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Some Tertiary Rocks and Mineralization of the Tonopah District—Interpretations and Reinterpretations.

Stop 1. Mizpah Formation. Old Powder House. [38.07997, -117.22496; NAD83] Exposures of plagioclase-hornblende-pyroxene-biotite trachyandesite to dacite lavas and breccias are found along the road here. The Mizpah Formation is the major ore host in the Tonopah District. The large equant plagioclase are distinctive, even in strongly hydrothermally altered rocks. Nolan (1935, p. 23) reported that the Mizpah is at least 610 m thick in the main part of the district. This considerable thickness is not observed to the north in outcrop. The thick section in the district and the occurrence of mostly lavas and breccias in the district with more lahars to the north all suggest that the center for the composite or compound Mizpah Formation volcano was probably near or south of the main Tonopah district. Biotite from two Mizpah samples yielded a K-Ar age of ~20.5 Ma.

The Mizpah is underlain in the subsurface in the district and at the surface about 9 km to the north by the Tonopah Formation, another ore host. In the district, according to Nolan (1935), the Tonopah Formation consists of interbedded silicic ash-flow tuffs, tuffaceous sedimentary rocks, flow-banded rhyolitic lavas, volcanic breccias, and andesite and basalt lavas (Sandgrass Andesite). The andesite lavas are reported to be interbedded with the silicic rocks of the Tonopah Formation, and they reportedly resemble the Mizpah Formation (Nolan, 1935, p. 18). The breccias, according to Nolan (1935, p. 15) contain fragments of rhyolitic and andesitic rocks that are not definitely correlatable to any in the district. In the subsurface, the Tonopah Formation is locally at least 300m thick (Nolan, 1935, p. 16), with no base exposed. The pre Tertiary basement was not encountered in the district; to the north it is Ordovician(?) marine rocks and Cretaceous granitic rocks. Ash-flow tuff from the area of Tonopah Formation crop out north of the district yielded a zircon fission-track age of 34.8± 4.2 Ma. The rhyolitic intrusive and lava unit yielded a zircon fission-track age of 24.3± 2.8 Ma.

Because of lack of access underground, we are dependent on Nolan’s (1935) interpretations (and reinterpretations of earlier work) of the district units and stratigraphy. If the ~35 Ma age of a tuff in the Tonopah Formation is correct, this is the oldest volcanism in the Tonopah area. But it is not clear whether these tuffs and breccias are locally derived or from more distant sources. Also, it is possible that the intermediate and mafic volcanic rocks described in the Tonopah Formation in the district are sills of Mizpah Formation and related rocks. The 24 Ma rhyolitic lavas and intrusive rocks dated to the north of the district presumably correlate with similar rocks described in the district; these are the earliest certain local magmatism. An ash-flow tuff, correlated by Bonham and Garside (1979, p. 41) with the 24-26 Ma tuff of White Blotch Spring, crops out north of the district and was reported to lie between the Tonopah and Mizpah Formations. The tuff of White Blotch Spring has its source in the Kawich caldera 60 km to the east. Mizpah Formation magmatism is apparently followed closely (based on K-Ar dating) by probable caldera-forming ash-flow tuffs of the Fraction Tuff (Bonham and Garside, 1979). Is the Mizpah part of the western andesite assemblage (mainly equivalent to rocks of the ancestral Cascades magmatic arc; e.g., John, 2001), and is the subsequent Fraction magmatism also then Cascades arc or are both interior andesite-rhyolite assemblage. Alternatively, is Fraction magmatism an early representative of bimodal magmatism (Christiansen and Yeats, 1992)?

Stop 2. Megabreccia blocks in the lower part of the King Tonopah Member of the Fraction Tuff. [38.07884, -117.23175; NAD83] The King Tonopah Member lies directly on the Mizpah about 1 km north of Tonopah. The King Tonopah is lithic rich, moderately to densely welded tuff, containing phenocrysts of plagioclase, alkali feldspar, rare vermicular quartz, and accessory biotite, hornblende, augite, and sphene. In this area, near its base, it contains megabreccia blocks (up to 5x14 m) of flow-banded rhyolite and Mizpah andesite.

