



Lunar Exploration Initiative

Briefing Topic:

Cinder Lakes Crater Field, Arizona Lunar Analogue Test Site

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Cinder Lakes Crater Field, Arizona

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Cinder Lakes Crater Field, Arizona

Geologic Context

Volcanic Rocks in Arizona

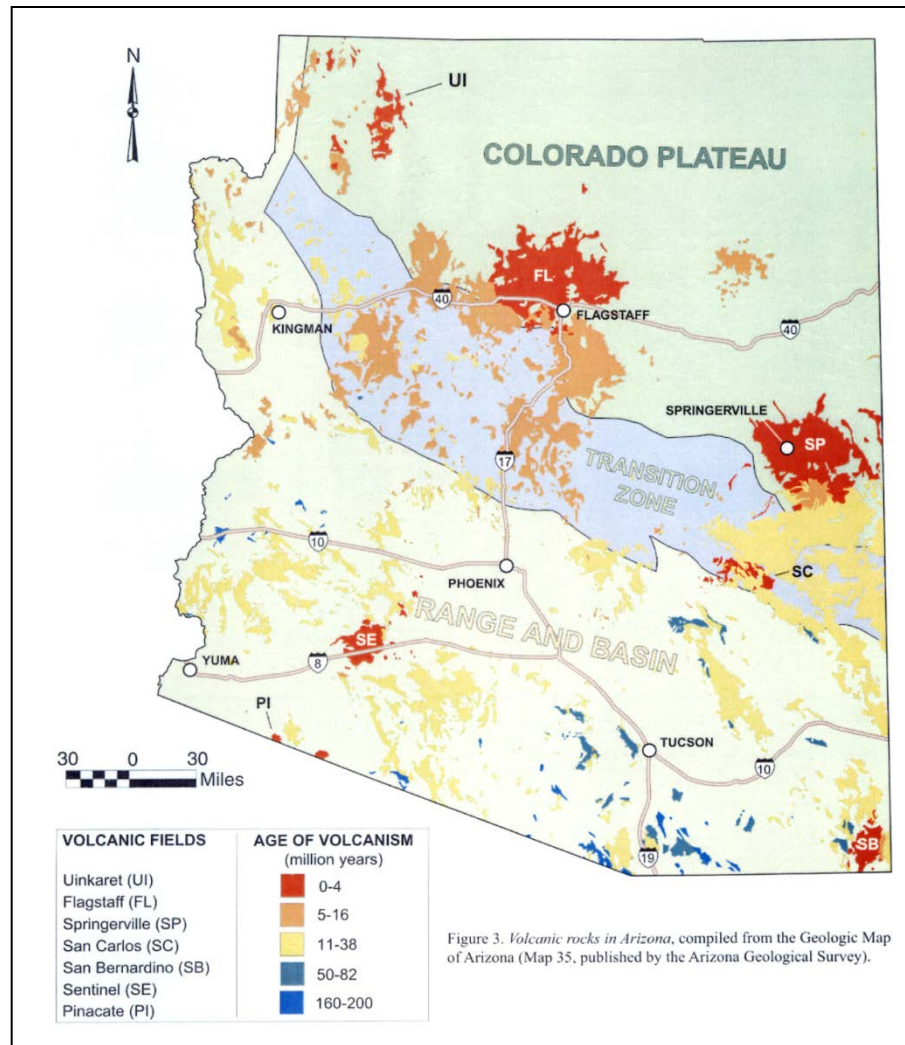


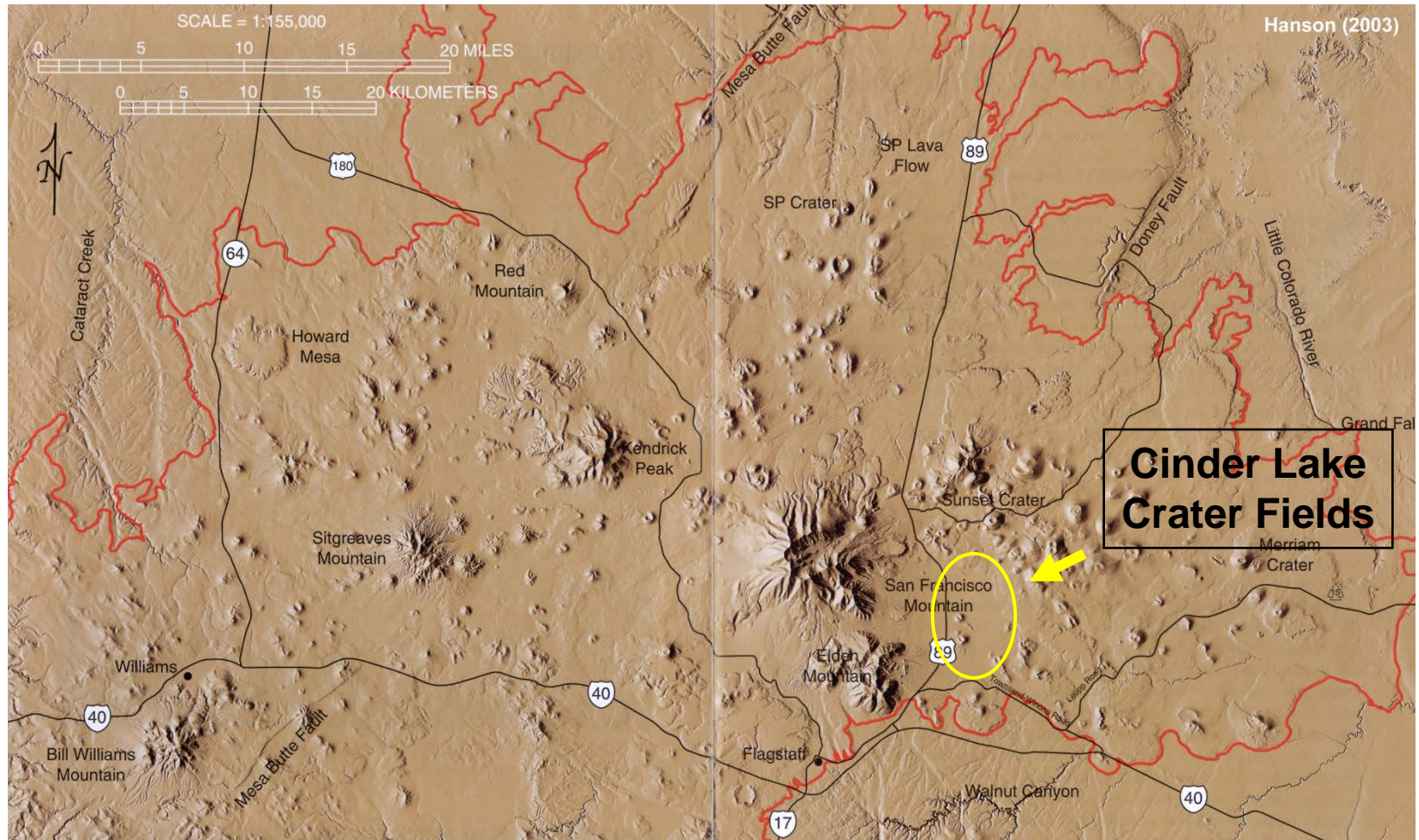
Figure 3. *Volcanic rocks in Arizona*, compiled from the Geologic Map of Arizona (Map 35, published by the Arizona Geological Survey).

The San Francisco Volcanic Field is one of several very young (0 to 4 million-year-old) volcanic fields in Arizona.

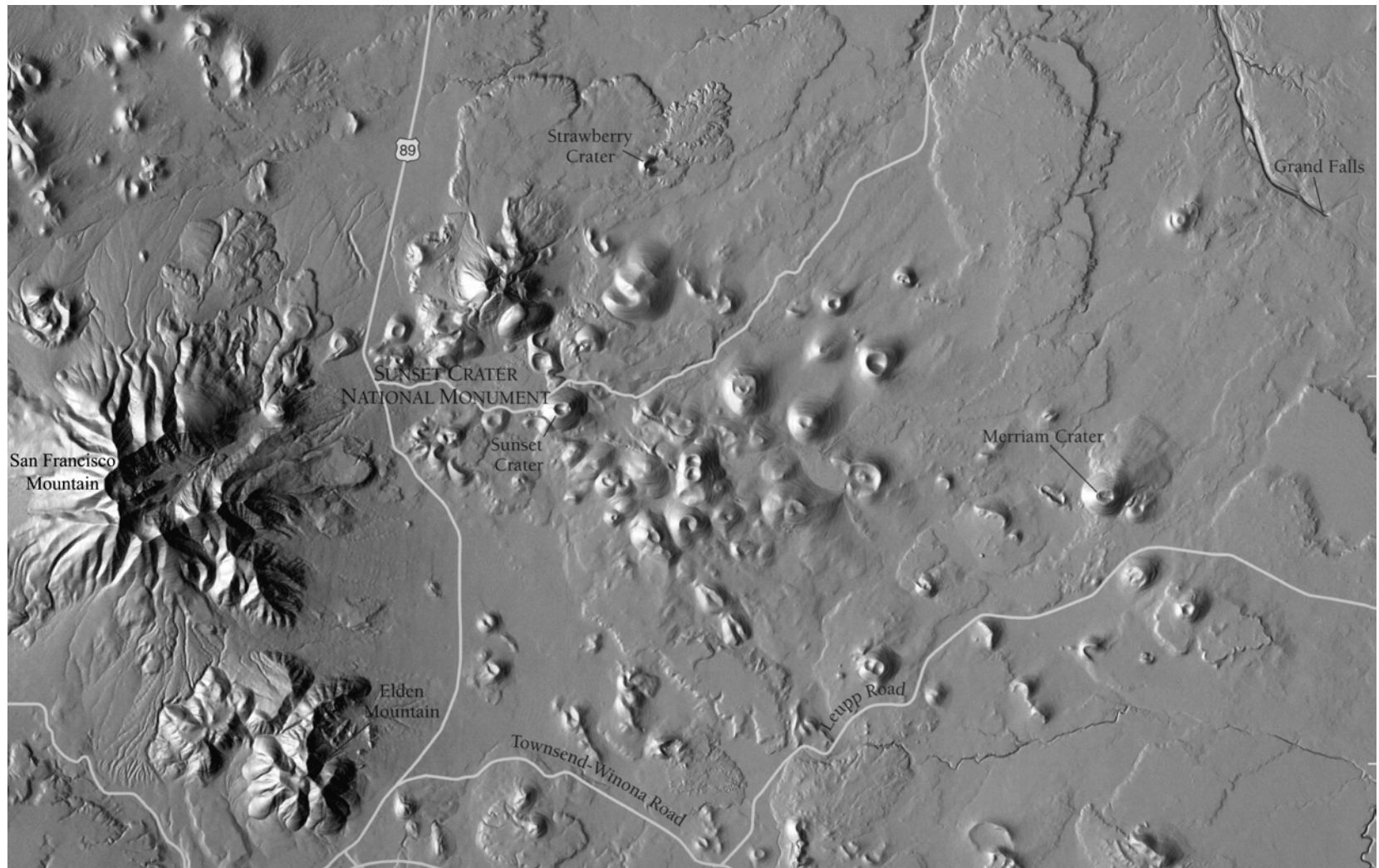
It is located around Flagstaff on the Colorado Plateau.

