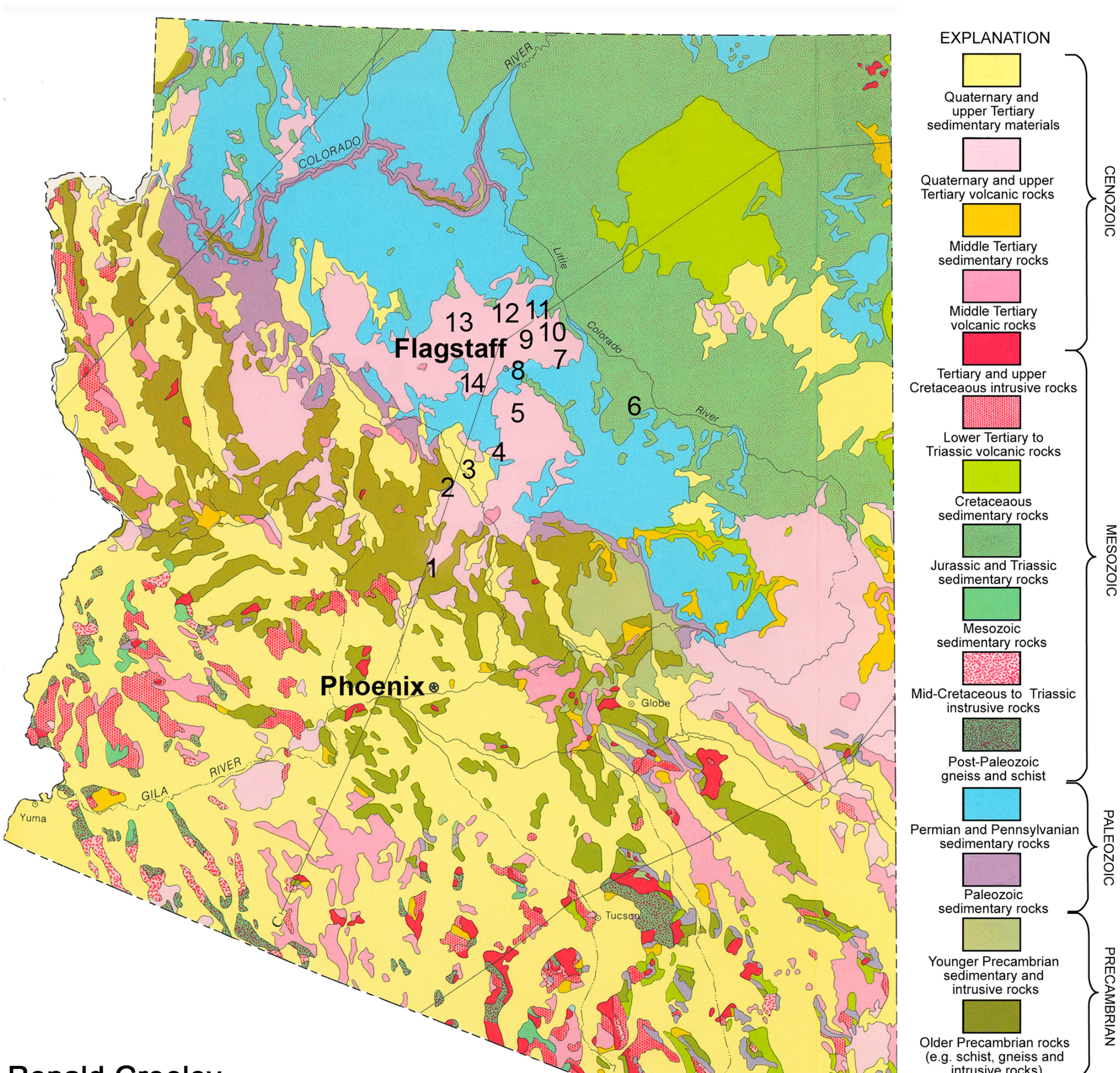
THE 'HOLEY' TOUR: CRATERS AND VOLCANOES

Fundamentals of Planetary Geology



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Geologic Map of Arizona, modified from Cooper and Cone, courtesy of Arizona Geological Survey

100 miles

100 km

NAME ____________________________________

PLANETARY GEOLOGY FIELD TRIP EXERCISE
Ronald Greeley

This field trip introduces some basic geologic principles and emphasizes those facets that are important in planetary geology. We will visit several localities, shown as numbered "STOPS" on the cover of this exercise.

