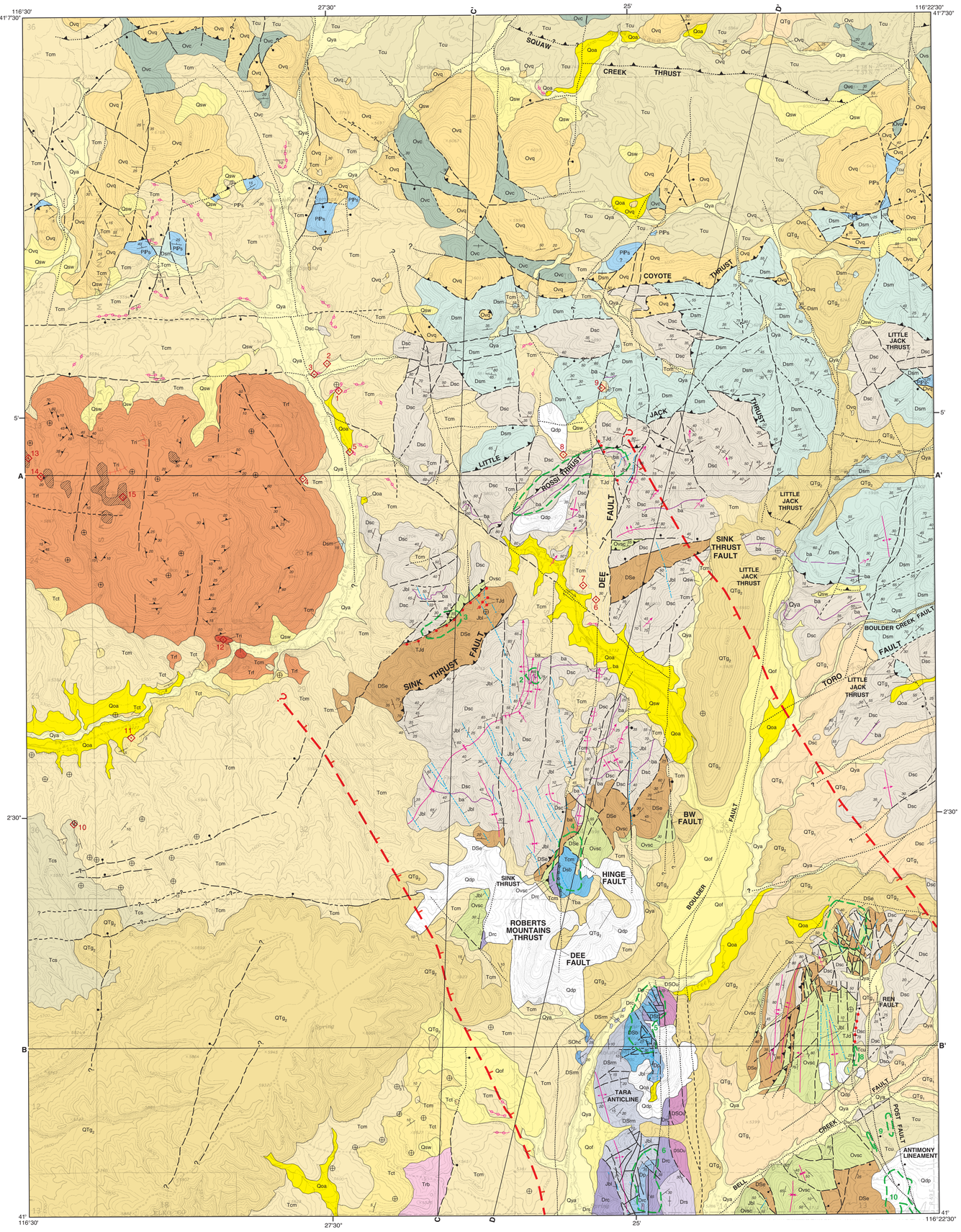
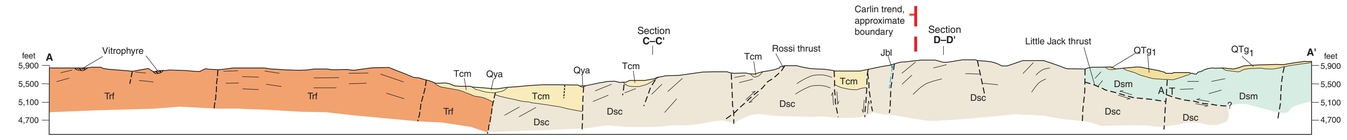
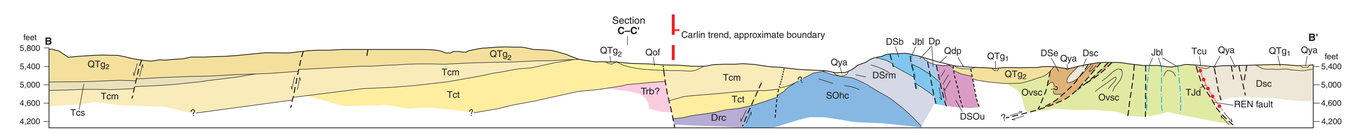