Stop 3. King Tonopah Mine. [38.08606, -117.22193; NAD83] The following is summarized from Bonham and Garside (1979, p. 119-121). In 1946, Calumet and Hecla followed a suggestion by Nolan (1935, p. 49) and explored along the Halifax fault north of the district. They found quartz-sericite-adularia alteration on the dump of the King Tonopah shaft, which was sited just west of the Halifax fault, in footwall Mizpah Formation. Vein mineralization was originally explored at ~70 m, where adularia was recognized microscopically (Spurr, 1906). Subsequent drilling encountered mineralization in the Mizpah at about 250 m depth. American Smelting and Refining drilling in 1950 defined a mineralized quartz vein, and Homestake and Summit King Mines rehabilitated the shaft and drove a crosscut northerly to hit the vein. This 2.44 m vein contained high-grade Ag-Au mineralization with significant pyrargyrite and argentite. This mineralization is similar to that of the main district. Summit King apparently mined 15,000 to 20,000 tons of ore (30 oz/ton Ag and 0.3 oz/ton Au); possibly up to 30,000 tons were mined (Tonogold Resources, http://www.tonogold.com/s/KingTonopah.asp). Also, some direct-shipping ore was mined in 1958-1961 by leasers. In the late 1970s, drilling by Huston Oil and Minerals encountered more mineralization and extensions of the previously discovered veins (Tonogold Resources, http://www.tonogold.com/s/KingTonopah.asp). The veins at the King Tonopah are apparently cut off by the northeast dipping Halifax fault. The Tonopah Formation is present below the Mizpah at 127 m depth in a drill hole north of the King Tonopah Mine (Barker, 1986, p. 59).

Stop 4. Megabreccia within the King Tonopah Member. [38.09253, -117.21858; NAD83] Nolan (1935) considered the Fraction Breccia (now the Fraction Tuff) to be post Tonopah-style mineralization. However, the breccias mapped as Fraction Breccia in the district by Spurr (1906) and Nolan (1935) are probably a part of the lower Siebert Formation as redefined by Bonham and Garside (1979). The main ash-flow tuffs of the Fraction Tuff are considered to be pre-ore, based on that interpretation and K-Ar dating (Bonham and Garside, 1979, p. 58). The King Tonopah Member of the Fraction occupies the hanging wall of the Halifax fault just east of the King Tonopah Mine. Bonham and

Garside (1979, p. 51-54) reported that the unit consisted of two members separated by a cooling break which included sedimentary sandstone and breccia; however, Barker (1986) argued that they are parts of the same unit. A brief re-examination of the contact area about 1 km east of the mine suggests that the break between the upper and lower King Tonopah Member may be a zone of megabreccia and mesobreccia infusion. There are blocks within the tuff up to several meters in diameter. The zone of megabreccia is apparently associated with local development of vitrophyre, possibly only giving the appearance of a cooling break. Barker (1986, p. 93) proposed that the source vent of the King Tonopah Member was in this area. However, the outcrops of pre King Tonopah Mizpah severely limit the size of any such caldera. A source caldera could be concealed to the southeast, in Ralston Valley and under post-Fraction Brougher Rhyolite domes. The megabreccia and mesobreccia blocks in this interpretation would be in near-caldera outflow.

Bonham and Garside (1979, p. 55) argued that at least the upper part of the King Tonopah Member is younger than the Tonopah Summit Member, which is outflow in this area and intracaldera south of Tonopah. Barker (1986) reported that the Tonopah Summit Member in the area of his study unconformably overlies the King Tonopah (at least the lower King Tonopah as mapped by Bonham and Garside (1979)). If there is no cooling break between the lower and upper King Tonopah, it does not seem possible for the Tonopah Summit to have been erupted during that interval, as originally suggested by Bonham and Garside (1979, p. 55). A breccia unit of the King Tonopah (Tfbx), interpreted as equivalent to both upper and lower King Tonopah (Tfkl, Tfku) lies on the Tonopah Summit Member (Tft) in many areas south of Tonopah (see Stops 5 and 6). K-Ar and zircon/apatite fission-track dating did not resolve the Fraction age questions. K-Ar ages of the King Tonopah range from 21.5 to 18.7; disregarding the 21.5 age, which is older than the underlying Mizpah, the other four ages average 19.6 Ma. Three K-Ar ages on the Tonopah Summit Member (2 biotite, 1 alkali feldspar) average 16.7 Ma (Bonham and Garside (1979, Table 4). These were thought to be too young, probably reflecting hydrothermal alteration related to the Oddie Rhyolite magmatism in the Divide and Tonopah Districts. Fission-track ages (17.0±1.3 Ma on zircon and 18.4±3.1 Ma on apatite) have too much error to be significantly helpful. The Tonopah Summit is older than the 17 Ma Heller Tuff (an outflow unit presumably from a remote source) and is clearly younger than 20.5 Ma Mizpah.

