Nevada Mining Association Education Committee Field Trip

Nevada Bureau of Mines and Geology Educational Series E-55

Geo- and Eco-Mapping around DRI
(The Great Altered Rock Walking Tour)

Jonathan G. Price, Elisabeth M. Price, and Daphne D. LaPointe

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This geo- and ecotour is an opportunity to identify and sample local rocks and minerals, see how geologists use the presence of various desert plants to help map the distribution of rocks, and learn about the significance of the local geology. It is designed as an exercise that can be done by students. They can identify several types of rocks and plants, indicate the distribution of the rocks and plants on a map, and discuss why geologists and ecologists make maps: **So what? Who cares?**

You will 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. You will also be able to describe and recognize many species of plants, several of which grow on acidic soils that form above altered volcanic rocks. Two of the most distinctive plants are *Eriogonum robustum* (altered andesite buckwheat, fig. 1) and *Pinus jeffreyi* (Jeffrey pine, fig. 2).

Figure 1. *Eriogonum robustum* (altered andesite buckwheat); quarter for scale. Photo by A.D. Price.

Figure 2. *Pinus jeffreyi* (Jeffrey pine).

The exercise, which should take three to four hours, is a slow walking trip centered on the Great Basin Science Sample and Records Library (figs. 3 & 4), the Nevada Bureau of Mines & Geology (NBMG) building for public information, publication sales, geologic and topographic maps, and geological samples. The building also houses the office of the Geological Society of Nevada (http://www.gsnv.org/), which provides field-trip grants to teachers to pay for buses to take students on geological field trips, such as this exercise. Guidelines for the grants are at http://www.gsnv.org/gsn-foundation/2008%20rev%20Grant%20Application%20and%20Guidelines.pdf .

Equipment needed for the exercise includes a **hand lens** and **magnet**, preferably an iron-neodymium-boron ($Fe_{14}Nd_2B$) high-strength magnet on a string, to identify minerals in the rocks; **safety glasses**, if you bring along a **rock hammer**; **sturdy shoes** (sneakers are o.k., but sandals are not), **clipboards**, **pencils**, **tracing paper**, and copies of the **base map** (fig. 5), **sunscreen**, and a **first aid kit**. **Long pants** and a **water bottle** are advisable. You'll have opportunities to use drinking fountains and restrooms in the building.