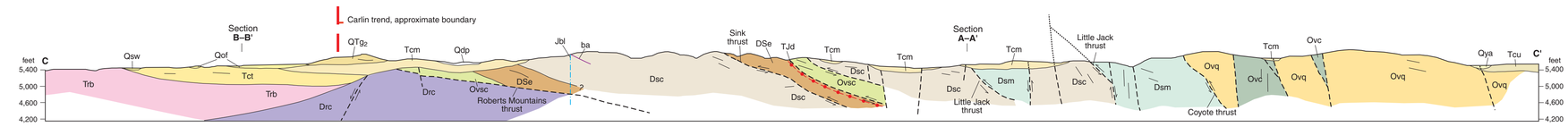
GEOLOGIC MAP OF THE SANTA RENIA FIELDS QUADRANGLE, ELKO AND EUREKA COUNTIES, NEVADA

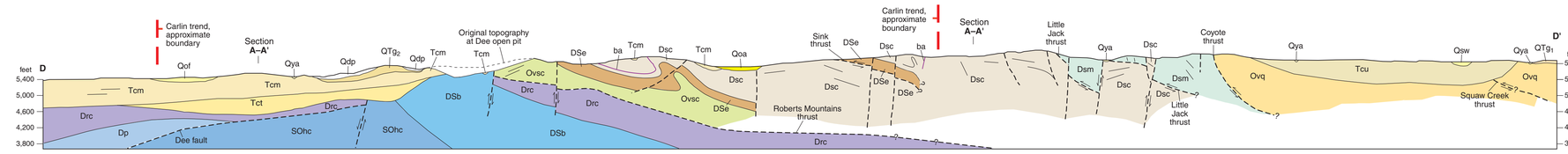
Ted G. Theodore, Barry C. Moring, Thomas Chadwick,
Paul J. Dobak, J. Kelly Cluer, and Robert J. Fleck

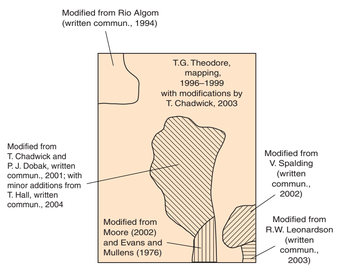
2006



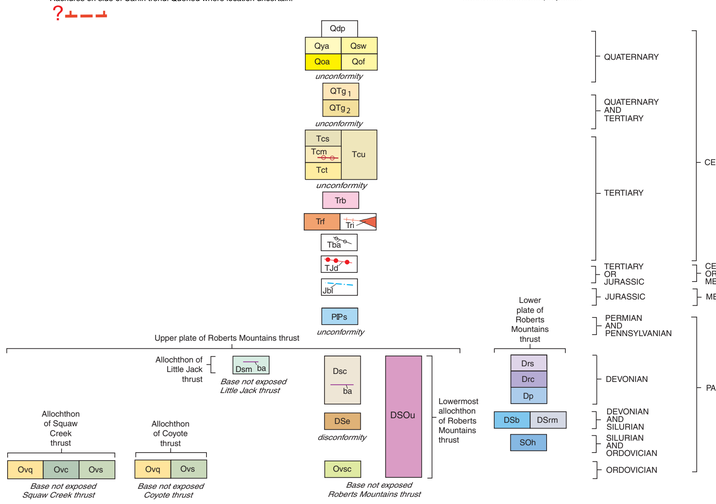








SOURCES OF GEOLOGIC DATA



Qdp **Waste dumps, tailings ponds, and other mine-related cover (Quaternary)** Outer limit of dumps and tailings ponds near mines as of late 2001, as well as active mining operations in general area of Meikle Mine as of 1998. Covered areas associated with haul roads present near Tara and Capstone-Bootstrap Mines are not shown.

Qya **Younger alluvium and fanglomerate (Quaternary)** Unconsolidated sand and gravel deposits. Include approximately 2- to 3-m-high locally raised benches adjacent to present-day active and intermittent streams, as well as some fanglomerate near upper reaches of major drainage in Boulder Creek near south boundary of quadrangle.

Qsw **Slope wash (Quaternary)** Locally includes talus deposits and landslide deposits, the latter near Antelope Creek.

Qoa **Older alluvium (Quaternary)** Unconsolidated gravel and sand deposits generally along flanks of major drainages. Locally underlies broad gently inclined benches as much as 25 m above present day active or intermittent drainages.

Qof **Older fanglomerate (Quaternary)** Broadly exposed unconsolidated cobble and boulder deposits flanking Boulder Creek mostly in southeast quadrant of quadrangle.

Gravel deposits (Quaternary and Tertiary) Unconsolidated, poorly sorted cobble and boulder deposits containing minor silt and sand. Present at several different erosion levels. Lower and younger level deposits (QTg_1) marked by deposits incised through, and largely reworked from, locally underlying gravel deposits (QTg_2). Older gravel deposits (QTg_2), cap topographically high, broad mesa near southwest corner of quadrangle. In this area includes:

QTg_1 **Younger gravel deposits** Contains unconsolidated rounded cobbles and boulders of chert and quartzarenite. Crops out in southeast quadrant of quadrangle, east of Boulder Creek where some Carlin Formation (Tcm) also may be present.

