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Density, porosity, and magnetic susceptibility of rocks
from the Silver City 1° x 2° quadrangle, Arizona and New Mexico

by

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Abstract

Petrophysical data on dry bulk density, porosity and magnetic susceptibility from 52 rock specimens from southeast Arizona and southwest New Mexico are tabulated and summarized by major geologic map units. The rock specimens were collected within the Silver City 1° x 2° quadrangle, primarily in parts of the Pinaleno, Peloncillo, Gila, Summit and Big Burro Mountains. All but ten of the samples are from Tertiary volcanic units.

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INTRODUCTION

This report presents data obtained from petrophysical examination of 52 rock samples collected in conjunction with geophysical field work in southeastern Arizona and southwestern New Mexico (fig. 1). Physical properties measured were dry bulk density, porosity and magnetic susceptibility. Rock samples were taken as time permitted during the course of gravity surveys in the Silver City 1° x 2° quadrangle. The distribution of sample sites is shown on fig. 2.

DATA

Table 1 of the appendix tabulates the locations, geologic map-unit identifications, and petrophysical measurements for all samples of this report.

Sampling consisted of collecting one or more hand-sized specimens from each locality. The specimens were broken from outcrops without determining orientation. These specimens were subsequently cored to produce, on the average, about five cylindrical samples from each locality for analysis. Each core was one-inch (25 mm) in diameter and 1-2 inches (25-50 mm) in length. The appendix lists the average of results of laboratory measurements on samples from each locality. The measurement techniques followed procedures documented by Hunt and others (1979). A generalized description of the techniques can be found in Klein and Johnson, 1983. The samples were not petrologically identified, thus the following analysis groups the rocks by geologic map units according to the generalized geological base map used by Wynn (1981) and Richter and Lawrence (1983).

The International System of units (SI) is used in this report. Inasmuch as cgs-emu units are commonly reported, conversions between systems for the quantities used here are summarized below (Sheriff, 1973, p. 134, U.S. National Bureau of Standards, 1974, American Society for Testing and Materials, 1976).

Percent porosity and specific gravity (numerically equivalent to cgs density) are constant between systems. SI density (kg/m^3) is related to cgs density (g/cm^3) by:

$$10^{-3} \text{ kg/m}^3 = 1 \text{ g/cm}^3$$

Magnetic susceptibility (S) is a dimensionless ratio of induced magnetization to external magnetic field. The relationship between systems is

