UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Physical properties of rock samples from the Butte 1^{o} x 2^{o} quadrangle, Montana

by

J. H. Hassemer and D. J. Lidke

Open-File Report 86-435

1986

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INTRODUCTION

This report presents density, porosity, and magnetic properties of 144 rock samples collected from the Butte 1° x 2° quadrangle, Montana (fig. 1). Rock samples with a sample number beginning with b were collected during a gravity survey of the Butte quadrangle (Hassemer, 1984). The remaining samples were collected during geologic field mapping of the Butte quadrangle by Chester A. Wallace (cw as characters 3 and 4 of the sample number), James E. Elliott (sample number beginning with e), and David J. Lidke (dl as the 3rd and 4th character or sample number beginning with 1). Physical properties were measured by J. H. Hassemer while D. J. Lidke assigned a rock type classification to each sample. All work was done as part of the Conterminous United States Mineral Appraisal Program (CUSMAP).

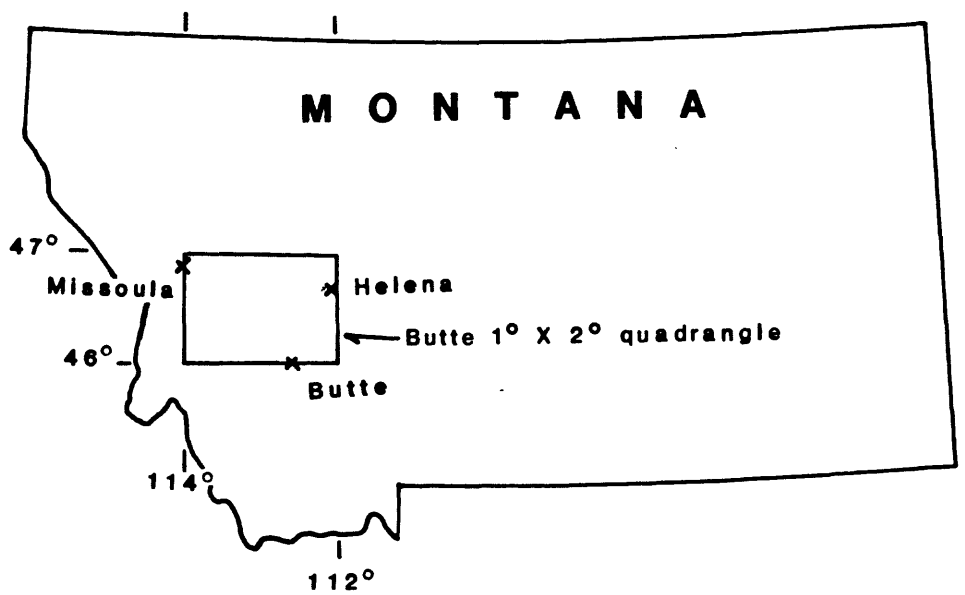


Figure 1. Location of the Butte 1° x 2° quadrangle.

DATA

The rock sample data are listed in table 1. The samples are listed first by rock type and then by geologic map unit. Abbreviations used for rock type are listed in appendix A. Identification of rock type was based on macroscopic examination of cores and the rocks. Geologic map unit for each sample location was determined from the geologic map of the Butte 1^{o} x 2^{o} quadrangle (Wallace, and others, 1986). Appendix B lists of geologic map units appearing in table 1. Sample locations are shown on figure 2.

Rock samples were of hand-sized specimens broken from rock outcrops. Orientation of 51 samples was determined with a brunton pocket transit before breaking them from the outcrop. Most of the specimens were later cored to produce a core one inch in diameter and approximately one inch in length. Those samples that were not cored are identified in table 1 with a -1.0 under the remanent magnetization column.

Magnetic susceptibilities were measured with an instrument as described by Christie and Symons (1969). Cores were measured in a one and a quarter inch diameter coil whereas small hand samples were measured in a four inch diameter coil. Both coils were calibrated with known specimens.

Remanent magnetization and density measurements were made in the petrophysics laboratory using techniques documented by Hunt and others (1979) and are briefly described below.

Natural remanent magnetization intensity and its direction with respect to magnetic north for the oriented samples were measured with a Schonstedt spinner magnetometer. The spinner used has a computerized system that converts the fluxgate signal to digital form to process the data and continues the spin until a predetermined signal-to-noise ratio is attained. The six-spin method was used where each sample is spun in opposite directions on each of the three axial orientations.

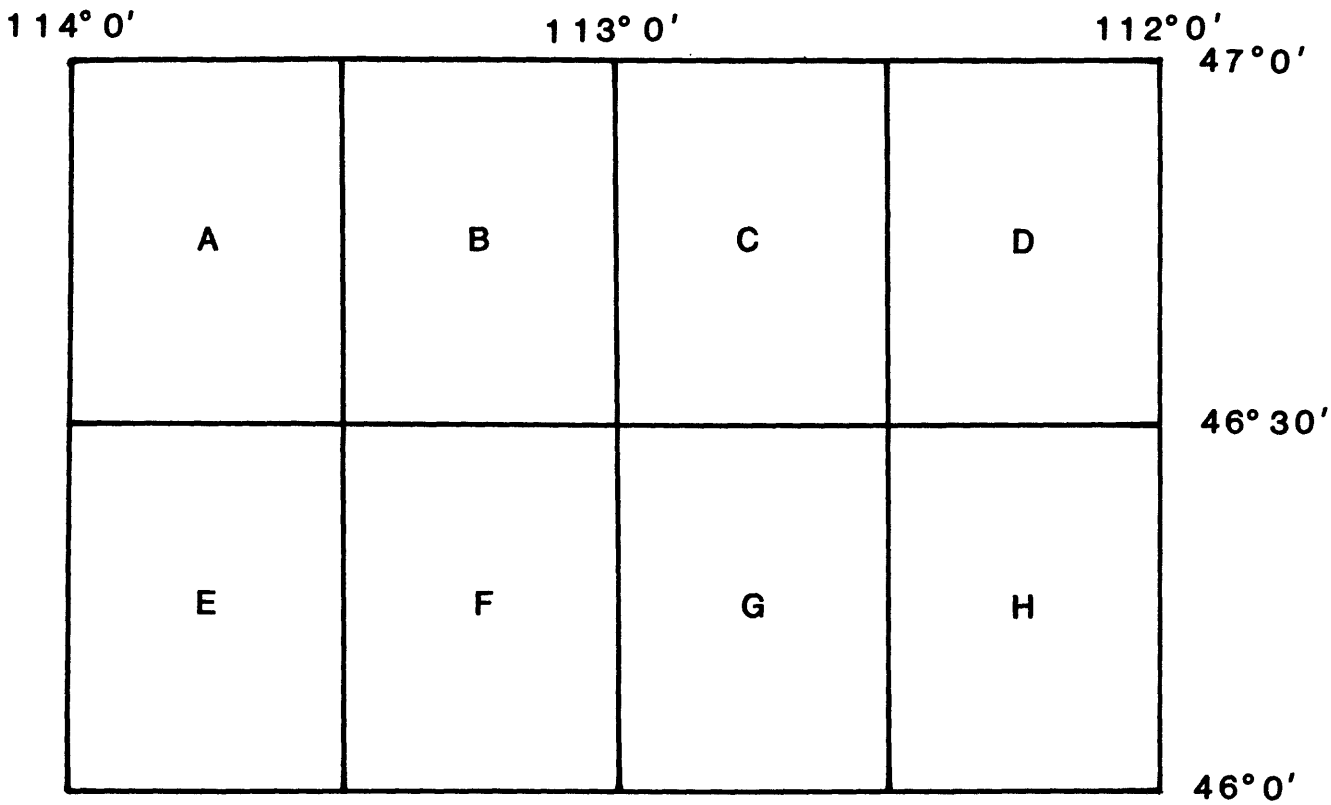


Figure 2. Index of figures 2A through 2H showing the location and sample ID's of samples listed in table 1.