One of the objectives of this trip is to make observations that will aid in the identification of various types of craters. At each of the "crater" stops, be sure to record ***critical*** data and make sketches on the back of the page that will help to distinguish one crater type from another. A second objective is to note the ***form*** of each of the several types of volcanoes that will be seen. Questions regarding ***craters*** and ***volcanoes*** will be asked at a future time.

In order to obtain credit you must turn in this completed exercise at the end of the trip. All of the answers will be provided during the trip.

While driving to Stop 1:

1. Examine the geologic map of Arizona (cover). What are the age and type of the youngest rocks we will drive across (or near) on the trip?

   What are the age and type of the oldest rocks we will drive across (or near) on the trip?

2. What do the pink and red units on the map represent?

3. Many rocks in the lower desert show white, chalky surfaces; other rocks show shiny, dark surfaces. What are these? Would a fresh exposure of these rocks be dark? Why or why not? What is the significance to planetary science?

4. What are the physiographic provinces we will visit on the trip?

   a)

   b)

   c)

5. Notice the basalt flows exposed in road-cuts between mileposts 247 to 250. What is the range of thicknesses of the flows?

   What is the origin of the red zones between some flows?

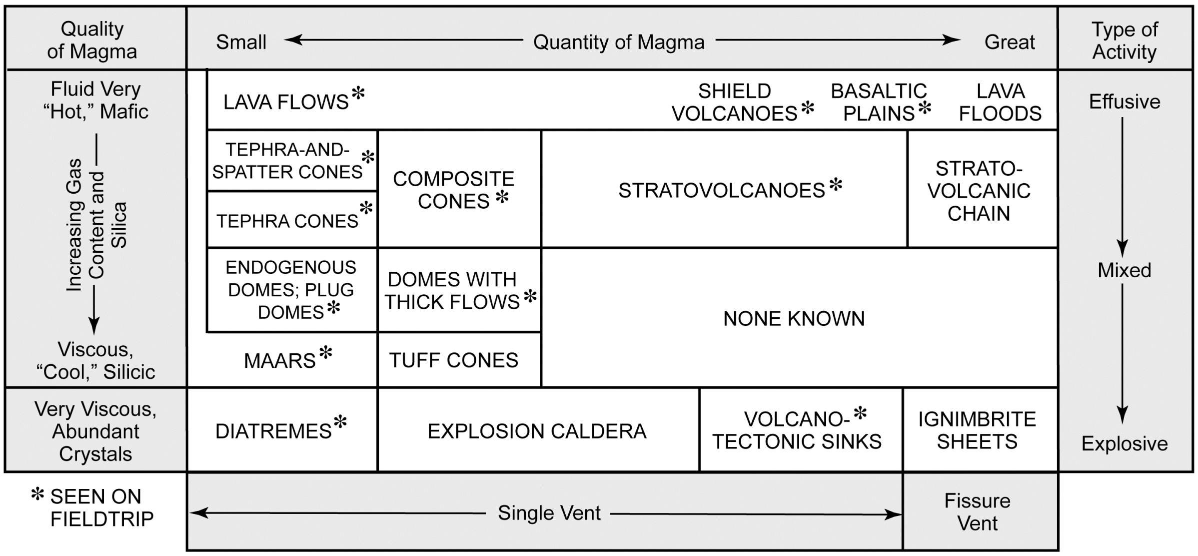

Figure 1. Critical factors (shaded) governing the forms of various volcanoes, a wide variety of which can be seen on the Holey Tour **(modified from Rittmann, 1962).**

Stop 1 (Sunset Point Rest Area):

1. What is the rock type here on Black Mesa?

2. Look eastward toward ***Joe's Hill***, the rounded low mound toward the horizon. In the space below, draw a simple profile and cross section of Joe's Hill, and give a short description of its origin.

