Guide for the Earth Science Week Field Trip, October 12 and 13, 2013

Nevada Bureau of Mines and Geology Educational Series E-53

Mapping the Geology around the Desert Research Institute and Truckee Meadows Community College

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National Earth Science Week (ESW) 2013 encourages people everywhere to explore the natural world and learn about the geosciences. The Nevada Bureau of Mines & Geology (NBMG), University of Nevada, Reno; Desert Research Institute (DRI); and Truckee Meadows Community College (TMCC) welcome you to participate in the sixteenth annual Earth Science Week field trip. In keeping with the National ESW theme, "Mapping Our World," this year's trip will focus on identifying rocks and minerals, then mapping the geology around the NBMG office on the DRI campus. You'll be able to collect volcanic rocks and several minerals that are characteristic of the hydrothermal (geothermal) alteration associated with volcanoes that were active in the Reno area about 16 million years ago.

This year's trip—a slow walking trip—will be centered on the Great Basin Science Sample and Records Library (figs. 1 & 2), NBMG's new building for information, publication sales, geologic and topographic maps, and geological samples, on the west side of the DRI campus, **2175 Raggio Parkway**, Reno, NV 89512. We will start **promptly at 8:00 a.m. each day**. The trip is free and open to the public. Be sure to **bring your own lunch, sunscreen, hat, first-aid kit, and plenty of water**. We will return to the building for breaks and lunch together to discuss what has been discovered so far. Most people will be ready to finish mapping by 3:00 or 4:00 p.m.

You can use this guide to take the trip on your own at another time, if you can't join us either day this year.

Geologists from NBMG and the Geological Society of Nevada will be available throughout the day, both Saturday and Sunday, as field-trip guides. **Feel free to bring rocks, minerals, and fossils from home for the geologists to try to identify.** Dr. Christopher Ross will help us identify the desert plants.

Items to have for the field trip:

Water – lots of it, a gallon per person (you'll be able to fill bottles during breaks)
Food for lunch and snacks
Sunscreen and hat
First aid kit
Walking stick and gloves
Camera and binoculars
Bag, bucket, or box for samples
Safety glasses if you bring a hammer
GPS receiver (optional)

Be extra careful when crossing the roads, which commonly carry a lot of traffic.

GPS

If you have a handheld global positioning system (GPS) receiver, bring it along, although it is not necessary, because it is easy to locate yourself on the map (figs. 2 and 3, an aerial photograph from Google Earth). Locations in this guidebook are given in longitude and latitude (degrees and decimal minutes) using the WGS 84 datum, the default in most global positioning system (GPS) instruments. For this location, GPS=39˚34.303´N, 119˚48.190´W, which in degrees, minutes, and decimal seconds equals 39˚34'18.18"N, 119˚48'11.40"W. For those interested in using topographic maps, the field trip will be on the Reno 7.5' quadrangle. The most recent geologic map of the region was compiled by Ramelli et al. (2011), who for this area relied largely on previous reconnaissance mapping by Bonham and Bingler (1973).

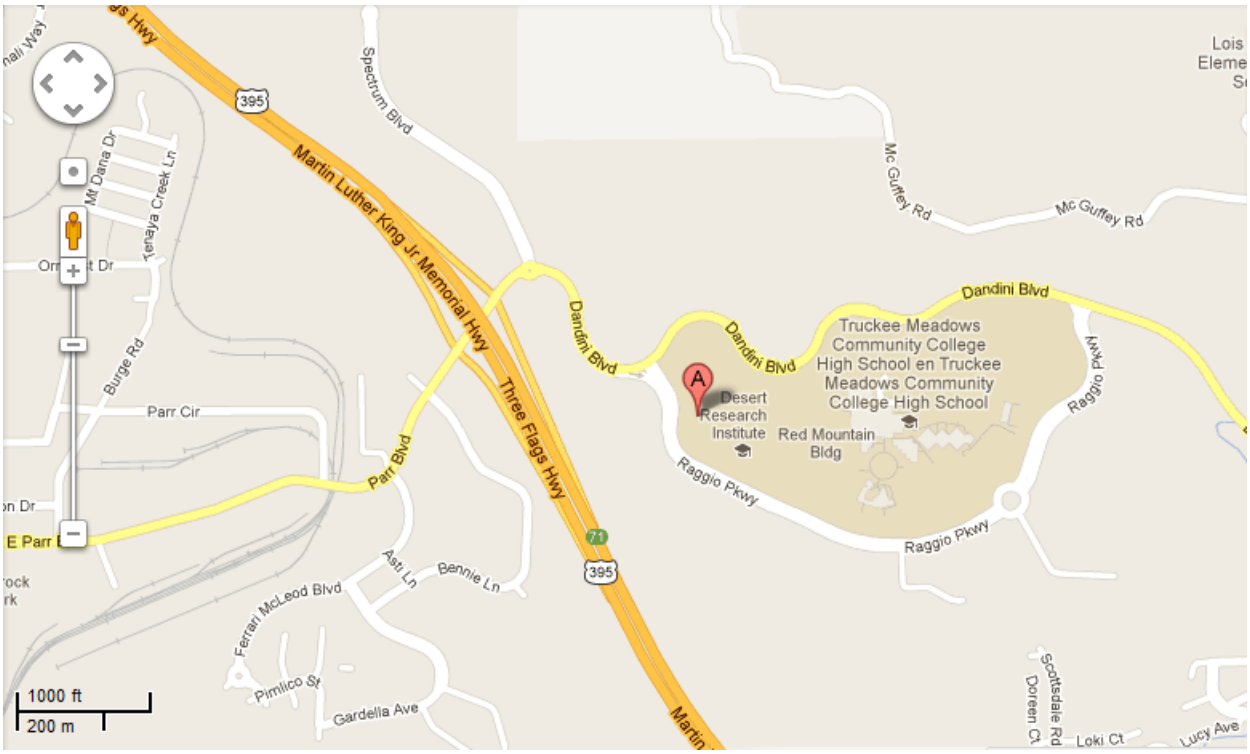

Figure 1. Location of the Great Basin Science Sample and Records Library, 2175 Raggio Parkway, Reno, NV 89512, on the west side of the campus of the Desert Research Institute. (Map from Google Maps)

We will begin the morning by examining rocks that you are likely to find in the area. Samples from Points 1 through 9 on figure 2 will be available for comparison.

Point 1: Andesite with millimeter-diameter crystals of epidote (characteristic of propylitic alteration near ore deposits) and abundant magnetite (easily attracting a high-strength magnet hung from a string).

GPS = 39˚34.525´N, 119˚48.340´W = 39˚34'31.51"N, 119˚48'20.38"W

Point 2: Andesite with visible millimeter-size plagioclase crystals and abundant magnetite, unaltered except for a rind due to weathering. Clinopyroxene (black prismatic crystals) is visible on some samples.

GPS = 39˚34.306´N, 119˚48.229´W = 39˚34'18.36"N, 119˚48'13.71"W

Point 3: Silicified andesite (silica ledge) with some quartz veins. The hydrothermal alteration has converted much of the rock to silica (the mineral quartz). Some of the rocks contain abundant, red hematite, which probably formed from the oxidation of pyrite. Alunite may be present in the silica ledges.

