DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

Helium and radon soil-gas surveys of collapse features on the Hualapai Indian Reservation

By

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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ILLUSTRATIONS

INTRODUCTION

This is one of a series of reports summarizing soil-gas surveys of collapse features and breccia pipes on the Hualapai Indian Reservation in Arizona (Bowles and Reimer, 1986; Reimer and Been, 1987; Reimer, 1985). Breccia features and breccia structures are used synonymously. The collapse breccia pipes are commonly characterized by a shallower surface basin.

Many new exploration techniques for energy resources have been developed over the last ten years. The analysis for helium is one technique that is gaining acceptance by the exploration industry. Helium is found virtually everywhere in small concentrations. It is derived from alpha particles emitted during the natural decay of uranium. The average helium concentration in ambient air is about 5,240 parts per billion (ppb) and it is often found in uniquely higher concentrations that are associated with various types of energy sources: for example, uranium minerals, oil and gas deposits and with geothermal occurrences (Reimer, 1976b; Reimer and others, 1979; Roberts, 1975; Roberts and others, 1974).

The Hualapai Indian Reservation is located on the south-western corner of the Colorado Plateau in northern Arizona. Thousands of collapse-solution breccia pipes exist in northern Arizona. These pipes initially occurred in the Mississippian Redwall Limestone and stoped their way upward through the Pennsylvanian Supai Group into the Triassic Moenkopi and Chinle Formations (Wenrich and others, 1986). More than 900 confirmed and suspected collapse breccia pipes have been previously mapped on the Hualapai Indian Reservation (Wenrich and others, 1988). The numbering convention developed by Wenrich and others (1986, 1988) is used in this report.

Confirmed breccia pipes consist of the dissolution of any underlying rock; the Redwall Limestone in this case and the stoping and brecciation of the overlying rock. When uranium-containing minerals are concentrated, such as in a fractured, brecciated collapse structure, there is more source material available for the production of helium. The nature of a pipe structure may allow helium easier access to the surface from uranium-mineralized areas below. Similarly, faults are important to helium surface concentrations as they provide more permeable pathways for the flow of gas than adjacent, unfaulted rock. Therefore, higher helium values can be expected in faulted, brecciated rock, such as that found in collapse features. These geologic structures provide a unique setting, where helium may possibly be used as a uranium exploration tool.

Twelve structures were sampled during this survey with three being resampled from previous studies (Bowles and Reimer, 1986; Reimer, 1985). Samples for helium were collected at 12 structures and samples for radon were collected at 9 of the 12 locations (table 1). All structures were located on the Coconino Plateau; 10 were within the Hualapai Indian Reservation boundary. Structures 1179 and 1180, located off the reservation, were used as control structures. Structure 1179 is a known gypsum collapse feature (Wenrich, personal communication, 1989), and 1180 is mineralized with uranium. Energy Nuclear Fuels in 1984 reported an ore-body in structure 1180 about 300 feet in diameter, existing 900 to 1400 feet below the surface within the Coconino Sandstone Formation (Energy Nuclear Fuels, 1984). The high grade of the ore is indicated by a core sample, containing 70% total uranium, that was collected at a depth of 1286 feet by Andy Kwarteng of the U.S. Geological Survey (Wenrich, personal communication, 1989).

Overall there is a positive correspondence between radon and helium values, as would be expected because both measure decay products of uranium and thorium (table 1).

SAMPLING TECHNIQUE

The helium and radon sampling technique consists of pounding a hollow steel 3/4-meter probe into the ground, using a split slide-hammer that bolts together on the probe. The sliding hammer strikes a lower pounding collar to drive the probe into the ground, and the probe is removed by using the hammer to strike an upper pounding collar. The bottom of the probe is sealed and the soil-gas sample is taken through 10 small holes in the side of the probe. A brass fitting containing a septum is attached to the probe top and a hypodermic syringe with a side-hole needle is used first to purge the probe, and then to take a 10 cm^3 sample. Helium samples were analyzed in the field with a mass-spectrometer (Reimer, 1976a). Helium values of about 80 ppb above ambient air, at 5,240 ppb, are considered anomalous (Reimer, 1985). An alpha scintillometer was used in the field to measure radon concentrations (Reimer, 1977). Because it was not calibrated before this study, the radon values are relative, not absolute. Radon anomalies are defined as concentrations four times background or more.

Diurnal variations in barometric pressure, moisture content of the soil, and wind speed can influence helium and radon values as can geologic factors such as rock type and structure. During the period of sample collection for each structure, weather conditions were constant. Each structure was sampled in a single day so that meteorologically induced variations were of a minimal influence on soil-gas concentrations.

DISCUSSION

Earlier helium studies showed that it was important to obtain background helium samples approximately 1,000 feet or more from the collapse structures to insure that there was no influence from higher concentrations of uranium mineralization in the collapse features (Reimer, 1985; Reimer and Been, 1987). Collapse features 534, 1107, and 1134 were the only structures with background samples taken closer than 1,000 feet. Helium concentrations for background samples, as a rule, were similar to those of the collapse structures. Collapse feature 1180, a uranium-mineralized control, had a mean helium concentration of +23 (ppb) and a helium background mean of +40 (ppb), both with respect to air. Background samples near Owl Tank (fig. 23) were collected at a distance of about one-half mile from structure 1180. The selection of Owl Tank for background sampling may have been unfortunate in that the area of Owl Tank could define a mineralized collapse feature (Wenrich, personal communication, 1989). The possibility for Owl Tank to contain uranium mineralization is, in fact, supported by the observed helium soil-gas concentrations. It has one of the highest mean helium concentrations of this survey.

Occasionally, the anomalously high values were found as a small group or pattern within the surface expression of the collapse feature such as with 478 and 1134. Water movement may act to redistribute helium anomalies over a broader area in the direction of water flow. Ground-water flow and surface-water migration may be one explanation for higher background relative to the sample mean.

Table 1 lists mean helium, helium range, standard deviation, mean helium background, and radon comments recorded over the structures. Structure 494, a confirmed breccia pipe, exhibited high concentrations of helium. Drilling at structure 494 revealed a 20-foot-thick, anomalous radiation zone with a one-foot-thick section containing 0.52% U_3O_8 at a 1,191-foot depth (Wenrich and others, 1988). Structure 534 had a mean helium value of +40 ppb in this study compared to a

previous study mean of +45 ppb, which remains consistent with higher uranium concentrations (Reimer, 1985). The mean helium values would suggest that structures 478, 534, 1179, and 1180 are worthy of further consideration for exploration. Structure 1102, resampled this year, shows lower mean helium values than in past surveys (Reimer, 1985). This may be due to seasonal variations. Structure 1102 was found to have high surface radioactivity in the north-east corner of the structure (Wenrich, personal communication, 1989). Structure 1134 is presumed to be a sinkhole due to its steep sides and flat bottom with uncemented rock fragments. Background value means did not differ from collapse structure value means recorded during the 1987 survey. Table 2 contains comments on the uranium potential of the collapse features based on the helium surveys.

CONCLUSION

One of the 12 structures sampled (1179) had anomalously high helium values indicative of possible high uranium concentrations. Three additional structures (478, 494, and 534) had higher helium distributions grouped within the features to suggest high uranium concentrations. Higher radon concentrations were correlative to the greater helium values to further suggest uranium-containing minerals. Both helium and radon measuring techniques can be used to supplement other exploration techniques. Logistically, both are quick and inexpensive methods for obtaining preliminary data before using more expensive techniques, such as drilling.

Collapse features 478, 494, 534, 1179, and 1180 have the highest helium values, indicating a greater possibility of uranium minerals. Of these features, confirmed breccia pipes 494 and 1180 have known uranium reserves. Structure 1179 is a suspected, non-uranium mineralized gypsum collapse. By themselves, helium and radon soil-gas sampling techniques do not appear to be diagnostic for revealing which structures have the potential for containing economically recoverable uranium. If structures surveyed in this and past studies are drilled, then additional information could enhance the knowledge of interpreting the gas surveys

ACKNOWLEDGEMENTS

This project was funded by the Bureau of Indian Affairs in cooperation with the Hualapai Indian Tribe. Much appreciation goes to Mike Reimer, Don Murrrey and Randy Forgey of the U.S. Geological Survey for their help on this project.

Table 1.--Breccia pipe structure helium values and radon comments.

Collapse feature	Mean helium[†]	Helium range[†] low	high	One standard deviation	Mean helium background	Radon comments[§]
478	43	-20	84	25	26	Slightly higher
494*	43	0	80	23	50	No samples
534*	40	-9	76	20	20	No samples
571	14	-38	76	25	-4	Not Unique
1102*	20	-74	76	38	21	No samples
1107	-4	-80	63	31	-4	Low
1108	-4	-76	76	26	-3	Low
1119	2	-37	37	20	10	Low
1134	19	-40	80	31	19	Not Unique
1144	-14	-80	60	34	15	Not Unique
1179	97	0	144	28	52	Highest of Survey
1180	23	-84	84	34	40	Higher

*Resampled (Reimer, 1985; Reimer and Been, 1987).

[†]Helium values are expressed in parts per billion with respect to ambient air.

[§]Radon comments are based on radon concentrations that are relative to the mean radon concentrations of this survey.

Table 2.--Helium-based interpretation of breccia pipe structures.

Collapse feature	Uranium potential	7.5 minute quadrangle location	Comments
478	High	Prospect Point	Higher values within structure
494	High	Vulcan's Throne and Vulcan's Throne SE	High values (known uranium-ore bearing breccia pipe)
534	High	National Tank	High values
571	High	National Tank	Lower than average values
1102	Uncertain	Vulcan's Throne SE	Averages slightly lower than mean
1107	Low	National Tank	Low average values
1108	Low	Dike Tank	Low average values
1119	Low	National Tank	Low average values
1134	High	Prospect Point	Some higher anomalous values
1144	Low	National Tank	Overall low values
1179	High	Metzger Tank	Overall high values with contrast to background (possible gypsum collapse)
1180	Medium-high	Tusayan East	Higher near structure center (known uranium-ore bearing breccia pipe)

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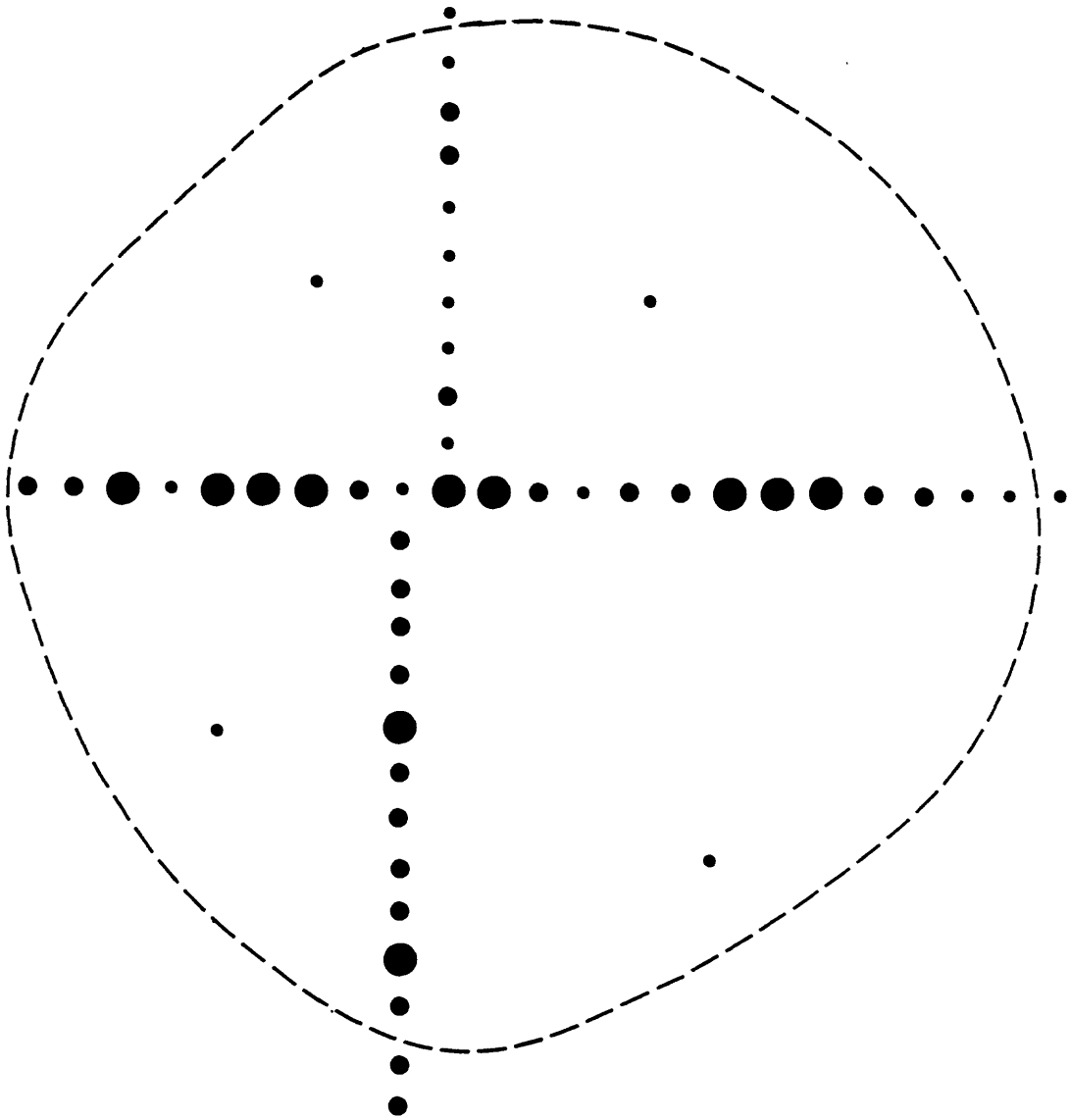


Figure 1.--Collapse feature 478; helium soil gas distribution.

