WARFORD RANCH VOLCANO, ARIZONA, FIELD EXERCISE

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ANSWER KEY

1.0 Introduction

This field trip is designed to acquaint the participant with some fundamental aspects of general geology, volcanology, and the kinds of observations that are made in "real time" in the field by humans. While jargon and specialized vocabulary are kept to a minimum, some terms are unavoidable. The field area is west southwest of Phoenix on paved roads and can be reached in about 1.5 hours. Warford Ranch volcano is a "low shield" that is one of some two dozen structures that comprise the Sentinel-Arlington Volcanic Field (SAVF), but is the smallest of the volcanoes, enabling it to be studied in about a day.

The exercise is designed to be self-discovery with the help of a guide who will walk you through the field. If you don't "catch" the answers, be sure to ask. If the concepts that are behind the answers are unclear, ask for an explanation. We have plenty of time to cover the fundamentals.

2.0 Overview

Arizona includes three physigraphic provinces: the ***Basin and Range, Colorado Plateau,*** and the ***Central Highlands*** (which is a transition zone between the other two provinces). All of southern Arizona, including Warford Ranch volcano (the subject of this trip) and the journey to the field area are within the Basin and Range province. This province is characterized by mountain ranges uplifted by faults and separated by valleys. Most of the ranges trend NW-SE and are composed of rocks as old as 1.7 Ga (billion years; Precambrian Era). Much of the faulting that formed the province occurred at about 15 Ma (million years). The valleys are partly filled with sediments derived from the mountains and rivers, and can be thousands of meters thick.

The field trip is within the ***Sonoran Desert***, characterized by saguaro *(sah-waur-oh)*, barrel, cholla *(cho-ya)*, and other cacti, plus mesquite, palo verde, ocatillo *(oca-tee-yo)*, and creosote bush.

3.0 Getting to the field area

Find your way to I-10 South toward Tucson and travel about 10 miles south of Phoenix Sky Harbor airport; take **Exit 163** off the interstate onto Arizona Highway 347 west where the road log begins.

Mileage

0.0 Intersection of I-10 and AZ 347; go west (right) toward *Maricopa*

The range to the west is *South Mountain*, formed as a special type of geologic feature known as a *metamorphic core complex*. It includes Precambrian (1.7 Ga) granites and metamorphic rocks that were intruded by magma at about 25 Ma, leading to additional metamorphism (the "core complex") and deformation of the overlying rocks. The structural fabric of the core complex trends SW-NE, which is orthogonal to most of the mountains in the Basin and Range.

1.8 *Huhugam Heritage Center* (Native American) on the right

7.0 (milepost 182) *Gila River* bridge (where's the river!?)

The *Gila (hee-la) River* drains much of southern Arizona and flows (when there is water) northwest where it merges with the *Salt River* about 25 km west of Phoenix. The Gila River then flows westward through our field area and joins the Colorado River near Yuma, Arizona.

14.4 Junction with AZ Highway 238 (Smith-Encke Road), **turn right**

27.5 *Mobile community school*; the tan hill to the right in the distance is the Phoenix garbage dump.

The mountain range to the north is *Sierra Estrella*, composed mostly of Precambrian schist; the southern part of the range (closest to our road) is composed of Precambrian granite. Typical of the Basin and Range; these mountains trend NW-SE.

30.2 (milepost 28) entering the *Sonoran Desert National Monument*

The road passes through the NW-SE trending *Maricopa Mountains*, composed mostly of Precambrian granites. Much of the surface is covered with fine gravel and coarse sand, called *grus*, which is the weathered product of granite. Many of the rocks throughout the Basin and Range have a dark surface called *desert varnish*, a manganese-rich coating formed by dust that settles on the rocks and interacts with dew, with reactions possibly aided by biologic processes.

53.4 Junction with AZ Highway 85, turn left toward *Gila Bend*; follow signs to Business Route I-8 through Gila Bend.

Gila Bend is named for the "dog-leg" course of the river, which makes an abrupt (nearly right-angle) shift from its north-to-south path to the west.

56.1 Intersection with I-8; take I-8 west toward San Diego

The *Gila Bend Mountains* are visible north of the community of Gila Bend and consist of Tertiary and Quaternary volcanic rocks overlying Precambrian granite and metamorphic rocks, all of which are heavily eroded. As we travel west along I-8, the dominant features visible in the Gila Bend Mountains are *Woosley Peak* (east, or right-hand side) and *Bunyan Peak* (west, or left-hand side).