Stop 5. <u>Megabreccia blocks in the breccia unit of the King Tonopah Member.</u> [38.01727, -117.21655; NAD83] Megabreccia blocks up to 400 m long are found in the breccia unit of the King Tonopah about 4 km south of Tonopah (Bonham and Garside 1979, p. 52). The breccia unit was so named because of weak to pervasive brecciation, which is confined to the unit itself. It was considered by Bonham and Garside (1979) to be equivalent to the unbrecciated and petrographically similar King Tonopah units in the vicinity of the King Tonopah Mine. The Tfbx lies on the Tonopah Summit Member, which is interpreted as an intracaldera unit in the area between Tonopah and Klondyke. The Tonopah Summit Member is over 420 m thick in a shaft in the Divide District; no base was penetrated. Probable megabreccia and a caldera wall are found about 1 km north of the Klondyke District. With a north margin just south of Tonopah, the caldera would be about 15 km in north-south dimension, and was presumably underlain by a large magma chamber.

Stop 6. Tfbx unit and underlying bedded units, road cut on old highway. [38.00339, -117.24069; NAD83] The Tfbx lies on bedded tuffaceous units that have low-angle and trough cross bedding and slump folds. These are possible surge deposits. The tuff below these bedded rocks could be the Tonopah Summit Member, but it was mapped within the Tfbx member by Bonham and Garside (1979, Plate 1). Both this stop and stop 5 demonstrate the Tft-Tbx stratigraphic relations. Is it possible that Tfbx does not correlate with the upper and lower units of the King Tonopah Member? A contact between Tfkl and Tfbx is present about 1.5 km north of Tonopah; does that map scratch contact represent the end of brecciation in the Tfbx unit or a boundary with a different unit? In the 1970s (Bohnam and Garside, 1979), the relationship was considered equivocal.

Stop 7. Tonopah Mining District; Tonopah Historic Mining Park. [38.06947, -117.22766; NAD83] The area of open stopes and caved ground (glory hole) on the southwest flank of Mt. Oddie is the area of the original discovery in 1900. The veins crop out in Mizpah Formation here, but mineralization is only present in the subsurface to the northwest. The open stopes that can be seen (but are fenced) in the vicinity of the Silver Top shaft (Valley View claims) generally have attitudes of 50º-75º, 45-60ºS. In the vicinity of the Burro stope, just south of the Mizpah shaft, veins of similar strike dip steeply north. The area of these veins in the most intensely hydrothermally altered in the district, with overlapping selvages of quartz-sericite-adularia alteration. The potassic zones grade outward to intermediate argillic and propylitic. The veins exposed at the surface are apparently relatively steep splays off of the Tonopah fault, a “recumbent crescent” or “anticline-shaped” compound fault having limbs with relatively shallow (commonly 30º or less) dips. A contour map of the productive zone at Tonopah suggests a domed shell, deepening toward the northwest (Nolan, 1935, Fig. 3).