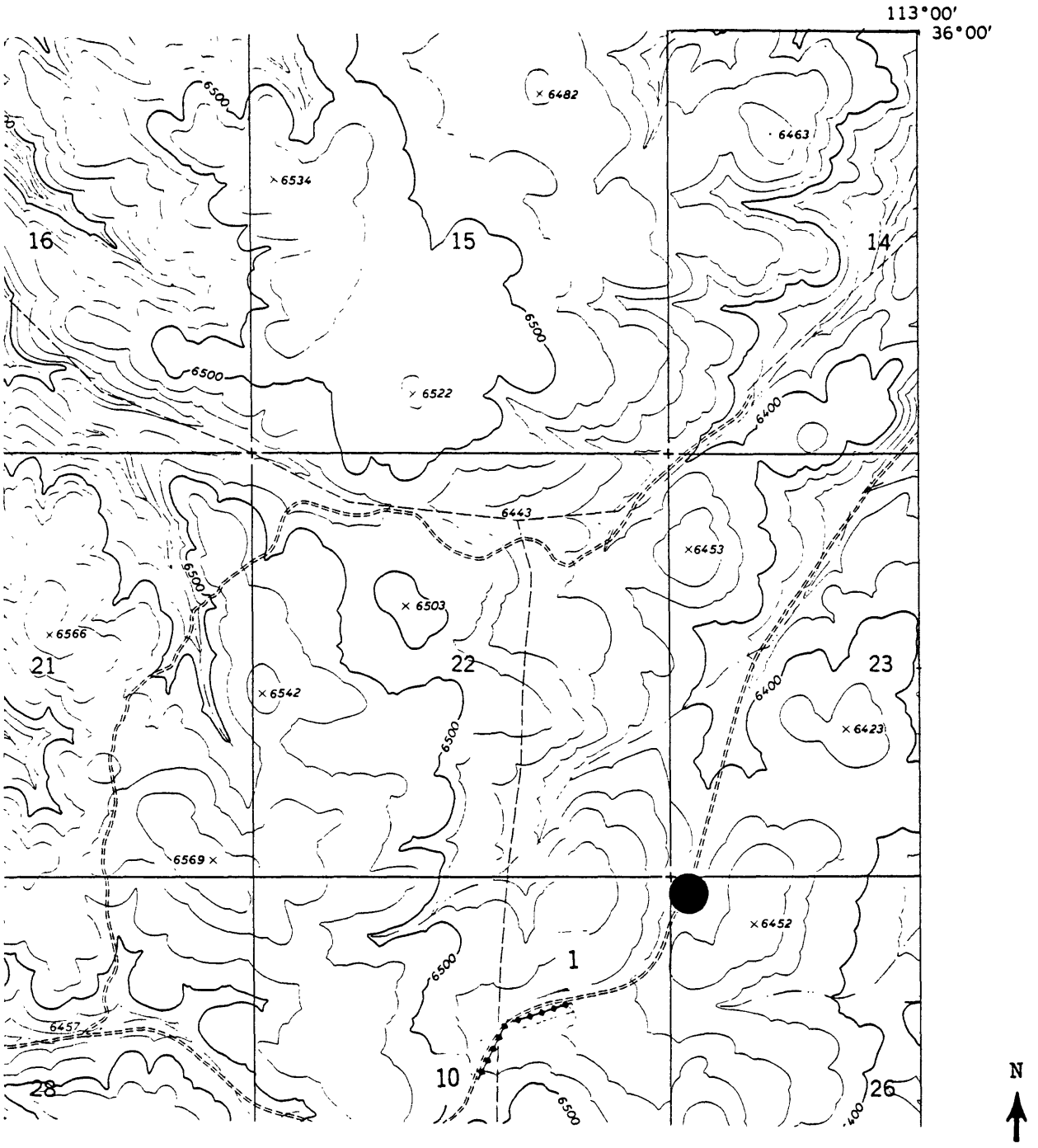


Figure 2.--Collapse feature 478; topographic relief.

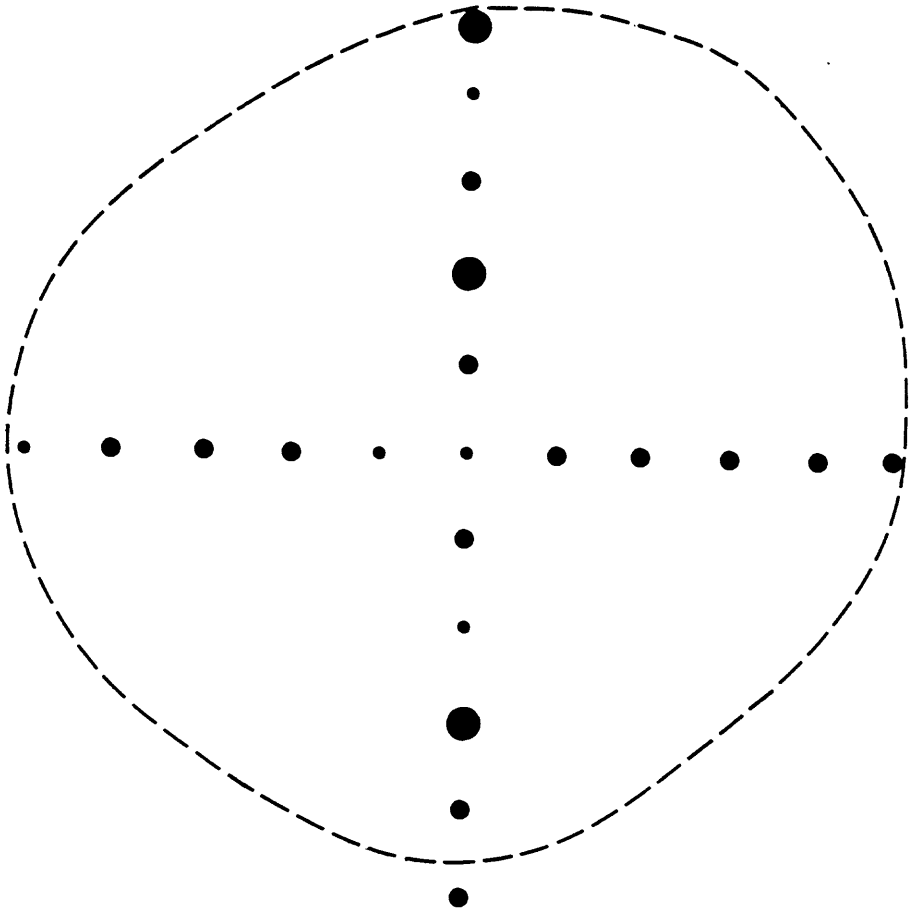
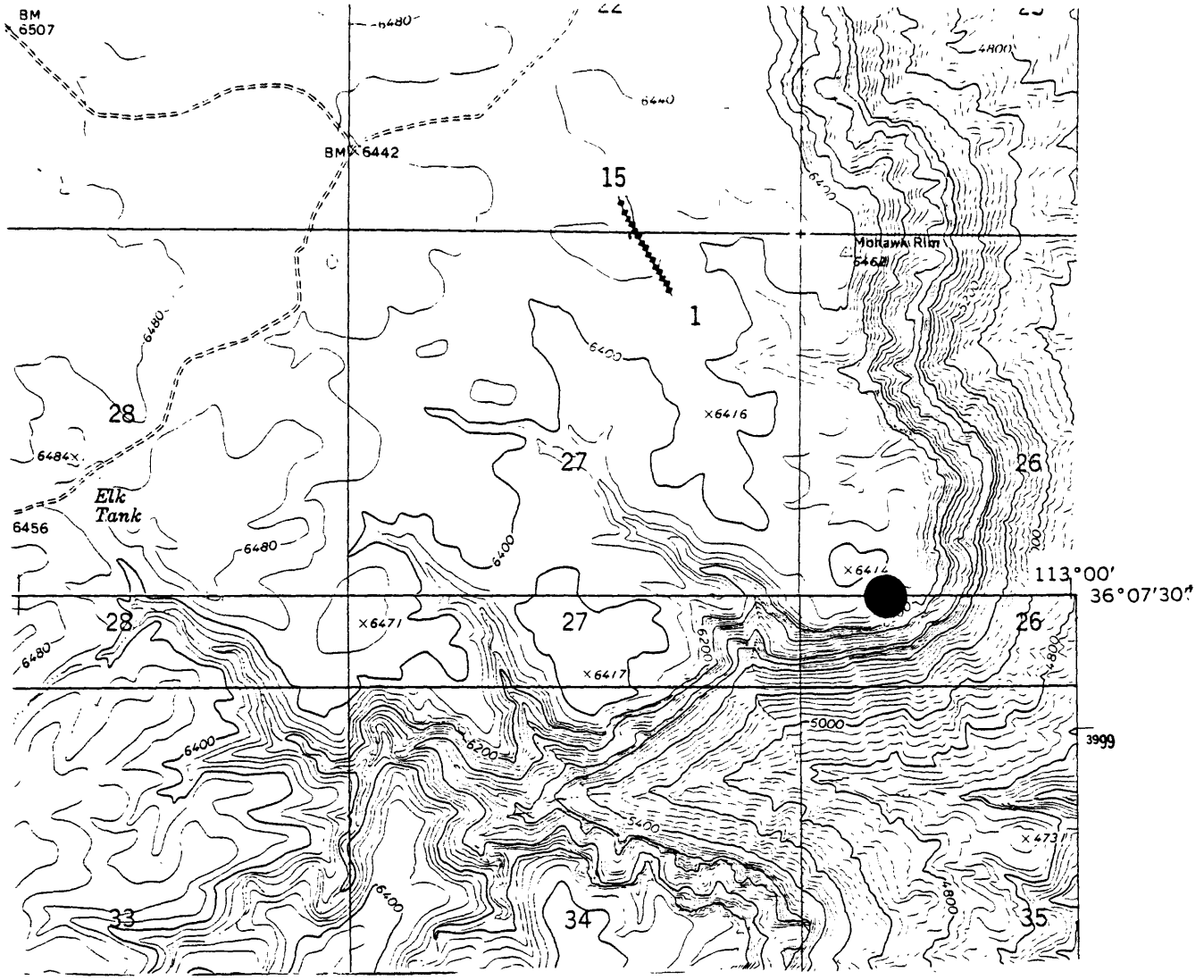
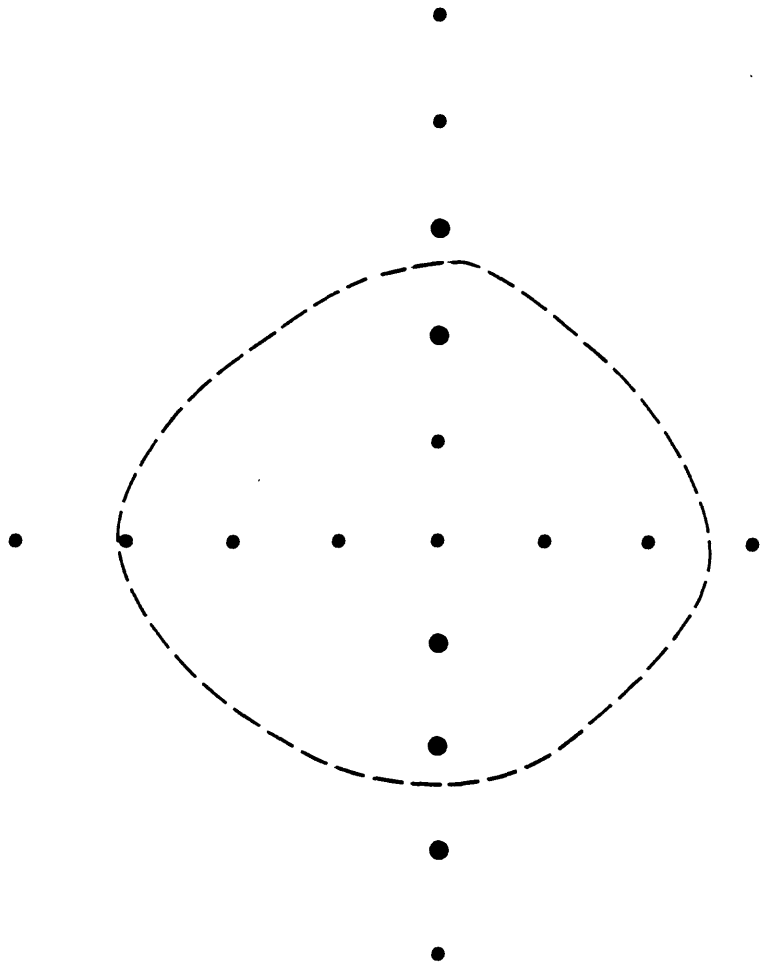