3. Compare and contrast the morphology of flood basalt regions, Hawaiian shield volcanoes, and shield-field volcanism (see **Fig. 1)**.

4. The ***Bradshaw Mountains*** are to the west on the horizon. What are their age, composition, and economic significance?

While driving to Stop 2:

Notice the terrain between mileposts 258 and 259; how does this terrain and the exposed rocks differ from the basaltic surface of Black Mesa? Explain what this terrain and rocks might be.

Stop 2 (Verde Valley Overlook):

1. What "caps" the Colorado Plateau, visible to the north from here?

2. What underlies the "cap"?

3. What is the origin of Verde Valley?

4. What are the age and origin of the whitish beds in Verde Valley?

5. What is the origin of the white strata visible to the south in the cliffs?

Stop 3 (Montezuma Well):

We will take the trail to Montezuma Well, just past the ranger shack; review **Table 1**.

1. Explain the origin of the pits and hollows on the surfaces of the rocks. What type of feature is Montezuma Well?

2. What is a possible origin for the "raised rim" around the well?

3. Take the trail down to the creek. Explain why the level of the lake in the well remains ~constant.

4. Are the deposits exposed in the cliff above the spring all of the same composition? Explain your answer.

TABLE 1. CRITERIA FOR THE RECOGNITION OF IMPACT CRATERS (MODIFIED FROM DENCE 1972)

Criterion	Characteristics	Reliability
Remote sensing		
Plan view	Distinctly circular; may be modified by slumping, tectonic patterns, or erosion	Fair, but can be attributed to other processes
Rim structure	Inverted stratigraphy	Definitive
Central zone	Floor lower than surrounding plain; may contain central uplift	Fair, but can be attributed to other processes
Geophysical observations		
Gravity anomaly	Generally negative	Supportive, but not conclusive
Magnetic field	Variable; may be distinct anomaly over melt rock	Supportive, but not conclusive
Seismic velocities	Generally lower in brecciated zones	Supportive, but not conclusive
Ground observations		
Presence of meteorites	Rare except in very young craters	Definitive
Shock metamorphism	Features such as high pressure minerals, impact melt, planar shock features and shatter cones	Definitive
Brecciation	Observed in ejecta, rim and floor of craters	May be attributed to other processes

Stop 4 (Stoneman Lake):

1. What is the rock type here?

   What ***phenocrysts*** can be identified in the rock?

2. Examine the air photo of Stoneman Lake **(Fig. 2)**. How does the shape of the lake compare with that of the crater-depression?

3. Consider the origin of the depression containing Stoneman Lake. Record your observations as to rim morphology, evidence of faulting, evidence that there was (or was not) a volcanic vent here. What underlies the rock units? What volcanic term could be applied to this crater?

4. Describe briefly the differences and similarities among the ***Black Hills, Mormon Lake***, and ***San Francisco*** volcanic fields, especially as to age, rock types, and volcanology **(Fig. 3)**.