68.5 Exit 102, Painted Rock Road / Petroglyph site, travel north (right from I-8) on Painted Rock Road, passing through cotton fields; watch for egrets along the canals

69.4 Cattle feed-lot on the right

To the west (left of the road) are the *Painted Rock Mountains*, composed of Tertiary rocks dated at 20-25 Ma, including basalt, andesite, rhyodacite, and granodiorite rocks. At the north end of this range, the Gila River passes through a *water gap* between the Painted Rock and the Gila Bend Mountains.

79.3 Bear left at "fork" in the road toward Painted Rock campground/picnic site

79.8 Turn left on gravel road into Painted Rock Petroglyph site and park in picnic area; *lock the vehicles*

4.0 Orientation

This is the last rest-stop until the end of the field exercise when we return to this picnic area. The picnic tables under the ramada provide the opportunity to:

1) Discuss the *Sentinel-Arlington Volcanic Field* (SAVF) and set the context for the *Warford Ranch volcano*; note the *Painted Rock shield volcano* visible in profile to the southwest;

2) Outline some basic geology and the rocks and minerals that we will see;

3) Examine the *Digital Orthophoto Quadrangle* (Fig. 1) of the field site and compare with the *Thermal Infrared Multispectral Scanner* (TIMS) image (Fig. 2);

4) Outline the field exercise

Some general questions to keep in mind regarding the geology of this, or any, volcanic site:

(The answers given here should be discussed at the end of the field exercise.)

1. How thick are the lava flow(s) that compose the shield volcano? If there is more than one flow, was there substantial time between their emplacement(s); justify the answer.

> ***Answering this question requires exposed sections through the shield volcano; such outcrops can be seen on the northwest part of the shield in a large arroyo, and on the east side. Multiple flows are exposed in some areas, with individual flows as thick as ~10 m, typical for the relatively thin basalt flows in shield volcanoes. Soil horizons are absent between the flows, indicating short time intervals between the effusive eruptions.***

2. How much erosion has occurred on the surface of the shield; what is the basis of your estimate?

At least 1-2 m has been eroded in the summit area, indicated by the height of exposed dikes. The flanks probably were eroded less than this, suggested by the high degree of vesicularity of the surfaces of the basalt flows.

3. What is the reason for the different appearance of the summit area in comparison to the flanks of the shield, as seen in the remote sensing data?

The summit area is mantled with tephra (cinders and other pyroclastic materials), while the flanks are composed of lava flows.

4. Does the current outline of the shield seen in over-head view represent the full extent of the volcano; why or why not?

No, the present outline does not reflect the maximum extent of the shield volcano because the northern and eastern margins have been eroded by run-off.

5. What is the composition of the rock upon which the shield was emplaced, and what is the nature of the “contact” (the interface) between the lavas of the shield and the underlying rock?

Warford Ranch volcano was emplaced on Tertiary-age rhyodacite on the northwest and west parts, and on alluvium in Citrus Valley. The lower contact is sharp and well defined, with a "baked zone" in places, representing heating and oxidation of the soils by the lava flows.

6. Does the surface of the shield represent the texture of the lava flow(s) at the time of emplacement; why or why not? If you have seen fresh lava flows in Hawaii or elsewhere, do a comparison with the Warford Ranch lava flows.

No, the upper surface of the lava flows has been slightly eroded; fresh basalt flows typically have abundant glass that "crunches" underfoot. Such material weathers chemically and physically rapidly, even in arid climates.

7. Is there evidence of water interaction with the lava; if so, what is the evidence?

No evidence has been found for direct water-lava interactions. Such evidence can include "pillow lavas," which are bulbous, rounded masses of basalt a half meter or more across, surrounded by yellow glass called palagonite; internally, pillows often exhibit fracture patterns radiating from the center.

5.0 The field exercise

Return to vehicles and travel back toward I-8 on Painted Rock Road ~1.5 miles and park off the road.

Stop 1 (Optional)
Examine the rocks exposed in this area. Identify the primary minerals: ***quartz, feldspar, biotie***

Name this rock: ***granodiorite***

Continue on Painted Rock Road toward the Interstate to the field site parking area near milepost 8 (at about mile-post equivalent 8.4) on the north side of the road. Vehicles will remain here for the field exercise; take lunch, water, field exercise, cell phones and vehicle keys with you.