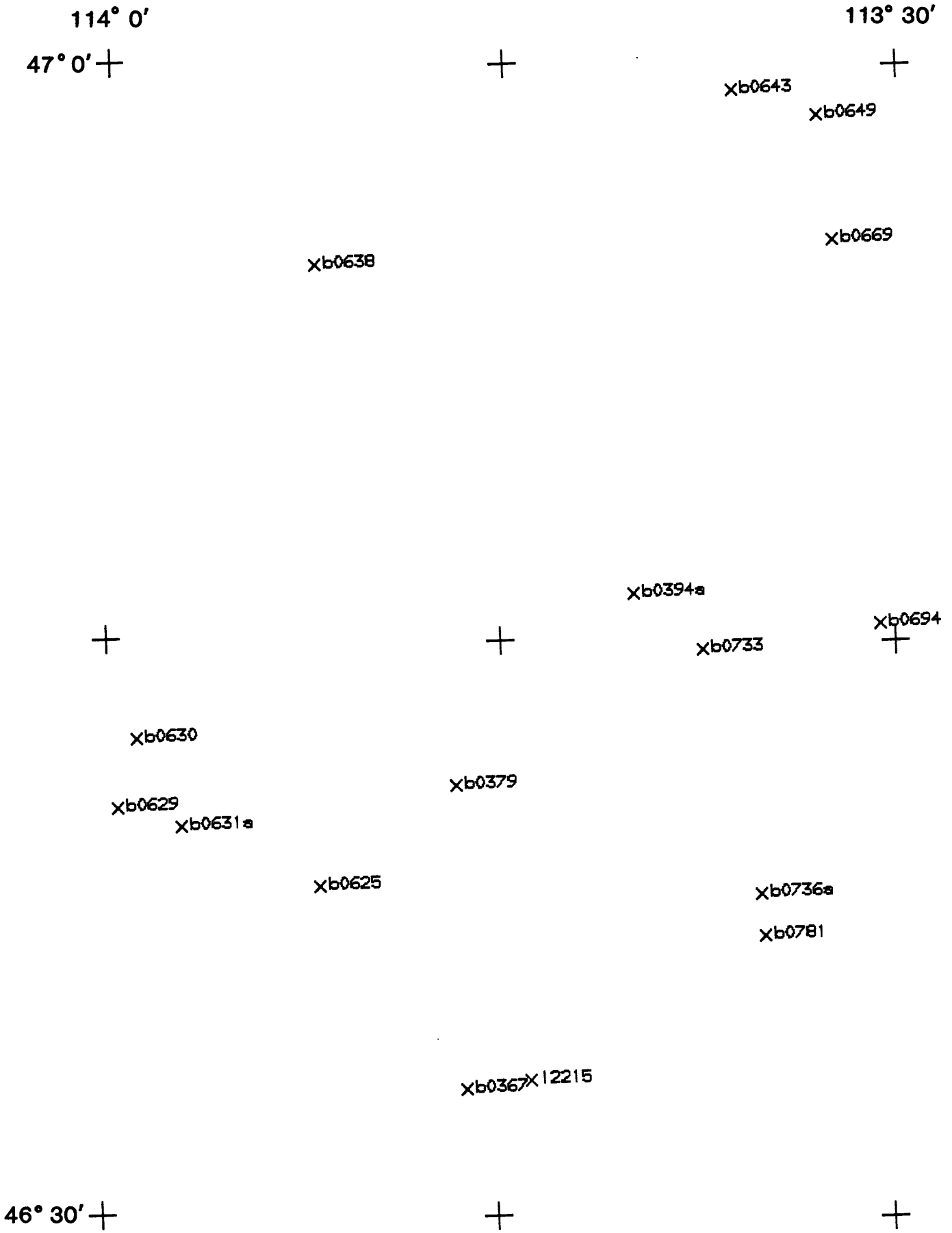

114° 0′
113° 30′
47° 0′
xb0643
xb0649
xb0669
xb0638
xb0394a
xb0694
xb0733
xb0630
xb0379
xb0629
xb0631a
xb0625
xb0736a
xb0781
xb0367
X12215
46° 30′
0
Scale
10 MILES
0
15 KILOMETERS