QTg_2 **Older gravel deposits** Contain abundant subrounded cobbles and boulders of quartzarenite. Represent paleo-fanglomerate deposits derived largely from broad expanse of Ordovician quartzarenite belonging to Vinini Formation, and cropping out widely in Beaver Peak Quadrangle to the east (Theodore and others, 2000b). Locally includes fragments derived from underlying Miocene air-fall tuff unit (Tcm) of Carlin Formation. Deposits are as much as 130 m thick on flat-topped mesa near southwest corner of quadrangle, but may be much thicker immediately west of Boulder Creek—as much as 600 m—in upper reaches of feeder channel to paleo-fanglomerate. Unit north of Joker 99 deposit may include some Carlin Formation. Shows slight angular discordance with underlying units (Tcm, Tct) of Miocene Carlin Formation. Unit continues to west-southwest into Willow Creek Reservoir SE Quadrangle where it is mapped by Wallace (2003b) as Middle and Upper Gravel Deposits Members of Pliocene(?) and Quaternary Gravel. To the north, unit also present in Toe Jam Mountain Quadrangle (Henry and Boden, 1999).

Carlin Formation (Miocene) Mostly drab unconsolidated cobble- and boulder-bearing silts and sands that contain variable proportions of white tuff. Although most cobbles and boulders are derived from various Paleozoic units, formation also includes variably rounded fragments of locally underlying Miocene rhyolite flows (Trf) and rhyolite of Boulder Creek (Trb). Crops out mostly in the western half of the quadrangle where formation is best exposed along moderately incised drainages and below ledges of resistant tuff and sedimentary breccia in the formation. Correlated with Carlin Formation of Regnier (1960). In this area includes:

Tcs **Silt and sand deposits** Mostly unconsolidated, poorly exposed silt and sand, but including widespread clay-rich areas that yield soft surfaces. Unit crops out only in approximately 2- to 3-km^2 area near southwest corner of quadrangle where it is approximately 70 m thick. Unit conspicuous by absence of white tuff and presence of abundant 2- to 4-cm wide, subrounded black chert fragments. Cobble-size fragments of chert are sparse. Also include angular fragments of brick red to ochre jasperoid as well as subrounded fragments of yellow and drab pinkish red tuffaceous sandstone derived from tuff unit (Tct) of formation.

Tcm **Silt, sand, and mudstone deposits including abundant tuff** Mostly unconsolidated poorly exposed silt, sand, and mudstone, as well as resistant 2- to 3-m-thick sedimentary breccias. Unit, as much as 400 m thick, contains abundant and widespread, generally well-laminated white tuff (red lines and circles). Tuff, locally as much as 15 m thick, may be continuous along strike for several hundred meters; some outcrops show extensive bioturbation. The tuff beds are commonly underlain by drab red-brown silty mudstone and overlain by sandy gray-brown mudstone. Base near south boundary of quadrangle locally marked by 2-m-thick sedimentary breccia. Sanidine that was separated from volcanic glass shards in 15 samples from 10 localities has been dated by $^{40}Ar/^{39}Ar$ methods (locs. 1-10, table 2). Apparent ages range from 15.1±0.08 to 14.4±0.08 Ma. Microprobe analyses of 13 samples of volcanic glass shards indicate K_2O contents between 6.11 and 6.91 weight percent (Fleck and others, 1998). In general area of NW¼ sec. 31, T37N, R49E, fracture and joint surfaces in 1- to 1.5-m-thick sedimentary breccia and chert-pebble conglomerate are coated with low-temperature quartz-adularia ± Mn-oxide mineral veins that have slightly elevated contents of Se (Fleck and others, 1998; Theodore and others, 2000b). Chert-pebble conglomerate typically weathers into 2-m-wide blocks that are scattered randomly on ground surface.

Tct **Welded tuff, silt, and tuffaceous sandstone** Widespread, variably welded, drab gray-green, yellowish to pinkish brick-red quartz crystal tuff in poorly exposed sequence of unconsolidated silt and some tuffaceous sandstone. Unit is as much as 30 m thick but south boundary of quadrangle. Welded tuff typically well bedded in 1-m-thick beds that comprise sporadic exposures as much as 50 m wide. Unit includes minor amounts of resistant sedimentary breccia, made up largely of angular chert fragments, that crops out in 2- to 3-m-thick ledges. Near west-central edge of quadrangle north of Antelope Creek, unit flooded by silica and heavily stained by drab orange to red-orange Fe-oxide minerals. Near base of unit, many outcrops of sedimentary breccia are silicified by open-space-filling opal and late-stage chalcedonic quartz. Extremely small crystals of sanidine that were separated from a sample selected from a 5- to 8-cm-thick layer in a 1-m-thick ash bed south of Antelope Creek (loc. 12, SW¼ sec. 30, T37N, R49E) have been dated by $^{40}Ar/^{39}Ar$ methods (table 2). Apparent age is 14.68±0.08 Ma.

Tcu **Undivided silts, sands, tuffs, and fanglomerate deposits** Crops out only in northernmost part of quadrangle.