GPS = 39˚34.221´N, 119˚48.147´W = 39˚34'13.28"N, 119˚48'08.83"W

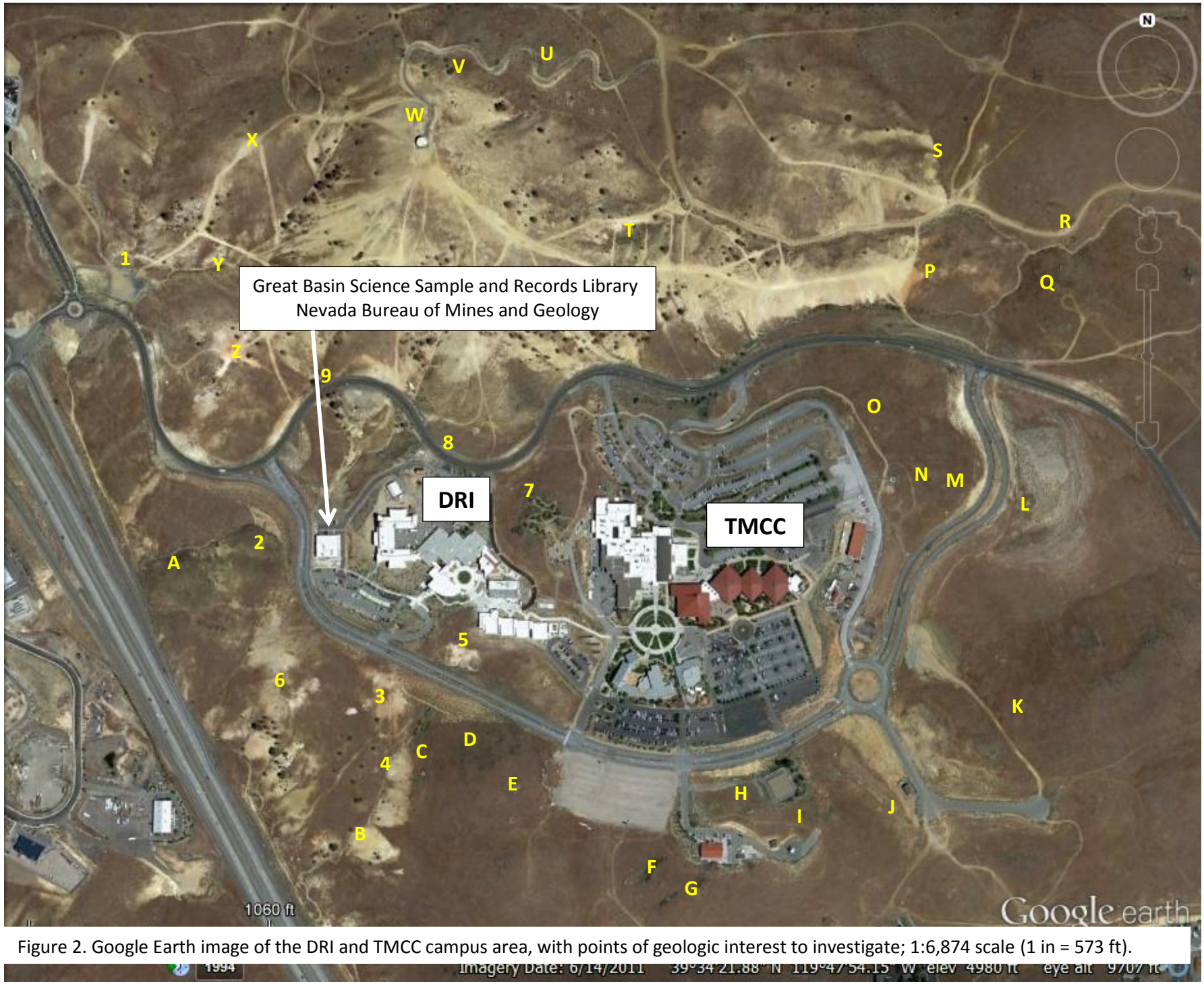

Figure 2. Google Earth image of the DRI and TMCC campus area, with points of geologic interest to investigate; 1:6,874 scale (1 in = 573 ft).

Figure 3. Google Earth image as a base map for creating a geologic map of the DRI and TMCC campus area; 1:6,874 scale (1 in = 573 ft).

Point 4: Clay-altered andesite with white clay mineral(s). NBMG confirmed the presence of smectite and illite-smectite clays next to the Great Basin Science Sample and Records Library. These clay minerals appear to be similar, but may also include kaolinite. These clays are typical of argillic alteration associated with many hydrothermal ore deposits of gold, silver, and copper.
GPS = 39˚34.148´N, 119˚48.113´W = 39˚34'08.85"N, 119˚48'06.80"W

Point 5: Breccia composed of fragments of silicified andesite, with some surfaces coated with goethite. Nearby, on the mine dump, are rocks containing mostly quartz and tiny (less than 1 millimeter in size) pyrite crystals, commonly with a coating of jarosite (sample 5A).
GPS = 39˚34.253´N, 119˚48.047´W = 39˚34'15.19"N, 119˚48'02.80"W

Point 6: Silicified andesite (silica ledge) with some quartz veins. The hydrothermal alteration has converted much of the rock to silica (the mineral quartz). Some of the rocks contain abundant, orange goethite, which probably formed from the oxidation of pyrite. Hudson (1977) noted that some samples contain alunite, diaspore and pyrophyllite occur close to the silica ledges, and illite occurs in the clay-altered andesite farther from the silica ledges.
GPS = 39˚34.225´N, 119˚48.216´W = 39˚34'13.50"N, 119˚48'12.95"W

Point 7: Breccia with fragments of silicified andesite.
GPS = 39˚34.370´N, 119˚47.965´W = 39˚34'22.19"N, 119˚47'57.92"W

Point 8: Epidote-altered and clay-altered tuff (probably dacite or andesite) with trace amounts of magnetite. This rock has considerably more clay than the rock at Point 1. It contains clasts of other volcanic rocks and has distinct fractures that may parallel compaction of the tuff.
GPS = 39˚34.395´N, 119˚48.052´W = 39˚34'23.69"N, 119˚48'03.11"W

Point 9: Epidote-chlorite-altered andesite with abundant pyrite and trace amounts of magnetite.
GPS = 39˚34.453´N, 119˚48.152´W = 39˚34'27.15"N, 119˚48'09.11"W

As you create a geologic map of the area by noting on figure 3 (or on a piece of tracing paper over figure 3) where different types of rocks occur, you may want to examine Points A through Z on figure 2. **What rocks do you find at these points and nearby? Can you map the boundaries of the rock units that you identify? Do certain types of plants seem to prefer to grow near certain types of rock?**

Point A: GPS =	39˚34.268´N, 119˚48.329´W	= 39˚34'16.10"N, 119˚48'19.73"W
Point B: GPS =	39˚34.102´N, 119˚48.147´W	= 39˚34'06.11"N, 119˚48'08.79"W
Point C: GPS =	39˚34.149´N, 119˚48.082´W	= 39˚34'08.96"N, 119˚48'04.92"W
Point D: GPS =	39˚34.164´N, 119˚48.017´W	= 39˚34'09.85"N, 119˚48'01.03"W
Point E: GPS =	39˚34.143´N, 119˚47.990´W	= 39˚34'08.55"N, 119˚47'59.38"W
Point F: GPS =	39˚34.081´N, 119˚47.857´W	= 39˚34'04.85"N, 119˚47'51.40"W
Point G: GPS =	39˚34.070´N, 119˚47.808´W	= 39˚34'04.18"N, 119˚47'48.45"W
Point H: GPS =	39˚34.142´N, 119˚47.766´W	= 39˚34'08.54"N, 119˚47'45.94"W
Point I: GPS =	39˚34.123´N, 119˚47.708´W	= 39˚34'07.40"N, 119˚47'42.47"W
Point J: GPS =	39˚34.126´N, 119˚47.621´W	= 39˚34'07.55"N, 119˚47'37.25"W
Point K: GPS =	39˚34.219´N, 119˚47.404´W	= 39˚34'13.11"N, 119˚47'24.24"W
Point L: GPS =	39˚34.357´N, 119˚47.482´W	= 39˚34'21.44"N, 119˚47'28.89"W
Point M: GPS =	39˚34.372´N, 119˚47.558´W	= 39˚34'22.34"N, 119˚47'33.49"W
Point N: GPS =	39˚34.369´N, 119˚47.583´W	= 39˚34'22.16"N, 119˚47'35.00"W
Point O: GPS =	39˚34.426´N, 119˚47.642´W	= 39˚34'25.54"N, 119˚47'38.51"W
Point P: GPS =	39˚34.531´N, 119˚47.582´W	= 39˚34'31.88"N, 119˚47'34.92"W
Point Q: GPS =	39˚34.524´N, 119˚47.458´W	= 39˚34'31.45"N, 119˚47'27.50"W
Point R: GPS =	39˚34.573´N, 119˚47.436´W	= 39˚34'34.37"N, 119˚47'26.13"W
Point S: GPS =	39˚34.624´N, 119˚47.572´W	= 39˚34'37.46"N, 119˚47'34.29"W
Point T: GPS =	39˚34.571´N, 119˚47.854´W	= 39˚34'34.25"N, 119˚47'51.25"W
Point U: GPS =	39˚34.684´N, 119˚47.953´W	= 39˚34'41.03"N, 119˚47'57.15"W
Point V: GPS =	39˚34.673´N, 119˚48.035´W	= 39˚34'40.36"N, 119˚48'02.10"W
Point W: GPS =	39˚34.637´N, 119˚48.068´W	= 39˚34'38.20"N, 119˚48'04.09"W
Point X: GPS =	39˚34.619´N, 119˚48.237´W	= 39˚34'37.14"N, 119˚48'14.22"W
Point Y: GPS =	39˚34.533´N, 119˚48.275´W	= 39˚34'32.00"N, 119˚48'16.52"W
Point Z: GPS =	39˚34.465´N, 119˚48.255´W	= 39˚34'27.87"N, 119˚48'15.31"W