San Francisco Volcanic Field

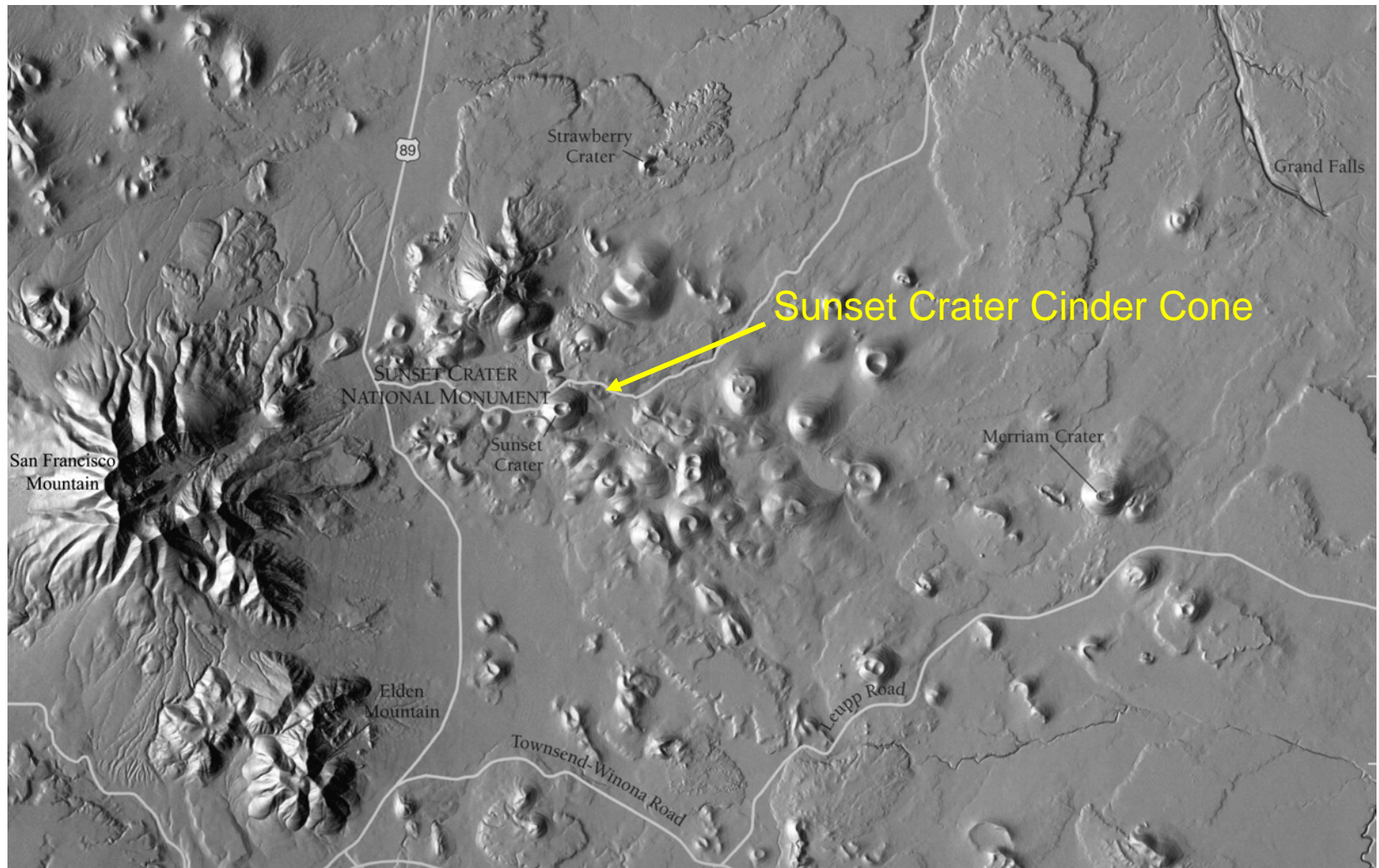
- Adjacent to Flagstaff, Arizona



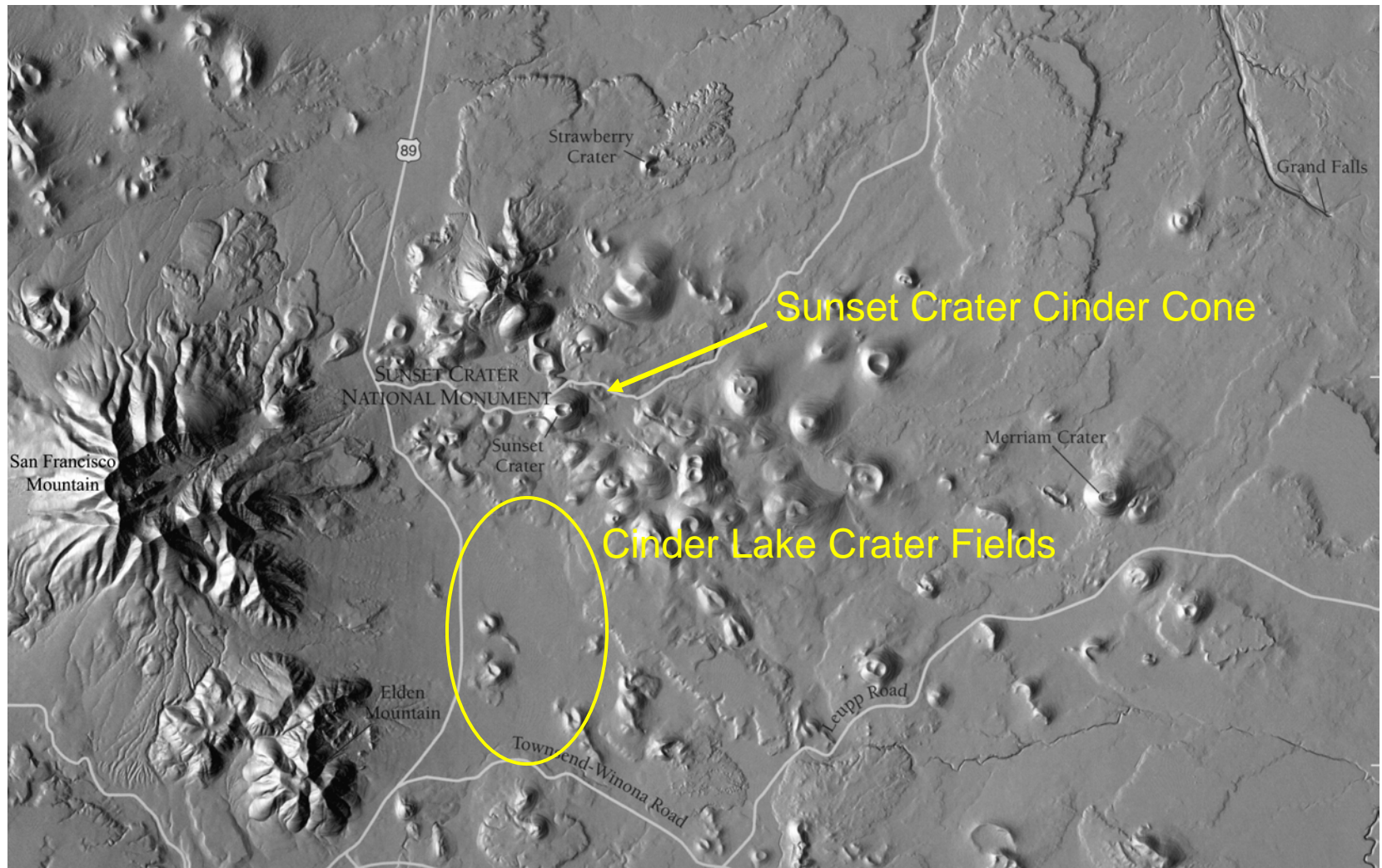
Eastern Portion of SFVF