Tpr **Rhyolite of Boulder Creek (Miocene)** Crops out only in small area—west of Boulder Creek near south edge of quadrangle—that is the northern end of several km-long body in Rodeo Creek NW Quadrangle to the south. Generally brick-red rubbly exposures of flow-banded, phenocryst-poor almost aphyric, peralkaline rhyolite flows. Mostly euhedral sanidine microphenocrysts—typically 0.2 to 1.0 mm wide and, at most, 5 to 7 volume percent—are set in holocrystalline finely intergrown (0.04-mm-long crystals) felted aggregate of generally aligned alkali feldspar needles and Fe-oxide minerals. Overlain by welded tuff, siltstone, and tuffaceous sandstone unit (Tct) of Carlin Formation. In Rodeo Creek NW and NE Quadrangles, includes, on average, approximately 600 ppm Zr, 30 ppm Th, 60 ppm Nb, 200 ppm Rb, 20 ppm U, and 200 ppm Ce (S. Ludington, written commun., 2003). Sanidine that was separated from three samples of rhyolite of Boulder Creek in the Rodeo Creek NW and NE Quadrangles, south and southeast of the Santa Renia Fields Quadrangle, has been dated by $^{40}Ar/^{39}Ar$ methods (table 2). Apparent ages range from 14.97±0.05 to 14.91±0.04 Ma.

Rhyolite of Antelope Creek (Miocene) Thick pile of numerous porphyritic rhyolite flows that crop out west of Antelope Creek near west boundary of quadrangle. Includes well-exposed vitrophyre (hachured). Contiguous and correlative with informally named Craig rhyolite of Bartlett and others (1991) that is mapped as unit Tcr by Wallace (2003) in Willow Creek Reservoir SE Quadrangle to the west. In this area includes:

Trf **Rhyolite flows** Multiple generally flow-banded gray, porphyritic to porphyry, holocrystalline to vitrophyric, rhyolite flows that form bold outcrops, and that locally weather brownish red. Flow bands mostly are horizontal, but also are contorted, in places yielding steep dips. Unit more than 500 m thick near west edge of quadrangle on the basis of drill hole collared in S½ sec. 13, T37N, R48E (E.A. Lauha, oral commun., 2002). In Willow Creek Reservoir SE Quadrangle, partly interfingers with Carlin Formation (Bartlett and others, 1991), and, in that area, total alkalis (Na_2O+K_2O) range from 5.3 to 9.4 weight percent, and SiO_2 ranges from 74.2 to 78 weight percent (Wallace, 2003b). Gray-brown groundmass commonly varies between 45 and 55 volume percent, and is generally spherulitic to microperthitic. Rhyolite is marked by conspicuous quartz phenocrysts, partially resorbed and broken, that average approximately 2–4 mm wide. Additional phenocrysts include sanidine, plagioclase (oligoclase to andesine), and ubiquitous but sparse (approximately several volume percent) highly Fe-oxide-mineral-stained orthopyroxene, mostly in glomeroporphyritic clots. Vitrophyric facies (hachured pattern) includes a light-gray matrix in thin section as well as well-developed perlitic cracks. Sanidine that was separated from three samples (locs. 13-15) has been dated by $^{40}Ar/^{39}Ar$ methods (table 2). Apparent ages range from 15.15±0.08 to 14.99±0.08 Ma. Overlain by silt, sand, and mudstone deposits, including abundant tuff unit (Tcm) of Carlin Formation.

Tri **Rhyolite intrusions and minor dikes** Small rhyolite body straddling Antelope Creek in NW¼ sec. 29 and NE¼ sec. 30, T37N, R49E., characterized by vertical flow banding that cuts surrounding gently dipping rhyolite flows (Trf). Unit also includes small number of 2- to 3-m-wide dikes that intrude rhyolite flows in SW¼ sec. 18, T37N, R49E, and probably represent self-intrusive phase of rhyolite flows. Sanidine that was separated from one sample obtained from body straddling Antelope Creek (loc. 12) has been dated by $^{40}Ar/^{39}Ar$ methods (table 2). Apparent age is 15.01±0.08 Ma.

Tba **Basaltic andesite dike (Eocene)** Crops out only at Dee Mine where present as prominent northstriking, irregularly distributed dark-gray dike. Contains abundant fresh plagioclase microlites and olivine phenocrysts, partly altered to calcite, set in a biotite-bearing, partly devitrified fine-grained groundmass (M.D. Ressel, oral commun., 2002). Apparent age, on the basis of matrix $^{40}Ar/^{39}Ar$, is 37.6±0.3 Ma (Ressel, 2000; see also Henry and Ressel, 2000).

TJd **Altered diorite dikes (Tertiary or Jurassic)** Iron-oxide-stained felsic diorite dikes that are dark-gray to pale-orange weathering. Dikes are altoriromorphic granular fabric. Oligoclase has been altered variably to kaolinite. Dispersed Fe-oxide minerals, probably oxidized pyrite, are present near oligoclase crystal boundaries and in areas of discontinuous, wispy millimeter-wide quartz veins. Crop out in N½ sec. 28 and SE¼ sec. 21, T37N, R49E, as well as along Post fault at REN Mine in NW¼ sec. 12, T37N, R49E, in the Sage Hen pit at the Rossi Mine in SE¼ sec. 15, T37N, R49E, and along a low angle fault in SW¼ sec. 21, T37N, R49E.