Figure 3.--Collapse feature 494; helium soil gas distribution.



Vulcan's Throne and Vulcan's Throne SE Quadrangles, Arizona

Figure 4.--Collapse feature 494; topographic relief.



N

• < 40 ppb He

0 ——— 200 feet

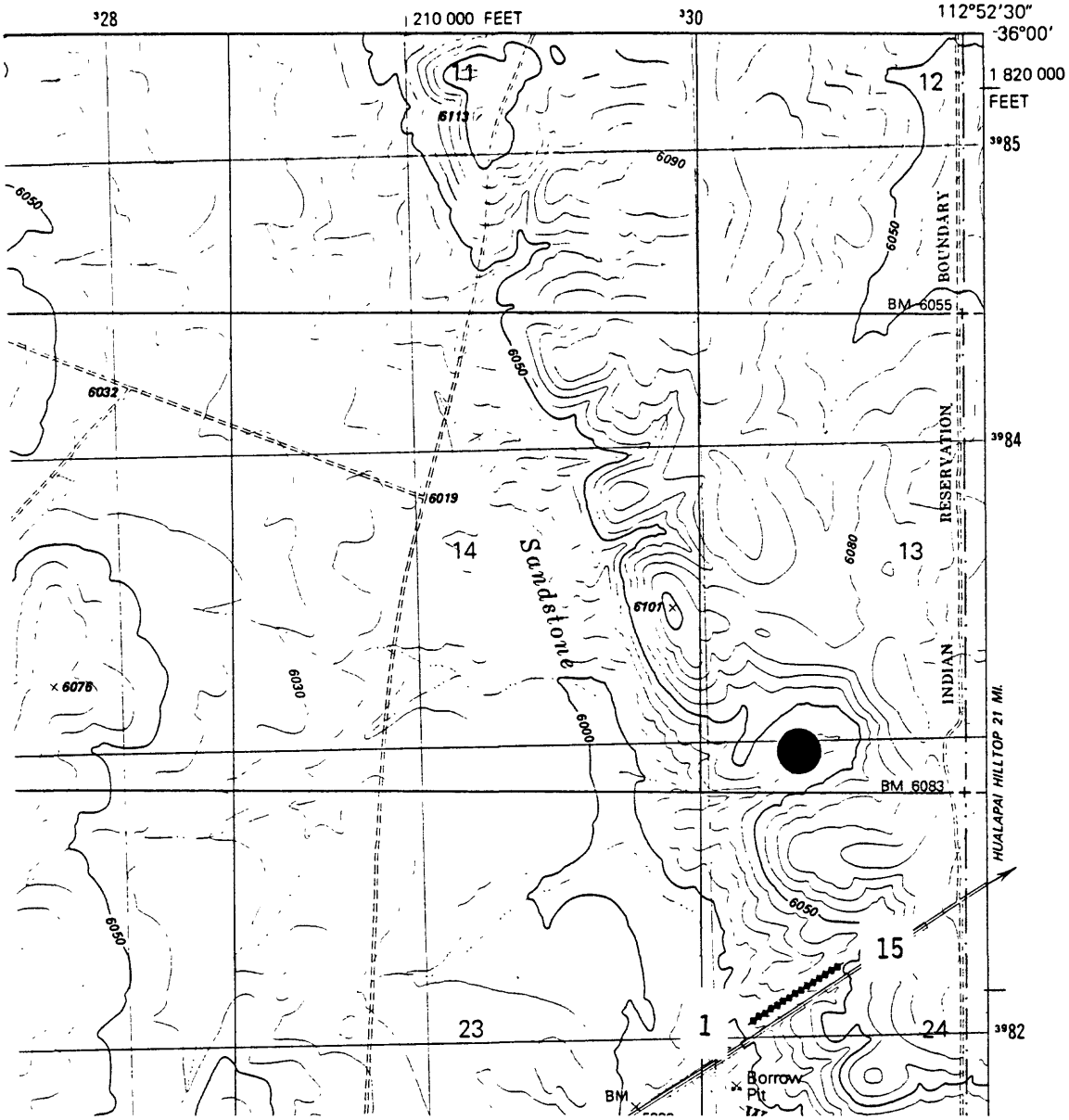
● 40 - 80 ppb He

All values are with respect
to ambient concentrations.

Lat. 35°58'35"

Long. 112°53'00"

Figure 5.--Collapse feature 534; helium soil-gas distribution.



National Tank Quadrangle, Arizona

● Collapse feature location

Background samples on 50 foot spacing

Figure 6.--Collapse feature 534; topographic relief.

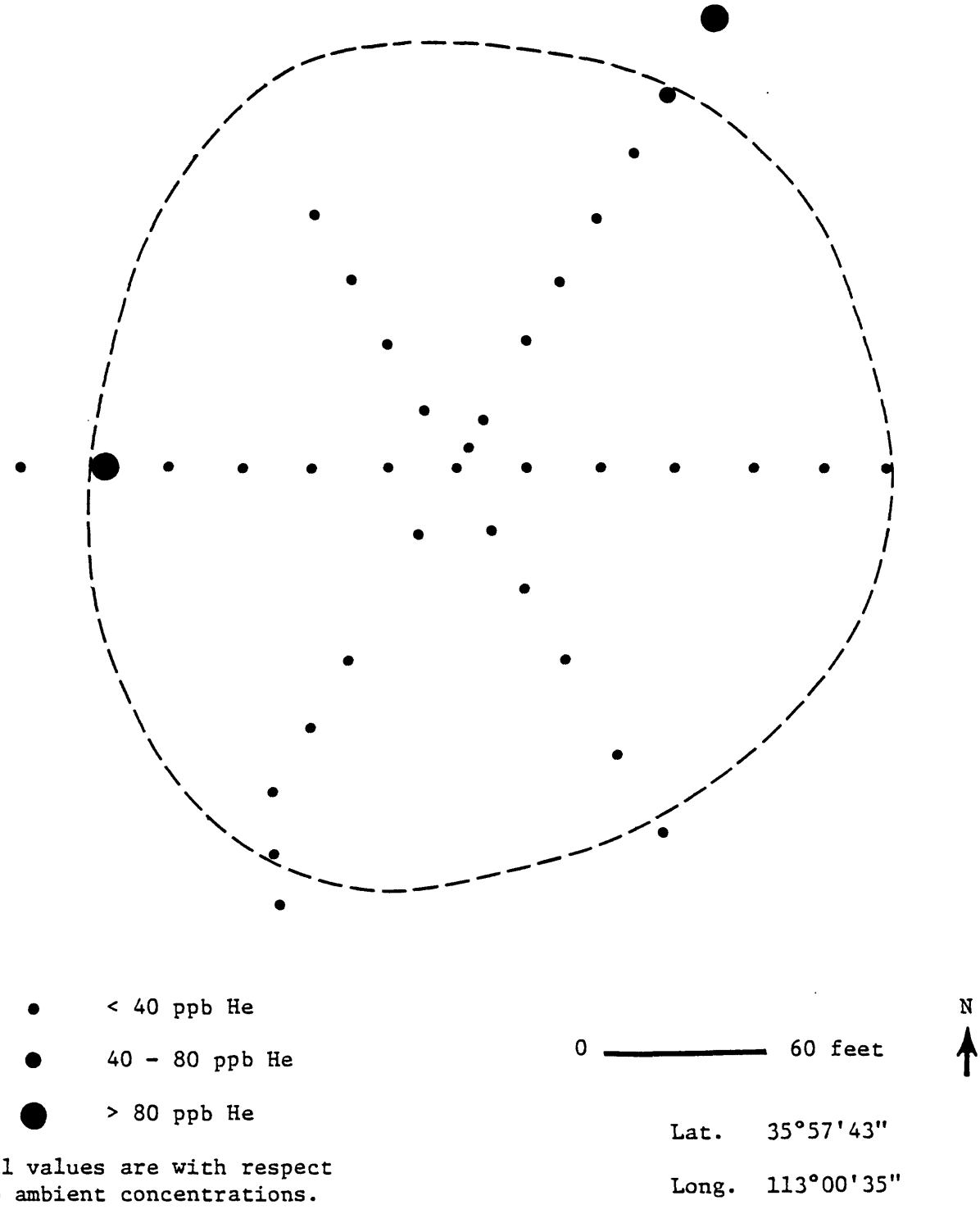
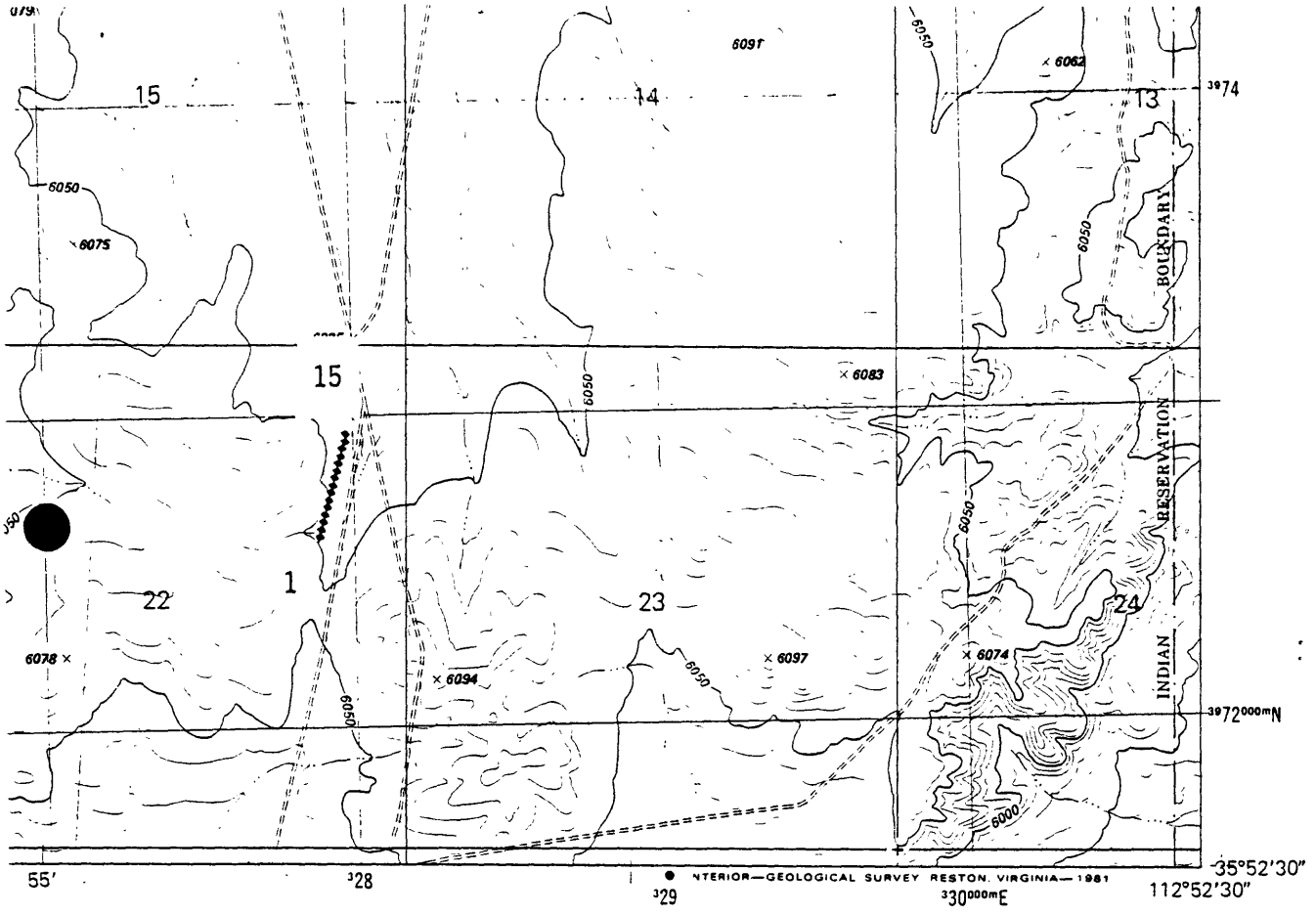


Figure 7.--Collapse feature 571; helium soil gas distribution.