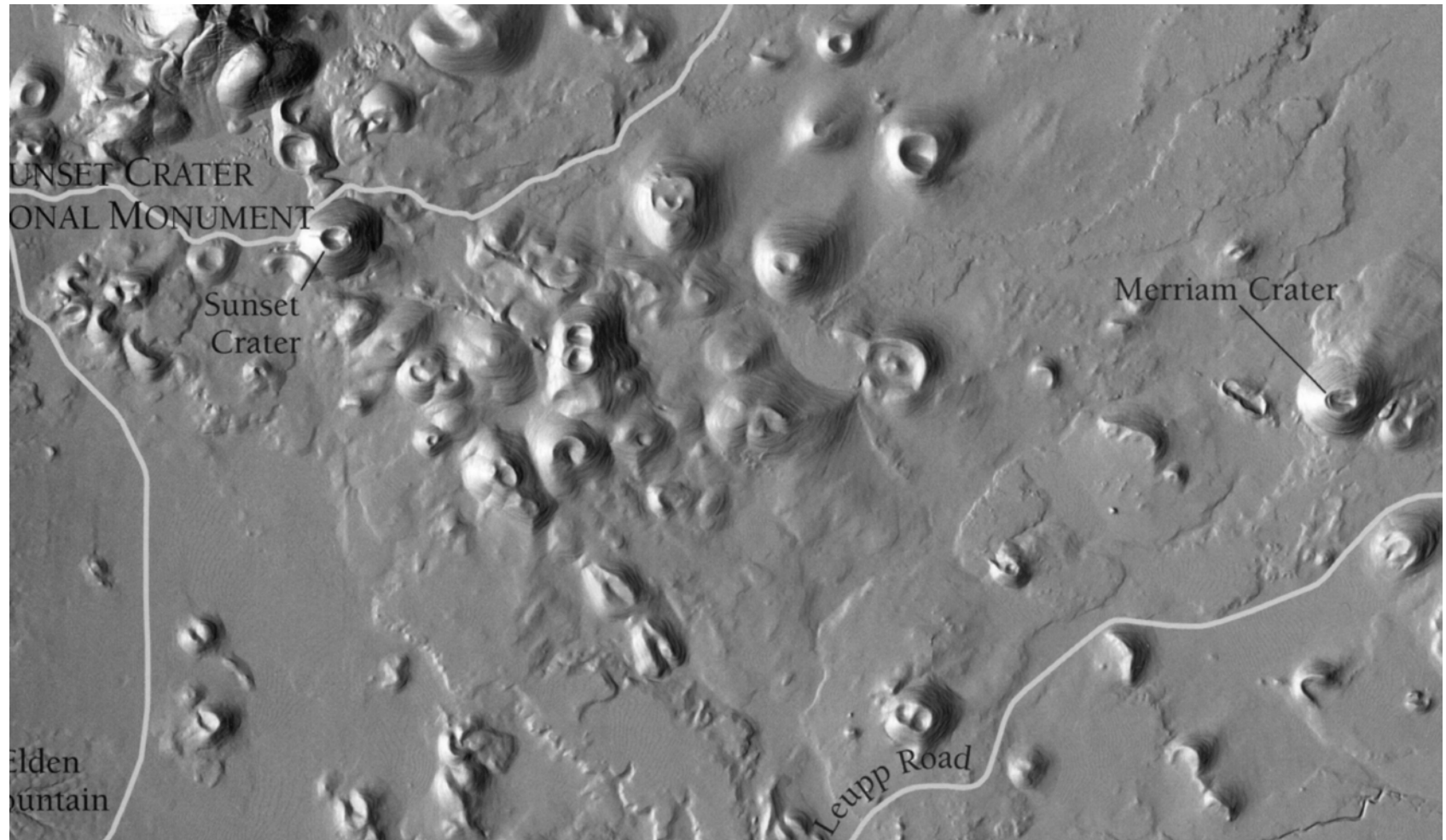
Eastern Portion of SFVF



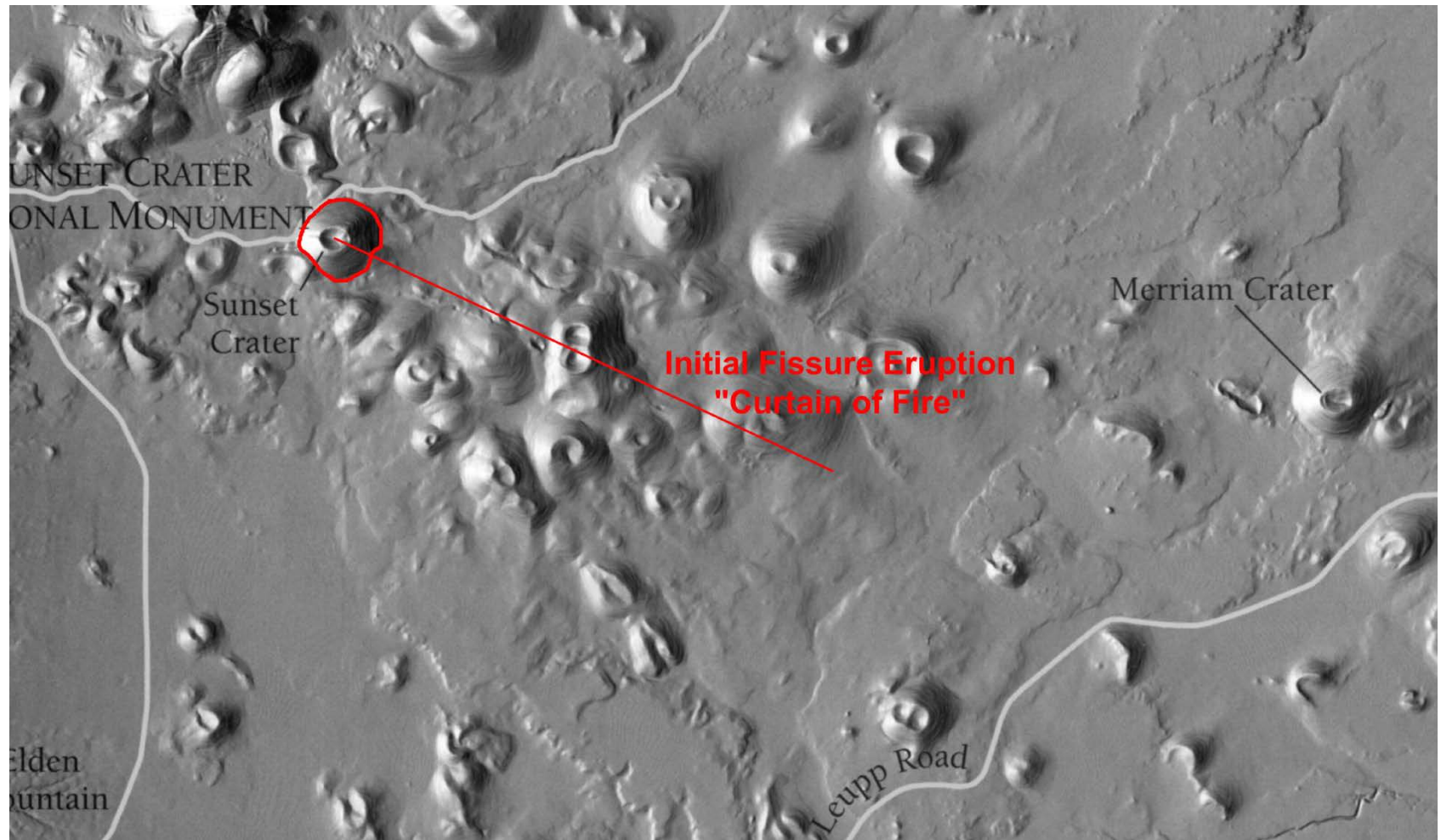
Eastern Portion of SFVF



Sunset Crater (c. 1064 AD)



Sunset Crater (c. 1064 AD)