Jbl **Biotite lamprophyre dikes (Jurassic)** Most dikes are concentrated in general areas of the Dee and REN Mines where the dikes, respectively, have northwest and north strikes. Some also are present in the general area of the Tara Mine and the Rossi Mine. Generally fine grained, 1 to 3 m wide, and include strongly aligned felted aggregates of abundant euhedral biotite—as much as 50 volume percent—and lesser amounts of clinopyroxene. Groundmass feldspar, as calcic as andesine, generally clouded and altered to clay minerals. Dikes are yellow brown to orange where included sulfide minerals of superposed quartz-sericite-pyrite assemblages are oxidized. Where dikes are emplaced into calcite-rich wallrock, within several centimeters of their knife-edge contacts, they contain millimeter- to centimeter-wide, ovoid to angular xenoliths of spar calcite progressively converted first to garnet and then to clinopyroxene towards dike centers. Map unit includes the informally named Arturo dike exposed in the Dee Mine that has an apparent age greater than 147 Ma (Theodore and others, 1998). Unit also includes some porphyritic rhyodacite dikes at the Capstone-Bootstrap Mine (Moore, 2002). Lamprophyre dikes in quadrangle are correlative with lamprophyre dikes emplaced into 158-Ma (Arehart and others, 1993) Goldstrike intrusive complex approximately 5 km to south. Lamprophyre dikes were first dated as Jurassic by L. Snee (J. Conrad oral commun. cited in Ressel and Noble, 1998), and then subsequently dated between 147 and 166 Ma by many others (Ressel and Noble, 1999).

PIPs **Strathearn Formation of Dott (1955) (Early Permian and Late Pennsylvanian)** Generally poorly exposed strata, drab gray-brown to reddish brown ledges or rubble strewn slopes of mostly chert-pebble conglomerate similar to overlap assemblage deposits elsewhere in region (Roberts, 1964) and derived, in part, from reactivated highlands of Antler orogeny of Roberts and others (1958). Crops out in a number of small discontinuous bodies in the northern one-third of the quadrangle. Only lower part of formation, at most the basal 50 m, is present; upper contact where exposed is structural. Commonly includes poorly sorted chert and quartzarenite pebble, clast-supported, and structureless conglomerate. Variably rounded monocrystalline quartz grains and quartzarenite fragments are derived from quartzarenite of Middle and Late Ordovician Vinini Formation. Westernmost exposure near west edge of quadrangle is strongly recrystallized and includes abundant quartz overgrowths and complexly sutured grain boundaries. Upper parts of formation also onlap quartzarenite of Vinini Formation in upper plate of Coyote thrust in adjoining Beaver Peak Quadrangle to the east (Theodore and others, 2003b, 2004). Ranges in age from middle Late Pennsylvanian to middle Early Permian (see also, Berger and others, 2001; Theodore and others, 2000, 2003a).

UPPER PLATE OF ROBERTS MOUNTAINS THRUST

In this area includes allochthons of Squaw Creek, Coyote, and Little Jack thrusts, which apparently make up a tectonic package of rocks that were reactivated during the late Paleozoic Humboldt (see also Ketner, 1977) phase of Antler orogeny of Roberts and others (1958) and Roberts (1964). Initial reactivation involving mostly southeast-directed shortening during a short time interval between middle Late Pennsylvanian and middle Early Permian was followed by subsequent regional shortening in the Mesozoic and extension in the Tertiary.

Allochthon of the Squaw Creek thrust Ordovician Vinini Formation of Merriam and Anderson (1942) comprises strata in the upper plate of the Squaw Creek thrust and is exposed in a narrow, east-trending area near the north edge of the quadrangle. In this area includes:

Ovq **Quartzarenite of Vinini Formation (Ordovician)** Resistant, mostly massive light-orange buff to yellow ochre-weathering quartzarenite containing prominent well-rounded quartz granules. Prominent strata are 3 to 8 m thick and weather into highly disoriented 1- to 2-m-wide blocks. Locally includes less abundant siltstone and intraformational pebble conglomerate. Quartzarenite typically mature and made up of medium-grained, well-sorted fabrics of monocrystalline quartz grains showing size-specific rounding. Isolated exposures of quartzarenite near north edge of quadrangle contain locally abundant opal and low temperature chalcedonic silica/acaly mineral(s) assemblages that fill open spaces. Some detrital quartz grains also are recrystallized. Shale in green chert interbedded with quartzarenite approximately 30 m above trace of Coyote thrust near northwest corner of Beaver Peak Quadrangle includes *Cryptograptus schaeferi*, *Glossograptus* sp., *Nemagraptus* sp., (?)*Leptograptus*, and *Pseudoclimacograptus* sp. that are uppermost Middle Ordovician (Theodore and others, 2003b). Unit is apparently correlative with quartzarenite in upper member of Vinini Formation in Roberts Mountains (see also Finney and others, 2000).

Ovc **Chert of Vinini Formation (Ordovician)** Mostly chert, but includes some shale characterized by semi-continuous bedding surfaces. In places, contains intense dark brick-red Fe-oxide minerals along fractures spaced 20 to 30 per meter and oriented at high angles to projected trace of underlying Squaw Creek thrust. Provisionally assigned to Vinini Formation.

Ovs **Siltstone of Vinini Formation (Ordovician)** Reddish buff siltstone present only in small area near northeast corner of quadrangle. Provisionally assigned to Vinini Formation.