National Tank Quadrangle, Arizona

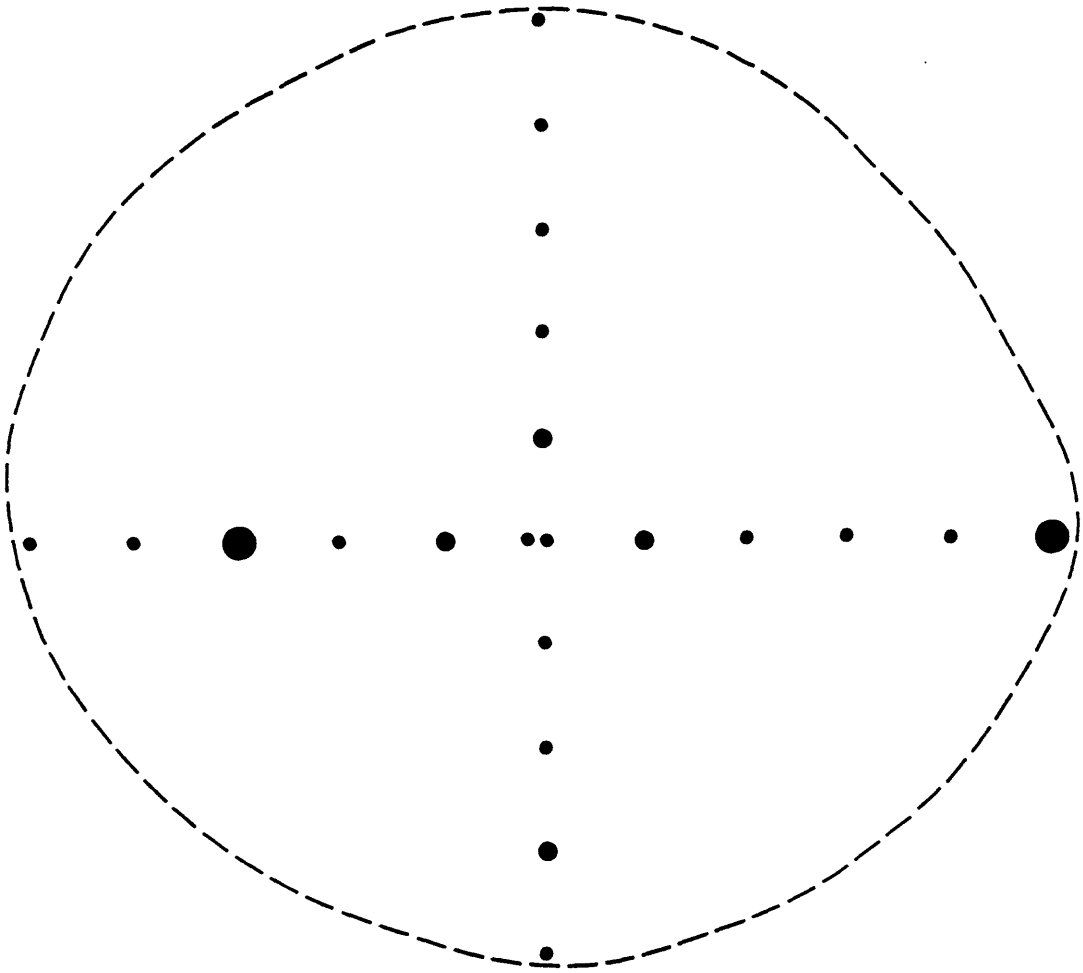
N

Collapse feature location

Background samples on 50 foot spacing

0 ——— 1000 feet

Figure 8.--Collapse feature 571; topographic relief.



< 40 ppb He

40 - 80 ppb He

> 80 ppb He

All values are with respect to ambient concentrations.

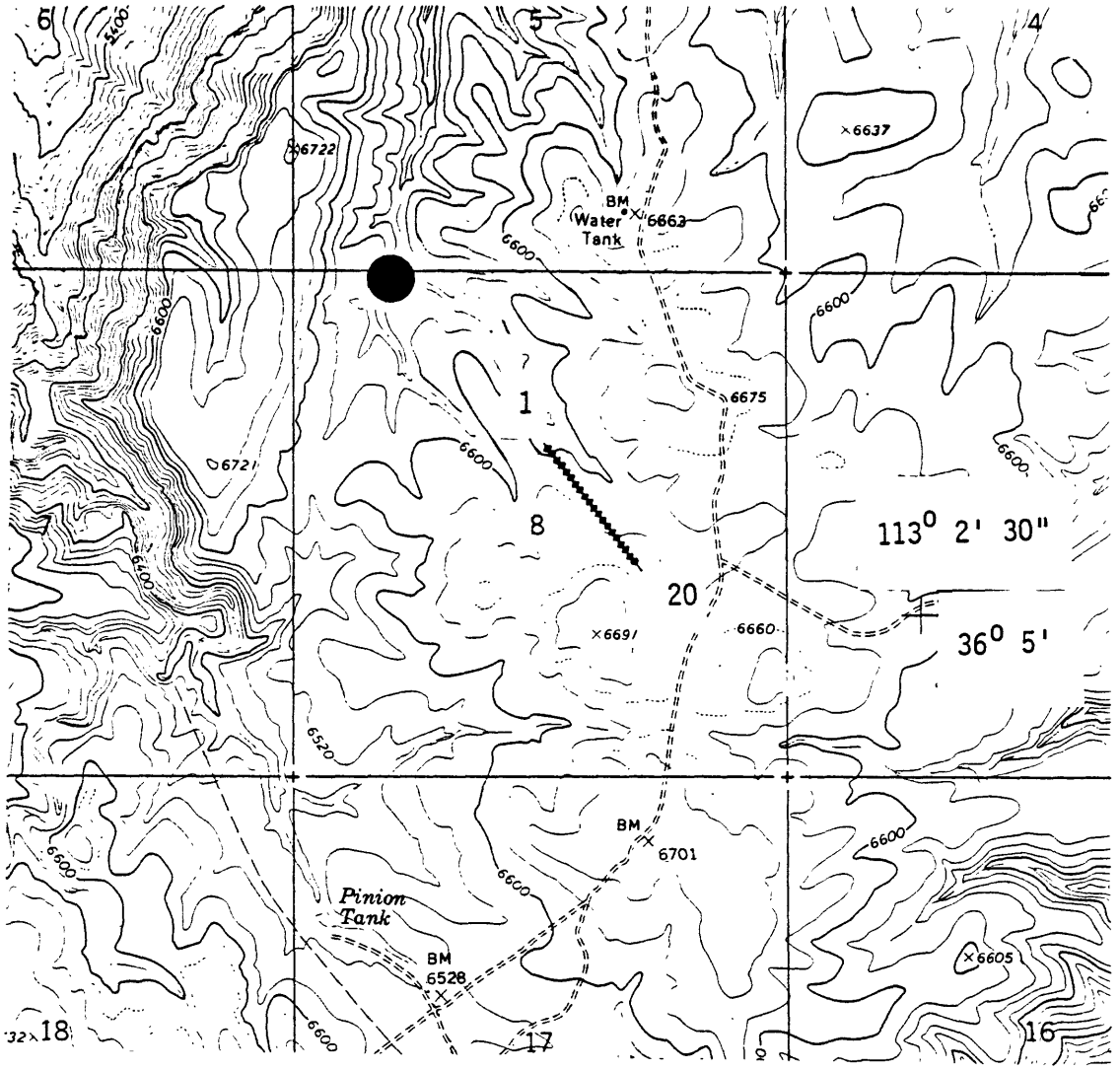
0 —— 10 feet

N

Lat. 36°05'35"

Long. 113°03'40"

Figure 9.--Collapse feature 1102; helium soil-gas distribution.



Vulcan's Throne SE Quadrangle, Arizona

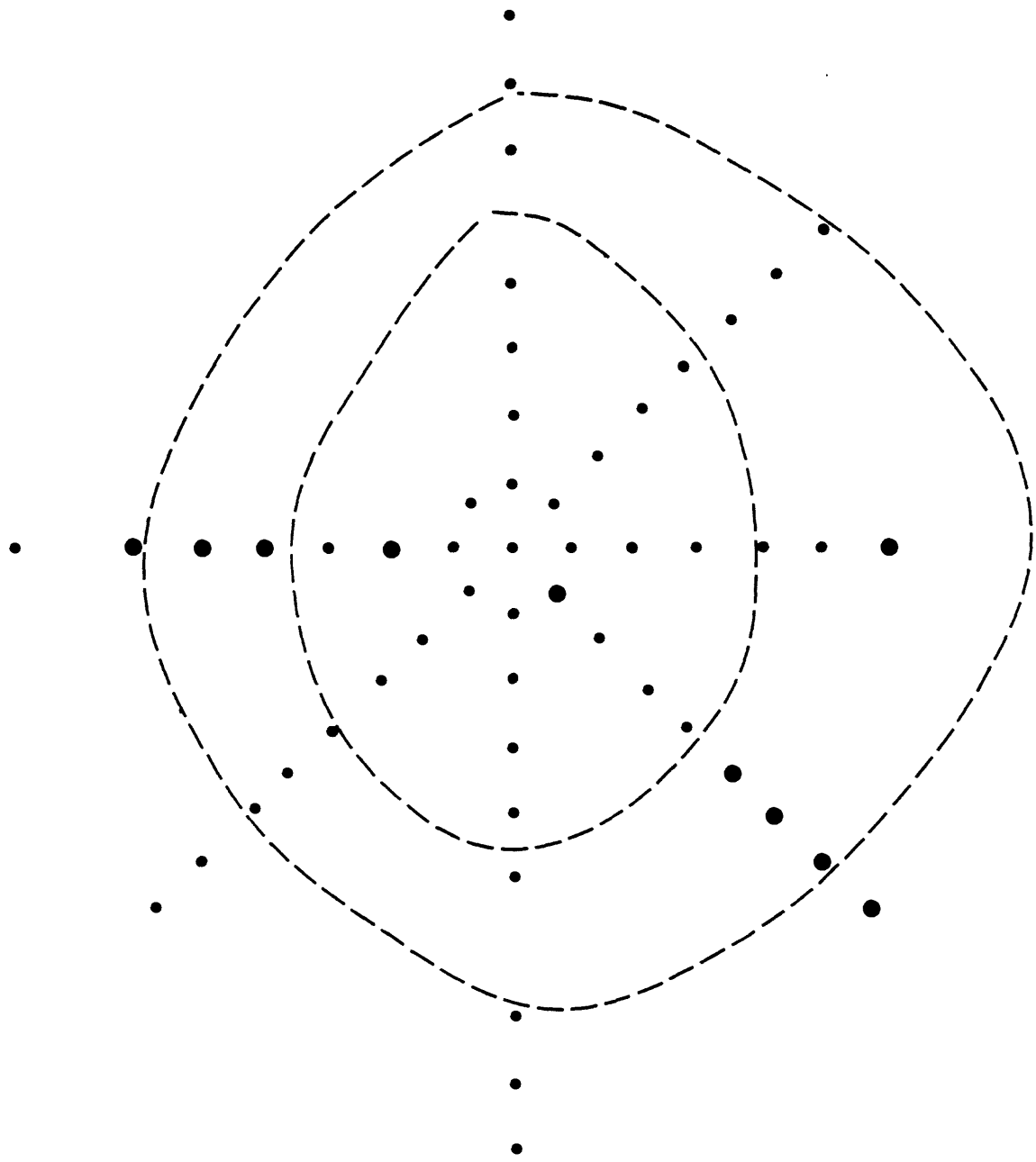
N

Collapse feature location

Background samples on 50 foot spacing

0 ——— 1000 feet

Figure 10.--Collapse feature 1102; topographic relief.