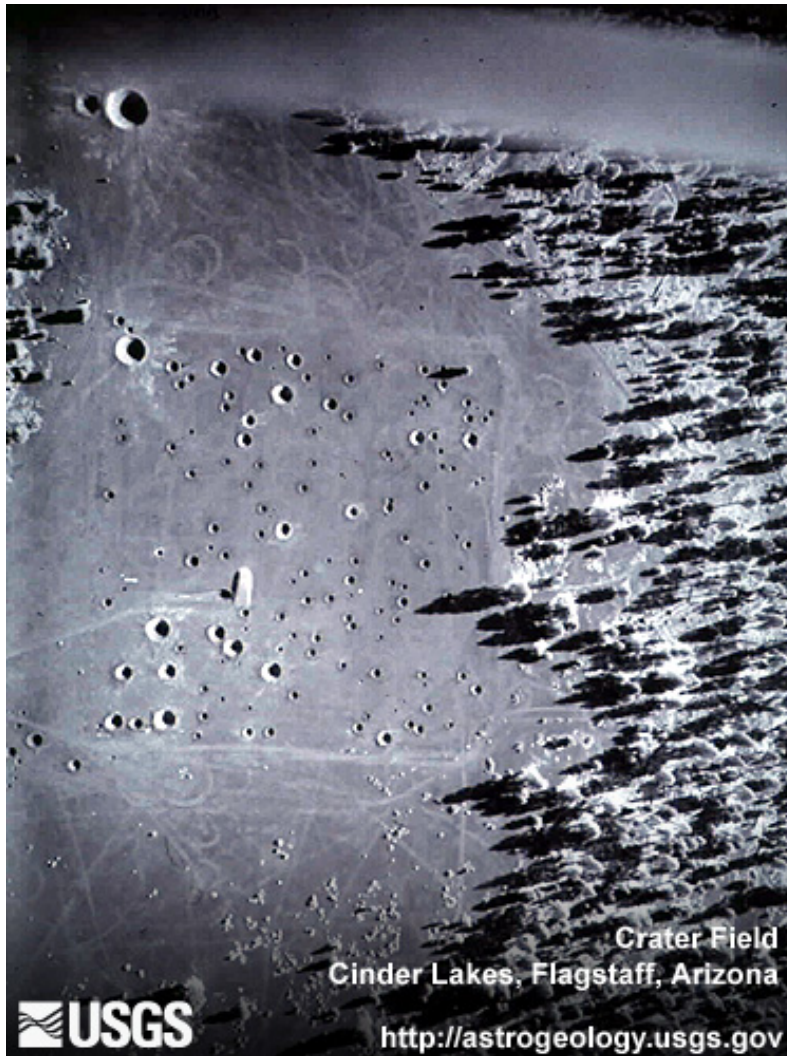


Cinder Lakes Crater Field, Arizona

Creation of Lunar Analogue
Impact Crater Field

Cinder Lakes Crater Field #1

Cinder Lakes Crater Field, Arizona



Origin of the Crater Field

Cinder field is covered by Sunset Crater debris that erupted c. 1064 AD.

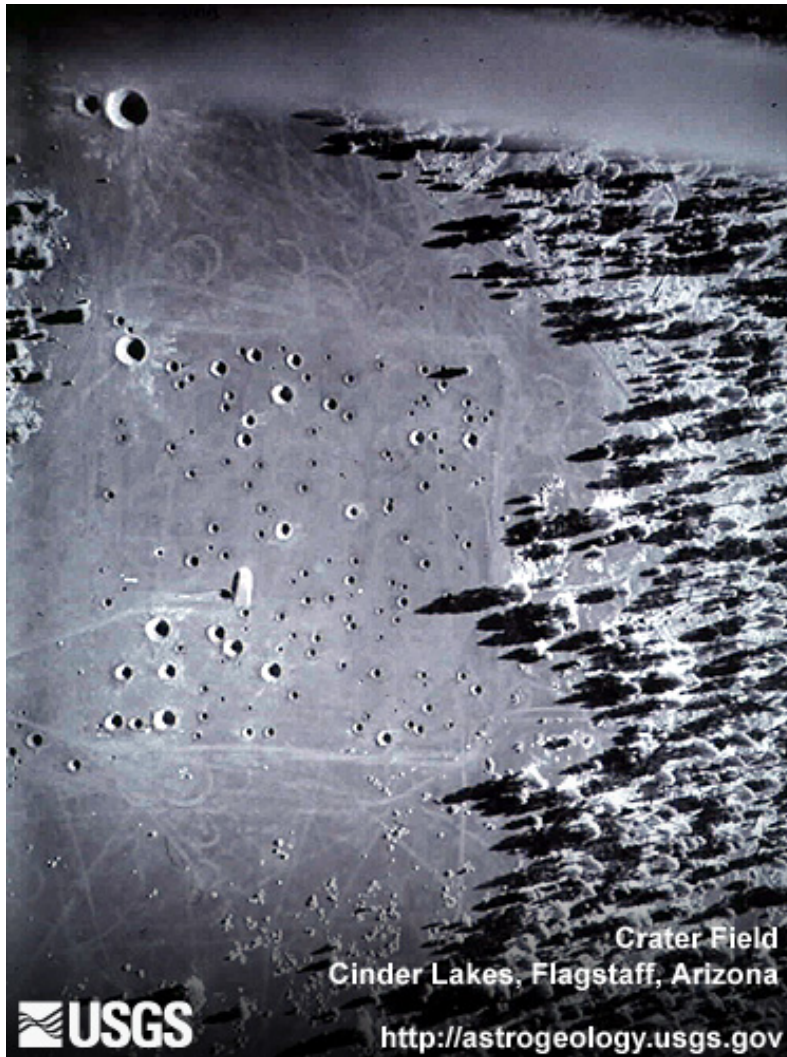
Construction of the first phase of the field (47 craters) occurred 28-31 July 1967, creating a field of 500 ft²

Designed to duplicate (at 1:1 scale) an area within Mare Tranquillitatis that was visible in a Lunar Orbiter II image (potential landing site P-6-1)

Craters range in diameter from 5 to 40 ft.

Field was expanded 8-12 October 1967, which added 96 craters (or 143 total) in an area of 800 ft².

Cinder Lakes Crater Field, Arizona



Apollo-era Tests at the Crater Field

Training area for astronauts in a realistic lunar-like landscape.

Suitable for testing rovers (prototypes of the A15-17 LRV).

Used to test procedures for determining location within a cratered lunar landscape.

Used to test crews' ability to describe crater morphologies and stratigraphic relationships in unconsolidated materials.

Used to test hand tools.

Used to test deployment methods for scientific experiment packages (prototypes of ALSEP).

Cinder Lakes Crater Field, Arizona



Construction Phase

1967

Excavated holes were filled with dynamite & ammonium nitrate.

312.5 lbs dynamite

13,492 lbs Nitro-Carbo-Nitrate™ (a mixture of common agricultural fertilizer and fuel oil)

USGS Photo P447, F106757

See Schaber's
USGS Open-File Report 2005-1190

Cinder Lakes Crater Field, Arizona



Test explosions were used to calibrate the amount of explosive needed to generate craters of specific sizes.

USGS Photo P447, F106756

Cinder Lakes Crater Field, Arizona



A large explosion was detonated using explosives that remained after the main crater field was produced.

USGS Photo

Cinder Lakes Crater Field, Arizona



Cinder Lake Crater Field #1

The crater field was produced in two stages.

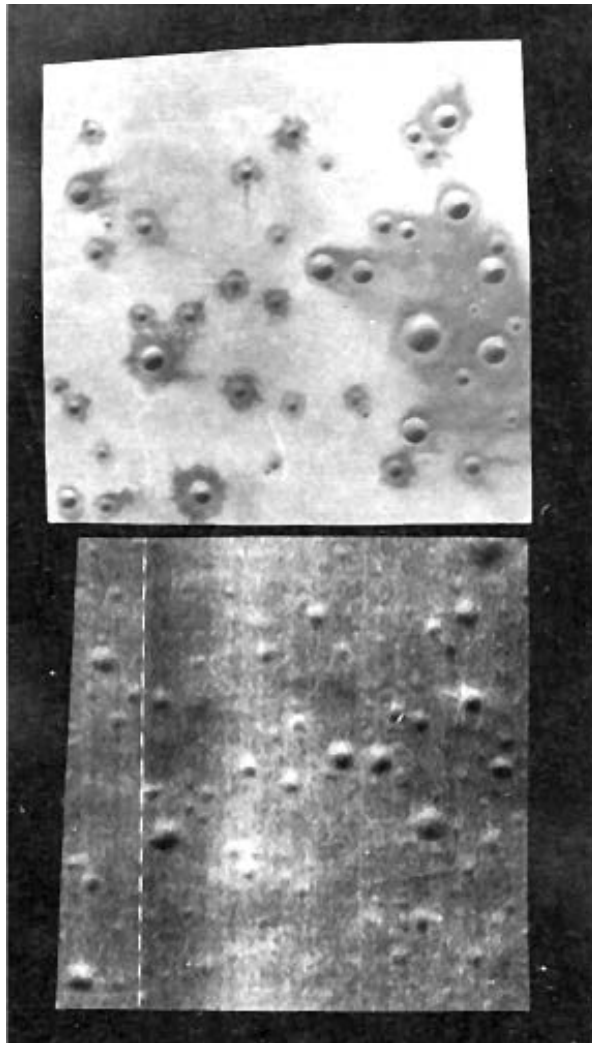
This is the appearance of the crater field after the first stage was complete.

Test explosions were used to calibrate the amount of explosive needed to generate craters of specific sizes.

A simulated lunar module (LM) was constructed on top of a ramp to approximate the height of the Apollo ascent stage windows.

USGS Photo P448, F106763

Cinder Lakes Crater Field, Arizona



Part of the first stage of the Cinder Lake Crater field (top) was designed to simulate a small area of the Apollo 11 landing site that was observed in a Lunar Orbiter image (bottom).

