I-2394.

Wallace, A.R., and McKee, E.H., 1994, Implications of Eocene through Miocene Ages for volcanic rocks, Snowstorm Mountains and vicinity, Northern Nevada *in* Berger, B.R. editor, Advances in research on mineral resources: U.S. Geological Survey Bull. 2081, p. 13–18.

Willden, R., 1964, Geology and mineral deposits of Humboldt County, Nevada: Nevada Bureau of Mines and Geology Bulletin 59, 164 p., scale 1:250,000.

Wise, J.M., Donovan, P., Wright, J.L., and Kelsey, G.L., 2007, Reactivation of mineralized fault sets during Basin-and-Range extension at the Twin Creeks Carlin-type deposit, Potosi mining district, Humboldt County, Nevada *in* Johnson, M.K. editor, 2007, Faults, folds, and mineral belts—regional structural systems, gold mineralization, and exploration potential in the Great Basin: Geological Society of Nevada Special Pububublication 46. p. 121–126.

Wojniak, W.S., Hoover, D.B., and Grauch, V.J.S., 1993, Electromagnetic survey maps showing apparent resistivity of the Getchell gold trend, Osgood Mountains, north-central Nevada: U.S. Geological Survey Geophysical Investigations Map GP-1003-A

Zoback, M.L., and Thompson, G.A., 1978, Basin and Range rifting in northern Nevada—clues from a mid-Miocene rift and its subsequent offsets: Geology v.6, p. 111–116.

***Suggested Citation:***

Laravie, J.A.,2018, Preliminary geologic map of the Kelly Creek area, Humboldt, Elko, and Lander counties, Nevada: Nevada Bureau of Mines and Geology Open-File Report 18-6, scale 1:24,000, 10 p.