• < 40 ppb He

● 40 - 80 ppb He

All values are with respect to ambient concentrations.

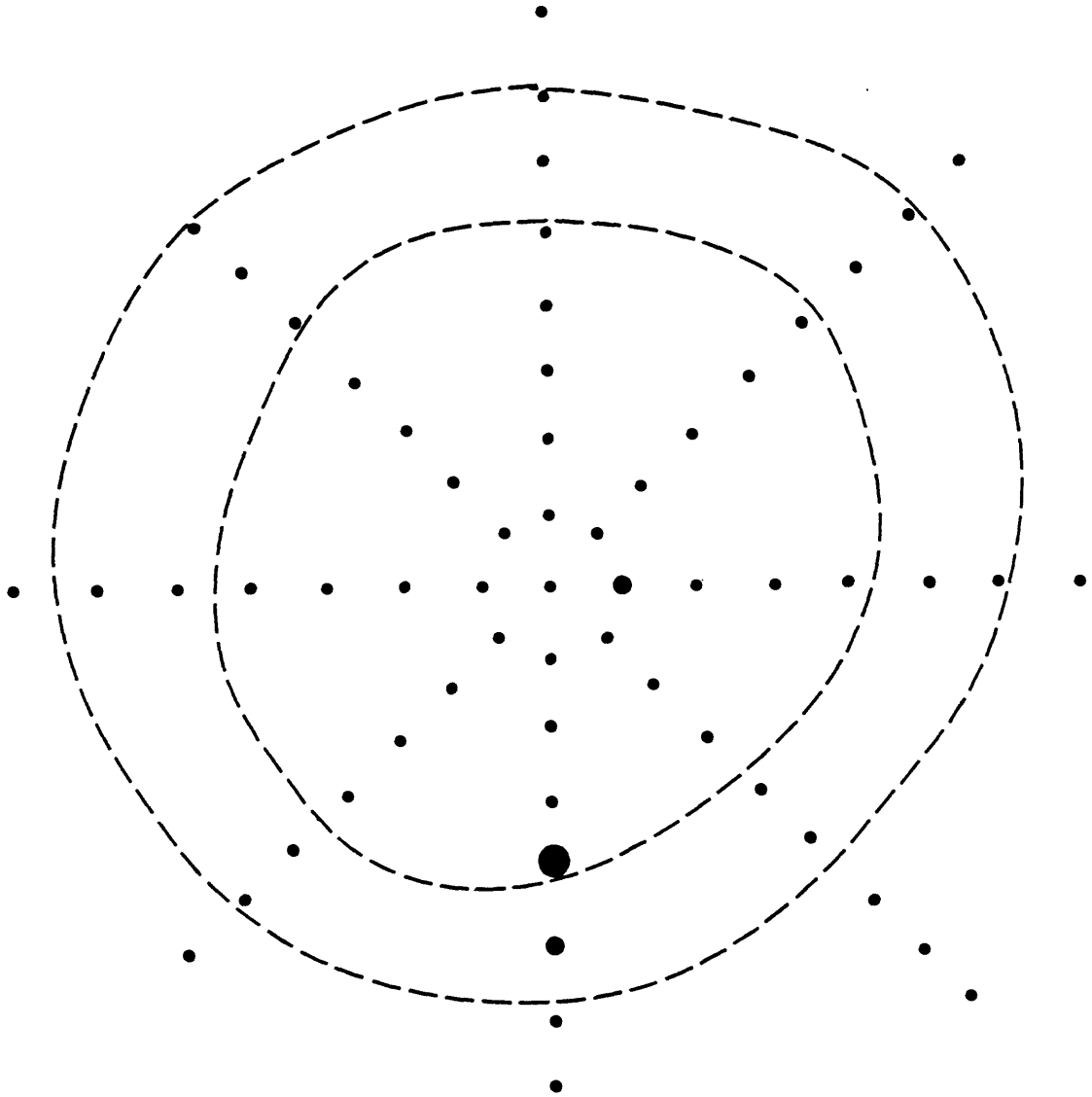
0 ——— 20 feet

N

Lat. 35°52'34"

Long. 112°55'26"

Figure 11.--Collapse feature 1107; helium soil-gas distribution.



< 40 ppb He

40 - 80 ppb He

> 80 ppb He

All values are with respect to ambient concentrations.

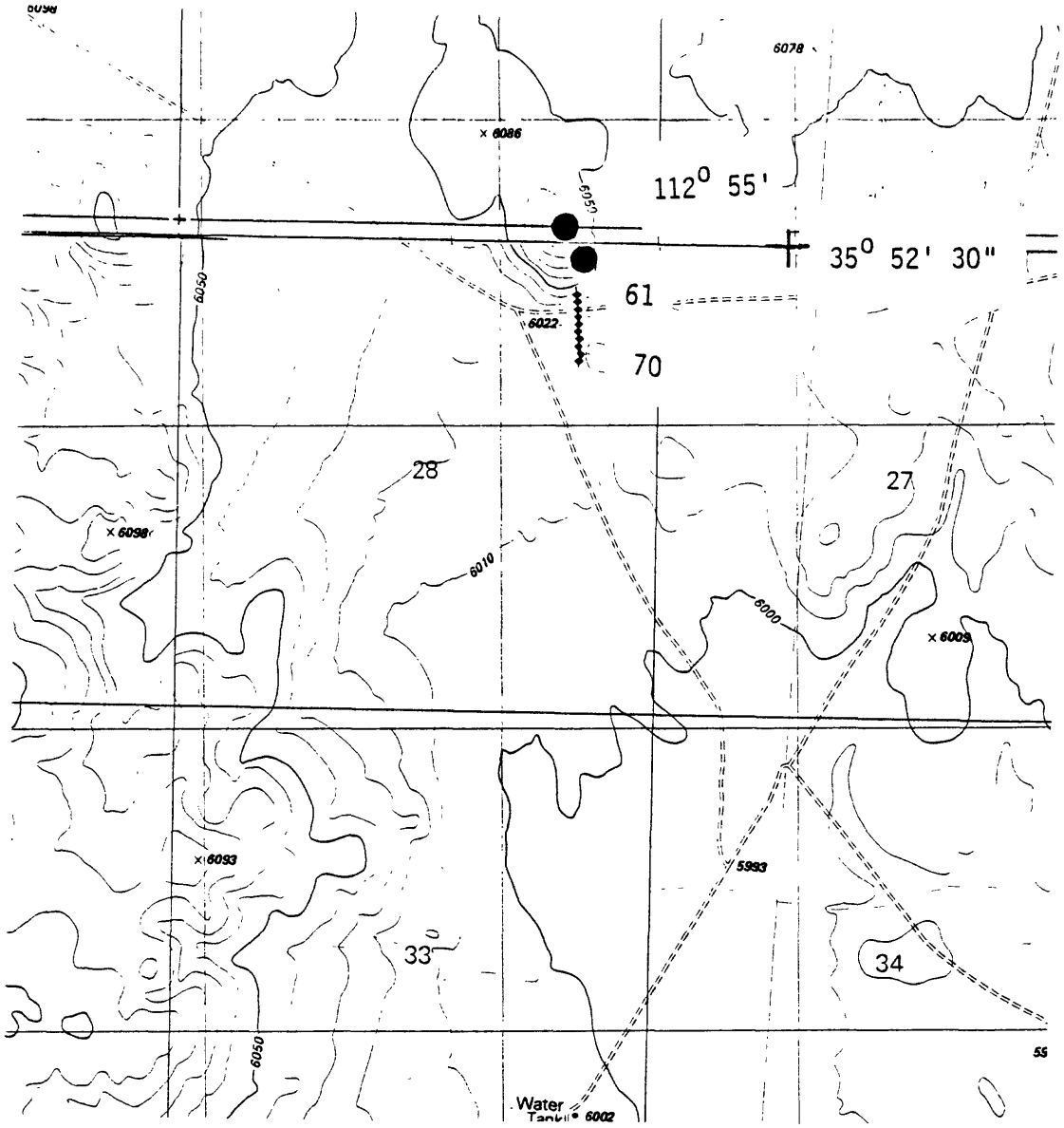
0 ——— 50 feet

N

Lat. 35°52'30"

Long. 112°55'30"

Figure 12.--Collapse feature 1108; helium soil-gas distribution.



National Tank and Dike Tank Quadrangles, Arizona

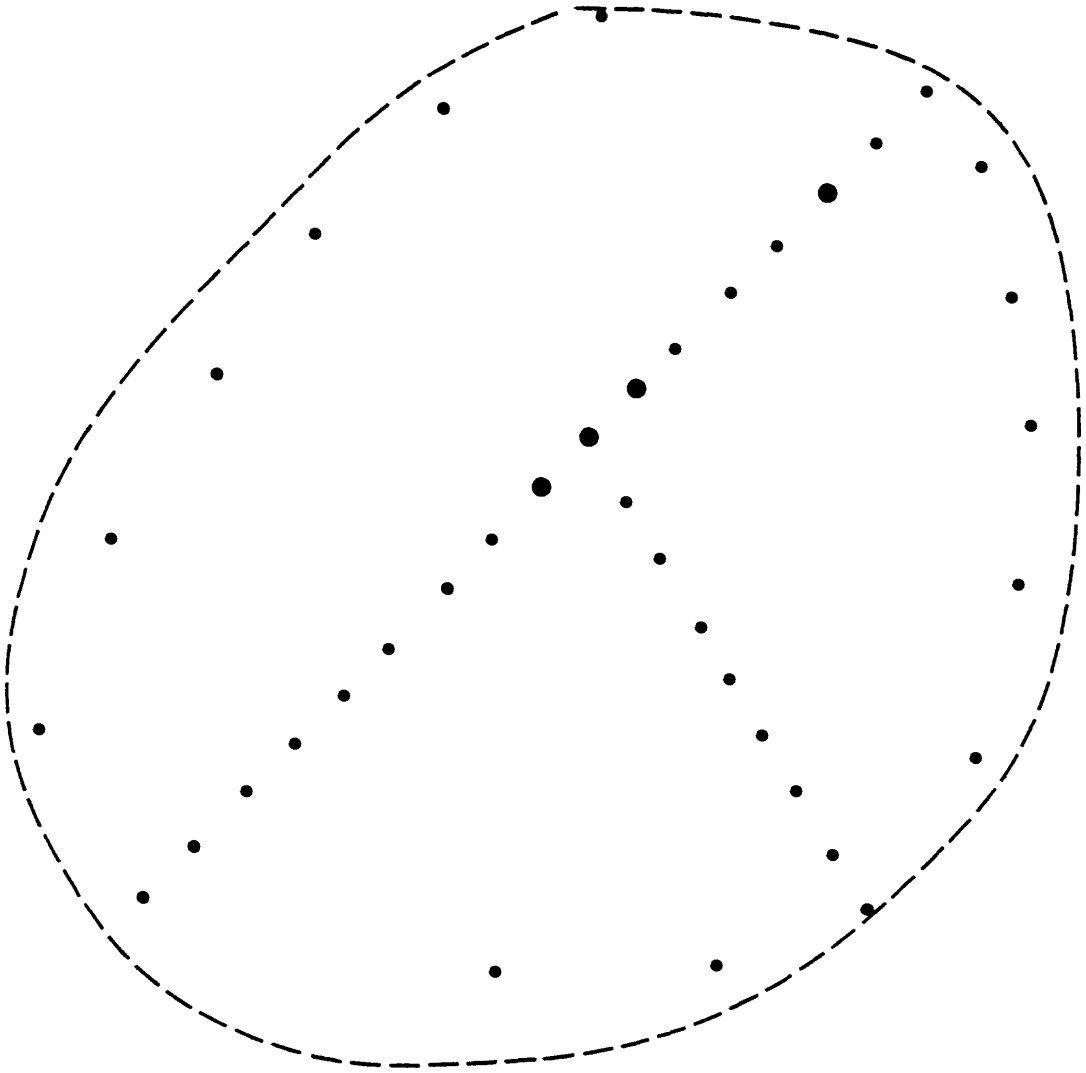
● Collapse features 1107 (north) and 1108 (south) locations

◆◆◆ Background samples on 50 foot spacing

N

0 ——— 1000 feet

Figure 13.--Collapse features 1107 and 1108; topographic relief.