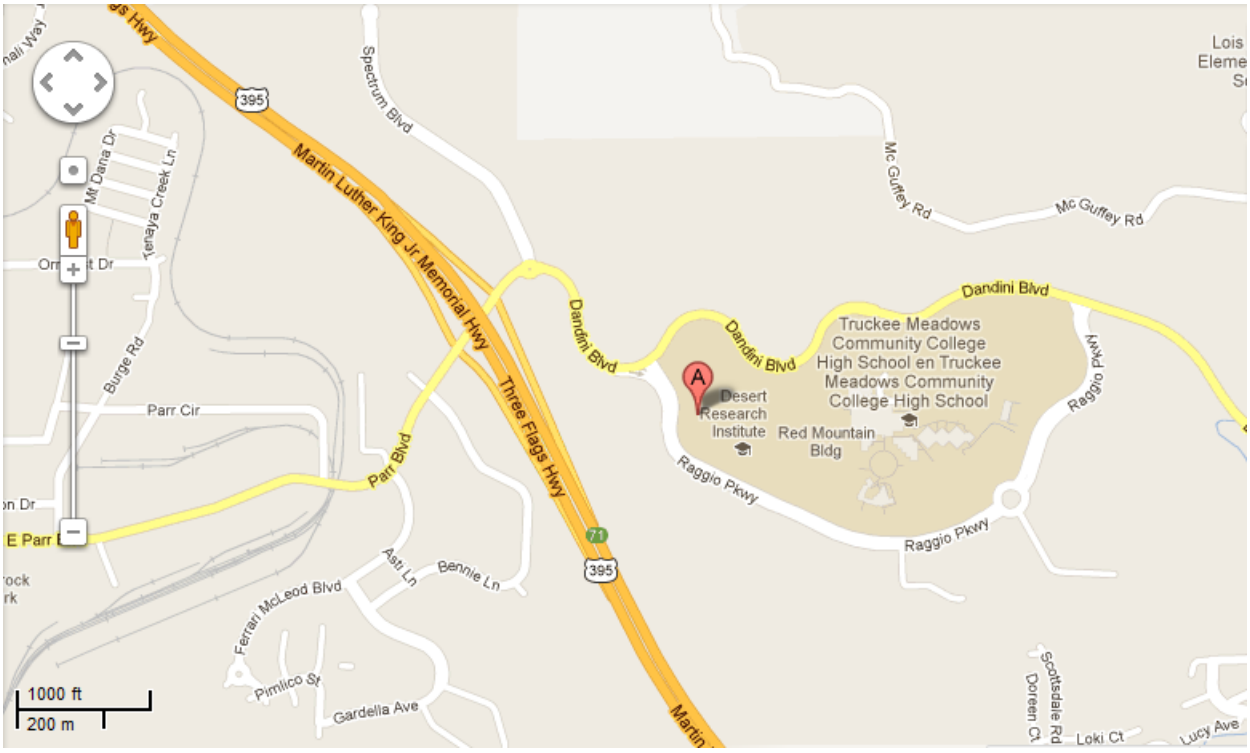

Figure 3. Location of the Great Basin Science Sample and Records Library, 2175 Raggio Parkway, Reno, NV 89512. (Map from Google Maps)

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. 4 and 5, 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 the building, 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).

We will begin by examining rocks at several points on figure 2.

Point 1: Andesite with visible millimeter-size plagioclase crystals and abundant magnetite, unaltered except for a rind due to weathering. Clinopyroxene is visible on some samples.
GPS = 39˚34.308´N, 119˚48.240´W = 39˚34’18.46”N, 119˚48’14.41”W

Point 2: 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˚34.233´N, 119˚48.213´W = 39˚34’14.00”N, 119˚48’12.80”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, 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˚48.209´W = 39˚34’13.48”N, 119˚48’12.53”W

Point 4: Breccia with fragments of silicified andesite.
GPS = 39˚34.364´N, 119˚47.962´W = 39˚34'21.82"N, 119˚47'57.71"W

Point 5: 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 6. It contains clasts of other volcanic rocks and has distinct fractures that may parallel compaction of the tuff. Epidote is significant because, in modern geothermal systems, it forms at temperatures above 230˚C by hot water that alters calcium-, aluminum-, and silicon-rich minerals in the rocks. Water at that temperature would boil if it were at the surface, but it won't boil if it is under sufficient pressure from overlying rocks.
GPS = 39˚34.398´N, 119˚48.056´W = 39˚34'23.85"N, 119˚48'03.35"W

Point 6: Epidote-chlorite-altered andesite with abundant pyrite and trace amounts of magnetite. This type of alteration is also typical of rocks near many gold, silver, copper, and molybdenum deposits.
GPS = 39˚34.454´N, 119˚48.148´W = 39˚34'27.25"N, 119˚48'08.86"W

You will **create a geologic map** of the area by noting on figure 5 (or on a piece of tracing paper over figure 5) where different types of rocks occur. You may want to examine Points A through P on figure 4 to determine whether they are similar to the rocks from Points 1 through 6.

When geologists begin to look at an outcrop, their first question is generally: what type of rock is this? You should start by describing what you see –

Are there visible crystals?
Can you identify individual minerals?
Is the rock magnetic?
Is the rock hard or soft (harder than steel, softer than your fingernail)?

You don't need to know whether it is igneous, metamorphic, or sedimentary when you first look at the rocks, because your observations, including your map of the distribution of the rocks, will often help you create a geological history of how the rock formed.

What rocks do you find at Points A through P and nearby?

Can you map the boundaries of the rock units that you identify?

By describing the sizes and shapes of stems, branches, leaves, and flowers, how many different types of plants do you see?

Do certain types of plants seem to prefer to grow near certain types of rock?

How do the soils differ, relative to the underlying rocks?

Do all plants need soils?

So what, and who cares?

Why do geologists map the distribution of rocks?

Why do biologists map the distribution of plants?

Why do soil scientists map the distribution of soils?

Why do architects, engineers, and builders care about these maps?

Figure 4. Google Earth image of the DRI and TMCC campus area, with points of geologic interest to investigate; 1:3,875 scale (1 in = 320 ft).

Figure 5. Google Earth image as a base map for creating a geologic map of the DRI and TMCC campus area; 1:3,875 scale (1 in = 320 ft).

ADDITIONAL INFORMATION FOR THE TEACHERS

The rocks immediately around the DRI campus are relatively fresh to highly altered andesites (probably lava flows, tuff, and possibly dikes) 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 volcanic mountain chains (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 various clays (illite-smectite, smectite, illite, pyrophyllite, kaolinite), 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 of the Black Panther mine 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.

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 (fig. 6) 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, illite, 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:

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

or

$$2\, FeS_2 \text{ (pyrite)} + 4\, H_2O \text{ (water)} + {}^{15}/_{2}\, O_2 \text{ (dissolved oxygen)} = Fe_2O_3 \text{ (hematite)} + 4\, H_2SO_4 \text{ (sulfuric acid)}$$

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 or in veins within the clay-altered andesite.