Figure 2A

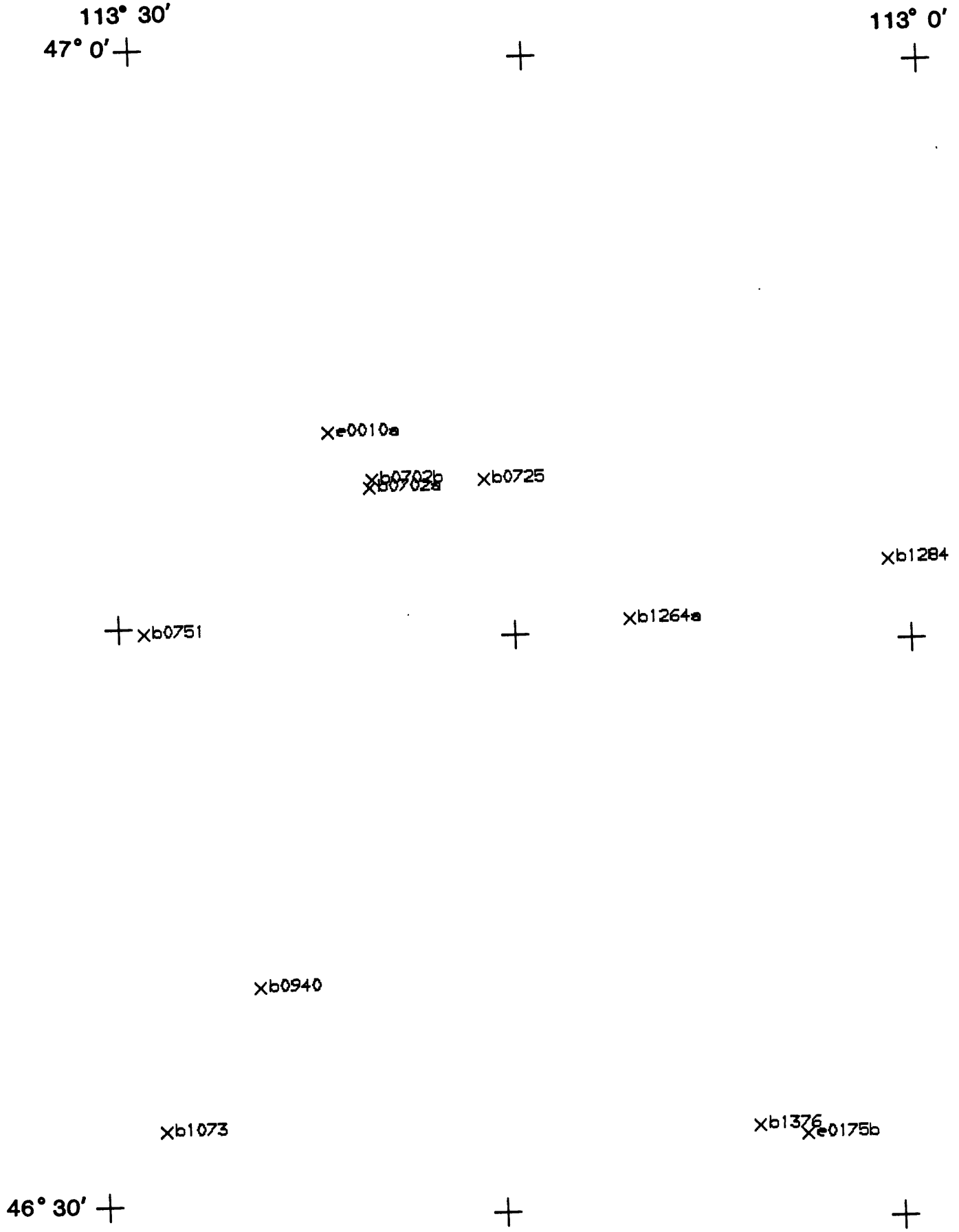

113° 30'
113° 0'
47° 0'
xe0010a
xb0702b
xb0702a
xb0725
xb1284
xb0751
xb1264a
xb0940
xb1073
xb1376
xe0175b
46° 30'
Scale
0
10 MILES
0
15 KILOMETERS

Figure 2B

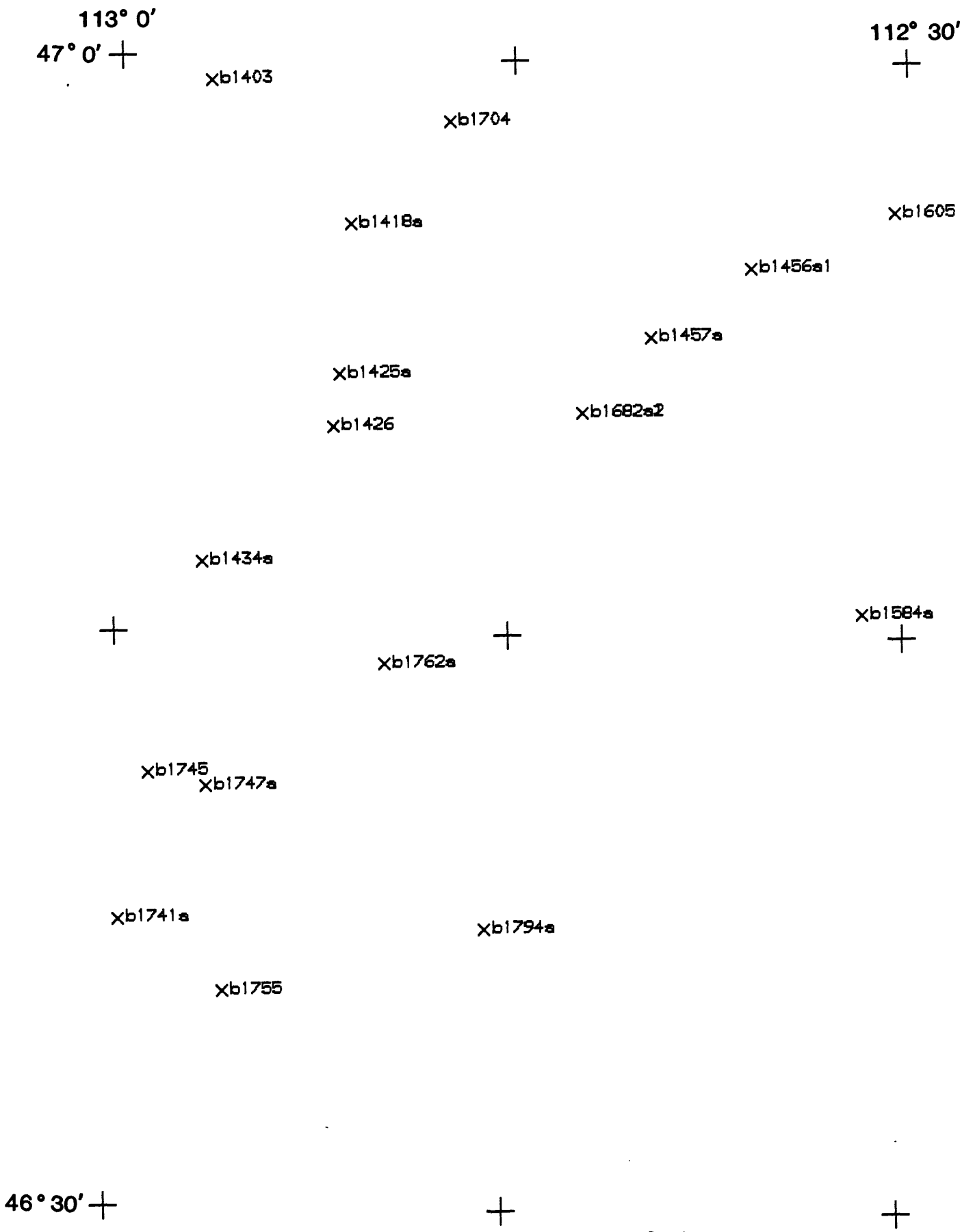

113° 0'
47° 0'
112° 30'
Xb1403
Xb1704
Xb1418a
Xb1605
Xb1456a1
Xb1457a
Xb1425a
Xb1682a2
Xb1426
Xb1434a
Xb1584a
Xb1762a
Xb1745
Xb1747a
Xb1741a
Xb1794a
Xb1755
46° 30'
Scale
0
10 MILES
0
15 KILOMETERS