The low-angle faulting in the district predates mineralization (variably dated at 17-19 Ma), and later (high-angle?) faults offset veins. Dreier (1984) and Seedorff (1991a, b) proposed that the above-described features indicate large-magnitude (ca. 50%) extension. Seedorff (1991a) proposed that magmatic heating of the crust facilitated this extension. Dreier (1984), using an unpublished cross section (below) by T.B. Nolan, reported that “many veins at Tonopah also occurred in downward-flattening, low-angle normal faults that rotated strata antithetically.” The cross section definitely shows the low-angle faults, in many respects better than Nolan’s (1935) block diagram. However, it is difficult to define areas of downward flattening or antithetic strata rotation (see figure below). If the district is on the north edge of a caldera, there should be pre- and post-caldera faulting associated with it.

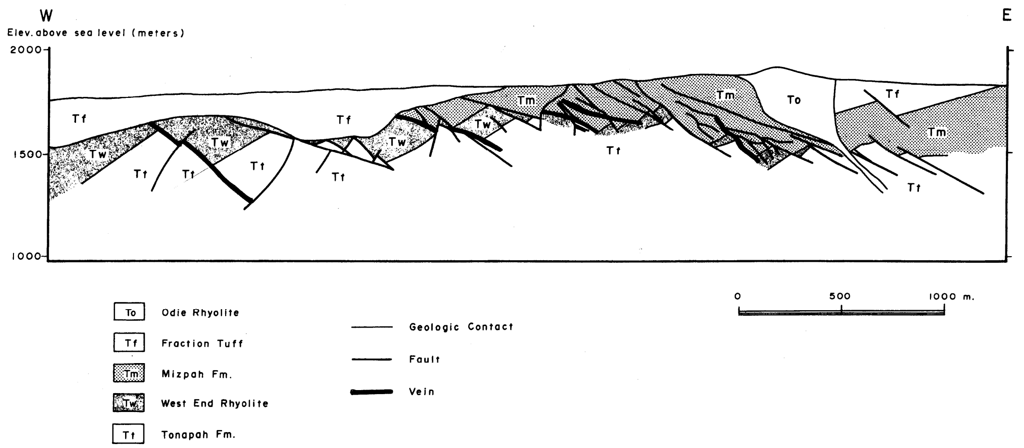


Figure 12. East-west cross section through the Tonopah mining district; after an unpublished, undated cross section by Nolan.

From Dreier (1984)

Two intrusive rock units, the West End Rhyolite and the Extension Breccia, are found along the Tonopah fault, which commonly separates the Mizpah and Tonopah Formations in the subsurface (Nolan, 1935; Fahley, 1981, p. 18). These units have chilled margins and smaller, dike-like bodies off of them. They have phenocrystic quartz, and 25% to over 50% breccia fragments (Nolan, 1935; Campbell, 1931; Fahley, 1981). The breccia fragments include black shale and limestone, presumably from the underlying Paleozoic rocks. They do not crop out at the surface and are probably hydrothermally altered everywhere in the underground workings. These silicic units are post-Mizpah and pre-mineralization in age (say between 20.5 and ~18.5 Ma), and represent magmatism closest in age to the mineralization. They may be a part of the Fraction caldera magmatism. So, is the intermediate sulfidation epithermal mineralization of the Tonopah District related to the interior andesite-rhyolite magmatic assemblage, the western andesite assemblage, or the bimodal basalt-rhyolite assemblage (see John, 2001)?