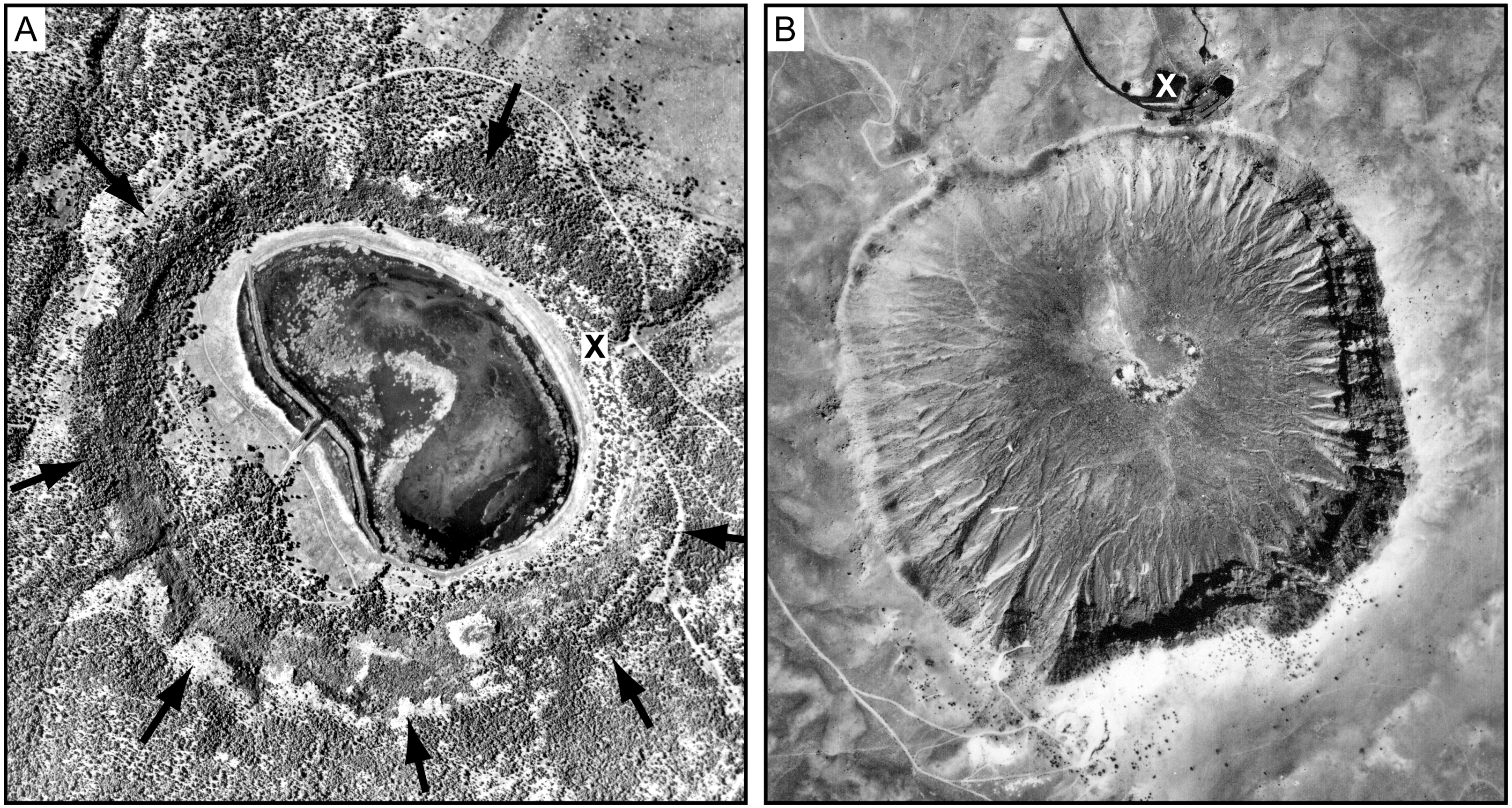

Figure 2.

A) Stoneman Lake (dark kidney-shaped area) and the circular depression (arrows outline the rim) containing the lake. The depresion is about 1.6 km in diameter; "X" marks the picnic area and Stop 4; north is toward the top (US Dept. Ag. Image ERZ-25-58 taken in 1967).

B) Meteor Crater is about 1.2 km in diameter and has a rectangular outline in planform, a consequemnce of excavation partly controlled by a regional set of orthoganoal joints; "X" marks the visitor center (Stop 6) (USGS image Ariz. 14-A, AGS-MCH, taken 1963).