Figure 2C

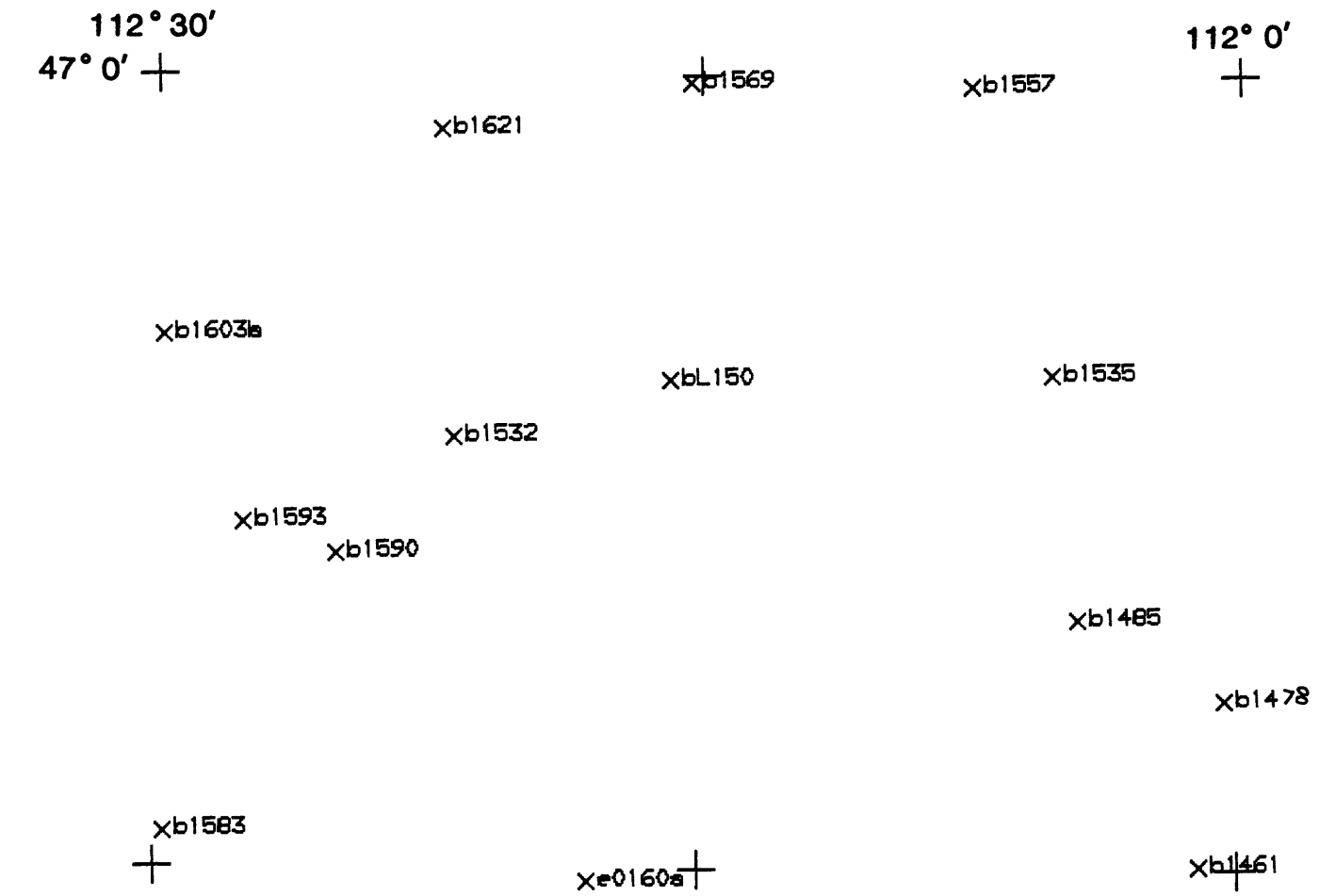
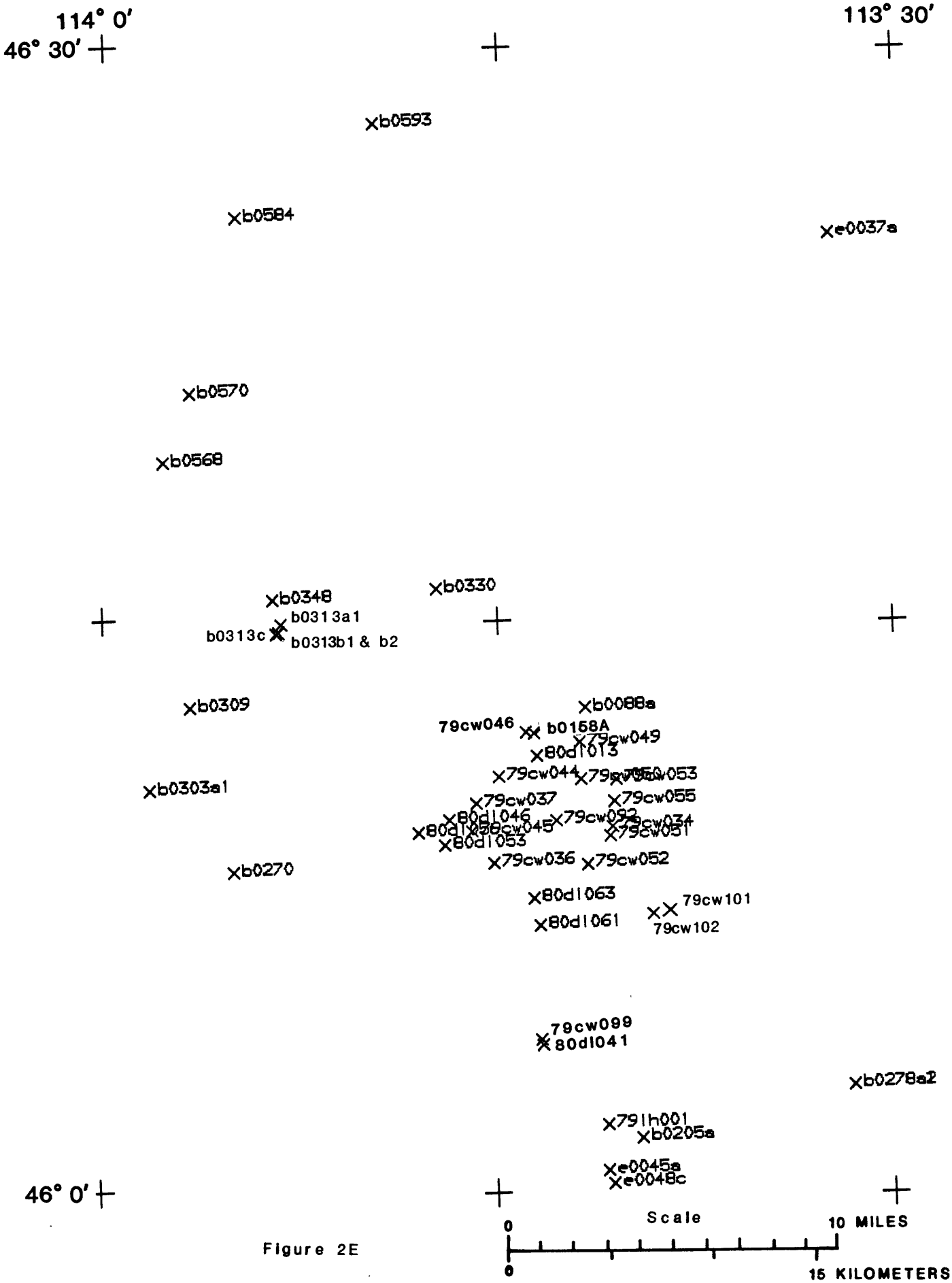