USGS Photo P421, F867187

Cinder Lakes Crater Field, Arizona



Final Crater Field

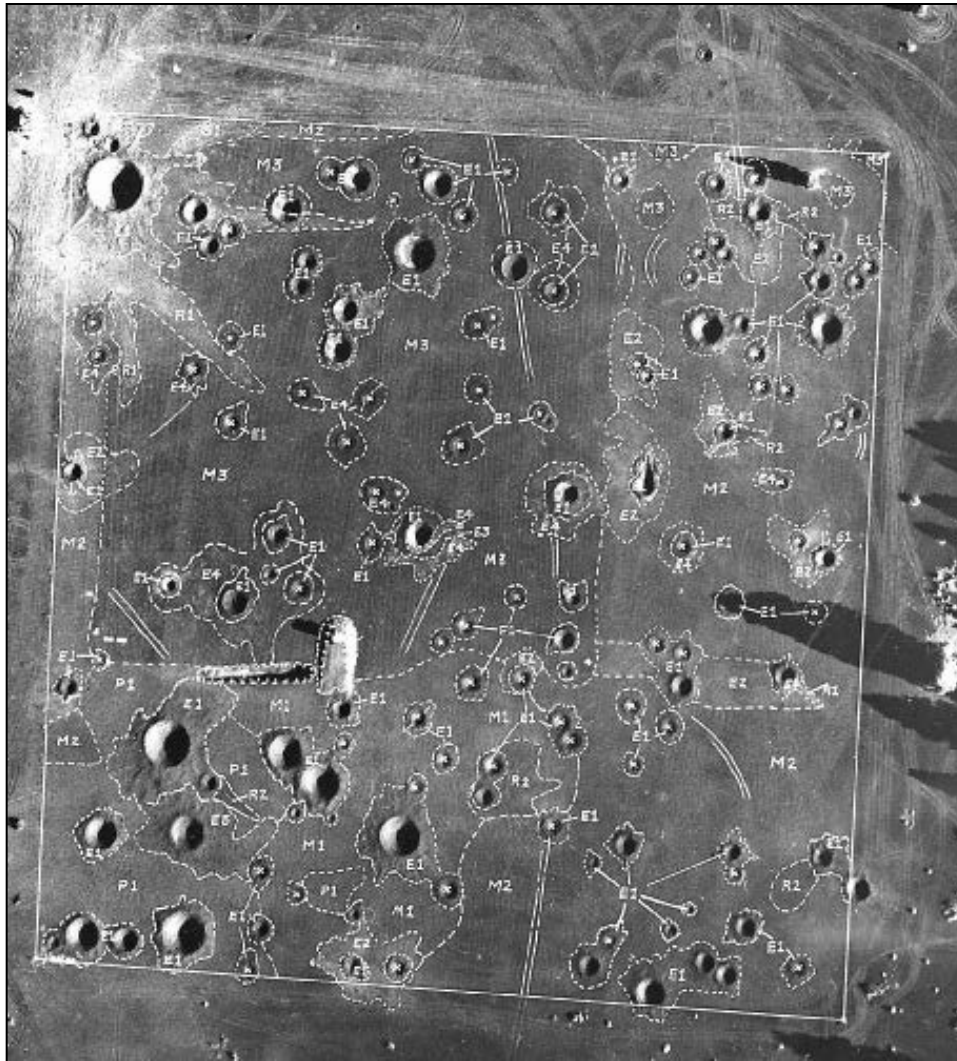
96 craters were added to the first stage field in 3-12 October 1967.

The final field contained 143 craters.

Crater rays are visible around the large crater in the upper left corner of the crater field.

USGS Photo P447, F106756

Cinder Lakes Crater Field, Arizona



Cinder Lake Crater Field #1

Geologic map of the crater field that was used to plan astronaut EVA traverses.



USGS Photo P549, F36846A

Cinder Lakes Crater Field, Arizona



Cinder Lake Crater Field #1

A simulated LM ascent stage was installed on a ramp within the crater field.

Tim Hait and David Schleicher are in “spacesuits,” testing equipment and protocols in Apollo Field Test-13.

USGS Photo P463, F11067199

Cinder Lakes Crater Field, Arizona



Cinder Lake Crater Field #1

Geologic tools (e.g., rakes, scoops) were tested in the simulated lunar environment.

Here, Tim Hait and David Schleicher examine material on the wall of a small crater.

Apollo Field Test-13

USGS Photo P466, F116779CPR

Cinder Lakes Crater Field, Arizona



Cinder Lakes Crater Field #1

Mobility systems were also tested in the crater field, including the "Explorer" vehicle.

Note the driver in the "spacesuit" at the front of the vehicle.

USGS Photo P741, F16924CPR

Cinder Lakes Crater Field, Arizona



Primary Crew Training

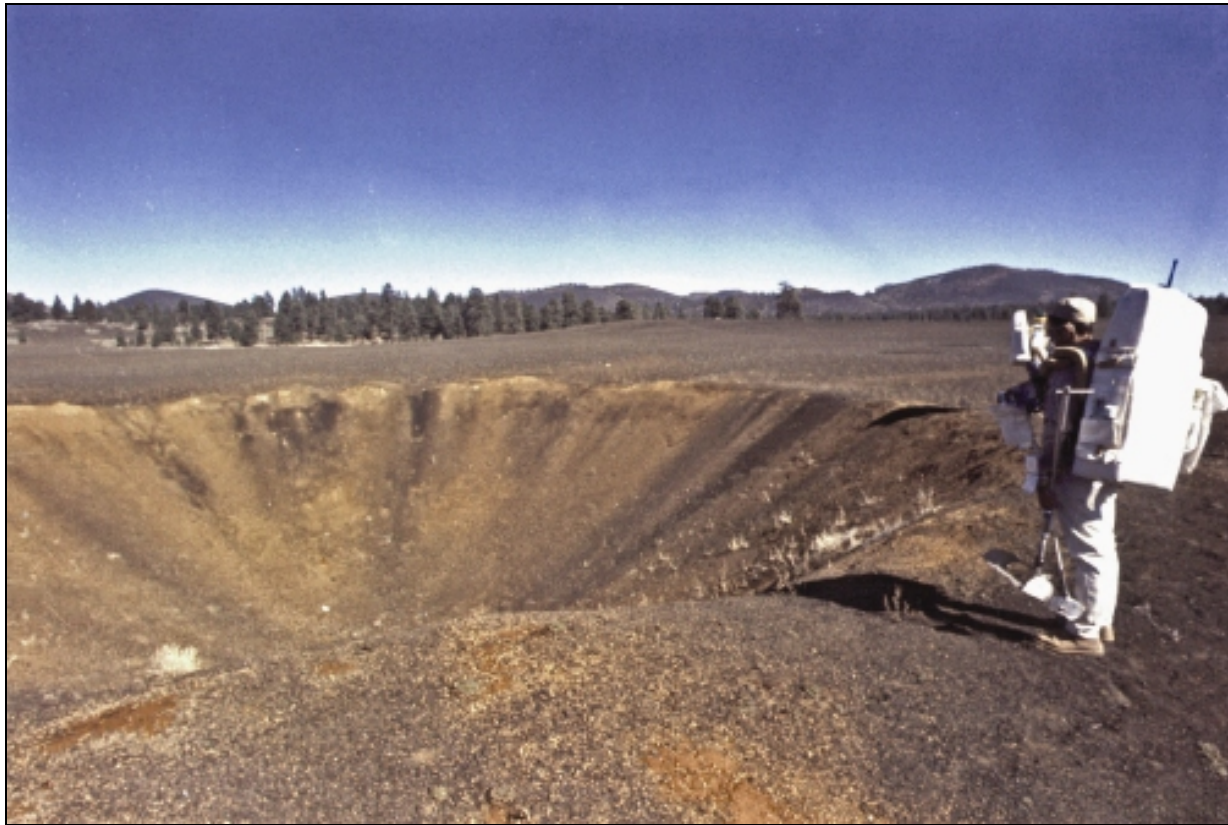
Another experimental vehicle, called “Grover,” was a better proxy for the Apollo LRV.

“Grover” was used for training of Apollo prime and back-up crews.

In this view, Jim Irwin and Dave Scott are in the vehicle on the rim of a small crater.

NASA Photo AP15-S70-53283.

Cinder Lakes Crater Field, Arizona



Primary Crew Training

Jack Schmitt and Gene Cernan standing on the rim of an explosion crater.

They are carrying mock-ups of packs, plus a rake and scoop.

Here they are describing the crater to test communication with Mission Control and the geology backroom.

NASA Photo S-72-54471.



Cinder Lakes Crater Field, Arizona

Creation of Lunar Analogue
Impact Crater Field

Cinder Lakes Crater Field #2

Cinder Lakes Crater Field, Arizona



Cinder Lake Crater Field #2

Located in an area where basaltic cinders cover clay beds. Thus, the light-colored clay was excavated by the blasts and produced distinctive ejecta, including rays.

Cinder was deposited on top of the clay by the Sunset Volcanic Crater eruption, c. 1064.

The field is 1200 x 1200 ft square and contains 354 craters.

Supplies:

1,153 lbs of dynamite

28,650 lbs of nitro-Carbo nitrate

40,000 ft of Primacord

USGS Photo P645, F768228

Cinder Lakes Crater Field, Arizona



Cinder Lakes Crater Field #2

Several sets of explosions were detonated to create crater field #2.

The sequence of blasts were designed to create craters with overlapping ejecta blankets and, thus, craters of different ages.

This is the first set of explosions.

USGS Photo 768227-3

Cinder Lakes Crater Field, Arizona



Cinder Lakes Crater Field #2

This is a ground-level view of the second set of explosions, which was designed to simulate lunar impact craters of intermediate age.

This explosion produced 61 craters.

USGS Photo P642, F768215

Cinder Lakes Crater Field, Arizona



Cinder Lakes Crater Field #2

A third and final set of 11 explosion craters were created to simulate lunar impact craters of relatively young age.