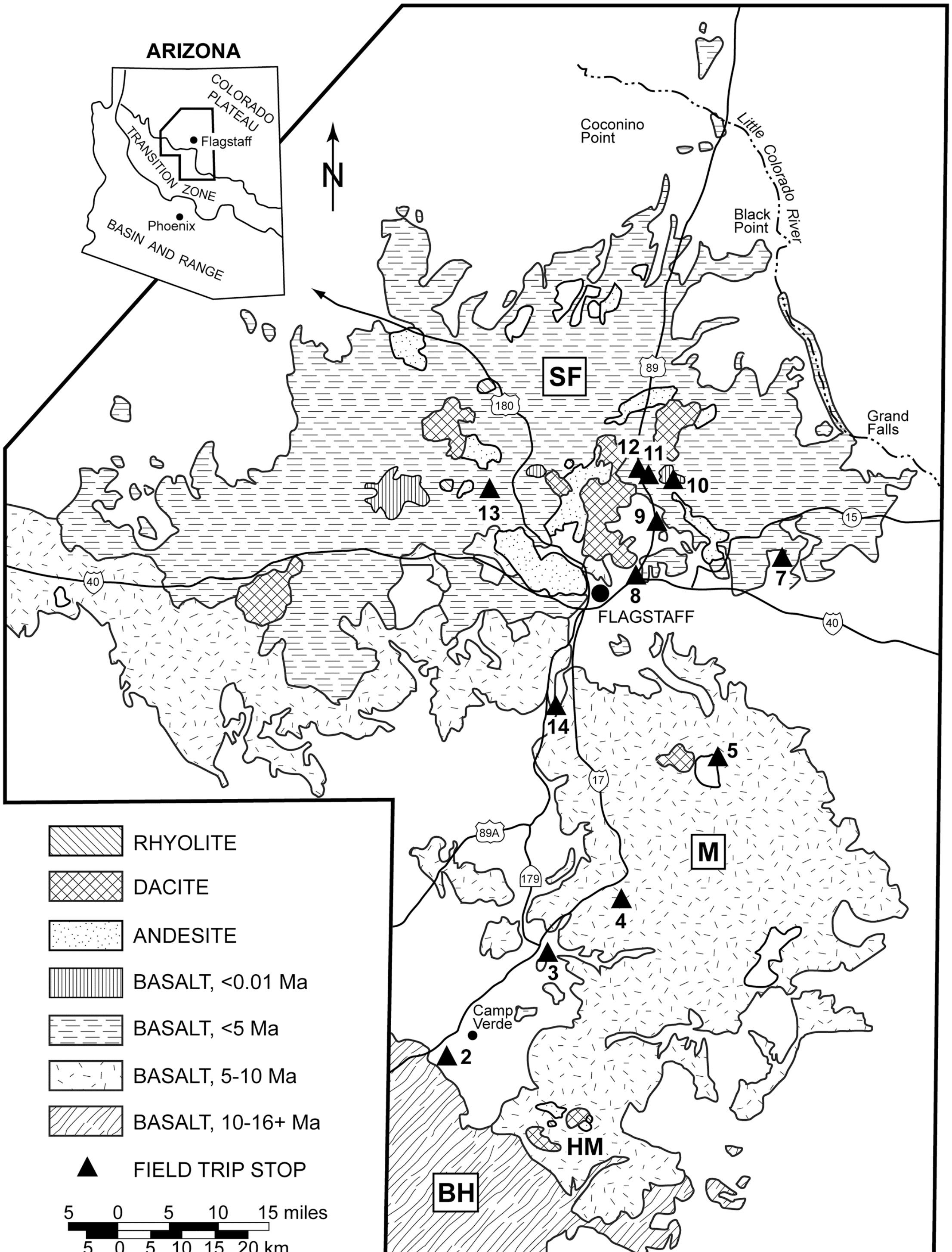

Figure 3. Map of the Black Hills (BH), Mormon (M), and San Framcisco (SF) volcanic fields and their predominant rocks types and ages (most rhyolite outcrops are too limited to be shown here); also shown is Hackberry Mountain (HM) **(after Holm and Ulrich, 1987).**

Stop 5 (Mormon Lake Overlook):

1. What is the rock type here?

2. Examine the hill ***(Mormon Mountain)*** west of the lake, and the hill at the south end of the lake. Compare and contrast their profiles and general morphology and explain their similarities/differences.