The rocks at this locality are relatively fresh to highly altered andesites and some presumably related intrusive rocks, mapped by Ramelli et al. (2011) as part of the andesite and breccia of Peavine Mountain, which are 15.9 to 16.0 million years old (Ma). We are uncertain whether the andesites formed as lava flows or shallow intrusions into a volcanic pile. A sample of relatively fresh andesite collected prior to construction of the NBMG building has a chemical composition typical of andesites found in volcanoes above subduction zones like the Andes and Cascades (table 1).

Table 1. Chemical and mineralogical composition of unaltered andesite at the Great Basin Science Sample and Records Library (values in weight percent).

SiO_2	58.7	In polished thin section, the rock contains phenocrysts of plagioclase, pyroxene, magnetite, and lesser biotite in a groundmass of aligned plagioclase crystals. Pyrrhotite occurs as rare grains within magnetite phenocrysts.
TiO_2	0.74	
Al_2O_3	18.5	
Fe as Fe_2O_3	6.99	
MnO	0.13	
MgO	2.85	
CaO	5.34	
Na_2O	3.44	
K_2O	1.82	
P_2O_5	0.22	
$H_2O + CO_2$	1.94	
Total	100.7	

Most bold outcrops on the south side of Raggio Parkway are silica (quartz) ledges that were formed by the same hydrothermal fluids that altered the andesites in the general area to assemblages of illite-smectite, smectite, quartz, and, locally, gypsum. Smectite and illite-smectite are swelling clays that have caused considerable problems with construction (differential settling and tilting) on the north side of Reno and Sparks, including McCarran Boulevard and the first building here on the DRI campus. The foundation of the NBMG building is underlain by approximately 2 feet (0.6 meters) of non-swelling fill on top of both fresh and highly altered andesite, and no problems have developed since the building was constructed in 2009.

Gold deposits formed by hydrothermal activity similar to what can be seen around the DRI-TMCC campuses have made Nevada the center of the current and biggest gold mining boom in American history. Although small mine dumps in the area attest to efforts to develop gold and silver deposits in the Peavine and Wedekind districts (centered on Peavine Peak to the west and the Pyramid Highway to the east, respectively) in the late 1800s, none of the deposits proved to be large. Because of urbanization, modern exploration has avoided what might otherwise be an attractive target for a high-sulfidation, quartz-alunite-type gold deposit. Quade et al. (1990) reported anomalously high concentrations of silver (500 ppm), gold (50 ppb), copper (>2%), zinc (480 ppm), lead (1500 ppm), arsenic (>1%), and antimony (1500 ppm) in a sample containing enargite (?) in pyritized “microdiorite” or andesite from the large dump near the intersection of US-395 and Dandini Boulevard.

The andesites near Reno and Virginia City were erupted during the Miocene Epoch when this area was part of the Cascades. As the San Andreas fault migrated northward with time, so did the southern end of the Cascades. Relatively minor volumes of basalt and rhyolite were erupted in the area during Quaternary time. The area remains tectonically active, as evidenced by numerous Quaternary faults, frequent small and infrequent large earthquakes, and movement of the ground as measured with high-precision GPS receivers.

Some features of geological interest in the NBMG building are the golden windows (made of double-pane glass with a 17 nanometer-thick coating of gold on the inside of the glass) that help save energy by reflecting infrared (heat), the base isolators on the rock-storage racks that should prevent rocks from falling off the shelves during an earthquake, and the representative Nevada rocks in the reception counter’s vertical “core boxes.” Behind the building to the north is NBMG’s rock garden, full of rock and

mineral samples that are available for exploration by rockhounds and the general public. Please feel free to take one of each rock type from the rock garden.

References

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Bonham, H.F., Jr., and Bingler, E.C., 1973, Reno folio geologic map: Nevada Bureau of Mines and Geology Environmental Series 4Ag, scale 1:24,000.

Hudson, D.M., 1977, Geology and alteration of the Wedekind and part of the Peavine districts, Washoe County, Nevada: University of Nevada, Reno, unpublished M.S. thesis, 102 p.

Quade, J., Tingley, J.V, Garside, L.J., and U.S. Geological Survey Office of Mineral Resources, Branch of Geochemistry, 1990, Mineral resource inventory, Bureau of Land Management, Carson City District, Nevada, Appendix B-Sample descriptions; and Appendix C-Sample analyses: Nevada Bureau of Mines and Geology Open-File Report 90-3, 228 p.

Ramelli, A.R., Henry, C.D., and Walker, J.P., *with contributions by* Bell, J.W., Cashman, P.H., dePolo, C.M., Garside, L.J., House, P.K., Trexler, J.H., and Widmer, M.C., 2011, Preliminary revised geologic maps of the Reno urban area, Nevada: Nevada Bureau of Mines and Geology Open-File Report 11-7, 3 plates with cross sections, scale 1:24,000.

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GLOSSARY

Geologic Time Scale for This Area

Era	Period	Epoch	
Cenozoic	**Quaternary**	**Holocene**:	11,700 years ago to present
		Pleistocene:	2.6 million to 11,700 years ago.
	Tertiary	**Pliocene**:	5.3 million to 2.6 million years ago
		Miocene:	23.0 to 5.3 million years ago
		Oligocene:	33.9 to 23.0 million years ago
		Eocene:	55.8 to 33.9 million years ago
		Paleocene:	65.5 to 55.8 million years ago
Mesozoic	**Cretaceous**		145 to 65.5 million years ago
	Jurassic		201 to 145 million years ago
	Triassic		251 to 201 million years ago

(Older rocks are not found in this area)

Minerals Found in This Area and their Chemical Formulas

Alunite, $KAl_3(SO_4)_2(OH)_6$, generally white, clay-like mineral formed when sulfuric acid breaks down volcanic rocks containing potassium and aluminum

Anorthoclase, a feldspar solid solution dominantly between the end members potassium feldspar, $KAlSi_3O_8$, and albite, $NaAlSi_3O_8$, with lesser amounts of anorthite, $CaAl_2Si_2O_8$, clear to white; with cleavage

Apatite, $Ca_5(PO_4)_3(OH,F)$, occurs as small (less than 1 mm) crystals in many igneous rocks

Biotite, $K(Mg,Fe)_3AlSi_3O_{10}(OH,F)_2$, dark brown to black mica found here as tiny flakes

Calcite, $CaCO_3$, generally white or clear, but sometimes black or other colors, rhombohedral cleavage, softer than steel or glass, fizzes when dissolved in acid, as described in the following chemical reaction:

$CaCO_3 + 2H^+$ (acid) = Ca^{2+} (calcium in solution) + H_2O + CO_2 (carbon dioxide released into the air)

Celadonite, $K(Mg,Fe^{2+})(Fe^{3+},Al)Si_4O_{10}(OH)_2$, green clay mineral

Chalcedony, a fine-grained variety of quartz, SiO_2, pale yellow and milky white

Chlorite, green, typically replacing other Fe-Mg minerals, $(Fe^{2+},Fe^{3+},Al,Mg,Mn^{2+})_{4\text{-}6}(Si,Al)_4O_{10}(OH,O)_8$