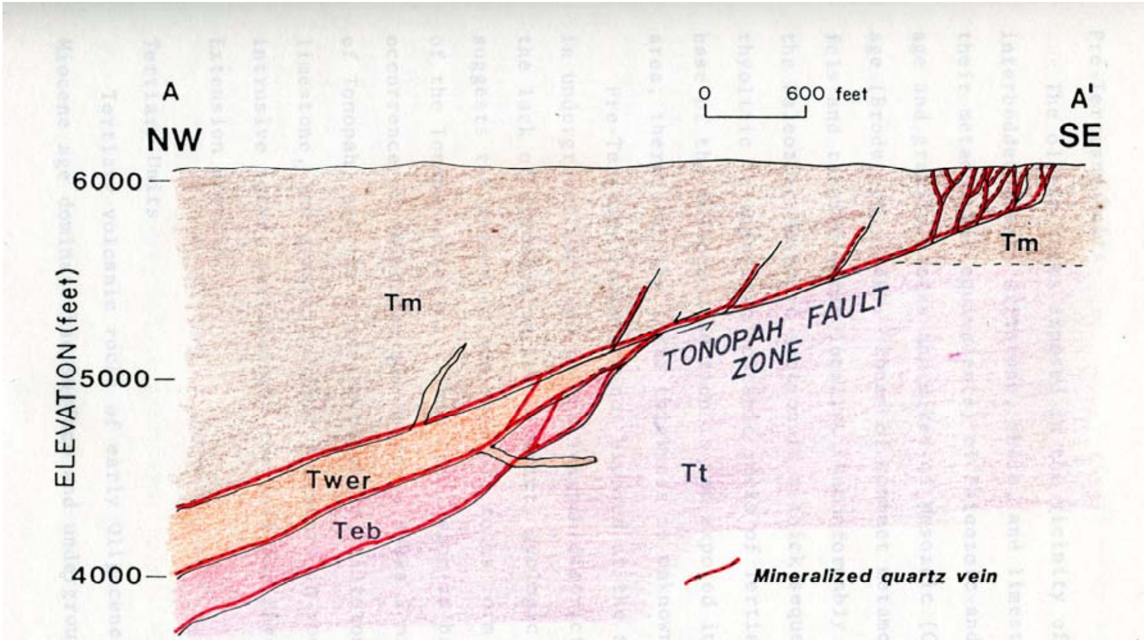


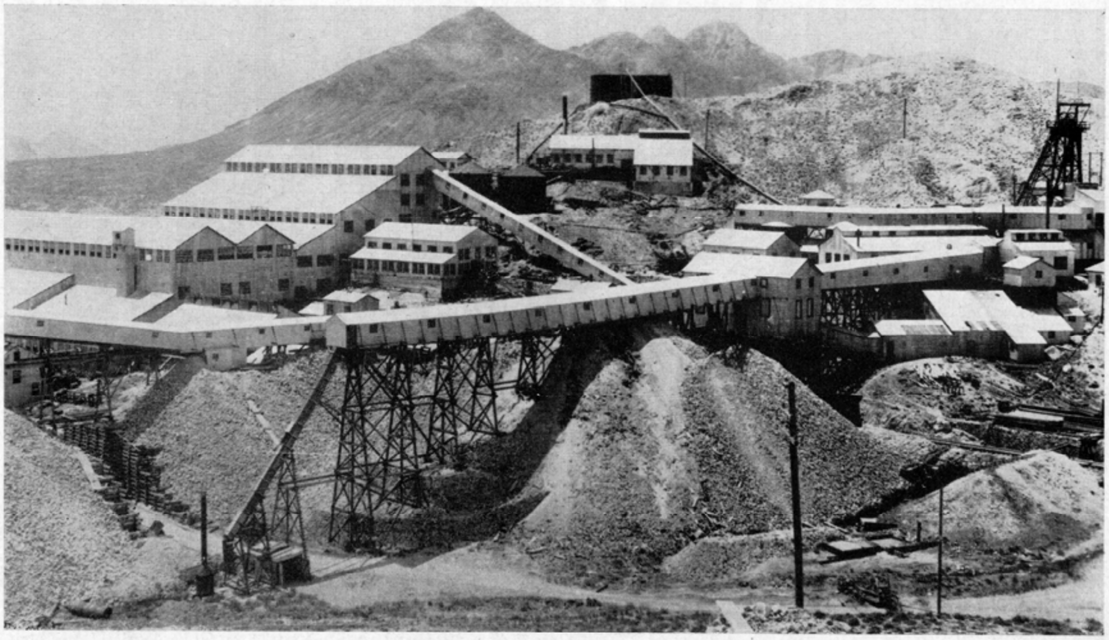
Figure 7: Generalized cross-section A-A' through the main part of the Tonopah district, looking northeast. For explanation see Figure 6.

From Fahley (1981)

A sample of adularized and sericitized Mizpah Formation from the Valley View vein (Silver Top shaft area) yielded a K-Ar age of 18.1±0.7 Ma (K_2O = 7.36%) (Bonham and Garside, 1979, p. 114; Garside and others, 1981). A small amount of relatively coarse adularia was collected recently from a narrow veinlet in Mizpah from a piece of mine waste (probably from the Silver Top Mine) in the roadbed to the grizzly.