USGS Photo P645, F768228-8



Cinder Lakes Crater Field, Arizona

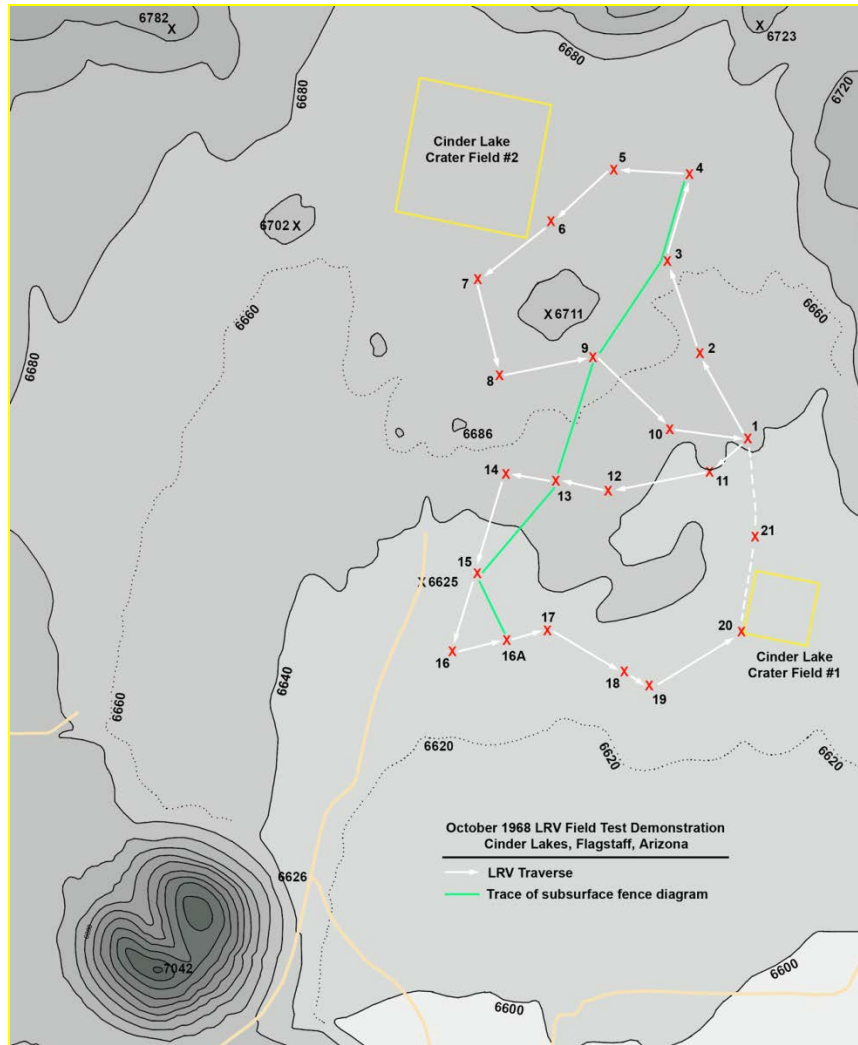
October 1968

LRV Field Test Demonstration

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Cinder Lakes Crater Fields #1 and #2

Cinder Lakes Crater Field, Arizona



Utilized the Explorer vehicle

Crew (a geologist) provided:

- Geologic description of area
- Collected samples
- Collected gravity measurements

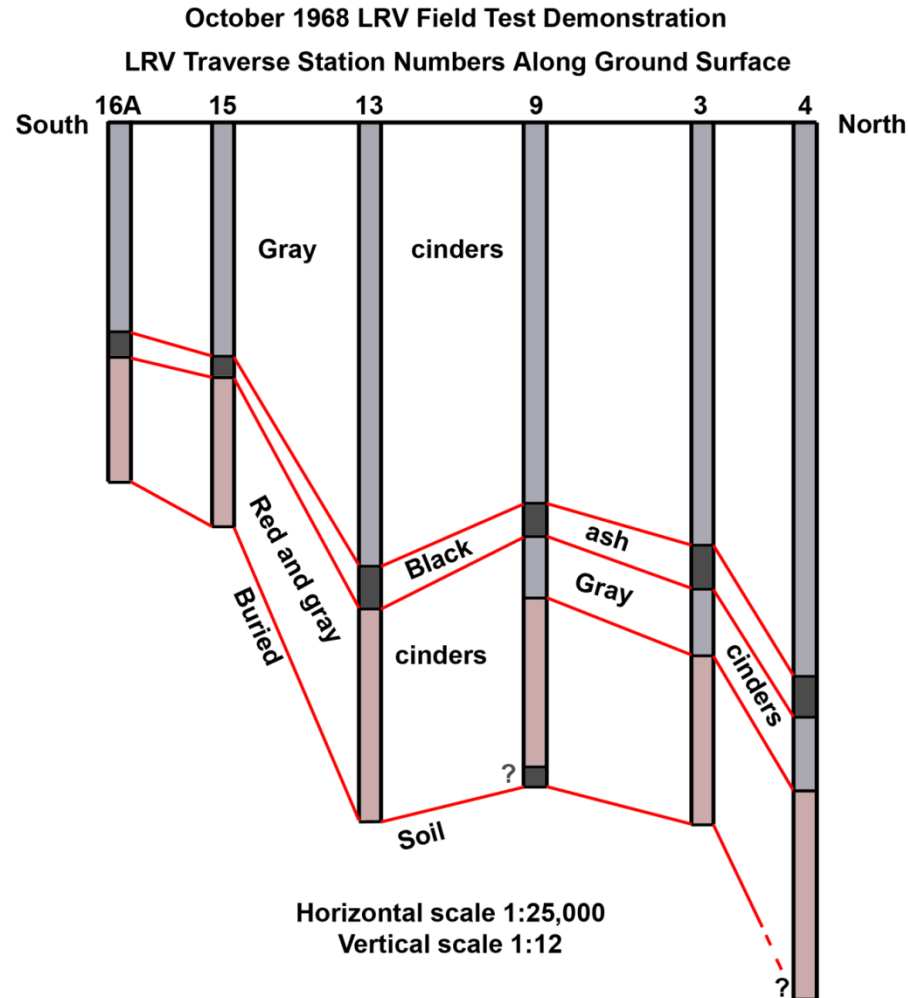
Rover also carried a vapor magnetometer

Two closed-loop traverses, each over 3 km long

Total traverse length ~7 km

Station spacing was ~0.5 km for gravity measurements

Cinder Lakes Crater Field, Arizona



Variations in cinder types and thicknesses were considered a direct analogue for hypothesized cinder fields on the Moon.

The layered cinder terrain also served as a proxy for tapering impact ejecta horizons and the lunar regolith.

~2.5 km separates Stations 16A and 4.

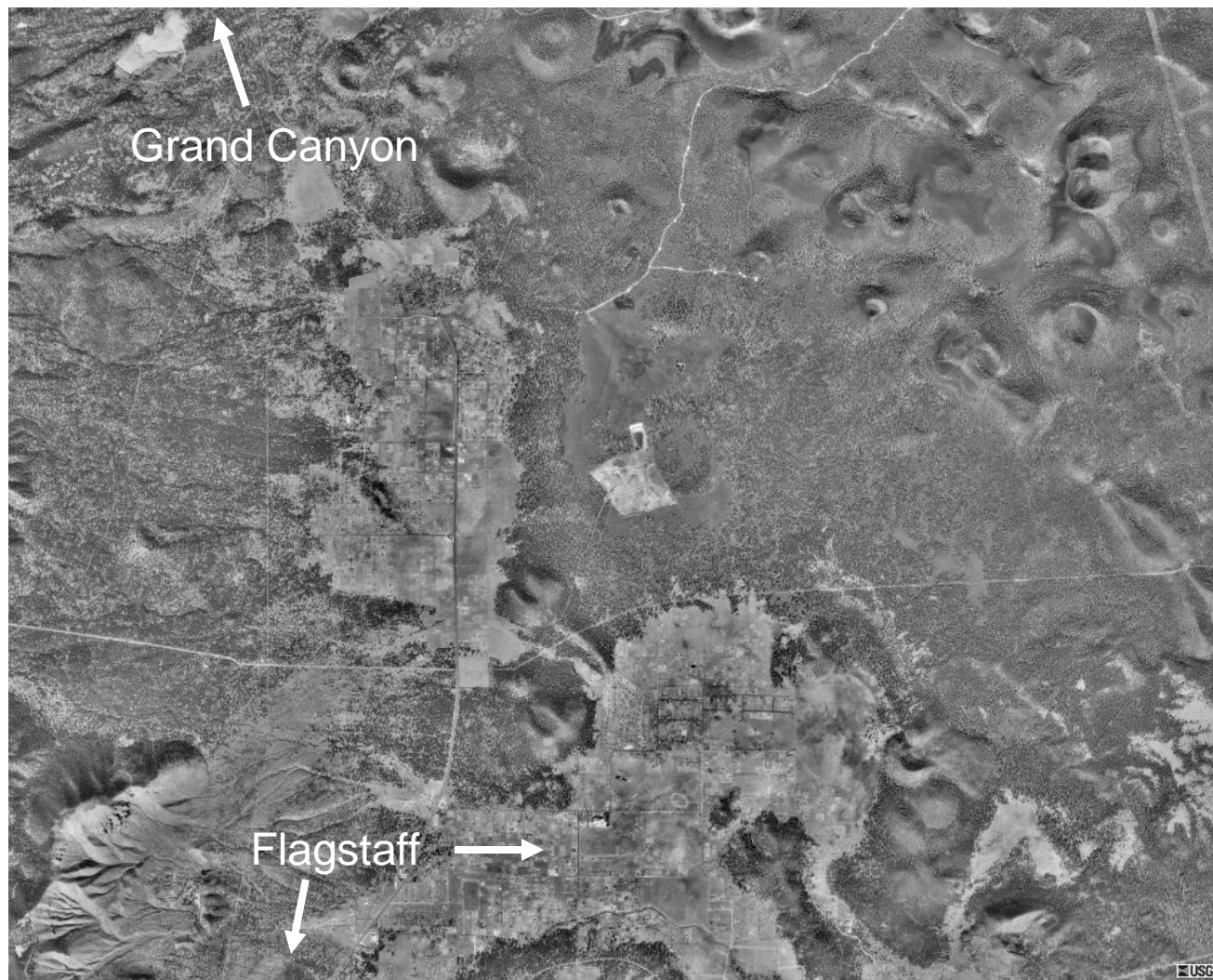
~1.5 m of stratigraphy is represented in the adjacent diagram.