Clinopyroxene, $Ca(Mg,Fe)Si_2O_6$, black or dark green, hard mineral common in basalt and andesite
Cristobalite, SiO_2, variety of silica similar to quartz but generally forms at higher temperatures
Cryptomelane, $K(Mn^{4+},Mn^{2+})_8O_{16}$, a black manganese oxide that commonly forms dendrites (branching crystals on a rock surface) – commonly mixed, as psilomelane, with romanechite and hollandite
Diaspore, AlO(OH), white clay-like mineral
Enargite, Cu_3AsS_4, black or dark gray metallic mineral; may have a green coating when oxidized
Epidote, $Ca_2(Fe^{3+},Al)_3(SiO_4)_3(OH)$, pistachio-green mineral, often with prismatic crystals
Goethite, FeOOH, orange, rust-colored mineral, usually coating other rocks
Gypsum, $CaSO_4 \bullet 2H_2O$, a white or commonly clear mineral with good cleavage; softer than most minerals (hardness = 2 on the Mohs scale; can be scratched with a fingernail)
Hematite, Fe_2O_3, red (giving some rocks a pink color); also occurs as small (generally less than 1 mm long) black crystals in igneous rocks, in a solid solution with ilmenite, $FeTiO_3$
Hollandite, $Ba(Mn^{4+},Mn^{2+})_8O_{16}$, a black manganese oxide that commonly forms dendrites (branching crystals on a rock surface) – commonly mixed, as psilomelane, with romanechite and cryptomelane
Hornblende, $Ca_2(Mg,Fe)_4Al(Si_7Al)O_{22}(OH,F)_2$, black prisms, common in many igneous rocks
Illite, $(K,H_3O^+)(Al,Mg,Fe)_2(Si,Al)_4O_{10}(OH)_2 \pm H_2O$, a white mica, clay-like mineral
Jarosite, $KFe^{3+}{}_3(SO_4)_2(OH)_6$, a pale yellow coating commonly on rocks containing pyrite
Kaolinite, $Al_2Si_2O_5(OH)_4$, white clay mineral
Magnetite, Fe_3O_4, black, magnetic, generally in a solid solution with ulvospinel, Fe_2TiO_4
Monazite, $CePO_4$, occurs as small (less than 1 mm) crystals in many igneous rocks, commonly contains many of the light rare earth elements in these rocks
Montmorillonite, $(Na,Ca)_{0.3}(Al,Mg)_2Si_4O_{10}(OH)_2 \cdot nH_2O$, part of the **smectite** group of clay minerals, also called **bentonite**, generally white or cream-colored but can be dark brown, red, or black, depending on impurities; because of its property of swelling when wet, it is used in drilling muds in oil fields
Opal, $SiO_2 \cdot nH_2O$, generally white, with conchoidal fracture
Orthoclase, a feldspar solid solution dominantly between the end members potassium feldspar, $KAlSi_3O_8$, and lesser albite, $NaAlSi_3O_8$, with small amounts of anorthite, $CaAl_2Si_2O_8$, generally pink, salmon, or white; with cleavage
Orthopyroxene, $Ca(Mg,Fe)Si_2O_6$, black or dark green, hard mineral common in basalt and andesite
Plagioclase, a feldspar solid solution dominantly between the end members albite, $NaAlSi_3O_8$, and anorthite, $CaAl_2Si_2O_8$, with lesser amounts of $KAlSi_3O_8$; with cleavage and striations from twinning within the crystals, clear when unaltered, commonly white when altered partially to clay minerals
Pyrite, FeS_2, brassy, metallic mineral (fool's gold), which, when oxidized by rain water, produces sulfuric acid that alters minerals in most volcanic rocks to various clay minerals, including montmorillonite, smectite, kaolinite, and illite
Pyrophyllite, $Al_2Si_4O_{10}(OH)_2$, white clay mineral that is softer than most other minerals
Pyrrhotite, $Fe_{1-x}S$, brassy, metallic mineral that is less bright than pyrite but slightly magnetic
Quartz, SiO_2 (silica), clear or white with conchoidal fractures (like glass, with no cleavage planes); scratches steel and glass
Romanechite, $BaMn^{2+}Mn^{4+}{}_8O_{16}(OH)_4$, a black manganese oxide that commonly forms dendrites (branching crystals on a rock surface) – commonly mixed, as psilomelane, with cryptomelane and hollandite
Sanidine, a feldspar solid solution dominantly between the end members potassium feldspar, $KAlSi_3O_8$, and lesser albite, $NaAlSi_3O_8$, with small amounts of anorthite, $CaAl_2Si_2O_8$, clear to white; with cleavage
Smectite, $(Ca/2,Li,Na)_{0.3}(Al,Cr^{3+},Cu^{2+},Fe^{2+},Fe^{3+},Li,Mg,Ni,Zn)_{2-3}(Al,Si)_4O_{10}(OH,F)_2 \bullet nH_2O$, a group of clay minerals that includes montmorillonite.
Titanite, $CaTiSiO_5$, occurs as small (less than 1 mm) crystals in many igneous rocks
Xenotime, YPO_4, occurs as small (less than 1 mm) crystals in many igneous rocks, commonly contains many of the heavy rare earth elements in these rocks
Zircon, $ZrSiO_4$, occurs as small (less than 1 mm) crystals in many igneous rocks

Rock Types Found in This Area

Intrusive igneous rock types have chemically equivalent extrusive (volcanic) rock types. With increasing silica concentrations (from lowest in gabbro to highest in granite), the common igneous rocks are:

Intrusive		Extrusive
Gabbro	=	**Basalt**
Diorite	=	**Andesite**
Granodiorite	=	**Dacite**
Granite	=	**Rhyolite**

Unconsolidated sediments in the area include **alluvium** (a mixture of clay, silt, sand, and gravel, generally deposited by streams), and **colluvium** (a mixture of soil material and rock fragments deposited by rainwash, sheetwash, or slow downslope creep on the sides of hills). Sediments classified by size of particles include **clay** (less than 1/256 mm in diameter), **silt** (1/256 to 1/16 mm), **sand** (1/16 to 2 mm), granule (2 to 4 mm), pebble (4 to 64 mm), cobble (64 to 256 mm), and boulder (greater than 256 mm). **Gravel** consists predominantly of rounded rock fragments larger than 2 mm.

Sedimentary rocks are consolidated sediments. With increasing grain size, these include, among other rock types, **claystone** (mudstone or shale), **siltstone**, **sandstone**, and **conglomerate**.

A **breccia** is rock composed of angular fragments held together by mineral cement or in a fine-grained matrix. Breccias can form by different geological processes, including deposition as a sediment (such as talus along a steep slope), at the base or top of a cooling lava flow, during a volcanic explosion, during a hydrothermal eruption (geyser), by collapse resulting from dissolution (in a cave or sinkhole), and by grinding along a fault. The breccias found in many of the silica ledges around the DRI-TMCC campuses are interpreted to be hydrothermal breccias.

Figure 4. Breccia composed of fragments of silicified andesite from a silica (quartz) ledge on the DRI-TMCC campuses. Photos by the authors, unless otherwise indicated.

Many of the plants in this area characteristically grow on highly acidic soils. Examples include *Eriogonum robustum* (altered andesite buckwheat, fig. 5) and stunted *Pinus jeffreyi* (Jeffrey pine, fig. 6).

Figure. 5. *Eriogonum robustum* (altered andesite buckwheat); quarter for scale. Photo by Alexander D. Price.

Figure 6. *Pinus jeffreyi* (Jeffrey pine).

The acidic soils are the result of two geological processes: (1) reaction of the rock with a sulfur-rich, acidic water associated with a hydrothermal (hot water or geothermal) system that is typical of volcanic vents and certain types of metallic ore deposits and (2) later oxidation of pyrite by rainwater.

The hot, sulfur-rich water precipitated pyrite, alunite, and quartz in some of the rocks, particularly close to the vents for the hydrothermal fluids. The silica ledges (bold outcrops of silicified andesite) are thought to be erosional remnants of these vents. The breccias that we see in the area may have formed in these vents, that is, in the throats of geysers during hydrothermal eruptions.

In the white, clay-altered rocks, most of the iron, magnesium, and manganese that was originally in the rock was probably dissolved by the hot acidic water and was probably transported away in the hot ground water. The feldspars that were originally in the rock formed clay minerals: smectite, illite-smectite, and kaolinite.