Stop 2 (Parking area)

Orient the images to the terrain. Examine the rocks in this area. Find an "outcrop" (rocks formed in place) and examine "fresh" rocks (hit them with a hammer!) Name the rock: ***Basalt***

Is there evidence of alteration of the rocks?

Yes, the white carbonate deposits (called caliche) on the basalt.

Stop 3 (Hill across the road opposite the parking area)

Make a "traverse" (walk toward) the hill and note the types of rocks that are encountered. Note which rocks are "float" (loose rocks on the surface that have migrated down-slope from above) and those that are exposed in outcrops.

Name the "float" rocks

Rhyodacite, obsidian

Name the outcrop rocks

Rhyodacite, obisian

Describe the "weathered" surfaces of the rocks versus "fresh" (use hammer) appearances of the rocks.

Weathered surfaces are dark with desert varnish; fresh rocks expose light-colored non-weathered rhyodacite.

Continue the traverse to the first small cliff and describe the appearance of the outcrop and the rocks in the hill. Relate the “float” rocks to the rocks in this outcrop.

The outcrop exposed in the cliff consists of massive rhyodacite and obsidian with little internal structure, such as flow banding and vesicles, and is the source for the “float” rocks.

Stop 3 provides a good perspective for viewing the ***Warford Ranch low-shield*** (LS) volcano. Find a comfortable rock to sit on and then sketch a general *profile* of the volcano; are the slopes in profile uniform, or do some slopes appear steeper? Consider the reasons for the slopes that you observe.

The Warford Ranch LS has a classic shield-shaped profile composed of very gentle slopes. The summit area, however, is slightly steeper, which is typical for "low shields" in many areas, including those in the Sentinel-Arlington Volcanic Field. Such steepening can result from a variety of processes, including 1) eruption of more viscous lavas, 2) eruption of lavas of less volume than those that comprise most of the shield (and thus would flow shorter distances and accumulate near the summit vent(s), 3) eruption of lavas at a lower rate of effusion, leading to shorter-length flows, and/or eruption of pyroclastic materials from mild explosions, leading to accumulations close to the vent(s).

Note also that the profile appears to have more than one summit zone.

Orient the two images of the field area to the terrain before you. *Geologic maps* provide the context for most geoscience investigations of planetary surfaces. Use tracing paper and make a simple geologic sketch map of the area, using the Color-Near IR Digital Orthophoto Quadrangle (Fig. 1) and the TIMS image (Fig. 2) as the base. Draw lines (called “contacts”) around the exposures of apparently similar rocks seen on the images. Note the differences in the general color “tone” of the surface and other characteristics of the terrain that you see across the road and compare to the images and your map.

From the sketch map that you produce, predict that rock types you might find on and around the Watford Ranch LS.

The TIMS image has been processed so that iron-rich rocks (basalt) are in shades of blue, rocks that are high in silica (such as quartz-rich) are reddish, and carbonate rocks are greenish.

Observe the reddish hill to the left (southwest) of the summit of Warford Ranch volcano. Pose some hypotheses regarding the origin of this hill. The hill is **Stop 5** and we will have a chance to “field-test” your ideas.

The reddish hill could be 1) composed of cinders or other tephra from a local vent, 2) an island, or kipuka, of older terrain surrounded by younger rocks, or 3) an erosional remnant of the shield volcano.

Traverse to Stop 4

We will now retrace our path back across the road (watch for traffic!) and walk down into the arroyo (small gulley) to the northwest (left) of the parking area. Remember the rock type at the parking area and the rock type at **Stop 3**. A "Holy Grail" in field work is the *contact* (the boundary between two different types of rock). On this traverse, find the contact between the two different types of rocks that you have seen and compare with your sketch map. Which of the two rock types is older; how can you tell?

> ***The basalt rests on top of the rhyodacite (most of the contact between the basalt and the rhyodacite is covered by loose rocks). The "Law of Superposition" (rocks on top are relatively young in non-deformed rock sequences) would indicate that the rhyodacite is older.***

Stop 4 (Floor of the arroyo)

The floor of the arroyo has scoured the bedrock and gives good exposures of the rock textures. Describe what you see, especially with regard to the *rhyodacite.*

> ***Large feldspar mineral grains are present; the elongate, flattened pieces of pumice and lapilli are indicative of ash flow.***

Traverse to Stop 5 ("Red Hill" to left of volcano summit)

Describe the rocks and remember the "Holy Grail" in field work. What is the origin of the white material on the surface of many rocks? What is this white material called?