3. Explain the possible origin for the basin containing Mormon Lake.

While driving along Lake Mary (milepost 336.8)

1. Notice the sedimentary rocks in road-cuts on the east side; what sedimentary structure(s) do you recognize?

2. What is the origin(s) of these features?

3. Explain the significance of these features as related to Meridiani Planum, Mars.

Stop 6 (Meteor Crater):

1. We will go straight to the crater rim overlook through the Visitor Center. When did Meteor Crater form?

   What happened to the impacting object that formed the crater?

   What type and size object formed the crater?

2. How much erosion has occurred on the surrounding ejecta blanket?

   What is the maximum size ejecta block?

3. What mineral(s) have been found in the Coconino Sandstone and what is their significance?

4. Examine the air photo of Meteor Crater **(Fig. 2)** and compare its plan-form to the depression containing Stoneman Lake. How do you account for the difference between the two crater shapes?

5. Notice the buttes visible to the north and northeast; what are these features called and what is their origin(s)?

6. Return to the Visitor Center for the exhibits. On the trail back to the Visitor Center search for evidence of over-turned stratigraphy in the rim.

Stop 7 (Rattlesnake Crater):

1. What is the morphology of this *maar crater* depression?

2. What is the composition of the rim material?

3. Why is the east rim higher than the west rim?

4. What is the age relationship between the crater and the hill to the east?

5. Explain the origin of Rattlesnake Crater.

Stop 8 (Elden Mountain overlook) Figure 4:

1. What is the composition and age of this volcano?

2. What type of volcanic landform is Elden Mountain?

3. What are the dimensions of the flow lobes?

4. Was the extrusion of lava the only volcanic activity at Elden Mountain? Explain.

Figure 4. Aerial photograph of Elden Mountain, showing dacite flow lobes for the exogenous part of the dome; endogenous part is indicated by the dendritic fluvial dissection on the upper east side of the dome. Flagstaff and I-40 are seen at the bottom of the image (ASU mosaic 4252-H).

Stop 9. Cinder Lake:

1. What is the origin of the cinders here?

2. Examine the small craters. Are they all the same size and shape?

3. What is the yellowish material on the rims?

4. Explain the significance of these craters.

Stop 10a (Sunset Crater Visitor Center):

Examine the displays in the Visitor Center and answer the following questions.

1. Identify the largest earthquake that occurred in the western United States today and its magnitude.

2. View the interactive panoramic images taken at the summit of Sunset Crater; match the aerial photograph in the exercise **(Fig. 5)** to the panoramic image and describe the crater as part of the "hole" assignment.

3. Describe the shape and size of the largest volcanic bomb on display.

4. Can fossils form from volcanic eruptions? Explain your answer.

5. What is the age and basis for the age-dating of the eruptions at Sunset Crater? Be specific.

6. Is there any pattern in the eruptions in the San Francisco Volcanic Field? Explain.

7. What is the ***style of eruption*** for Sunset Crater; how high were the ***fire fountains*** and the ***ash cloud***?

8. What is the range in thickness of the ash deposits from the Sunset Crater eruptions from the base of the cinder cone north to ***Waputki***? From the ash ***isopachous map***, what is the inferred wind direction at the time of the eruption?

Stop 10b (Bonito Lava Flow parking area):

1. Orient the aerial photograph **(Fig. 5)** to the terrain. What is the rock type here?

2. Take the trail across the flow northward to the cliff. Describe the surface of the flow (texture, vesicularity, relief, flow structures, etc.). What kind of flow is this?

3. What formed the cliff?

4. How thick do you estimate the clinkery texture to be?

5. Describe the interior of the flow.

6. Describe the probable manner in which this flow advanced.

Stop 10c (Sunset Crater Nature Trail):

We will take the trail; orient the aerial photograph **(Fig. 5)** to the terrain and proceed to Station 1(instructor will guide you)

Station 1. This feature is a ***lava tube.*** What is the lava type (texture) that makes up the roof of the tube? Is this the primary surface of the flow? Why or why not?

How do lava tubes form?

Do lava tubes typically form in a'a flows? Why or why not?

Station 2. What features identify this as a ***vent***?

What is the origin of the whitish deposits?