Later, pyrite was oxidized by rain water that penetrated the ground; this created more acid, some of which probably formed more clay minerals. The chemical reaction for the oxidation of pyrite can be described as follows:

FeS_2 (pyrite) + $^{5}/_{2}$ H_2O (water) + $^{15}/_{4}$ O_2 (dissolved oxygen from the atmosphere) = FeOOH (goethite) + 2 H_2SO_4 (sulfuric acid)
or
2 FeS_2 (pyrite) + 4 H_2O (water) + $^{15}/_{2}$ O_2 (dissolved oxygen) = Fe_2O_3 (hematite) + 4 H_2SO_4 (sulfuric acid)

Much of the iron in the rocks remains as goethite or hematite, which give the rocks and soils the orange, yellow, and red colors.

Gypsum forms from the reaction of sulfate in the oxidized ground water with calcium from the rocks. The occasional large crystals of gypsum found on the DRI campus probably formed near the surface as calcium- and sulfate-rich ground water evaporated.

Several other species of *Eriogonum* (wild buckwheat) and other acid- and drought-tolerant plants are present around the DRI-TMCC campuses (fig. 7), particularly north of Dandini Boulevard. Many are native plants, but some are invasive species.

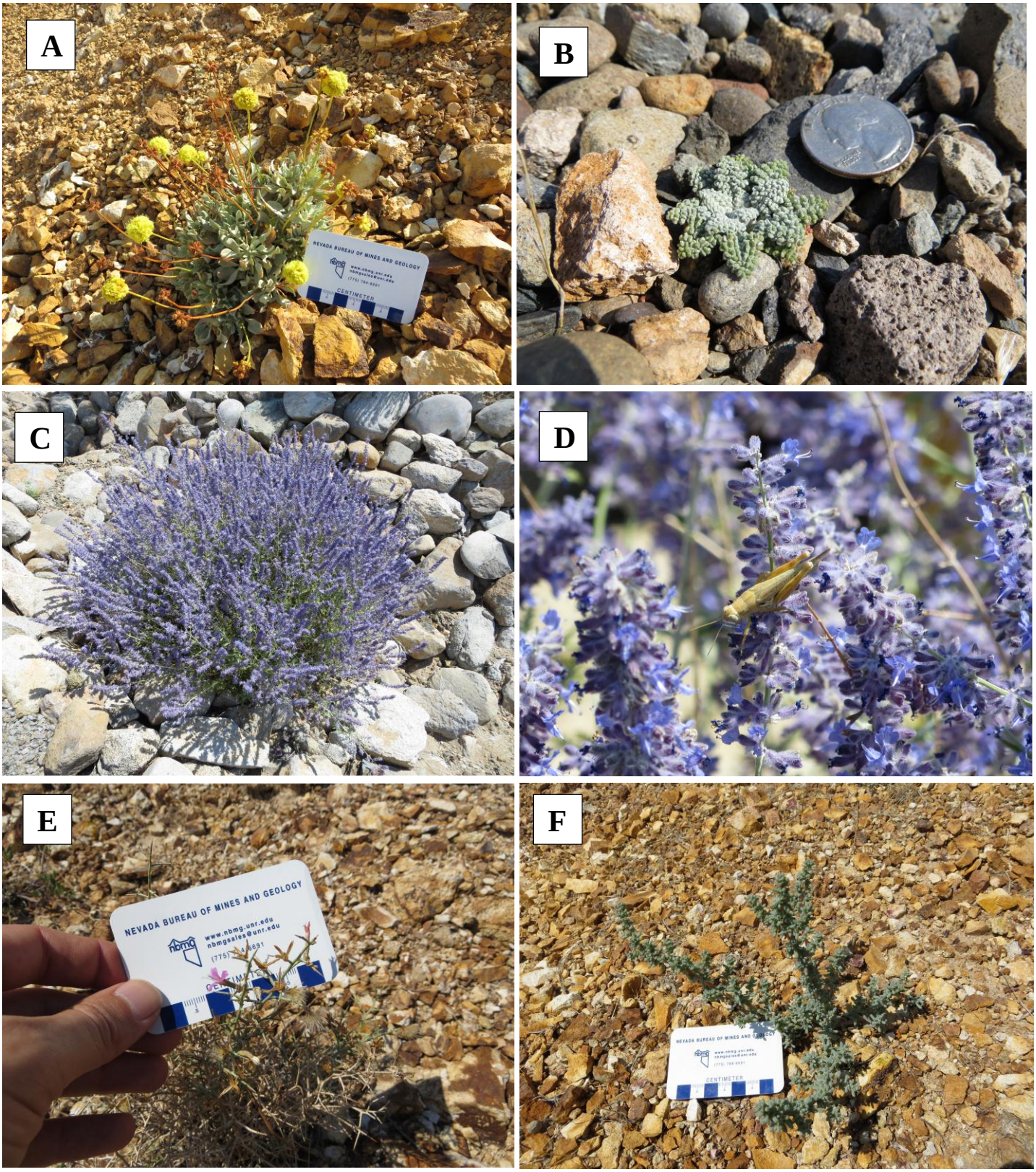


Figure 7. Examples of drought- and acid-tolerant plants around the DRI-TMCC campuses: (A) *Eriogonum* sp. [variety of buckwheat], (B) *Chaenactis* sp. [variety of dusty maiden, aster family], (C) *Perovskia atriplicifolia* [Russian sage, mint family - escaped from nearby landscape plantings], (D) close-up view of (C), (E) *Stephanomeria pauciflora* [brownplume wirelettuce, aster family], (F) *Halogeton glomeratus* [halogeton, Aral barilla, or saltlover, an invasive weed of Eurasian origin, responsible for many stock deaths in the west due to high levels of oxalic acid, which kills off the ruminant bacteria in sheep and other livestock]. Photos by Alexander D. Price; plant identifications by Christopher Ross.

Although the vegetation is sparse (fig. 8), there is abundant wildlife in the area, including some curious insects (fig. 9A) and reptiles (fig. 9B), rabbits, coyotes, and snakes.

Figure 8. *Pinus jeffreyi* (Jeffrey pine) in the foreground above the Desert Research Institute campus and the Great Basin Science Sample and Records Library of the Nevada Bureau of Mines and Geology, University of Nevada, Reno. Photo, looking south, by Alexander D. Price on 17 August 2013, when smoke from a wildfire in California obscured views in the Truckee Meadows.

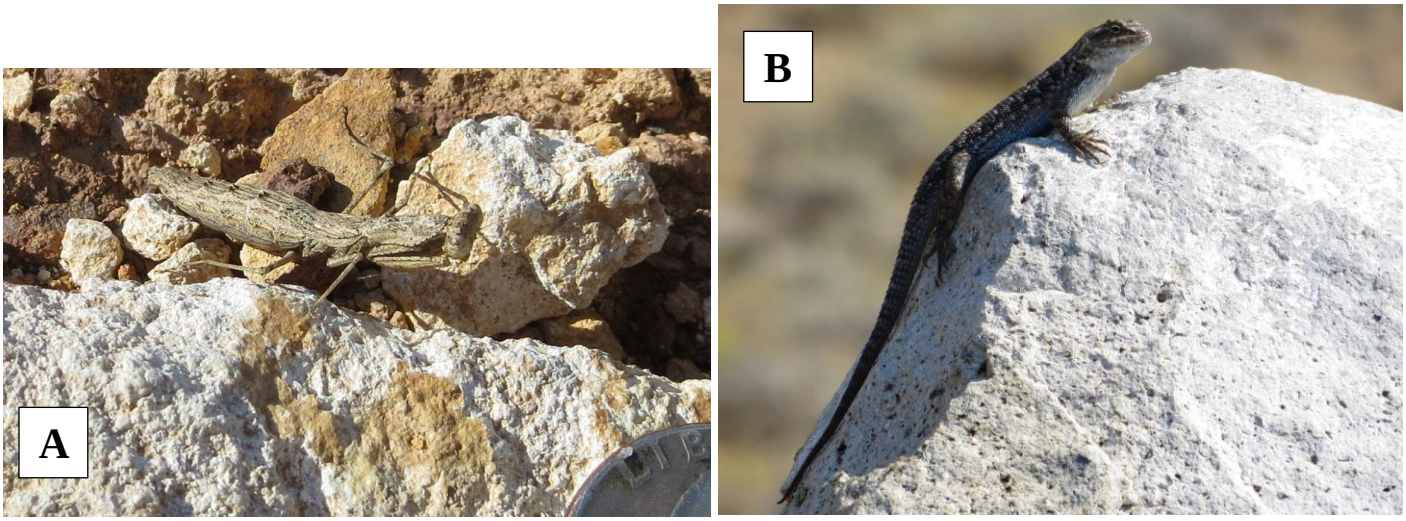


Figure 9. Examples of desert wildlife near the DRI-TMCC campuses: (A) mantis, (B) *Scelporus* sp. [western fence swift, or blue-belly]. Photos by Alexander D. Price.