112° 30′
47° 0′
112° 0′
Xb1569
Xb1557
Xb1621
Xb1603a
XbL150
Xb1535
Xb1532
Xb1593
Xb1590
Xb1485
Xb1478
Xb1583
Xe0160a
Xb1461
46° 30′
Scale
0
10 MILES
0
15 KILOMETERS

Figure 2D


114° 0'
113° 30'
46° 30'
46° 0'
b0593
b0584
e0037a
b0570
b0568
b0330
b0348
b0313a1
b0313c
b0313b1 & b2
b0309
b0088a
79cw046
b0168A
79cw049
80d1013
79cw044
79cw053
b0303a1
79cw037
79cw055
80d1046
79cw092
79cw045
79cw051
80d1053
79cw036
79cw052
b0270
80d1063
79cw101
80d1061
79cw102
79cw099
80d1041
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b0205a
e0045a
e0048c
Scale
0
10 MILES
0
15 KILOMETERS

Figure 2E

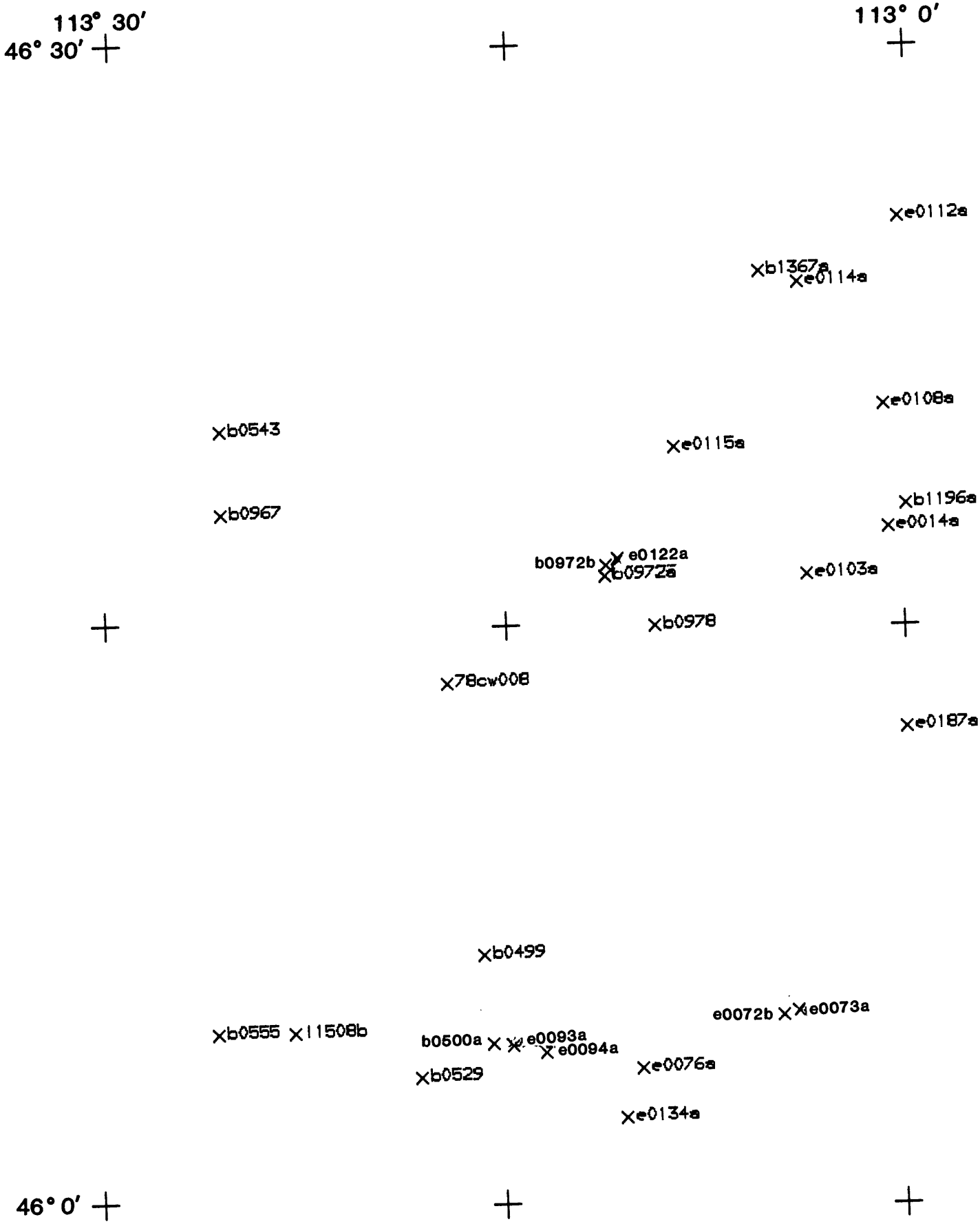
113° 30′
113° 0′
46° 30′
e0112a
b1367a
e0114a
e0108a
b0543
e0115a
b1196a
b0967
e0014a
b0972b
e0122a
b0972a
e0103a
b0978
78cw008
e0187a
b0499
e0072b
e0073a
b0555
11508b
b0500a
e0093a
e0094a
e0076a
b0529
e0134a
46° 0′
Scale
0
10 MILES
0
15 KILOMETERS