Allochthon of the Coyote thrust Made up mostly of quartzarenite and minor shale and chert of the Vinini Formation which crops out widely in the north-central part of quadrangle in upper plate of Coyoye thrust. In this area includes:

Ovq **Quartzarenite of Vinini Formation (Ordovician)** Moderately rounded ridges of mostly massive orange-brown- to drab ochre-brown-weathering quartzarenite. Locally includes pebble conglomerate. Lithological characteristics of unit are similar to quartzarenite in allochthon of Squaw creek thrust. Quartzarenite commonly is intensely recrystallized to white sucrosic hornfels near Coyote thrust that structurally cuts out lower parts of unit. Quartzarenite is brecciated and intensely fractured within several tens of meters of trace of Coyote thrust, and microphenocrysts—typically 0.2 to 1.0 mm wide and, at most, 5 to 7 volume percent—are set in holocrystalline finely intergrown (0.04-mm-long crystals) felted aggregate of generally aligned alkali feldspar needles and Fe-oxide minerals. Overlain by welded tuff, siltstone, and tuffaceous sandstone unit (Tct) of Carlin Formation. In Rodeo Creek NW and NE Quadrangles, includes, on average, approximately 600 ppm Zr, 30 ppm Th, 60 ppm Nb, 200 ppm Rb, 20 ppm U, and 200 ppm Ce (S. Ludington, written commun., 2003). Sanidine that was separated from three samples of rhyolite of Boulder Creek in the Rodeo Creek NW and NE Quadrangles, south and southeast of the Santa Renia Fields Quadrangle, has been dated by $^{40}Ar/^{39}Ar$ methods (table 2). Apparent ages range from 14.97±0.05 to 14.91±0.04 Ma.

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Allochthon of the Little Jack thrust Present in upper plate of Little Jack thrust and is most widely exposed in the east-central part of the quadrangle. In this area includes:

Dsm **Undivided chert melange unit of Slaven Chert of Gilluly and Gates (1965) (Devonian)** Commonly ridge-forming, marked by rubbly exposures that include chaotic depositional and intensely deformed tectonic fabrics. May include shale and chert of Vinini Formation (unit Ovsc). Unit typically weathers green gray with locally moderate amounts of yellow-brown Fe-oxide minerals. Striking feature of unit is absence of continuous bedding surfaces and presence of structurally transposed lithologic layering that yields flat-shaped chips whose shapes are controlled by closely-spaced foliation surfaces. Sequences dominated by somewhat more argillaceous chert and shale locally have highly contorted lithologic layering, including presence of numerous slip surfaces on individual outcrops. Such sequences yield broad areas of light-gray to tannish-gray debris-covered colluvial slopes. Generally, variably-colored millimeter- to centimeter-sized, angular to ovoid chert fragments set in either a chert matrix or ductile argillaceous matrix—some fragments have fabrics suggestive of soft-sediment deformation features. Fragmental nature of unit persists down to microscopic scale. Some sedimentary barite horizons (ba) present. Overall tectonostratigraphic thickness of unit is variable because of structural thinning to northwest. Unit marked by Fe-oxide-stained slip surfaces as much as 50–60 meters from trace of Coyote thrust at top of unit. Secondary strain-slip cleavage also is present in unit near Little Jack thrust at base of unit. Matrix locally includes Devonian radiolaria in Beaver Peak Quadrangle (Theodore and others, 2003b). Unit in Santa Renia Quadrangle includes Devonian conodonts in limestone interbed in NW¼ sec. 11, T37N, R49E (Theodore and others, 1998) and Devonian or younger entactinid radiolaria with bladed spines present in thin- bedded chert in NE¼ sec. 15, T37N, R49E. Unit may be correlative with Late Devonian sedimentological breccia and barite breccia unit of Slaven Chert in Shoshone Range (C.T. Wrucke, oral commun., 1999) and olistostromal unit above Devonian Scott Canyon Formation at Battle Mountain (Doebrich, 1994).

Lowermost allochthon of the Roberts Mountains thrust Present in upper plate of Roberts Mountains thrust, which crops out at the Dee and Capstone-Bootstrap Mines. This allochthon includes a number of thrusts within it and is exposed widely in the central and southeast parts of the quadrangle. In this area includes:

Dsc **Slaven Chert of Gilluly and Gates (1965) (Devonian)** Generally resistant, ridge-forming sequence of relatively thin-bedded, variably colored strata—including various shades of gray, black, brownish black, and green—of chert in rhythmically stratified sequences having mostly 2 to 4 cm between parting surfaces. May include shale and chert of Vinini Formation (unit Ovsc). Shale comprises generally less than 5 percent of sequences. Rocks have planar bedding surfaces and they weather typically to 2- to 5-cm-wide angular fragments. Near Dee and REN Mines, formation is tightly folded into numerous nappes (Cluer and others, 1997) that verge towards the east. Locally abundant sedimentary barite horizons (ba) present. Stratigraphic thickness of formation is difficult to establish because of folding and unmapped intraformational thrust faults. Numerous fossil localities in general areas of Dee (Hall, 2002) and REN Mines (Noble and Cellura, 2000; see also Noble, 2000) contain Devonian radiolaria, mostly entactinids with bladed spines, as does a sedimentary barite occurrence—0.5 m thick along a 1-m-long strike length—in NE¼ sec. 25, T37N, R49E. Conodonts obtained near apparent base of formation and near southeast corner of Beaver Peak Quadrangle include fauna indicative of Lower *Palmatolepis rhenana* Subzone (early late Frasnian) (Late Devonian) (Theodore and others, 2003b). Palmatolepid-polygnathid biofacies indicates outer-shelf or deeper water depositional setting.