Appendix 1

Plants around the DRI-TMCC Campuses

Plants around the DRI-TMCC Campuses

(photos by Alexander D. Price and J.G. Price, 17 August 2013; identifications by Christopher Ross and Elisabeth M. Price)

1. IMG_5537. *Juniperus utahensis* [Utah juniper] in center; *Eriogonum robustum* [altered andesite buckwheat] to the left.

2. IMG_5552. *Juniperus utahensis* [Utah juniper] in foreground; *Pinus jeffreyi* (Jeffrey pine) in background.

3. IMG_5553. *Pinus jeffreyi* (Jeffrey pine), growing on clay-altered andesite.

4. IMG_2562. Cone from *Pinus jeffreyi* (Jeffrey pine).

5. IMG_2554. *Eriogonum robustum* [altered andesite buckwheat]; quarter for scale.

6. IMG_2573. *Eriogonum robustum* [altered andesite buckwheat].

7. IMG_2565. *Eriogonum* sp. [variety of perennial buckwheat].

8. IMG_2595. *Eriogonum* sp. [variety of perennial buckwheat].

9. IMG_2574. *Eriogonum* sp. [variety of perennial buckwheat].

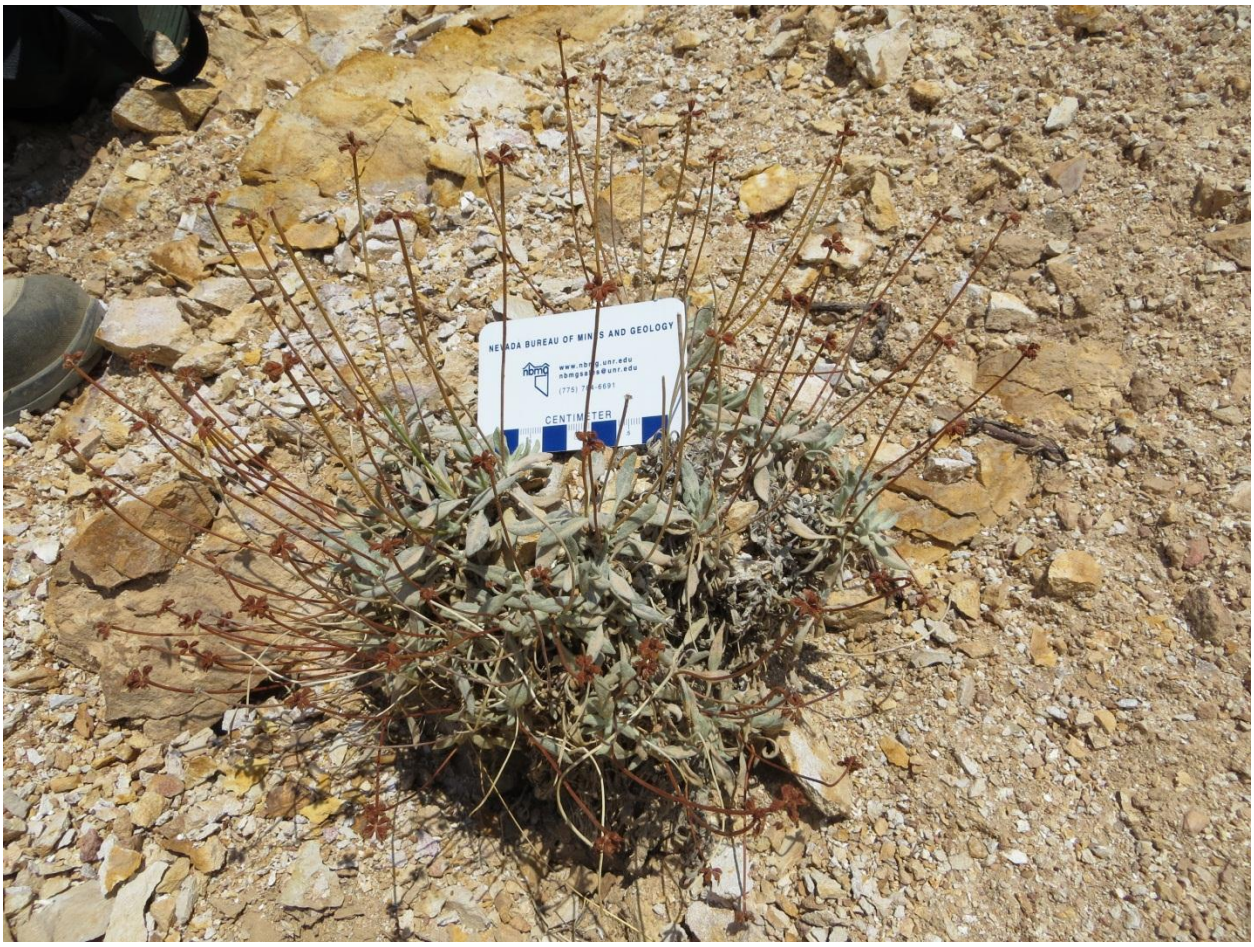
10. IMG_5548. *Eriogonum* sp. [variety of perennial buckwheat].