Figure 2F

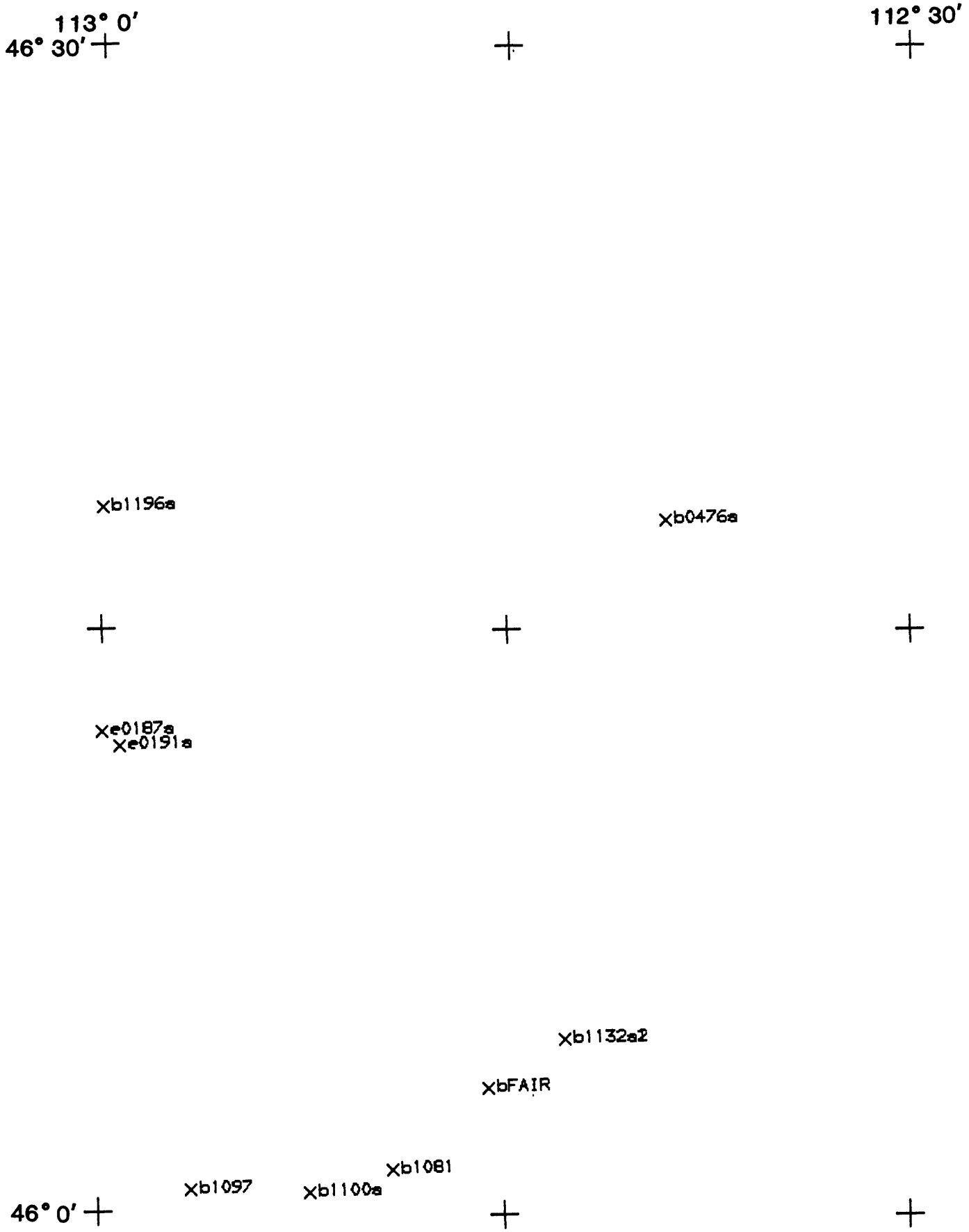
113° 0′
46° 30′
112° 30′
Xb1196a
Xb0476a
Xe0187a
Xe0191a
Xb1132a2
XbFAIR
Xb1081
Xb1097
Xb1100a
46° 0′
Scale
0
10 MILES
0
15 KILOMETERS

Figure 2G

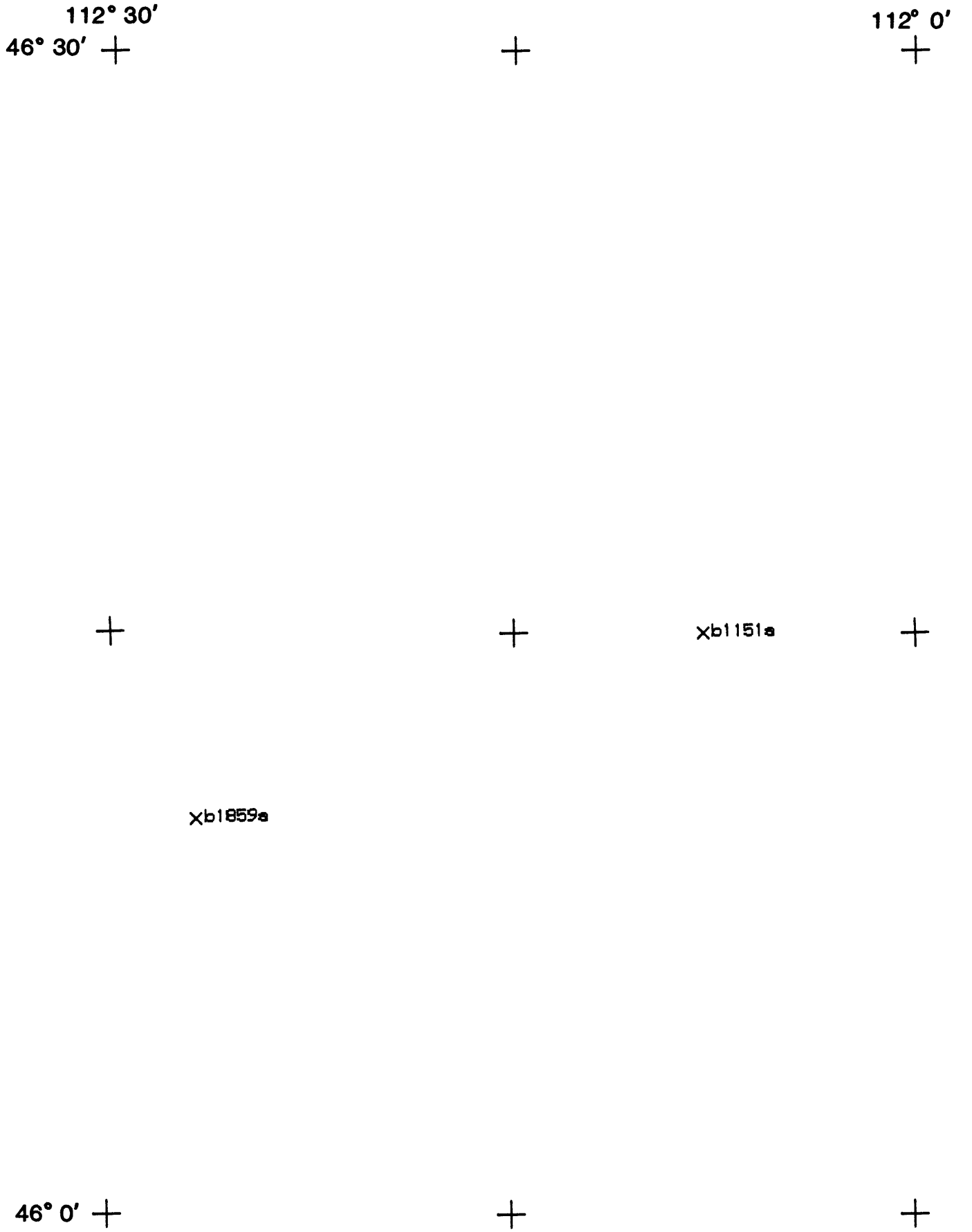
112° 30'
112° 0'
46° 30'
xb1151a
xb1859a
46° 0'
Scale
0
10 MILES
0
15 KILOMETERS

Figure 2H

For density measurements, all samples were dried in an oven at about 105° C. for at least three days and then weighed. The samples were then saturated with distilled water by submersion under a vacuum for another three days. Each sample was then weighed in a container of distilled water by suspending the sample in the water with a fine wire from the balance. After this each sample was surface dried with a towel to remove surface water and weighed again. The balance being used had sliding glass doors that were kept closed during weighings to minimize evaporation of water seeping from the sample. Bulk volume of a sample is the difference between the water-saturated weight and submerged weight divided by the density of water. G. R. Johnson (p. 69 in Hunt and others, 1979) discusses the errors in sample volumes using this method. The dry and wet densities were obtained by dividing the dry and saturated weights by the volume.

Water-accessible pore volume is the difference between the saturated and dry weights divided by water density. Effective porosity is determined by multiplying the ratio of this volume to the sample volume times 100.