• < 40 ppb He

● 40 - 80 ppb He

All values are with respect to ambient concentrations.

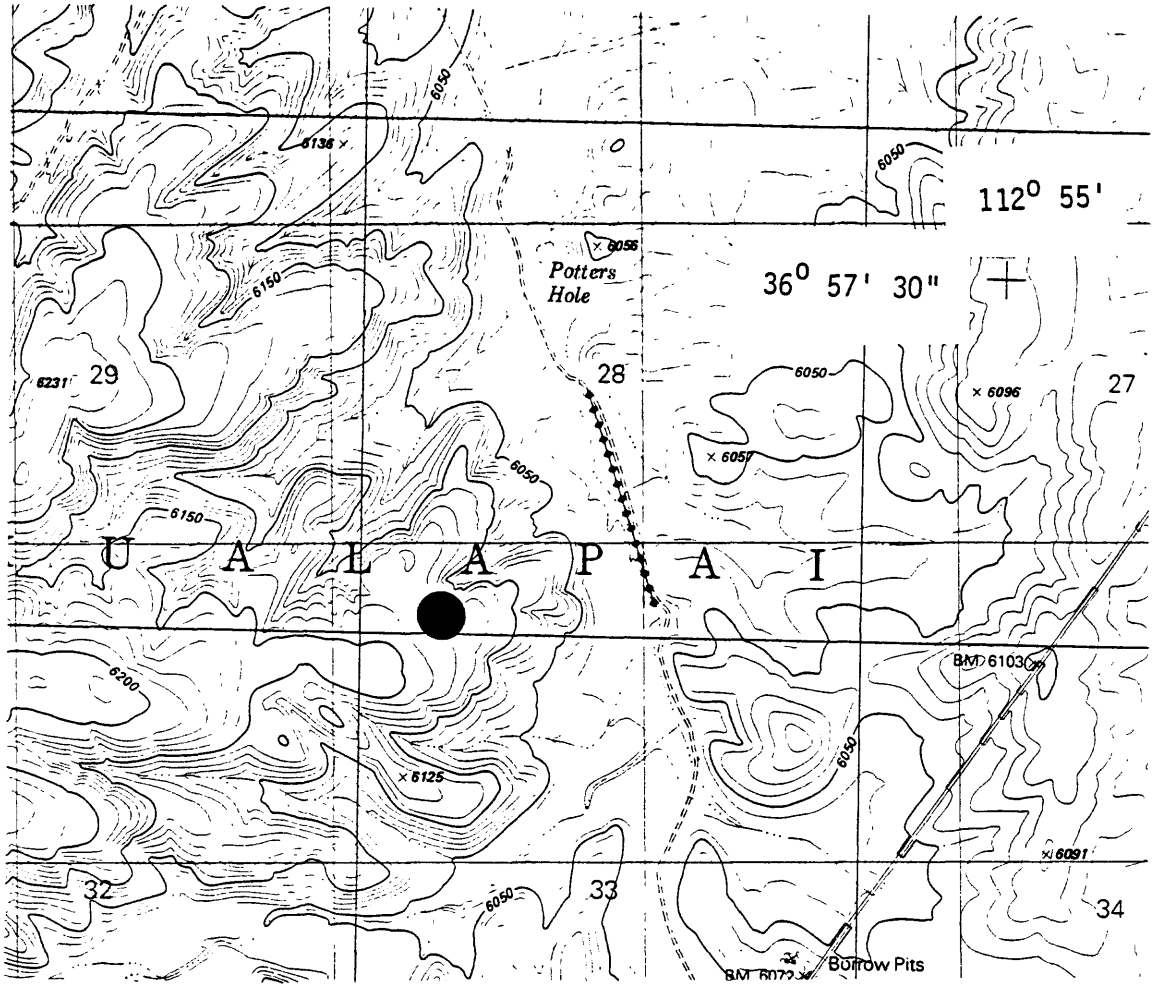
0 ——— 100 feet

N

Lat. 36°56'54"

Long. 112°56'12"

Figure 14.--Collapse feature 1119; helium soil gas distribution.



National Tank Quadrangle, Arizona

● Collapse feature location

⟷ Background samples on 100 foot spacing

N

0 —— 1000 feet

Figure 15.--Collapse feature 1119; topographic relief.

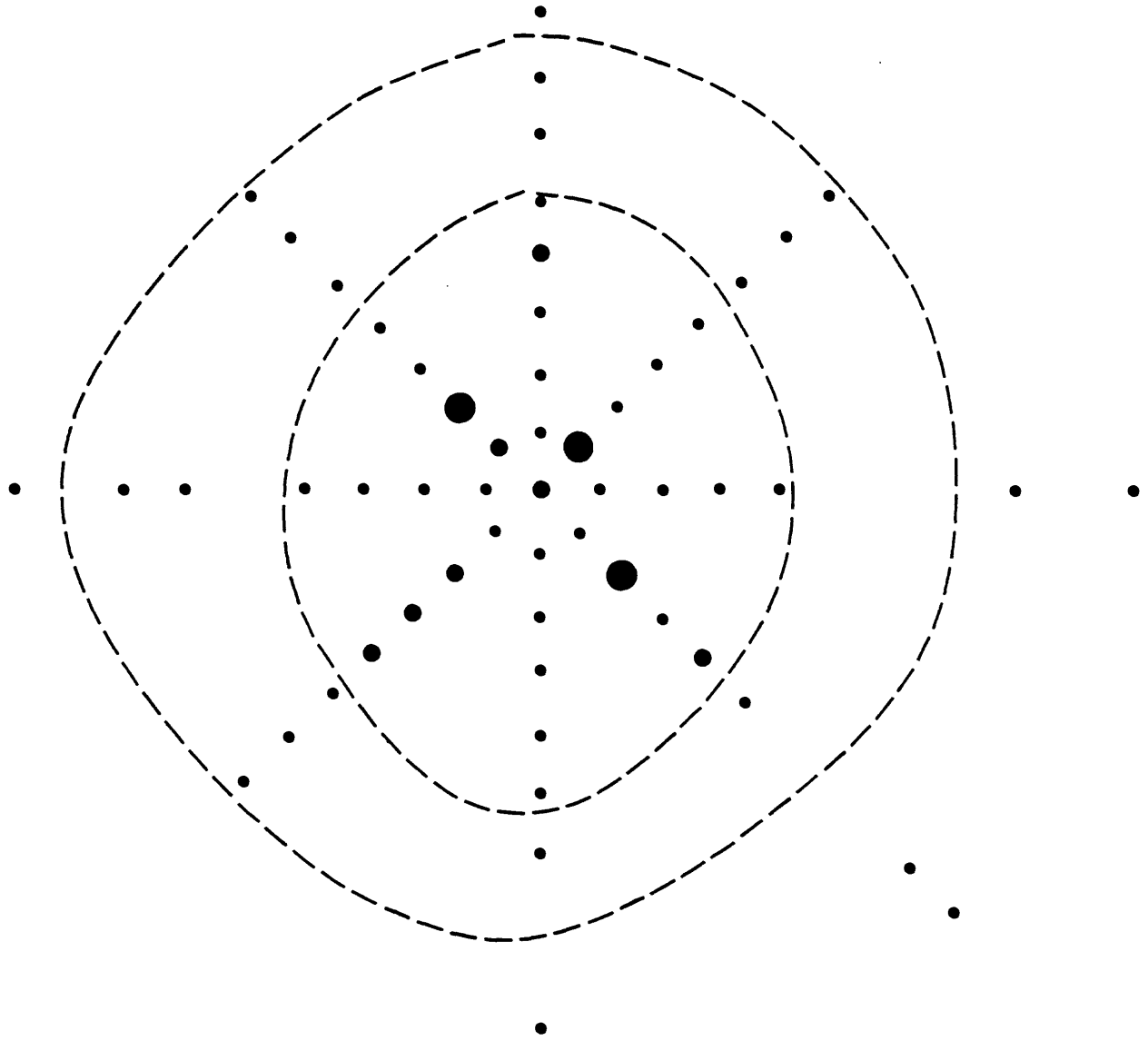
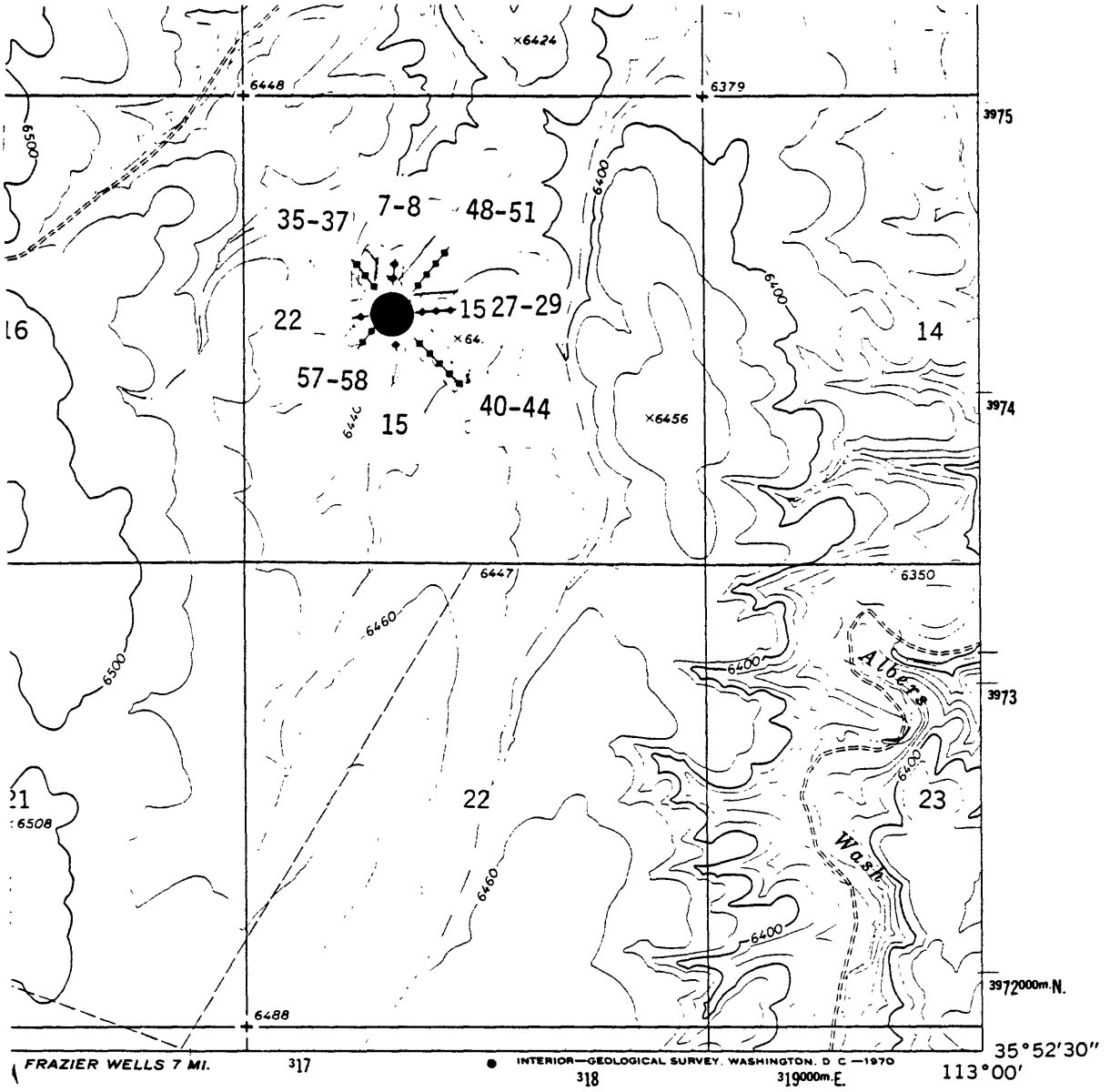


Figure 16.--Collapse feature 1134; helium soil gas distribution.