Stop 8. [Tonopah] Belmont Mine [38.07142, -117.21741; NAD83] The Tonopah-Belmont Mining Company was formed in 1902. There were two deep vertical shafts, 365m and 585 m, with underground workings covering almost 63 km. The company shipped ore to the mill at Millers until 1912, when its own 60-stamp mill was built. The mill had a capacity of 500 tons. During its years of activity, 1912-1923, it was regarded as one of the country's best equipped and most efficient silver cyanide mills.

According to Carpenter and others (1953, p. 139), "The Tonopah Belmont mill closed in 1923; much of its equipment was sold to other companies. In 1927 the buildings and remaining equipment was sold for a relatively small sum; leaving only the concrete foundations on the hillside as a reminder of the finest silver cyaniding mill of its day in the United States."



(8) Tonopah Belmont mine and mill, 1913.

From Carpenter an others (1953)

Adularia separated from a sample of vein material from the Belmont dump (Bonham and Garside, 1974, p. 47; 1979, Table 4) yielded a K-Ar age of 19.1±0.4 Ma. The sample was described as "vein material consisting of adularia with intergrowths of sericite, sulfides, and quartz." Based on the 12% K_2O reported, the sample must have been fairly pure. I could not find visible adularia in vein material from this dump on a recent visit.

Nolan (1935, p. 30) reported that the Halifax fault zone is named for the Halifax Mine, in which it is well exposed. The mine name is apparently mislocated on the Tonopah 7.5-minute topographic map; Fahley (1981, Plate 1) shows it at an unnamed shaft symbol much closer to the Belmont. The Halifax fault strikes northerly, dips 35–40^o east, and is exposed just east of the Belmont shaft. The Halifax shaft, located 300 m east of the Halifax fault at the Belmont shaft, was in ore at the 1000 (~300 m) level (map in the T.B. Nolan collection; http://www.nbmg.unr.edu/scans/4840/48400732.pdf and http://www.nbmg.unr.edu/scans/4840/48400881.pdf). However, Nolan (1935, p. 30) reported the Halifax fault was exposed in the 1100-foot level of the Halifax Mine. Based on an estimated dip of the Halifax fault, the ore at the 1000 level was probably in the footwall just below the fault. The fault is a zone, and it may have several strands.

According to Nolan (1935, p. 31), "a member of the Halifax fault zone terminated the Belmont vein eastward on the upper levels of the Belmont Mine, and other members have cut the Halifax vein into several segments…" Nolan (1935, p. 48) also reported that "work in the Halifax and other eastern mines leads to the conclusion that it was only locally possible for the ore solutions to penetrate this zone." Nolan (1935, p. 31) reported that the total amount of premineralization movement on the Halifax was probably more than 600 m, and the postmineralization movement was believed to be somewhat less than 450 m. Post-mineralization movement may be only 100–265 m (F. Saunders, quoted in Fahley, 1981, p. 28).

Nonetheless, Tonopah-style mineralization has been encountered in the hanging wall of the Halifax fault (J. Muntean, oral communication, 2009), and is a viable exploration target.

Stop 9. HASBROUCK PEAK [37.99185, -117.26539; NAD83]
The following is copied from Callicrate and others (2005):

The dump of the Tonopah Hasbrouck Mine is on the hillside. Cordex Exploration Co. defined a geologic resource of an estimated 5 million tons of ore containing 0.04 opt gold and 0.7 opt silver (Graney, 1985). Several companies including FMC Gold and Franco-Nevada have investigated the Hasbrouck Peak property. Disseminated gold deposits at Hasbrouck Peak are located in strongly silicified pyroclastic, volcanic-clastic, and tuffaceous sedimentary rocks of the Miocene Siebert Formation. Funnel-shaped areas of silicification, centered on major hydrothermal conduits are surrounded by argillic alteration. The alteration zoning, inward from relatively unaltered rock, progresses from quartz + illite + montmorillonite to quartz + illite to quartz + adularia (Graney, 1985). Fine-grained disseminated pyrite + electrum + acanthite mineralization accompanied this alteration, and siliceous hot spring sinter was deposited at the surface at the same time. Graney (1985) reported that disseminated precious metal mineralization formed 100-500 feet below this paleosurface. Late-stage hydrothermal breccias contain pyrite, acanthite, electrum, and minor pyrargyrite. Trace amounts of chalcopyrite and stibnite are also present. Gangue minerals include quartz and adularia (with calcite and minor fluorite in vugs).