Measurements in table 1 are in the International System (SI) of units. All of the magnetic values were measured in the cgs-emu units and converted using the following:

magnetic susceptibility, SI = 4 π times cgs-emu value

magnetization, SI units of ampere/meter = 1000 times the cgs-emu value

and for density:

density, SI units of kg/meter = 1000 times the g/cm value.

These relationships can be found in various publications, such as Sheriff (1973).

Explanation of headings on table 1

SAMPLE ID	Sample identification code.
LATITUDE LONGITUDE	Sample location in degrees and minutes.
QUAD.	Abbreviation for quadrangle name from which the samples was collected. See appendix C.
PHYSIOGRAPHIC LOCATION	Name of the prominent physiographic feature from the sample was collected.
MAP UNIT	Geologic map unit of sample. See Appendix B.
ROCK TYPE	Abbreviation for a general rock type classification. See appendix A.
MAGNETIC SUSCEPT.	Measured magnetic susceptibility in SI units times 10^{-4}. A 0.0 means the susceptibility of the sample was below the limits of the measuring instrument. Those samples not measured are indicated with a -1.0.

TABLE 1

Tabulation of rock properties from data file rocksort.dat from Butte 1° x 2° Quad., MT

SAMPLE ID	LATITUDE	LONGITUDE	QUAD.	PHYSIOGRAPHIC LOCATION	MAP UNIT	ROCK TYPE	MAGNETIC SUSCEPT.	REMANENT INTENSITY	MAGNETIZATION INCL.	MAGNETIZATION DECL.	DENSITY DRY	DENSITY WET	POROSITY %
b1603b	46 55.14	112 29.82	STP	Swan Range	Tav	and	145.8	124.4			2.44	2.50	6.2
b1603a	46 55.14	112 29.82	STP	Swan Range	Tav	and	102.7	120.8	53.0	66.9	2.38	2.48	9.6
b1403	46 59.46	112 56.58	MAN	Swan Range	Tbv	and	118.0	34.8	18.0	296.6	2.41	2.53	12.9
bFAIR	46 3.30	112 45.60	ANA	Boulder Bath	Tlv	and	52.8	11.8			2.45	2.52	7.9
b1605	46 56.16	112 30.42	SWG	Swan Range	Trv	and,tu	23.9	37.5			2.27	2.41	13.6
b1264a	46 45.48	113 10.68	WHP	Garnet Range	Tvg	and	52.8	-1.0			2.59	2.67	8.1
b1762a	46 44.28	112 49.68	GAR	Garnet Range	Tvg	and	33.9	98.6	63.9	338.7	2.12	2.28	15.7
b1461	46 45.12	112 1.08	RAM	Swan Range	Ye	arg	0.0	0.2	70.5	328.7	2.73	2.76	2.5
b1557	46 59.88	112 7.44	SHC	Swan Range	Yg	arg	6.0	0.0			2.64	2.68	3.5
b0394a	46 46.26	113 39.96	CLI	Garnet Range	Ym	arg	5.7	0.1			2.70	2.73	3.5
b0736a	46 38.46	113 35.10	RAV	John Long Mtns	Yms1	arg	4.8	0.0	20.6	275.4	2.77	2.78	1.7
b1532	46 53.22	112 21.78	WIL	Swan Range	Ys	arg	0.0	3.0	60.1	124.7	2.70	2.73	3.4
b1569	46 59.94	112 15.30	WIL	Swan Range	Ys	arg	0.0	0.4	40.8	227.8	2.68	2.69	1.4
b1621	46 59.04	112 22.20	WIL	Swan Range	Ys	arg	0.0	0.6	76.4	197.0	2.59	2.65	6.2
78cw008	46 13.56	113 17.22	GEL	Flint Creek Range	Ysn	arg	-1.0	-1.0			2.72	2.74	2.2
b0781	46 37.38	113 34.92	RAV	John Long Mtns	Ysn	arg	6.8	0.0	-55.2	348.2	2.73	2.75	1.4
78cw006	46 13.56	113 17.22	GEL	Flint Creek Range	Ysn	arg	-1.0	-1.0			2.74	2.74	0.2
b0568	46 19.20	113 57.66	WIM	Sapphire Mtns	Yhl	clsh	4.6	0.1			3.00	3.02	1.6
b0309	46 12.78	113 56.64	GIP	Sapphire Mtns	Ywm	clsh	1.9	0.5			2.72	2.72	0.0
b0313b2	46 14.76	113 53.28	GIP	Sapphire Mtns	Ywm	clsh	12.2	1.5			2.89	2.91	3.2
b0205a	46 1.50	113 39.48	WHR	Sapphire Mtns	Ywm	clsh	2.5	0.1	38.1	3.8	3.07	3.08	1.6
b0303a	46 10.62	113 58.14	GIP	Sapphire Mtns	Ywm	clsh	0.0	0.6	-51.9	137.0	2.57	2.60	3.6
b0313c	46 14.70	113 53.40	GIP	Sapphire Mtns	Ywm	clsh	6.8	3.2	67.0	329.9	2.65	2.68	3.1
b0303a1	46 10.62	113 58.14	GIP	Sapphire Mtns	Ywm	clsh	2.5	-1.0			2.55	2.58	3.0
b0313b1	46 14.76	113 53.28	GIP	Sapphire Mtns	Ywm	clsh,m	25.0	715.2			2.66	2.72	6.3
b1132a2	46 4.56	112 42.78	BUN	Boulder Bath	Tlv	dac,b	1.0	-1.0			2.50	2.54	3.8
b1100a	46 0.60	112 52.20	ANA	Boulder Bath	Tlv	dac,p	37.7	739.2			2.48	2.51	3.2
b1859a	46 10.26	112 26.76	ELP	Boulder Bath	Tlv	dac,tu	6.8	0.3	-70.8	145.0	1.96	2.20	23.7
e0175b	46 32.16	113 3.72	DRU	Flint Creek Range	Kdp	dio	206.1	47.3			2.91	2.92	1.0
e0093a	46 4.20	113 14.76	MEV	Anaconda Range	Kqds	dio	140.7	51.7			2.90	2.92	2.2
e0094a	46 4.02	113 13.50	MEV	Anaconda Range	Kqds	dio	183.5	12.5			2.77	2.78	1.5
b1794a	46 37.38	112 45.78	GAR	Garnet Range	Djm	do	0.0	0.2	-56.9	328.0	2.76	2.79	3.3
b1682a2	46 50.88	112 42.24	FIN	Swan Range	Kqmd	gab	111.8	45.3			2.87	2.90	2.9
b1682a1	46 50.88	112 42.24	FIN	Swan Range	Kqmd	gab	100.5	219.8			3.00	3.01	1.8
b0330	46 15.90	113 47.34	BFL	Sapphire Mtns	TKgb	gab	-1.0	-1.0			2.89	2.90	1.0
e0112a	46 25.62	113 0.24	PIP	Flint Creek Range	Kgdr	gd,bh	197.3	66.7			2.68	2.69	0.8
b0088a	46 12.78	113 41.70	MEM	Sapphire Mtns	Kgds	gd,bh	206.1	3.0			2.66	2.68	1.8
80d1053	46 9.18	113 46.98	SKP	Sapphire Mtns	Kgds	gd,bh	73.5	3.1			2.63	2.66	2.5
79cw036	46 8.70	113 45.12	SKP	Sapphire Mtns	Kgds	gd,bh	53.0	3.8			2.63	2.65	2.2
80d1056	46 9.48	113 48.00	SKP	Sapphire Mtns	Kgds	gd,bh	140.7	5.7			2.65	2.68	2.5
e0037a	46 25.20	113 32.40	ALG	Sapphire Mtns	Kgdm	gd	126.9	2.7			2.65	2.66	0.5
791h001	46 1.86	113 40.80	WHR	Sapphire Mtns	Kgds	gd,bh	137.0	9.5			2.63	2.66	2.5
e0010a	46 50.22	113 22.20	ELM	Garnet Range	Kgdg	gd,bh	307.9	35.7			2.69	2.70	1.1
79cw101	46 7.50	113 38.52	MEM	Sapphire Mtns	Kgds	gd,b	63.3	4.8			2.63	2.65	1.3
79cw049	46 11.88	113 41.88	MEM	Sapphire Mtns	Kgds	gd,bh	153.3	7.3			2.63	2.65	1.8