Prospect Point Quadrangle, Arizona

N

Collapse feature location

Background samples on 100 foot spacing (for each traverse, sample location numbers increase outward from the collapse feature)

0 ——— 1000 feet

Figure 17.--Collapse feature 1134; topographic relief.

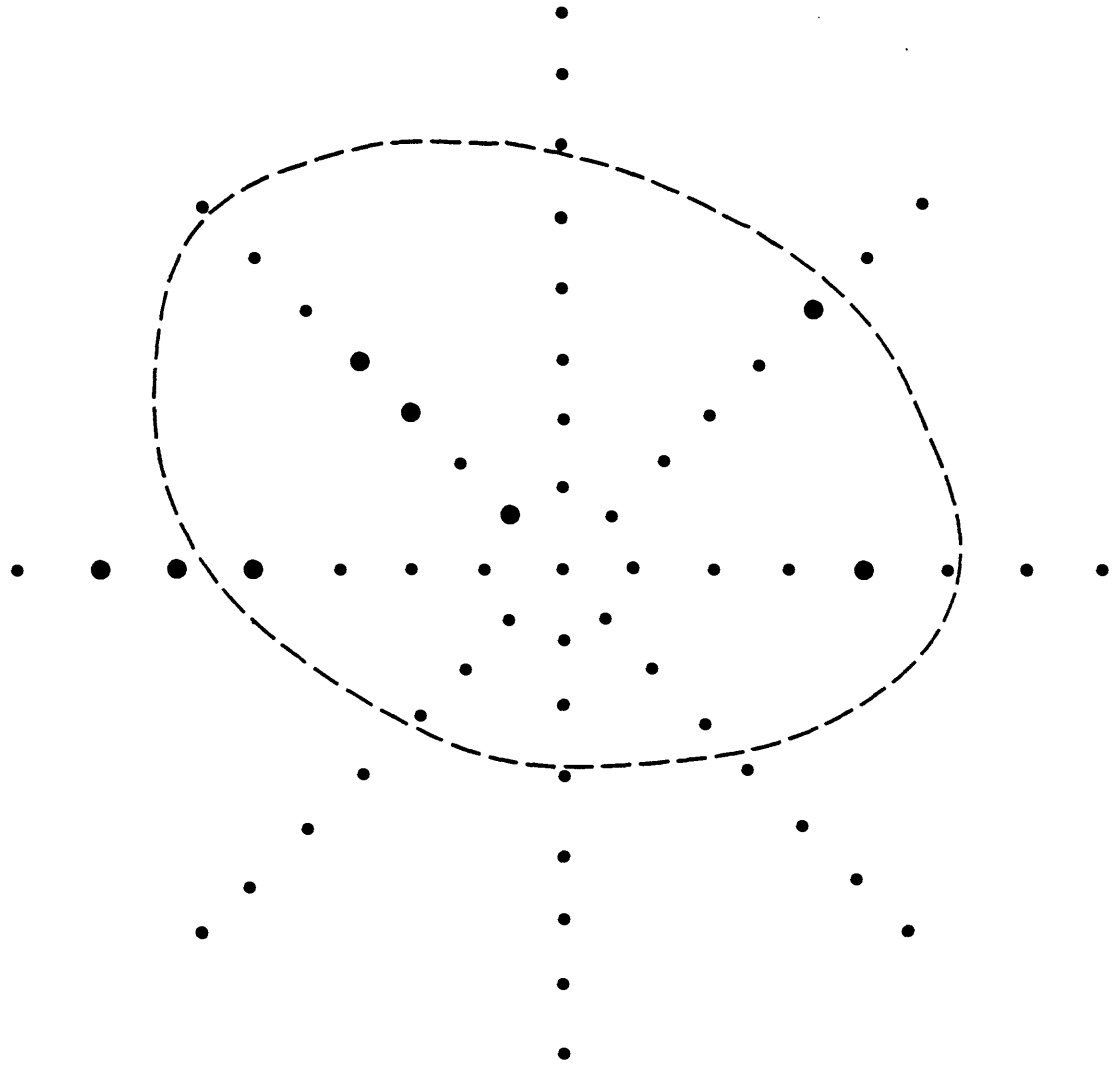


Figure 18.--Collapse feature 1144; helium soil gas distribution.

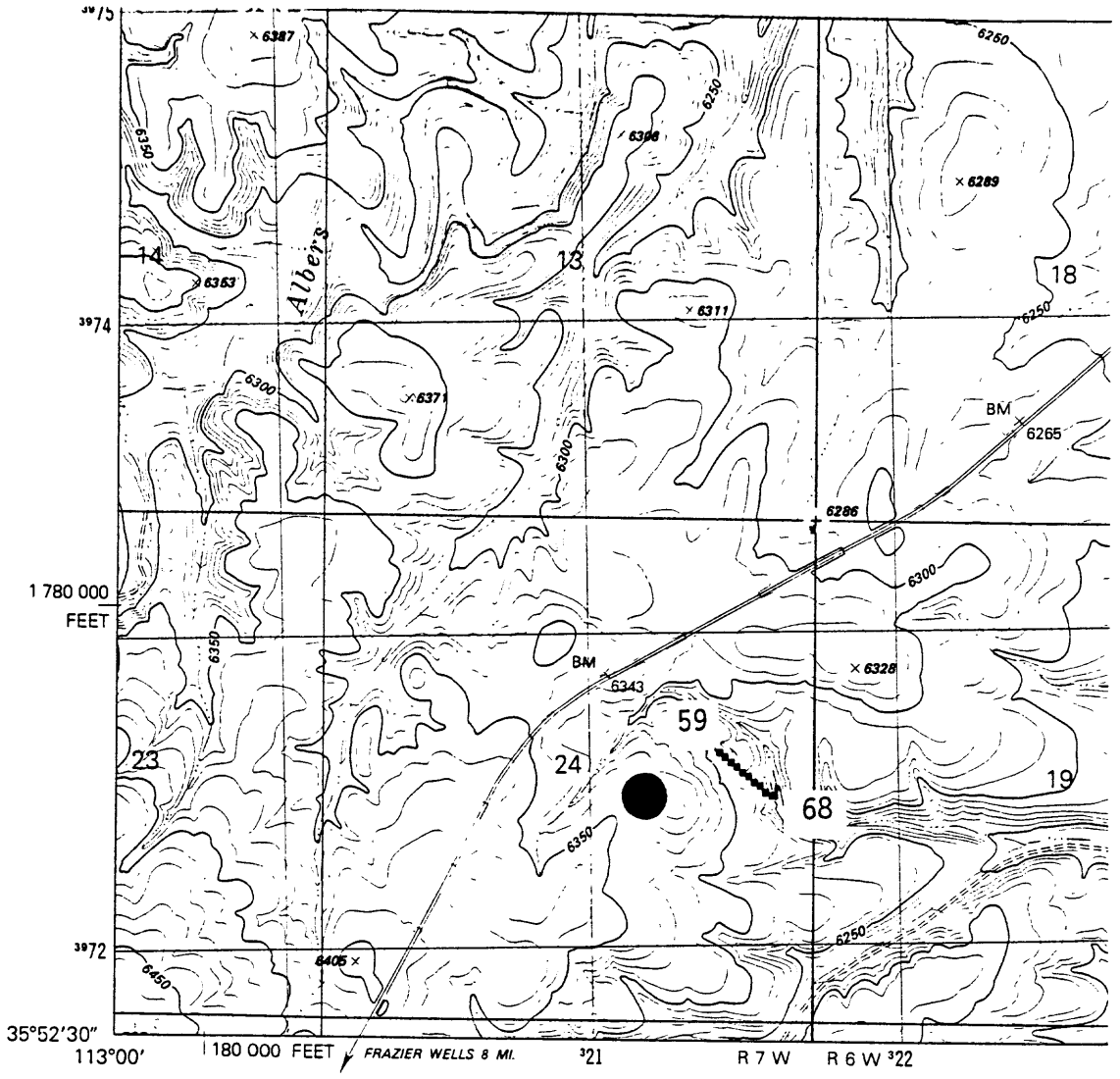
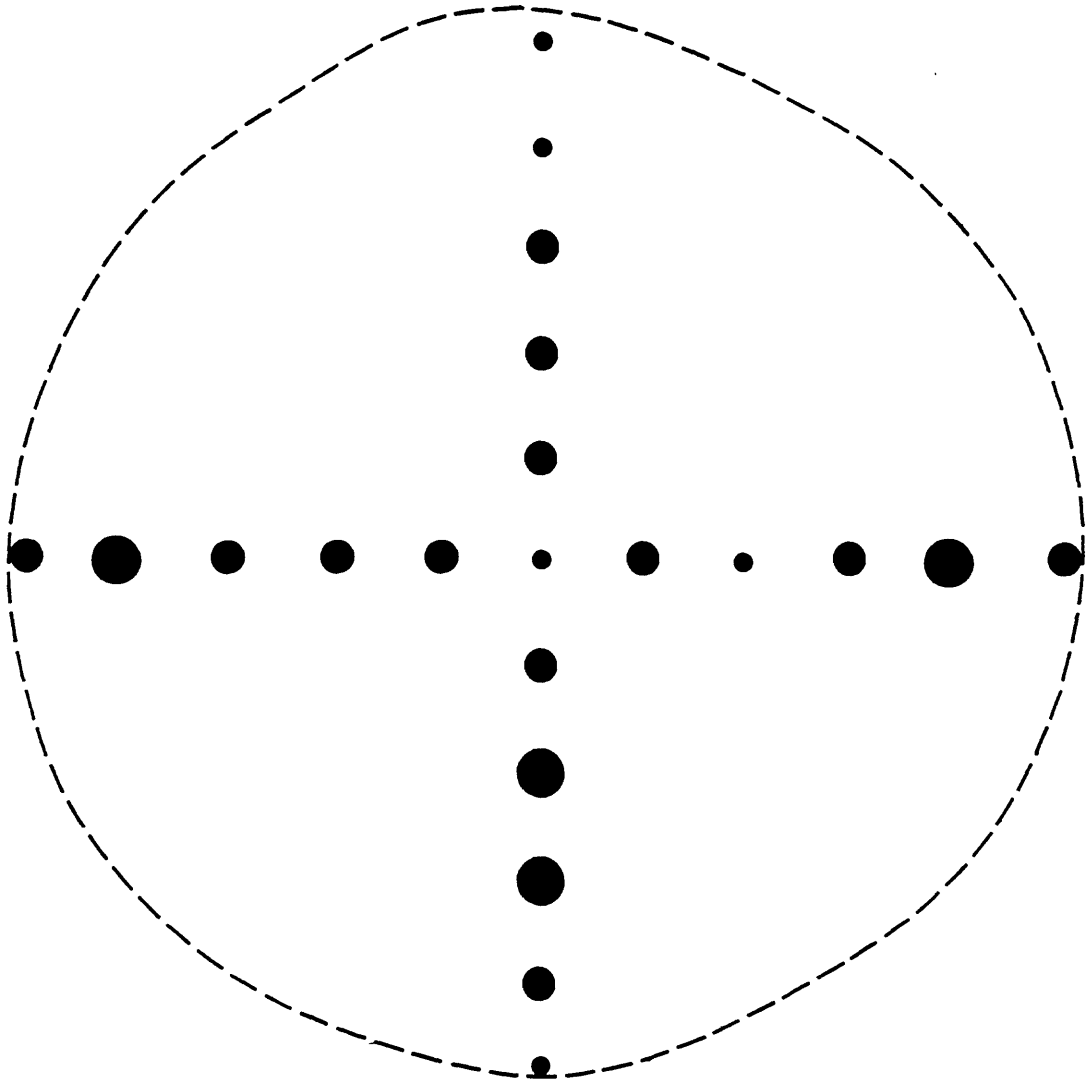


Figure 19.--Collapse feature 1144; topographic relief.