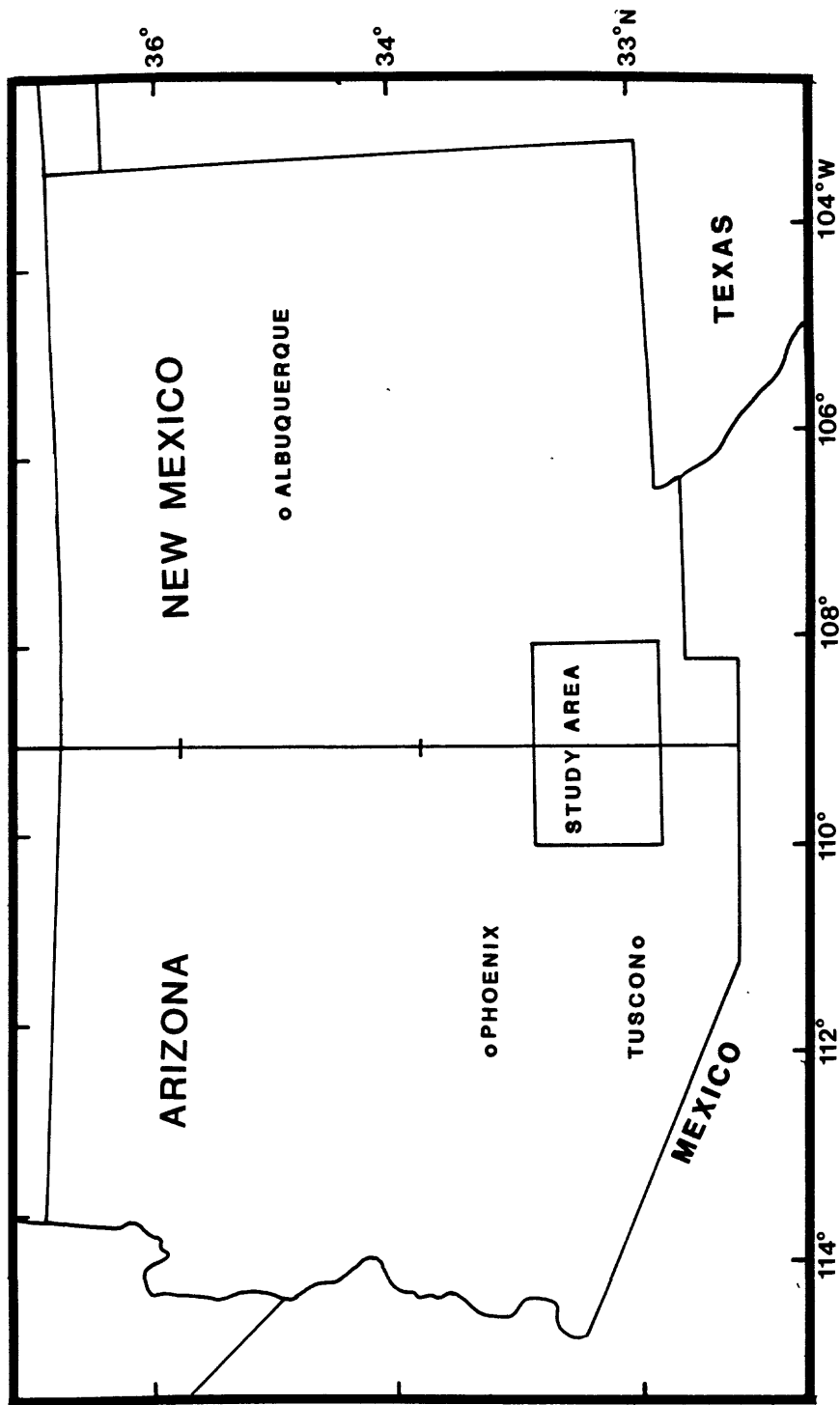


Figure 1. -- Map showing area of rock sampling in southeast Arizona and southwest New Mexico. The study area is that of the Silver City 1° x 2° quadrangle: lat. 32° - 33°N and long. 108°-110°W.