DSe **Elder Sandstone of Gilluly and Gates (1965) (Devonian and Silurian)** Slope-forming, generally olive gray-green, dolomitic and calcareous very fine sandstone and coarse siltstone (using the size-classification scheme of Folk, 1968) and dark-gray shale that weather to various shades of yellow-gray brown and gray brown. Thickness of formation is approximately 100 m. Forms recessive exposures in central and southeast part of quadrangle. Locally, also includes some interbeds of chert as well as prominent sequence of chert near base correlative with Early Silurian. (Llandoverian) Cherry Spring chert of Noble and others (1997) in the northern Adobe Range (Hall, 2002). Near REN Mine, unit includes (1) some sequences of chert that are as much as 6 m thick, and have 8- to 10-cm-wide parting surfaces and 3-cm-wide knobby compaction structures, and (2) 1- to 2-m-thick, K-feldspar-rich, rhyolitic volcaniclastic rock locally near stratigraphic base of formation. Laminae in siltstone are defined by millimeter-sized, discontinuous, wispy layers that show some weakly developed, centimeter-scale crossbeds. Sandstone and siltstone commonly include angular detrital grains of quartz, K-feldspar (from 5 to 20 volume percent), white mica, biotite, and opaque minerals. In places, siltstone is partly recrystallized to spar and silty dolostone. Locally in SE¼ sec. 22, T37N, R49E, is late Llandoverian-Wenlockian (middle-late Early Silurian) on the basis of presence of mazueloid (A.G. Harris, written commun., 2000). Near the Dee Mine, two radiolarian localities in the basal Cherry Spring unit of the formation are Llandoverian (Early Silurian) (Hall, 2002). At the REN Mine, Noble (2000) reports presence of Devonian radiolaria near top of unit, and S.C. Finney (written commun., 2002) describes presence of middle Silurian graptolites at several localities.

Ovsc **Shale and chert of Vinini Formation (Late and Middle Ordovician)** Mostly dark gray to black shale and chert, including some argillite, that crop out in several discontinuous areas in the southeast quarter of the quadrangle. Strata are, in places, slope forming and poorly exposed, and elsewhere well exposed. Locally include thin (approximately 0.5 m) laminated gray micrite that weathers light gray to buff gray near top of unit. Black radiolarian chert near interior of top of unit contains flattened disc-shaped phosphate- and chalcedonic quartz-rich nodules that have been referred to as suppository chert (Earl Abbott, oral commun., 2000; see also Cellura, 2001). Structurally bounded sliver of unit approximately 3 km northwest of Dee Mine contains Middle and Upper Ordovician acritarchs in four horizons to a depth of 500 m below the surface (Theodore and others, 2003a). Numerous localities near REN Mine contain Middle and Late Ordovician graptolites (J.K. Cluer, unpub. data, 2003). Two localities north of Little Jack Creek in Rodeo Creek NE Quadrangle, approximately 10 km east of REN Mine, are lithologically similar to the unit, and they contain graptolite faunas indicating correlation with the Middle Ordovician *Hustedeograptus teretiusculus* Zone (Zone 10 of Berry, 1960) (Theodore and others, 2003b).

DSOu **Siliceous rocks undivided (Devonian to Ordovician)** Mostly siliceous mudstone, chert, siltstone, shale, sandstone, and quartzarenite that crops out in a narrow, approximately 2-km-long fault-bounded block east of the Capstone-Bootstrap and Tara Mines near the south edge of the quadrangle (Moore, 2002).

LOWER PLATE OF ROBERTS MOUNTAINS THRUST

Several formations in the general areas of the Dee (Dobak and others, 2000, 2001), Capstone-Bootstrap, and Tara Mines (Moore, 2002) in the south-central part of the quadrangle make up the lower plate of the Roberts Mountains thrust. The lower plate has been fragmented structurally during a number of tectonic events. The lower plate also is present at moderate depths in much of the southern half of the quadrangle on the basis of drilling data. For example, approximately 3 km northwest of the Dee Mine, at the Rodeo Creek Ag-Sb-Au mineralized occurrence, the Devonian Rodeo Creek Formation, the Devonian Popovich Formation, and the Silurian and Devonian Bootstrap unit of the Roberts Mountains Formation have been encountered between approximately 500- and 1,600-m depths below the surface (Theodore and others, 2003a). In this area includes:

Rodeo Creek unit of Ettner (1989) (Devonian) Crops out in two fault-bounded blocks near the Dee Mine and in the general area of the Tara Mine near the south edge of quadrangle. Unit represents strata transitional between commonly eugeoclinal rocks of Roberts Mountains allochthon and underlying largely carbonate rocks (Teal and Jackson, 2002). Top of unit structurally terminated by Roberts Mountains thrust. Basal contact with underlying Popovich Formation is depositional at the Carlin West open pit (Ettner, 1989). Age of unit is Middle Devonian or younger on the basis of 13 samples containing *Entactinosphaera* sp. radiolaria obtained from the Carlin West pit, approximately 10 km southeast of the quadrangle (Ettner, 1989). In this area includes:

Drs **Silty limestone subunit** Crops out only near the south edge of the quadrangle (Moore, 2002).

Drc **Chert subunit** Generally black, rhythmically well bedded, blocky chert that includes siliceous mudstone and chert, as well as minor interbedded sandstone and silty limestone near the Tara Mine (Moore, 2002).