Several K-Ar ages on adularia and muscovite from Hasbrouck average about 16 Ma (Bonham and Garside, 1979, Table 4).

References:

Barker, Walter Blaine, 1986, The Tertiary igneous terrain in the vicinity of the King Tonopah mine, Tonopah, Nevada: An exploration case study [M.S. thesis] University of Arizona, Tucson, 119 p.

Bonham, H.F., Jr., and Garside, L.J., 1979, Geology of the Tonopah, Lone Mountain, Klondike, and northern Mud Lake Quadrangles, Nevada: Nevada Bureau of Mines and Geology Bulletin 96, 68 p.

Bonham, H.F., Jr., Garside, L.J., and Silberman, M.L., 1972, K-Ar ages of ore deposition at Tonopah, Nevada: Isochron/West, no. 4, p. 5-6.

Callicrate, T., Leavitt, E., O'Malley, P., and Crafford, E.J., eds., 2005, Field Trip Guidebook 1, Geology and structural controls of the precious metal deposits of the

Walker Lane and south-central Nevada, May 11-13, 2005: Geological Society of Nevada, Symposium 2005, Window to the World, 191 p.

Campbell, I., 1931, The petrography of the Tonopah mining district, Nevada [Ph.D. thesis]: Harvard University.

Dreier, J., 1984, Regional tectonic control of epithermal veins in the western United States and Mexico: Arizona Geological Society Digest, v. 15, p. 28-50.

Fahley, M.P., 1981, Fluid inclusion study of the Tonopah District, Nevada [M.S. thesis]: Colorado School of Mines, Boulder, 106 p.

Garside, L.J., Bonham, H.F., Jr., Ashley, R. P., Silberman, M. L., and McKee, E. H., 1981, Radiometric ages of volcanic and plutonic rocks and hydrothermal mineralization in Nevada: Isochron/West, no. 30, p. 11-19.

Graney, J.R., 1985, Geology, alteration, and mineralization at Hasbrouck Mountain, Divide district, Esmeralda County, Nevada [M.S. thesis]: University of Nevada, Reno, 106 p.

John, D.A., 2001, Miocene and early Pliocene epithermal gold-silver deposits in the northern Great Basin, western United States: Geologic setting, distribution, and relationship to magmatism: Economic Geology, v. 96, p. 1827-1853.

Ludington, Steve, Cox, D.P., Leonard, K.R., and Moring, B.C., 1996, Cenozoic volcanic geology of Nevada: Nevada Bureau of Mines and Geology Open-File Report 96-2, p. 5-1 to 5-10.

Nolan, T.B., 1935, The underground geology of the Tonopah mining district, Nevada: Nevada Bureau of Mines and Geology Bulletin 23, 49 p.

Nolan, T.B., 1930, The underground geology of the western part of the Tonopah mining district, Nevada: University of Nevada Bulletin, v. 24[9], no. 4, 35 p.

Seedorff, E., 1991a, Magmatism, extension, and ore deposits of Eocene to Holocene age in the Great Basin -- Mutual effects and preliminary proposed genetic relationships, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., Geology and ore deposits of the Great Basin: Geological Society of Nevada, symposium proceedings, Reno, p. 133-178.

Seedorff, E., 1991b, Royston district, western Nevada - a Mesozoic porphyry copper system that was tilted and dismembered by Tertiary normal faults, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., Geology and ore deposits of the Great Basin: Geological Society of Nevada, symposium proceedings, p. 359-391.

Spurr, J.E., 1905, Geology of the Tonopah mining district, Nevada: U.S. Geological Survey Professional Paper 42, scale 1:16130.