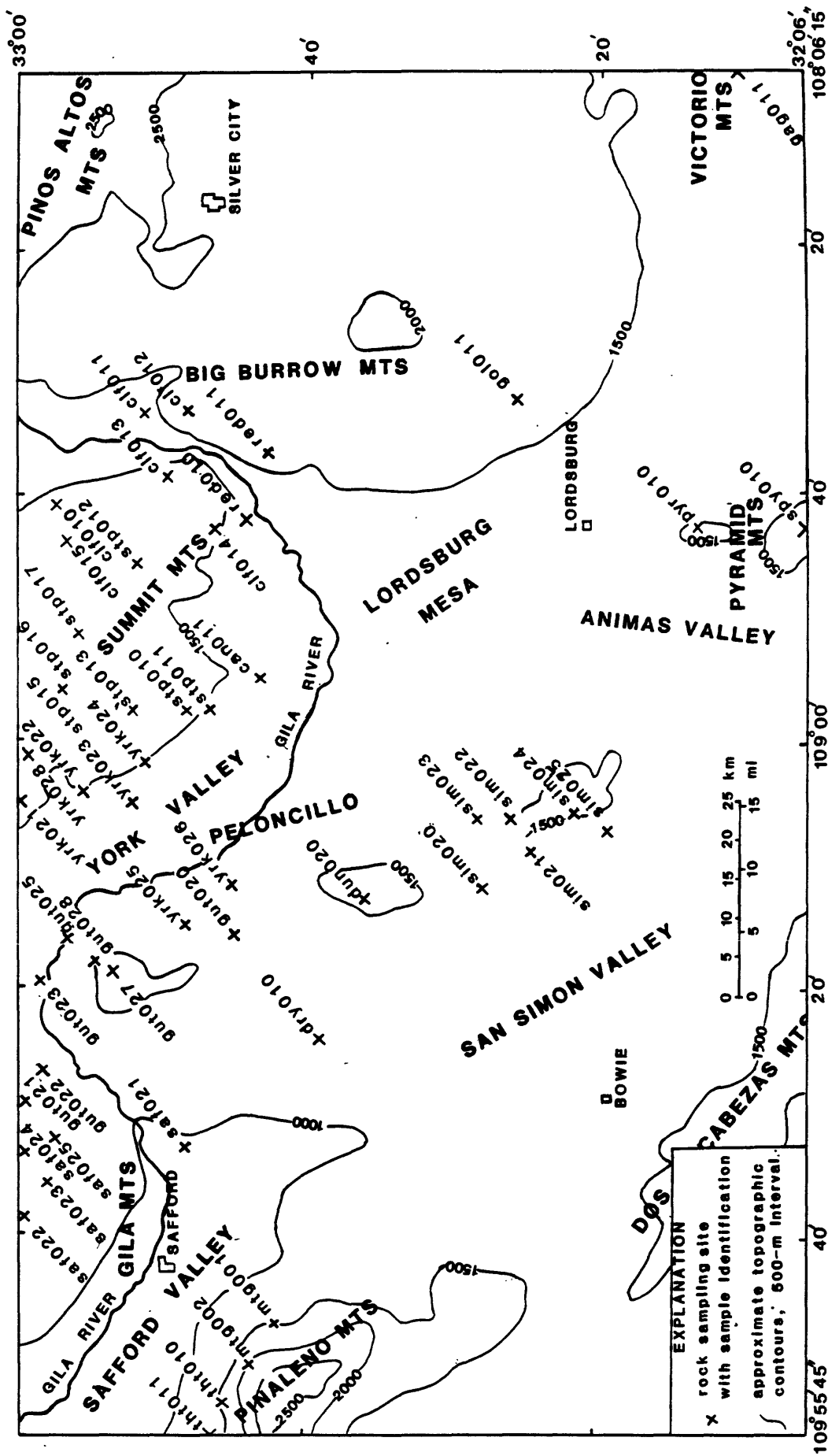


Figure 2. -- Map showing rock sample locations.

given by:

$$4\pi \text{ SI} = 1 \text{ cgs-emu}$$

The magnetic field is related between systems by:

$$\frac{10^3}{4\pi} \text{ amp/m (SI)} = 1 \text{ gauss (cgs-emu)}.$$

The Earth's total magnetic intensity in southern Arizona and New Mexico is typically 79.6 amp/m, equivalent to 0.5 gauss (50,000 gamma).

Wet bulk density (W) is computed from dry bulk density (D) and percent porosity (P) by using the expression:

$$W = D + \frac{P}{100}$$

DISCUSSION

Table 1 summarizes the measurements according to the geologic map units represented. Logarithmic-mean values are given for magnetic susceptibility; linear mean values are given for density and porosity. The range for each quantity is expressed as the limits within which 80-percent of the data fall, centered on the median.

The data provides reliable statistics only for the Tertiary volcanic units Tim (27 samples) and Tf (13 samples). The remaining units are all represented by 6 samples or less (see Table 1). Bearing this limitation in mind, the mean values of the data suggest the following order of units for decreasing magnetic susceptibility: Tim, Tcv, Tf, Xm, Yi, and MCs. The order of units for decreasing mean dry density is nearly the reverse of that for magnetic susceptibility, being: Yi, MCs, Xm, Tim and Tf, and Tcv. The mean porosity variations among units are not so great as to modify this order for the wet density, nor to substantially change the density differences between units for wet density as compared to the differences for dry density.

The magnetic susceptibility measurements on the Tim samples include four samples showing anomalously low values (samples STP 010, YRK 022, 023, 024) These four samples are all grouped on the west flank of the Summit Mountains suggesting that Tim rocks in this area may have uniqueness in terms of magnetic susceptibility. The 27 samples of Tim data also show a bimodal distribution of porosity with 62% of the data in the porosity range of 7.7 to 10.7 percent porosity, and 25% of the data in the range of 19.7 to 22.7 percent. The four samples with anomalous susceptibility are among those having the lower porosity. However, no overall consistent relationship was found in the spatial distribution of Tim-unit rocks having low porosity as compared to those having high porosity.

The range of magnetic susceptibility of the Precambrian metamorphic unit, Xm, indicates that this map unit has extreme variations in its magnetic properties. The highest magnetic susceptibility of the Xm unit is found in the northern Big Burro Mountains (sample RED011), the lowest magnetic susceptibility is found in the southern Big Burro Mountains (sample GOL011). However, with single sample sites there is no assurance that these values are

Table 1 -- Summary of petrophysical data from the Silver City 1° x 2° quadrangle. The range of values for each quantity are given as 80-percent limits centered on the median.