40 - 80 ppb He

80 - 120 ppb He

> 120 ppb He

All values are with respect to ambient concentrations.

0 ——— 200 feet

N

Lat. 35°59'08"

Long. 112°18'18"

Figure 20.--Collapse feature 1179; helium soil gas distribution.

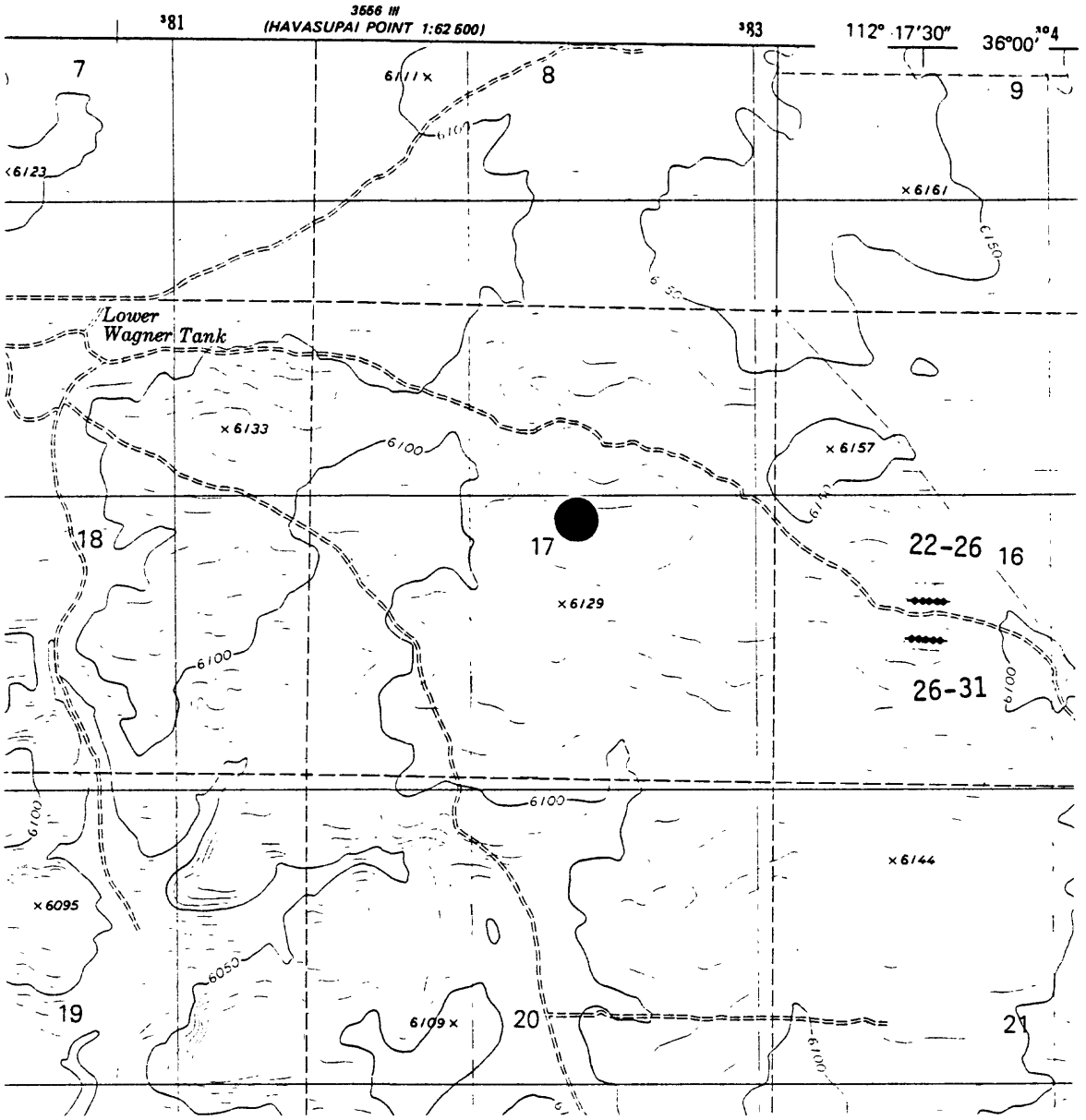
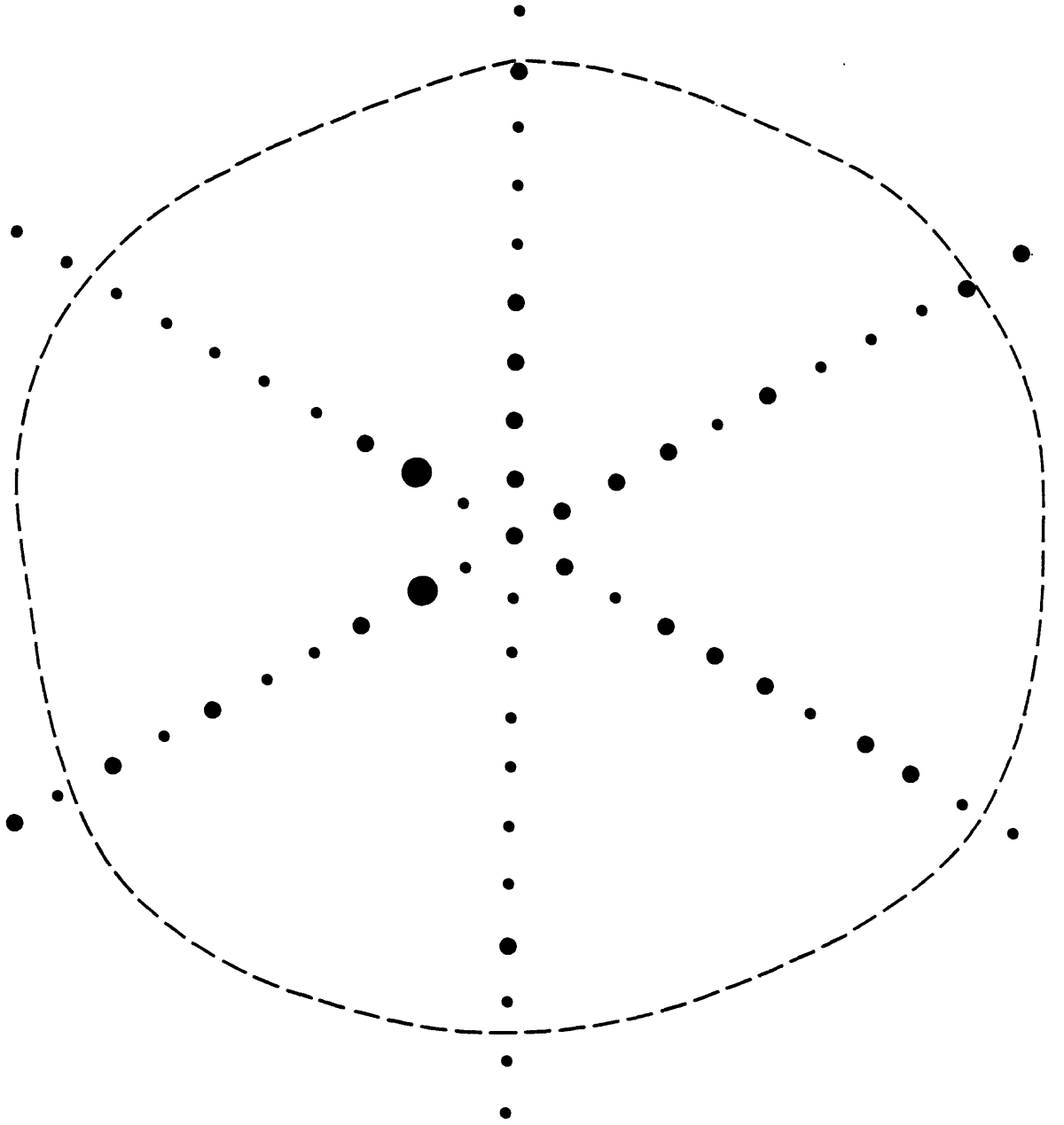


Figure 21.--Collapse feature 1179; topographic relief.



< 40 ppb He

40 - 80 ppb He

> 80 ppb He

All values are with respect to ambient concentrations.

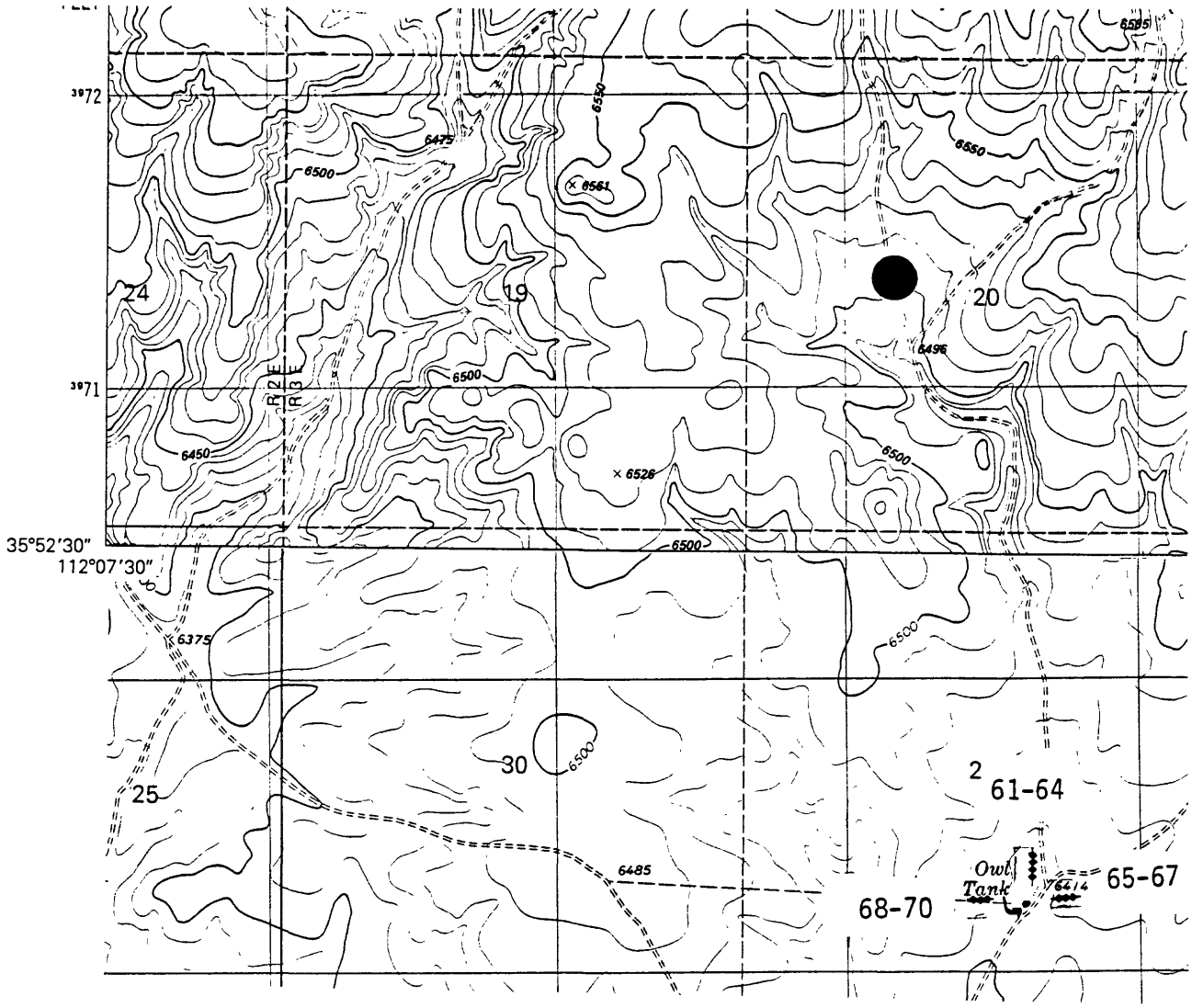
0 —— 200 feet

N

Lat. 35°52'48"

Long. 112°05'44"

Figure 22.--Collapse feature 1180; helium soil gas distribution.



Tusayan East and Red Butte Quadrangles, Arizona

Collapse feature location

Background samples on 50 foot spacing (for each traverse, numbers increase outward from Owl Tank)

Figure 23.--Collapse feature 1180; topographic relief.