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.

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. There is a key online at http://www.nbmg.unr.edu/GeneralGeology/RockGarden.html .

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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, prismatic, with cleavage at approximately 90˚ angles, when visible with a hand lens

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, with cleavage at approximately 60˚ or 120˚ angles, when visible with a hand lens

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

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

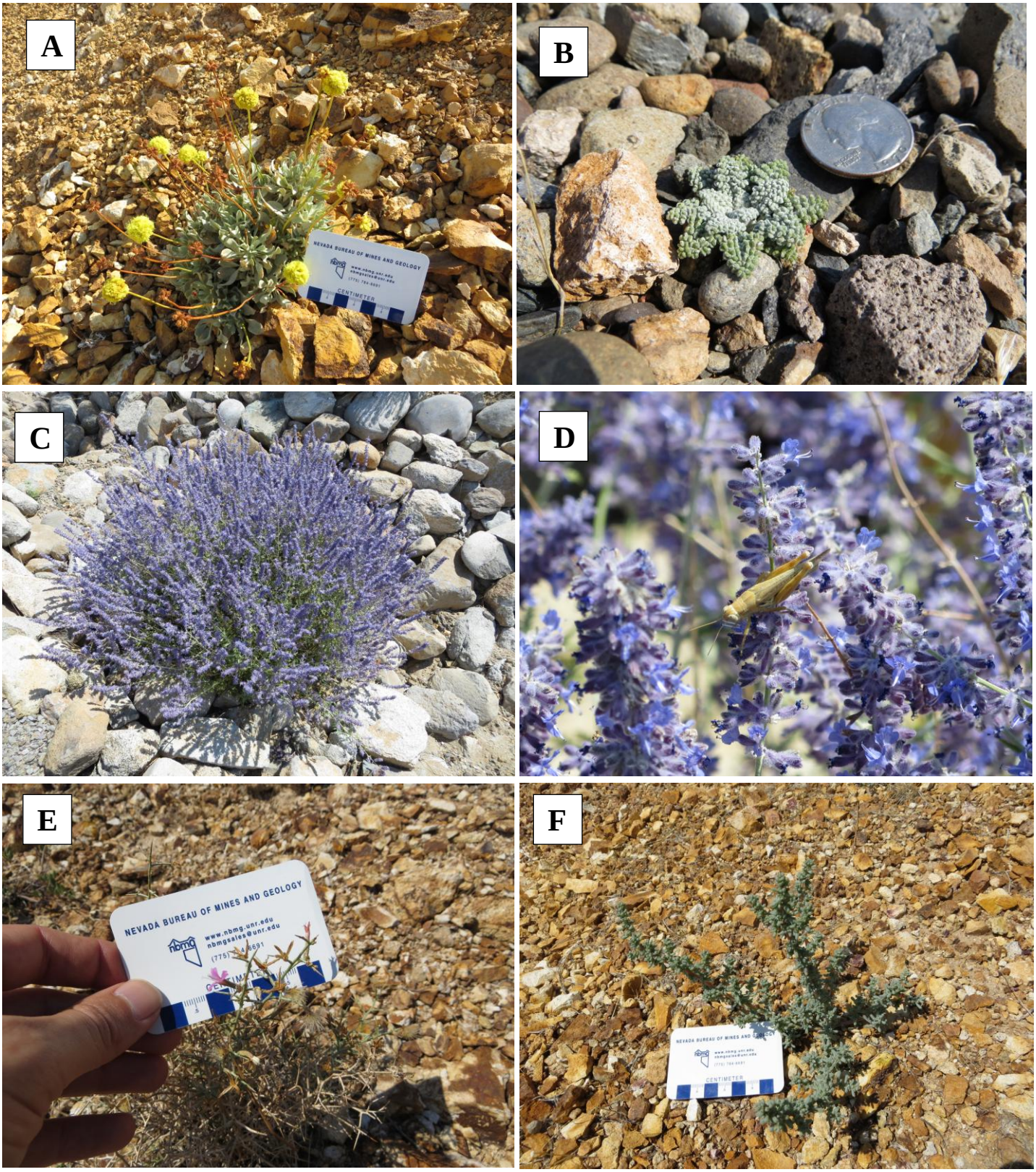

Figure 7. Examples of drought- and acid-tolerant plants around the DRI-TMCC campuses: (A) *Eriogonum* sp. [variety of buckwheat], (B) *Chaenactis* sp. [variety of dusty maiden, aster family], (C) *Perovskia atriplicifolia* [Russian sage, mint family - escaped from nearby landscape plantings], (D) close-up 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.