Cinder Lakes Crater Field, Arizona

1997 Imagery of Cinder Lakes Crater Fields #1 and #2

Cinder Lakes Crater Field, Arizona



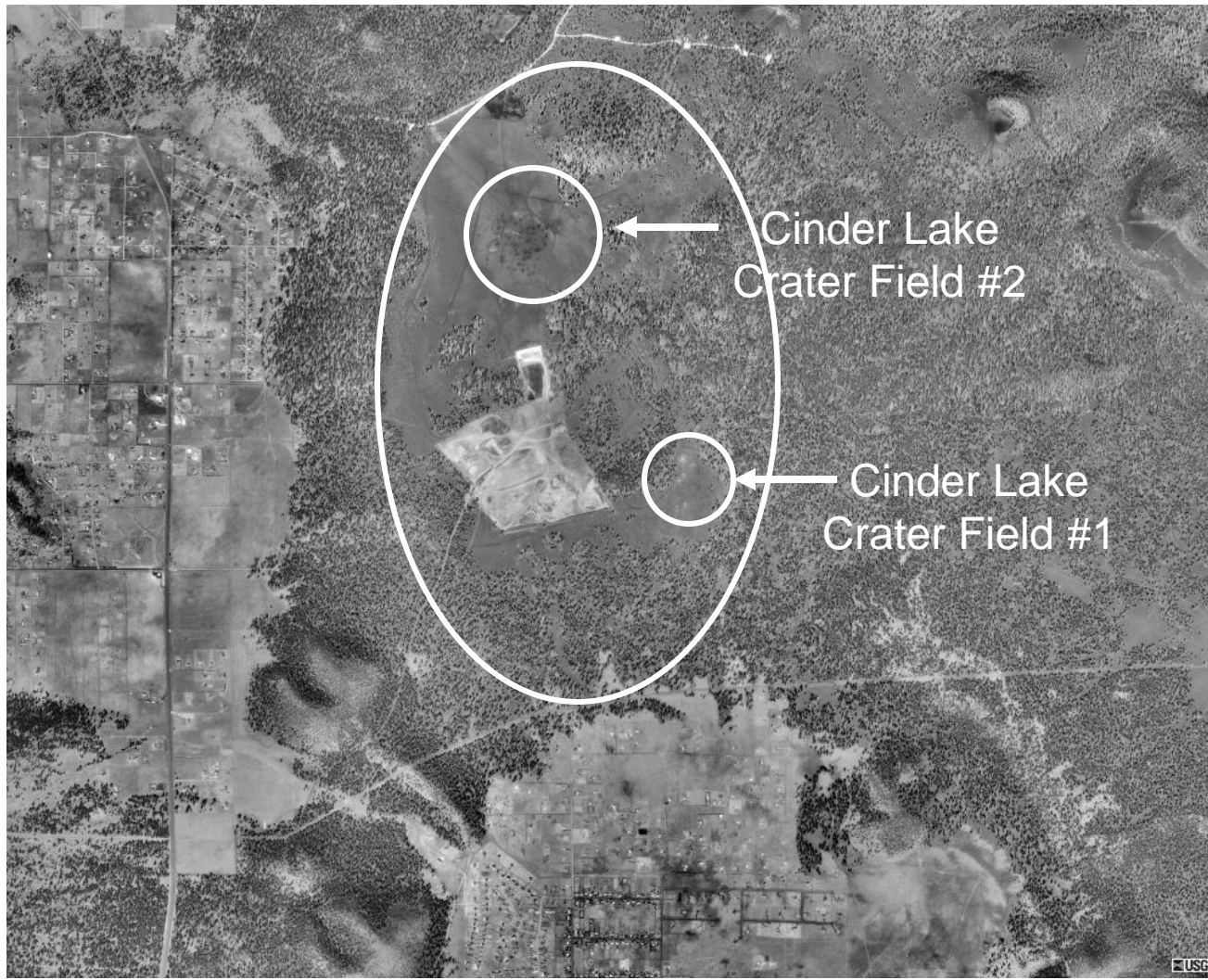
Cinder Lakes Crater Field, Arizona



Cinder Lakes Crater Field, Arizona



Cinder Lakes Crater Field, Arizona



Cinder Lakes Crater Field, Arizona



Crater Field #1

As seen
17 Oct 1997,
30 yrs after the
crater field was
created.

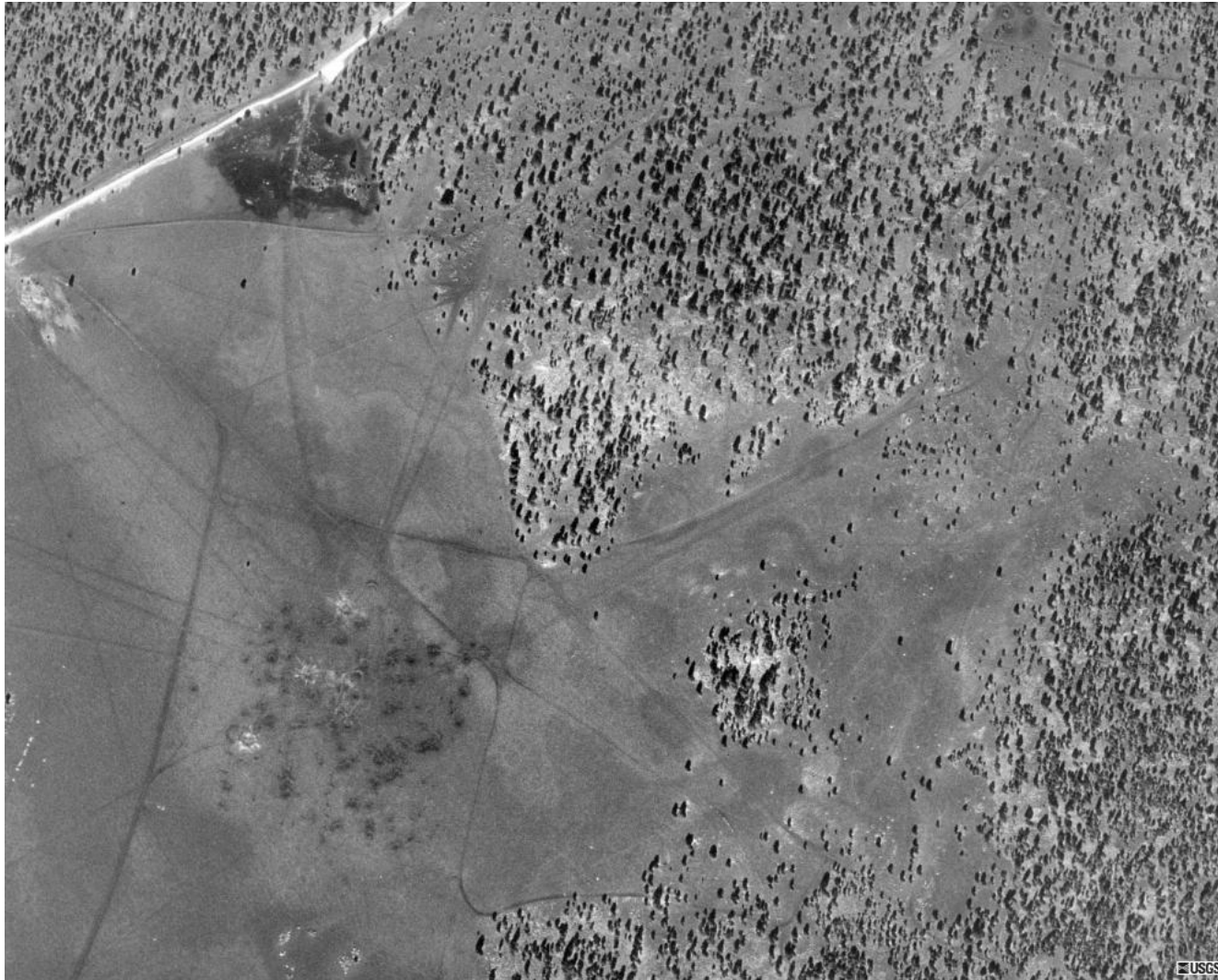
Cinder Lakes Crater Field, Arizona



Crater Field #2

As seen
17 Oct 1997,
30 yrs after the
crater field was
created.