Map Unit ¹	Number of Samples	Susceptibility		Dry Bulk Density		Percent porosity	
		SI x 10 ⁴ mean ²	range	kg/m ³ x 10 ⁻³ mean ³	range	mean	range
Tim ⁴	4	2.0	0.5-10.	2.25 (2.34)	2.09-2.44	8.9	8.9-9.4
	23	130.	62.-220.	2.21 (2.34)	1.74-2.61	13.	8.0-22.
	27	69.	2.9-220.	2.21 (2.34)	1.74-2.61	13.	8.0-22.
Tcv	2	54.	26.-110.	2.05 (2.21)	1.92-2.18	16.	11.-20.
Tf	13	39.	11.-210.	2.21 (2.30)	2.09-2.36	9.4	8.8-13.
Tcv + Tf	15	40.	11.-210.	2.19 (2.29)	1.92-2.36	10.	8.8-20.
Xm	6	25.	1.4-520.	2.37 (2.46)	2.18-2.47	9.2	8.7-11.
Yi	2	14.	4.0-45.	2.53 (2.58)	2.28-2.77	5.3	1.9-8.6
MCs	2	1.8	0.75-4.3	2.40 (2.47)	2.14-2.65	7.4	6.1-8.7

¹Map unit abbreviations are defined in Table 2 of the appendix.

²Mean susceptibility is computed as the logarithmic mean.

³The values in parenthesis are the computed mean wet bulk densities.

⁴Four anomalously low values of susceptibility from rocks sampled on the west flank of the Summit Mountains have been considered as a unique subset in calculations for the first two rows.

typical. The remaining four samples from the Xm unit (MTG001, MTG002, THT010, THT011) are in the Pinaleno Mountains. Three of these samples have magnetic susceptibility ranging from 3.4 to 36. $\times 10^{-4}$ SI; the fourth sample has a magnetic susceptibility of 190. $\times 10^{-4}$ SI.

CONCLUSIONS

1. Tertiary volcanic units, Tim, Tcv, Tf, (42 samples) have a mean dry bulk density of about 2.20×10^{-3} kg/m³. The mean porosity is about 10 percent, but is bimodally distributed. The majority of volcanic rocks have porosity near 8-percent and a smaller number having a porosity near 20-percent. Magnetic susceptibilities of the Tertiary volcanic rocks show three groupings: the majority of samples from the Tim unit has a logarithmic mean susceptibility of 130. $\times 10^{-4}$ SI; the combined Tcv and Tf unit has a logarithmic mean susceptibility of 40. $\times 10^{-4}$ SI, and four samples of the Tim unit on the west flank of the Summit Mountains have an anomalously low mean magnetic susceptibility of 2.0×10^{-4} SI.
2. Precambrian metamorphic rocks of the Xm unit (6 samples) have a mean dry density of 2.37×10^3 kg/m³, and a mean porosity of 9.2 percent. The magnetic susceptibility of rocks measured from the Xm unit varies from 1.4 to 520. $\times 10^{-4}$ SI.
3. The Precambrian granitic Yg unit (2 samples) on the west side of the northern Big Burro Mountains have dry bulk densities of 2.28 to 2.77×10^3 kg/m³, porosities of 1.9 to 8.6 percent, and magnetic susceptibilities of 4.0 to 45. $\times 10^{-4}$ SI.
4. Paleozoic sedimentary rocks of the MCs unit (2 samples) in the Victorio Mountains have dry bulk densities of 2.14 to 2.65×10^3 kg/m³, porosities of 6.1-8.7 percent, and magnetic susceptibilities of 0.75 to 4.3×10^{-4} SI.

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REFERENCES

- American Society for Testing and Materials, 1976, Standard for metric practice: Philadelphia, ASTM Publication E 380-76, 37 p.
- Hunt, G. R., Johnson, G. R., Olhoeft, G. R., Watson, D. E., and Watson, Kenneth, 1979, Initial report of the petrophysics laboratory: U.S. Geological Survey Circular 789, 74 p.
- Klein, D. P., and Johnson, G. R., 1983, Density, porosity and magnetic properties of rock specimens from southwestern Arizona: U.S. Geological Survey Open-file report 83-808, 16 p. and appendices.
- Richter, D. H., and Lawrence, V. A., 1982, Mineral deposit map of the Silver City 1° x 2° quadrangle, New Mexico and Arizona: U.S. Geological Survey, Miscellaneous Investigations Series, map I-1310-B, scale 1:250,000 with accompanying tables.
- Sheriff, R. E., 1973, Encyclopedic dictionary of exploration geophysics: Tulsa, Society of Exploration Geophysics, 266 p.
- Wynn, J. C., 1981, Complete Bouguer gravity map of the Silver City 1° x 2° quadrangle, New Mexico-Arizona: U.S. Geological Survey Miscellaneous Investigations Series, Map I-1310-A, scale 1:250,000.