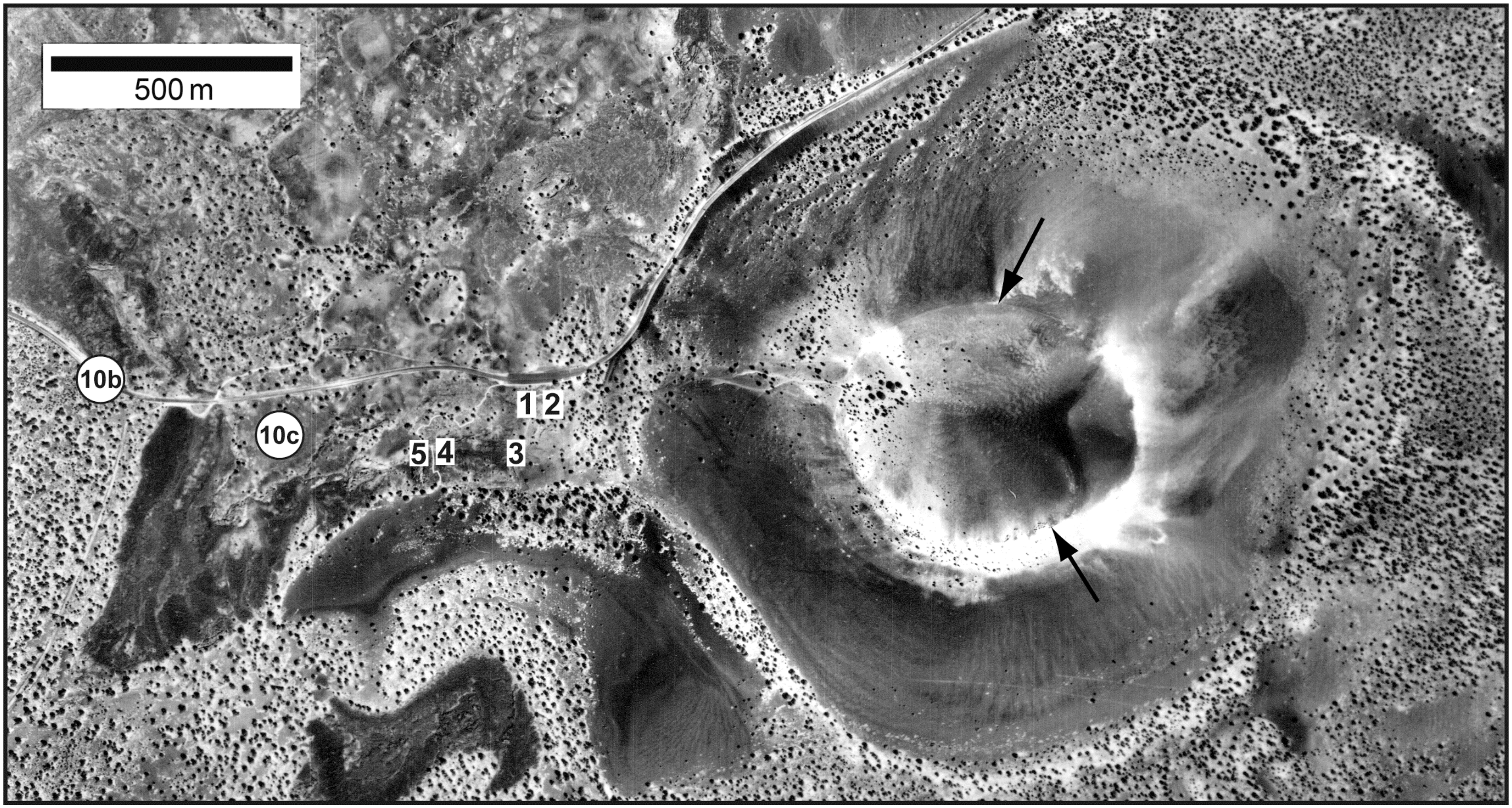

Figure 5. Aerial photograph of Sunset Crater cinder cone, showing the elliptical summit crater (arrows point to rim), the Bonito Lava Flow parking area (Stop 10c), and the Lava Flow Trail parking area (Stop 10c). Stations along the trail are 1) lava tube, 2) hornitos, 3) stratigraphic relations, 4) xenolith, and 5) squeeze up. Light-tones (as at 10c) indicate terrain covered by ash from Sunset Crater; very dark areas, such as the flow southwest of 10c, are free of ash. North is approximately toward the top; illumination from the south (thus, the southern wall of the crater is in shadow) (US Dept. Ag. image EGE-37-86 taken in 1960).