11. IMG_2588. *Eriogonum* sp. [variety of perennial buckwheat].

12. IMG_2557. *Eriogonum* sp. [variety of perennial buckwheat].

13. IMG_2564. *Eriogonum* sp. [variety of perennial buckwheat].

14. IMG_2626. *Eriogonum* sp. [variety of perennial buckwheat].



15. IMG_2630, *Eriogonum* sp. [variety of perennial buckwheat].

16. IMG_5555. *Eriogonum* sp. [variety of perennial buckwheat].

17. IMG_2651. *Eriogonum* sp. [variety of annual buckwheat].

18. IMG_2568. *Eriogonum* sp. [variety of annual buckwheat].

19. IMG_5538. *Artemesia tridentate* [Sagebrush].

20. IMG_5539. *Artemesia tridentate* [Sagebrush].

21. IMG_2570. *Chrysothamnus viscidiflorus* [green rabbitbrush, yellow rabbitbrush, daisy family].

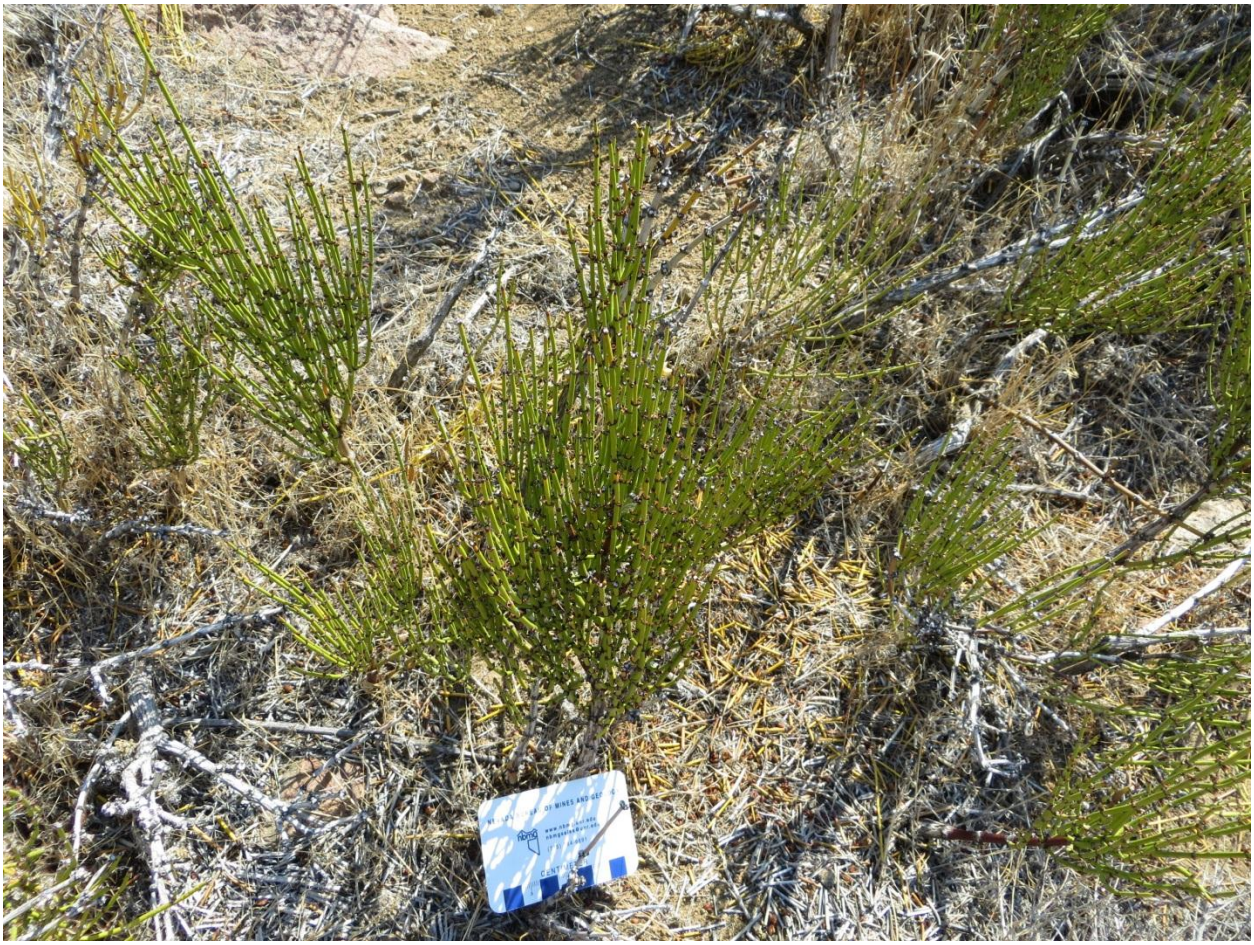
22. IMG_2575. *Prunus andersonii* [Desert peach] - beautiful pink flowers in spring, bark and leaves loaded with cyanogenic compounds and smell like bitter almond/cyanide.

23. IMG_2612. *Menodora spinescens* [Spiny menodora, olive family].

24. IMG_2616. *Menodora spinescens* [Spiny menodora, olive family].

25. IMG_2613. *Purshia tridentata* [bitterbrush, yellow flowered member of rose family, important for winter big game forage].

26. IMG_2614. *Cowania mexicana* [cliffrose; closely related to bitterbrush, with which it sometimes hybridizes; occurs naturally in southern and eastern Nevada, planted around DRI].

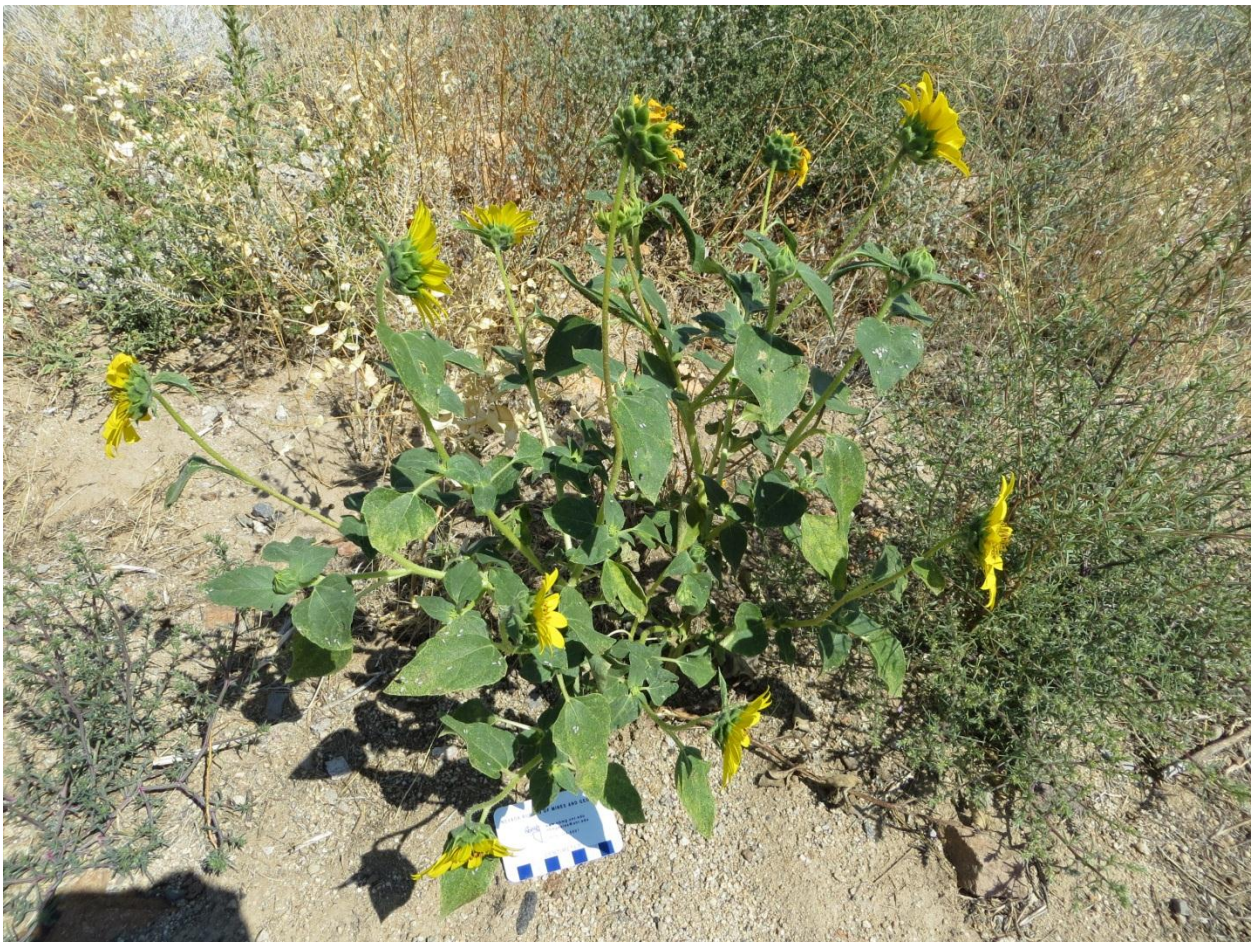


27. IMG_2618. *Ephedra nevadensis* [Mormon or indian tea].

28. IMG_2571. [to be identified].

29. IMG_2581. *Chaenactis* sp. [variety of dusty maiden, aster family].

30. IMG_2584. *Phacelia heterophylla* [Biennial phacelia - puts up a tall flower spike the second year so quickly that it is often not recognized as the same plant].