Cinder Lakes Crater Field, Arizona



Crater Field #2

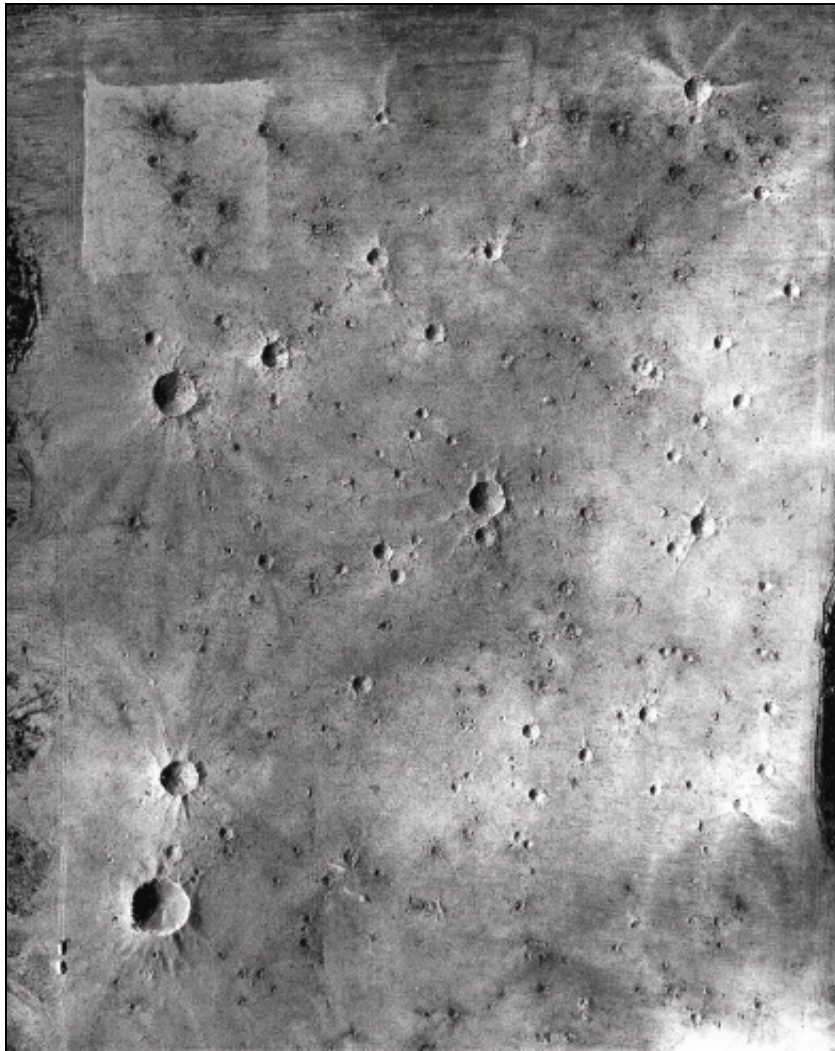
As seen
17 Oct 1997,
30 yrs after the
crater field was
created.



Black Canyon Crater Field, Arizona

Creation of Lunar Analogue Impact Crater Field — Black Canyon Crater Field

Black Canyon Crater Field, Arizona



Black Canyon Crater Field

Located in Verde Valley, south of Flagstaff at a much lower elevation.

This site is also called the Verde Valley Crater Field.

It is no longer available, because it has been covered with a housing development.

An aerial view of the crater field.

This aerial view of the field may be an early view, showing the field after the first shot rather than after the field was completed.

Photo credit: Red Bailey

Black Canyon Crater Field, Arizona



Black Canyon Crater Field

This test site was constructed
24-26 February 1970.

Bob Philpott of the USGS
is preparing the explosives
used to create the crater
field.

USGS Photo P965, F27096.

Black Canyon Crater Field, Arizona



Black Canyon Crater Field

View of buried charges that
are connected with
Primacord.

USGS Photo P965, F27098PR.

Black Canyon Crater Field, Arizona



Black Canyon Crater Field

As with Cinder Lakes
Crater Field #2, a sequence
of explosive shots was
fired to create overlapping
or cross-cutting “geologic”
features.

This is the second explosive
shot in a series of three
shots. It produced 52
explosion craters.

USGS Photo P978, F270185PR.

Black Canyon Crater Field, Arizona



Black Canyon Crater Field

This site is also informally called the Verde Valley crater field and is located near Cottonwood.

Schaber (personal comm., 1995) says the field was used to train Apollo 13 and 14 astronauts on their final geologic training before launch.

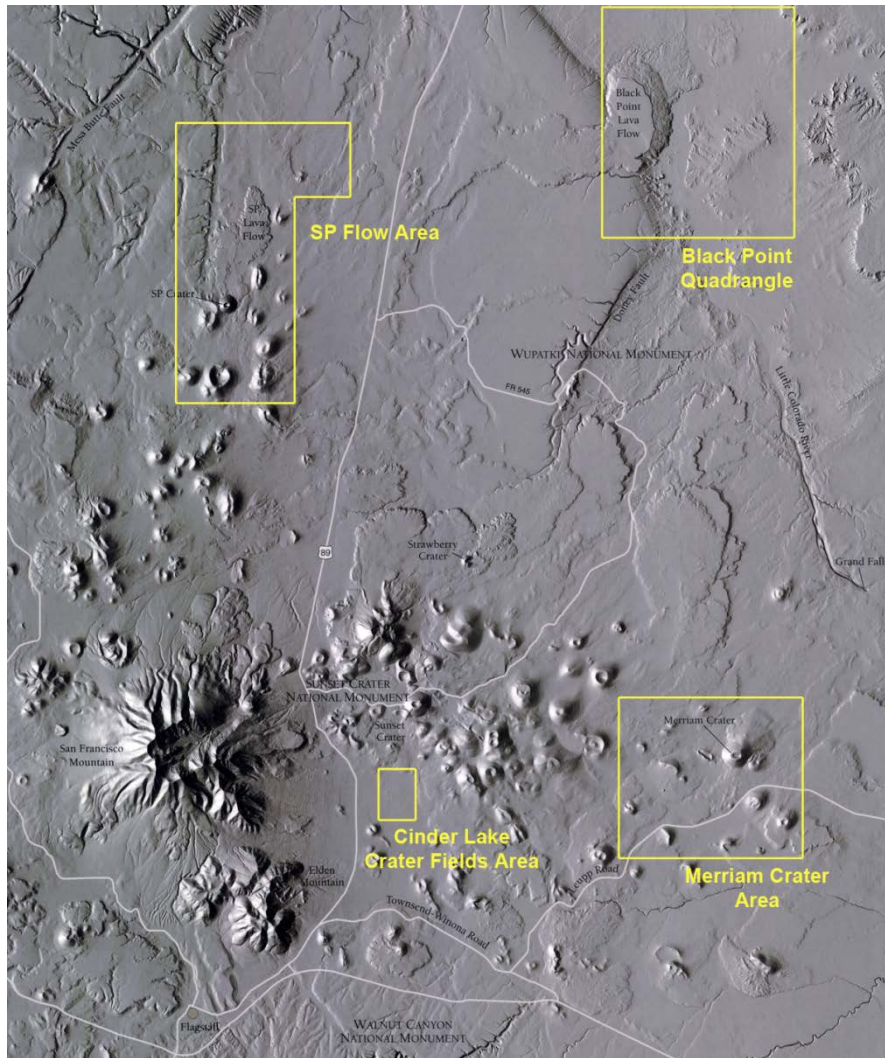
Schaber also reports (personal comm., 1995) that Iva Lucchitta told him that the Verde Valley crater field is now a housing development.



Black Point Lava Flow Crater Field, Arizona

Creation of Lunar Analogue Impact Crater Field — Black Point Lava Flow

Black Point Lava Flow, Arizona



Black Point Lava Flow

The Black Point location was one of four lunar analogue test sites in the Flagstaff area that were evaluated by the USGS for Apollo LRV and traverse studies.

The location included the eastern edge of the flow and the sediment basin that borders the Little Colorado River.

The other three test sites were

- a) Cinder Lake Crater Fields (described above),
- b) Merriam Crater area (which was compared to the Marius Hills on the Moon), and
- c) SP cinder cone and lava flow area.

Black Point Lava Flow, Arizona



A large explosion was detonated to create a crater on the Black Point Lava Flow.

Detonated 1 Aug 1968
(per Schaber 2005).

Located on the Spider
Web Ranch along the
Little Colorado River
on US 89, north of
Flagstaff.

This site was being explored
as a possible test site,
but abandoned in favor
of Cinder Lakes Crater
Field #2 and the Black
Canyon Crater Field.

USGS Photo P669, F868147.

Black Point Lava Flow, Arizona



Because the Black Point Lava Flow site was abandoned, there is little surviving information about it. The site is not, for example, described in an April 1969 USGS test site report, even though it still appeared on their map of test site locations.

Red Bailey and George Ulrich (personal comm., 2008) do not recall the location of the blast, nor is it recorded in Bailey's field notes. His notes provide other insights, however.

Black Point Lava Flow, Arizona



Per Red Bailey's notes:

Work was coordinated w/
John Babbitt.

He and Dave Haines
studied the east side of
the lava flow along the
L. Colo. River on 6/11/68.
The lava flow was drilled in
several locations. (Do
those cores still exist?)

He inspected test craters
(*plural*) on 8/19-22/68 and
discussed shooting what
he thinks may have been
a larger crater.

Holes (drill holes, craters, or
both?) were to be left to
the ranch foreman. He
thinks the foreman may
have filled them.

Black Point Lava Flow, Arizona



Best estimate:

The explosion site(s) is on the eastern marginal lobe of the lava flow, because that is within the test area defined by the USGS in their 1969 test site map (as reproduced above) and the part of the flow Bailey and Haines examined.

George Ulrich (personal comm., 2008) feels that is a reasonable conclusion.

Craters re-located by Fred Hörz and Gary Lofgren June 2009.