Station 3. Two lava flows are visible here, the relatively lower-level greenish-black aa flow, and a second reddish flow that forms the higher unit and which the trail in the distance climbs. The Park Service (and C.A. Hodges) tells us that the lower flow is younger. Do you agree? Give the evidence for your position (use superposition, geometric relations, etc.). Also use the air photo **(Fig. 5)**. You may want to reserve a final opinion until after you examine the surface of the reddish flow.

What was the vent for the older lava flow?

Station 4 (top of trail). Several light-toned rocks are found in the lava here. What are these features called? What kinds of rocks are they, and how did they get there?

Station 5 (viewing platform). How did this crack form and what are the features marked here?

Stop 10d (Cinder Hills Overlook):

There is a good view of Sunset Crater cinder cone and other small volcanoes from this stop.

1. What is the maximum slope on the various cones? Why is there an upper limit?

2. Is Sunset cinder cone composed solely of cinders?

3. Would you expect cones to have a different form on the Moon? Mercury? Venus? Why or why not?

4. Are all the cones of the same age? Why or why not?

5. How many of the cones show signs of erosion?

6. Is water an effective agent of erosion here? Why or why not?

7. Trees appear to grow predominantly on the north slopes; why is this?

8. Describe the appearance of O'Leary Peak. How is it different from the other hills in this area? Why?

Stop 11 (San Francisco Peaks Overlook):

1. Examine San Francisco Mountain and identify the principal summits and features (Agassiz, Doyle, Humphrey, Dry Lake Hills, Sugarloaf, North Sugarloaf, etc.). Is the current profile the pristine shape for San Francisco Mountain? Explain.

2. What is the principal composition (by volume) of San Francisco Mountain?

3. What is the relationship between sequence/evolution of San Francisco Mountain and silica content?

4. What is the oldest feature identified with the Mountain?

5. What is the origin of the inner valley?

Stop 12. Robinson Crater / O'Leary Peak, west flank

1. Collect the variety of rocks at this exposure; identify the mineral(s) present and the texture of the rocks. Name the rock(s).

2. Explain the differences among the samples.

3. Return to the vehicles and drive a couple of hundred meters back down the hill. Examine the outcrop on the left and explain the mode of growth for O'Leary Peak.

4. What is the age for O'Leary Peak, and what is the age based upon?

5. What is the origin of the black cinders seen on the slopes?

Stop 13. Lava River Cave (also called Government Cave):

1. What is the average thickness of the tube roof?

2. What is the role of the lava tubes in the emplacement of long flows? Explain.

3. What is the significance of lava tubes in the planetary context?

The return from Flagstaff to Tempe will be on US Highway 89A south to Sedona, then Arizona Highway 179 (turn left in Sedona) back to I-17.

Stop 14 **(Oak Creek canyon overlook):** US Forest Service "pullout" east of the highway.

1. This position marks the headward zone of Oak Creek Canyon. Explain the reason for the difference in elevation between the west side and east side of the canyon.

2. The "Red Rock" of the drive from here to I-17 is composed of what formation(s) and age(s)? What was the environment(s) of deposition for the rock(s)? To answer these questions, sketch a geological column showing the rock(s), age(s), and environment(s) below.

The drive to the interstate will be on narrow, winding mountainous roads. Be patient; enjoy the scenery/geology (except the driver!). Do not try to "caravan" from now to Tempe. There is a road-side rest area with rest rooms on I-17, just south of the junction of AZ 179 and I-17.