APPENDIX

Tabulation of rock sample locations and petrophysical measurements. The tabulation is sorted alphabetically by sample identification code.

Sample: Identification code for the sampling station. The first three letters abbreviate the quadrangle name in which the sample was acquired (see Table 3)

Physiographic location: The name of the prominent physiographic feature in the vicinity of each sample station.

Map Unit: Abbreviation of the geologic map unit on which the sample was acquired (see Table 2).

Rock Type: Rocks collected for this study were not petrologically identified, (unk = unknown).

Magn. Suscept.: Measured magnetic susceptibility in units of 10^{-4} SI.

Reman. Magn: Measurements not available.

Dry Dens.: Measured dry bulk density in units of $10^{-3} \times \text{kg/m}^3$.

Wet Dens.: Computed wet bulk density in units of $10^{-3} \times \text{kg/m}^3$.

Poros.: Measured percent pore space.

Source Code: Code for the source of data: 4, all rock samples were collected in the field by J. C. Wynn, U.S. Geological Survey.

Appendix Table 1 -- Tabulation of rock properties from the Silver City 1x2 degree Quadrangle.

Sample	Lat. N.	Long. W.	Physiographic Location	Map Unit	Rock Type	Magn. Suscept.	Rem an. Magn.	Dry Dens.	Wet Dens.	Poros.	Source Code
CAN011	32.721	108.920	Black Mountain	Tim	unk	280.7	----	2.34	2.42	8.00	4
CLF010	32.954	108.683	Summit Mts	Tim	unk	129.3	----	2.30	4.38	7.90	4
CLF011	32.853	108.560	Summit Mts	Tf	unk	41.7	----	2.36	2.45	8.80	4
CLF012	32.803	108.558	Big Burrow Mts	Tf	unk	1.6	----	2.29	2.38	8.90	4
CLF013	32.827	108.647	Summit Mts	Tf	unk	42.2	----	2.25	2.34	8.90	4
CLF014	32.773	108.717	Summit Mts	Yi	unk	45.1	----	2.28	2.37	8.60	4
CLF015	32.943	108.733	Summit Mts	Tim	unk	123.3	----	2.64	2.72	7.90	4
DRY010	32.651	109.407	Whitlock Mts	Tim	unk	162.4	----	1.94	2.14	20.00	4
DUN020	32.601	109.217	Peloncillo Mts	Tim	unk	132.4	----	2.54	2.63	8.70	4
GAG011A	32.178	108.095	Victorio Mts	MCs	unk	0.8	----	2.65	2.74	8.70	4
GAG011B	32.178	108.095	Victorio Mts	MCs	unk	4.3	----	2.14	2.20	6.10	4
GOL011	32.429	108.541	Big Burrow Mts	Xm	unk	1.4	----	2.47	2.56	8.70	4
GUT020	32.751	109.261	Peloncillo Mts	Tim	unk	27.1	----	1.59	1.79	20.20	4
GUT021	32.990	109.493	Gila Mts	Tim	unk	163.6	----	2.61	2.70	8.90	4
GUT022	32.967	109.446	Gila Mts	Tim	unk	319.1	----	2.22	2.31	8.90	4
GUT023	32.970	109.327	Peloncillo Mts	Tcv	unk	110.8	----	1.92	2.12	20.00	4
GUT025	32.939	109.270	Peloncillo Mts	Tim	unk	171.0	----	2.22	2.38	16.40	4
GUT027	32.888	109.313	Peloncillo Mts	Tim	unk	89.5	----	1.81	2.02	21.10	4
GUT028	32.907	109.300	Peloncillo Mts	Tim	unk	96.0	----	1.74	1.97	22.70	4
MTG001	32.700	109.788	Pinaleno Mts	Xm	unk	13.2	----	2.38	2.47	8.90	4
MTG002	32.728	109.842	Pinaleno Mts	Xm	unk	187.1	----	2.44	2.53	8.90	4
PYR010	32.224	108.712	Pyramid Mts	Tf	unk	56.7	----	2.36	2.46	9.80	4
RED010	32.738	108.702	Summit Mts	Yi	unk	4.0	----	2.77	2.79	1.90	4
RED011	32.713	108.612	Big Burrow Mts	Xm	unk	517.5	----	2.44	2.53	8.80	4
SAF021	32.804	109.548	Peloncillo Mts	Tim	unk	38.2	----	2.05	2.14	8.90	4
SAF022	32.987	109.646	Gila Mts	Tf	unk	117.4	----	2.19	2.28	8.90	4
SAF023	32.960	109.599	Gila Mts	Tf	unk	26.4	----	2.25	2.35	9.50	4
SAF024	32.986	109.558	Gila Mts	Tim	unk	217.9	----	3.14	3.26	11.50	4
SAF025	32.953	109.540	Gila Mts	Tim	unk	150.5	----	2.13	2.35	22.20	4
SIM020	32.469	109.198	Peloncillo Mts	Tf	unk	82.8	----	2.14	2.23	9.10	4
SIM021	32.412	109.148	Peloncillo Mts	Tf	unk	207.5	----	2.09	2.21	12.50	4
SIM022	32.436	109.104	Peloncillo Mts	Tim	unk	107.4	----	2.28	2.38	9.50	4
SIM023	32.475	109.104	Peloncillo Mts	Tim	unk	221.9	----	1.71	1.92	20.70	4
SIM024	32.364	109.095	Peloncillo Mts	Tf	unk	324.8	----	2.36	2.45	9.20	4
SIM025	32.327	109.119	Peloncillo Mts	Tf	unk	18.5	----	2.11	2.20	8.80	4
SPY010	32.099	108.709	Pyramid Mts	Tim	unk	61.7	----	2.34	2.43	9.40	4
STP010	32.806	108.959	Summit Mts	Tim	unk	0.5	----	2.28	2.36	8.40	4
STP011	32.780	108.959	Summit Mts	Tcv	unk	26.1	----	2.18	2.29	11.30	4
STP012	32.863	108.762	Summit Mts	Tim	unk	207.7	----	2.33	2.43	10.20	4
STP015	32.951	108.978	Summit Mts	Tim	unk	124.5	----	2.23	2.55	32.00	4
STP013	32.867	108.961	Summit Mts	Tim	unk	99.8	----	2.27	2.35	8.20	4
STP016	32.948	108.934	Summit Mts	Tim	unk	153.3	----	2.13	2.35	22.30	4
STP017	32.930	108.855	Summit Mts	Tim	unk	94.2	----	2.02	2.11	8.50	4
THT010	32.758	109.894	Pinaleno Mts	Xm	unk	35.7	----	2.31	2.40	9.20	4
THT011	32.773	109.943	Pinaleno Mts	Xm	unk	3.4	----	2.18	2.29	10.70	4
YRK021	32.996	109.077	Summit Mts	Tf	unk	32.4	----	2.11	2.20	9.50	4
YRK022	32.923	109.070	Summit Mts	Tim	unk	2.9	----	2.09	2.18	8.90	4
YRK023	32.867	109.084	Summit Mts	Tim	unk	10.3	----	2.18	2.27	9.40	4
YRK024	32.853	109.030	Summit Mts	Tim	unk	1.0	----	2.44	2.53	8.90	4
YRK025	32.807	109.248	Peloncillo Mts	Tf	unk	10.8	----	2.18	2.24	6.00	4
YRK026	32.753	109.195	Peloncillo Mts	Tim	unk	202.4	----	2.07	2.16	9.00	4
YRK028	32.986	109.021	Summit Mts	Tf	unk	23.5	----	2.01	2.13	12.50	4