> ***This material, called caliche, is a carbonate formed by weathering of the basalt.***

Note the loose black and white rocks on the surface and how they fit together so closely; what is such a surface called?

> ***Desert pavement***

Explain how such surfaces might form?

> ***Forms by 1) wind "winnowing" of finer grains, 2) wetting and drying of clay-rich dust to "jostle" the larger pieces into place, or 3) a combination of these processes.***

Stop 5 ("Red Hill")

This is the hill that you could see from **Stop 3**. Test your ideas about this hill and record your answer.

> ***This is an "island" of the older (Tertiary) rhyodacite that was not buried by the younger basaltic lava flows on the east nor the Quaternary sediments on the west.***

How might the observations here be applied to mapping other parts of the remote sensing data?

> ***Based on this "ground-truth," the remote sensing "signature" of the TIMS data can be used to infer the presence of other occurrences of rhyodacite.***

Numerous small white dots are visible on the image. What are these?

> ***These are places where ant colonies have concentrated sands, many of which are associated with small bushes.***

Traverse to the summit of Warford Ranch LS

Walk toward the summit of Warford Ranch LS. Look back toward "Red Hill" and note the difference in color "tone" of the surface, the vegetation, and the amount of caliche. Offer some possible explanations for the differences.

> ***As the term implies, "Red Hill" is red, due to the rhyodacite rocks, while the rocks on the shield are gray-to-black basalt. Rocks on the shield also have a greater percentage of fragments of caliche. Even though caliche is a weathering product, and the basalt is younger, there is more present on the basalt than on the rhyodacite. This can be explained by the difference in the type of feldspars that are involved: rhyodacite contains predominantly potassium feldspar (orthoclase), whereas basalt contains calcium-rich feldspar (Ca-) plagioclase, which weathers chemically to form the caliche carbonate materials. Vegetation prefers carbonate materials, which partly accounts for the greater density of cacti, etc. on the basaltic shield.***

Near the summit, note the small red rocks; what is this material called?

> ***This is tephra, a general term for pyroclastic materials such as cinders and ash.***

What *style of eruption* produces the small red rocks?

> ***Mild explosions, or Strombolian activity, named for the classic Mediterranean volcano.***

Note the ~meter-high "wall of basalt." What is this feature called, how did it form, and what is its relation to the small red rocks?

> ***This feature is a small dike, or intrusion of basaltic magma that forced its way through the overlying rocks of the shield. From observations of active volcanoes in Hawaii and elsewhere, these "feeder" dikes can produce lava flows and/or mild explosions called "curtains of fire" composed of lava spatter and cinders. In this oxidizing environment, the lavas and cinders are typically red. It is likely that most of the cinders in the vicinity of the dike were produced in this fashion.***

Explain how this feature (the wall of basalt) can be used to estimate the amount of surface erosion from the summit area?

There must be materials present for dikes to squeeze into; thus, the absence of such material at least to the height of the wall would indicate that the material has been eroded by some 1-2 m. This does not mean, however, that the entire surface of the volcano has been eroded by this amount; the summit area includes cinders and other pyroclastic material that is more easily eroded than the lava flows that comprise the volcano flanks.

Stop 6 (Summit area)

Was Warford Ranch LS built exclusively from lava flows?

No, the tephra also contributed to the volcano.

Was there more than one eruptive center ("vent") in the summit area?

Yes, indicated by the separate mounds in the summit area, each of which was a local vent.

What might account for the steeper slopes in the summit area?

The pyroclastic materials can accumulate in piles with slopes as steep as 34° (the "angle of repose"), while most basalt flows are low-viscosity and spread out as thin sheets.

Departure from summit

There are several options from this point, listed in increasing time required and distance to be traveled: a) return to the parking area if time is limited, b) traverse to the west contact of the volcano and then walk south to the parking area, c) traverse to the northwest to the large arroyo and exposures of the basalt unit(s) of the volcano, and then return to the parking area, or d) traverse east-southeast to the basalt exposure of the shield volcano lavas and then work along the contact south and then west back to the parking area.

After the field work, explain how your impression of the site differs from your impression before the field work based on the images.