31. IMG_2647. *Helianthus annuus* [Annual sunflower].

32. IMG_2619. *Stephanomeria pauciflora* [brownplume wirelettuce, aster family]

33. IMG_2622. *Stephanomeria pauciflora* (brownplume wirelettuce, aster family)

34. IMG_2623. *Stephanomeria pauciflora* [brownplume wirelettuce, aster family]

35. IMG_2638. *Aster* sp.

36. IMG_2639. *Aster* sp.

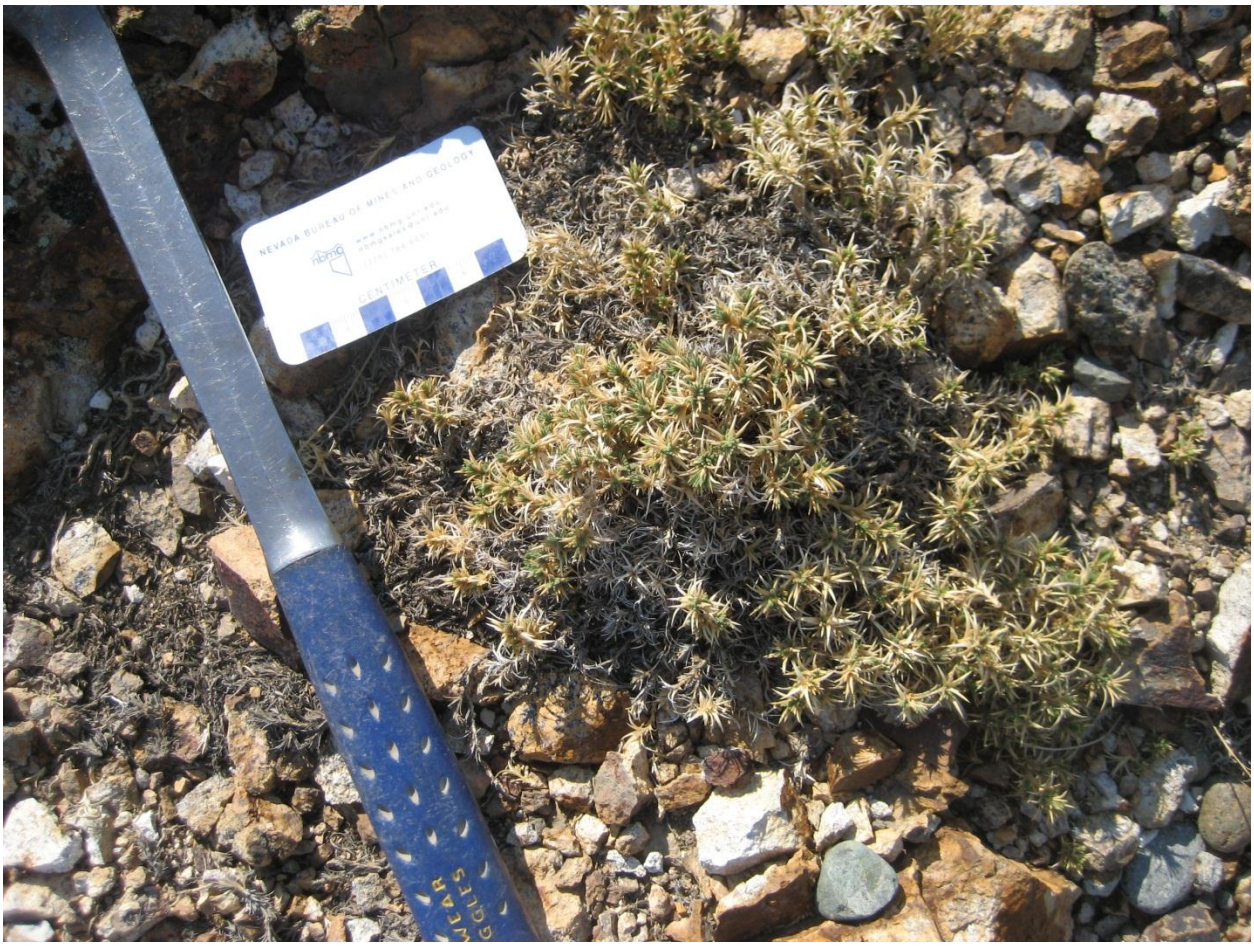
37. IMG_2640. *Erodium maculatum* [cranesbill or storksbill, so named for the seed pod shape; exotic weed of the geranium family].

38. IMG_2642. *Erodium maculatum* [cranesbill or storksbill, so named for the seed pod shape; exotic weed of the geranium family].

39. IMG_2636. Moss and lichen, on rock surface with hematite and goethite.

40. IMG_2637. Moss and lichen, close-up of image 2636.

41. IMG_2634. Lichen.



42. IMG_5557. Probably *Phlox hoodii* [spiny phlox].

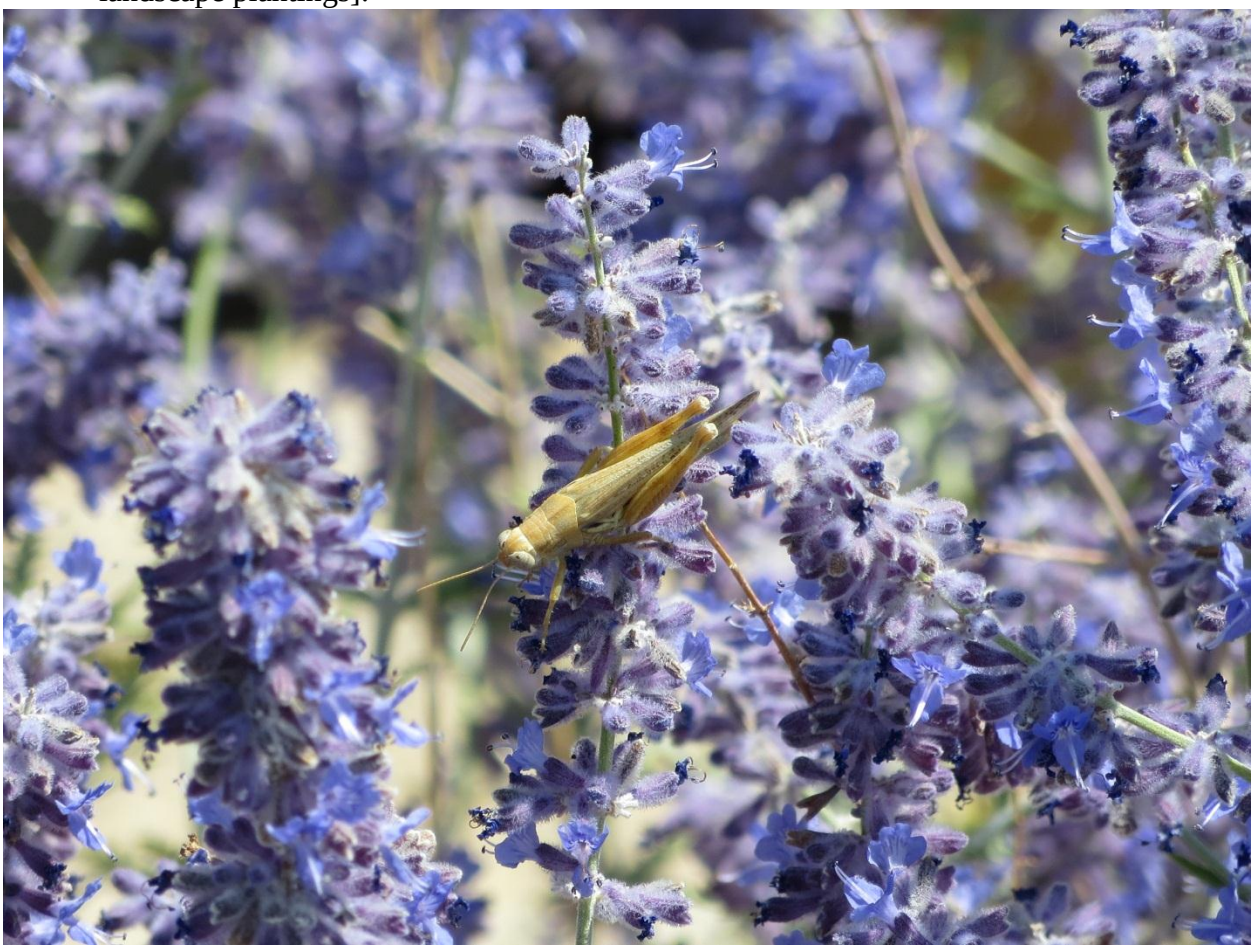
43. IMG_5564. *Ulmus Americana* [American elm, tree in foreground]; *Pinus jeffreyi* (Jeffrey pine) in background.

44. IMG_5572. *Grindelia squarrosa* [curly-top gumweed, curly-cup gumweed].

45. IMG_2648. *Lepidium perfoliatum* [Clasping pepperweed, so named for the way the leaves clasp the stem; an invasive exotic annual mustard].

46. IMG_2577. *Lepidium perfoliatum* [Clasping pepperweed, so named for the way the leaves clasp the stem; an invasive exotic annual mustard].

47. IMG_2653. *Perovskia atriplicifolia* [Russian sage, mint family - escaped from nearby landscape plantings].



48. IMG_2654. Close-up of IMG_2653.

49. IMG_2627. *Halogeton glomeratus* [halogeton, Aral barilla, or saltlover, an invasive weed of Eurasian origin, responsible for many stock deaths in the west due to high levels of oxalic acid, which kills off the ruminant bacteria in sheep and other livestock].

50. *Pinus jeffreyi* (Jeffrey pine) trees in the foreground above the DRI and GBSSRL buildings.