Appendix, Table 2 -- List of abbreviations used for geological map units in the data tabulation (Table 1). See Wynn, 1981; Richter and Lawrence, 1982.

Map Unit	Description	Geological Period
Tcv	Intermediate to mafic volcanoclastic and volcanic rocks	Tertiary
Tim	Intermediate to mafic volcanic rocks	Tertiary
Tf	Felsic volcanic rocks	Tertiary
MCs	Sedimentary rocks	Permian and Pennsylvanian
Yi	Granitic rocks	Proterozoic Y
Xm	Metasedimentary and Metaigneous	Proterozoic X

Appendix, Table 3 -- List of abbreviations used to suffix the sample designation in Table 1. The location for each abbreviation refers to the 7.5- or 15-minute quadrangle in Arizona or New Mexico.

Abbreviation	Location
CAN	CANDOR PEAK
CLF	CLIFF
DRY	DRY MOUNTAIN
DUN	DUNCAN
GAG	GAGE
GOL	GOLD HILL
GUT	GUTHRIE
MTG	MOUNT GRAHAM
PYR	PYRAMIC PEAK
RED	REDROCK
SAF	SAFFORD
SIM	SAN SIMON
SPY	SOUTH PYRAMID PEAK
STP	STEEP ROCK
THT	THATCHER
YRK	YORK VALLEY