Dp **Popovich Formation of Evans (1980) (Devonian)** Mapped only in the general areas of the Capstone-Bootstrap and Tara Mines. Medium to dark-gray carbonaceous silty limestone (Armstrong and others, 1998; Moore, 2002). Major host for gold deposits. Also includes significant Sb-Ag±Au vein-type mineralized rock at depth at Rodeo Creek mineralized occurrence (Theodore and others, 2003a).

DSb **Bootstrap limestone of Roberts Mountains Formation (Devonian and Silurian)** Crops out at the Dee, Tara, and Capstone-Bootstrap Mines; the latter locality includes the 275-m-thick type section (Evans and Mullens, 1976) that is made up of massive gray shoal and reef carbonate rock (Bettles, 2002). Present as wedge of shelfal material that overlaps the lower part of the Roberts Mountains Formation (Moore, 2002). At the Dee Mine, unit consists of two parts: (1) a near-surface, highly altered and structurally complex part, and (2) a lower, generally pristine part that has been examined to a depth of about 700 m below the open cut (A.K. Armstrong, written commun., 1998; see also Armstrong and others, 1998). The upper part at Dee probably includes some of the Devonian Popovich Formation. Where altered by decarbonatization, rocks have extremely low specific gravities and are variably stained pinkish gray. Where unaltered at depth, unit is a massive gray sequence of various types of limestone that include echinoderm-brachiopod-wackestone, echinoderm packstone, peloid-mud lump-echinoderm packstone, micrite, and many others. Almost all include sparse quartz silt and dolomite, and rhombs of the latter are, in places, concentrated in stylolites. Fractures typically are filled by spar calcite. Age of unit is well established as Late Silurian and Early Devonian on the basis of a large number of biostratigraphic determinations using conodonts (A.G. Harris, written commun., 2001). However, at the type section, the unit is restricted to the Early Devonian (Evans and Mullens, 1976).

DSrm **Roberts Mountains Formation (Devonian and Silurian)** Crops out near Capstone-Bootstrap Mines. Planar laminated, gray carbonaceous silty limestone (Moore, 2002).

SOhc **Hanson Creek Formation (Silurian and Ordovician)** Crops out in a small exposure south of the Dee Mine and west of the Capstone-Bootstrap Mine near the drainage bottom of Boulder Creek. Massive to thick-bedded gray bioclastic sandy and silty dolostone (Moore, 2002).

Contact

Fault, normal and high angle reverse, and strike slip Showing dip where known. Bar and ball on downdropped block of fault. Long dashed where approximately located; short dashed where inferred; dotted where concealed; queried where uncertain. Arrows indicate sense of displacement.

Thrust fault Sawteeth on upper plate. Showing dip where known. Long dashed where approximately located; short dashed where inferred; dotted where concealed; queried where uncertain.

Strike and dip of bedding
Inclined — Vertical — Overturned — Horizontal

Strike and dip of volcanic flow layers
Inclined — Horizontal

Folds Showing trend and plunge of axial trace.
Anticline — Syncline
Overturned syncline — Overturned anticline

Minor folds Showing trend and plunge of hingeline.
Minor anticline — Horizontal minor anticline
Minor syncline
Minor overturned folds, showing senses of vergence.
Horizontal minor overturned fold, showing sense of vergence.
Minor coaxial folds, showing polyclinal senses of vergence.
Horizontal minor coaxial fold, showing polyclinal senses of vergence.

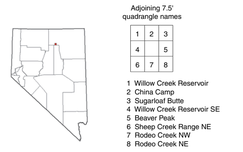
Lineations, stretching and cleavage intersections with bedding
Showing trend and plunge.
Inclined — Horizontal

$^{40}Ar/^{39}Ar$ locality Sample locations, table 2, in text.

Mine or major mineralized occurrence Approximate outer limit of open cut of mine or approximate surface projection of mineralized rock.

1. Rossi barite mine
2. Queen barite mine
3. Rodeo Creek silver-antimony±gold-mineralized occurrence
4. Dee gold mine
5. Bootstrap-Capstone gold mine
6. Tara gold mine
7. Joker 99 gold-mineralized occurrence
8. REN gold mine
9. East and West Banshee gold-mineralized occurrences
10. Meikle gold mine

Approximate outer limit of the Carlin trend of gold deposits Projected to surface. Hachures on side of Carlin trend. Queried where location uncertain.



Scale 1:24,000
0 0.5 1 kilometer
0 0.5 1 mile
0 1000 2000 3000 4000 5000 feet
CONTOUR INTERVAL 20 FEET
Base map: U.S. Geological Survey DRG Santa Renia Fields 7.5' Quadrangle, 1970
Transverse Mercator projection

See accompanying brochure for tables, references, and descriptions of the geologic framework and structural geology of the Santa Renia Fields area.

Note: This map is one of three geologic maps recently published by the Nevada Bureau of Mines and Geology that cover the northern part of the Carlin trend. The other two maps are by Moore (2002) and Keith (2003). Each of these maps shows similar geology but differs on significant aspects, due in part to the different scales of the maps. This statement is intended neither to criticize nor to favor the interpretations of any of the maps. We greatly appreciate the efforts of all the geologists involved in these maps and their willingness to publish them through the Nevada Bureau of Mines and Geology. Capable geologists commonly disagree about all aspects of geology, and disagreement should be particularly expected in this