SAMPLE ID	LATITUDE	LONGITUDE	QUAD.	PHYSIOGRAPHIC LOCATION	MAP UNIT	ROCK TYPE	MAGNETIC SUSCEPT.	REMANENT INTENSITY	MAGNETIZATION INCL.	MAGNETIZATION DECL.	DENSITY DRY	DENSITY WET	POROSITY %
e0045a	46 0.66	113 40.80	WHR	Sapphire Mtns	Kgds	gd,bh	163.4	-1.0			2.66	2.68	1.5
e0115a	46 19.68	113 8.70	FBL	Flint Creek Range	Kgdp	gd,bh	217.4	227.6			2.64	2.65	1.1
e0048c	46 0.30	113 40.56	WHR	Sapphire Mtns	Kgds	gd,bh	158.3	-1.0			2.63	2.65	2.0
b0725	46 49.08	113 16.26	ELM	Garnet Range	Kgdg	gd,bh	319.2	43.4			2.67	2.69	2.1
b1367a	46 24.24	113 5.52	PIP	Flint Creek Range	Kgdr	gd,bh	211.1	12.8	83.4	294.0	2.65	2.67	2.3
b0972b	46 16.62	113 11.28	FBL	Flint Creek Range	Kgdp	gd,bh	232.5	12.6	22.8	19.7	2.64	2.67	2.5
e0114a	46 23.94	113 4.08	PIP	Flint Creek Range	Kgdr	gd,bh	59.4	-1.0			2.65	2.67	1.3
80d1061	46 7.08	113 43.38	WHR	Sapphire Mtns	Kgds	gd,bh	175.9	16.6			2.63	2.65	2.3
79cw102	46 7.38	113 39.12	WHR	Sapphire Mtns	Kgds	gd,bh	144.5	12.5			2.66	2.67	0.8
80d1046	46 9.84	113 46.80	SKP	Sapphire Mtns	Kgds	gd,bh	102.3	1.9			2.64	2.66	1.8
79cw053	46 10.92	113 40.50	MEM	Sapphire Mtns	Kgds	gd,bh	138.2	17.1			2.65	2.66	1.5
e0122a	46 16.80	113 10.80	FBL	Flint Creek Range	Kgdp	gd,bh	285.3	21.3			2.68	2.69	1.0
b1425a	46 51.84	112 51.54	NEL	Swan Range	Kqmo	gd,bh	149.5	33.3			2.64	2.68	4.0
e0160a	46 44.82	112 18.00	ELL	Swan Range	Tgmm	gd,bh	140.7	-1.0			2.69	2.71	1.1
b0584	46 25.62	113 54.96	COG	Sapphire Mtns	Ymsc	ho	1.5	0.0	59.7	310.4	2.65	2.67	1.4
b0570	46 21.00	113 56.70	WIM	Sapphire Mtns	Ywm	ho	2.8	0.0			2.65	2.67	1.4
79cw092	46 9.84	113 42.78	MEM	Sapphire Mtns	Kmlm	lmg	2.1	9.6			2.52	2.56	4.1
b0702a	46 48.84	113 20.58	ELM	Garnet Range	Cmw	ls	0.0	0.0	13.7	357.7	2.65	2.68	3.0
b0978	46 15.06	113 9.42	FBL	Flint Creek Range	Mm	ls	3.9	0.0	80.1	163.4	2.63	2.66	2.8
b0555	46 4.50	113 25.74	CAR	Anaconda Range	Mm	ls	1.8	0.0			2.67	2.69	2.8
b1593	46 51.60	112 27.60	GRB	Swan Range	Yh	ls,si	0.0	0.1			3.00	3.01	1.4
b1418a	46 55.74	112 51.18	MOC	Swan Range	Yh	ls	0.0	3.8	85.4	212.6	2.90	2.95	4.7
b0529	46 3.36	113 18.18	STL	Anaconca Range	Yh	ls,si	0.4	0.2			2.64	2.65	1.0
b1456a1	46 54.66	112 35.88	SWG	Swan Range	Yh	ls,si	0.0	0.0	70.7	285.3	2.63	2.70	6.7
b1704	46 58.44	112 47.46	MOC	Swan Range	Yh	ls	0.0	0.1	54.5	277.3	2.68	2.70	3.8
b0379	46 41.28	113 46.68	CLM	Sapphire Mtns	Yh	ls,si	2.6	0.5			2.66	2.67	1.0
b1590	46 51.00	112 25.02	GRB	Swan Range	Yh	ls,si	0.0	0.4	52.7	288.2	2.67	2.68	0.9
b0499	46 6.54	113 15.84	STL	Anaconda Range	Crh	mar	0.4	0.0			2.78	2.79	1.0
b1196a	46 18.18	113 0.00	MPO	Flint Creek Range	Crh	mar	0.0	22.5	69.5	96.9	2.73	2.74	1.1
b0972a	46 16.32	113 11.28	FBL	Flint Creek Range	DCs	mar	0.0	0.0	12.8	291.0	2.68	2.70	2.1
b0629	46 40.68	113 59.52	CLM	Sapphire Mtns	Ywm	mar	-1.0	-1.0			2.67	2.69	1.5
e0103a	46 16.38	113 3.72	MPO	Flint Creek Range	Kbmp	mg,bm	18.6	-1.0			2.58	2.61	3.2
e0108a	46 20.76	113 0.84	POL	Flint Creek Range	Kbmp	mg	46.2	3.0			2.61	2.63	1.5
80d1063	46 7.80	113 43.62	MEM	Sapphire Mtns	Kmgs	mg	42.0	-1.0			2.62	2.64	2.0
79cw034	46 9.66	113 40.62	MEM	Sapphire Mtns	Kmgs	mg	25.8	1.9			2.62	2.64	1.4
79cw055	46 10.32	113 40.56	MEM	Sapphire Mtns	Kmgs	mg	12.2	0.5			2.57	2.59	2.4
b0158a	46 12.12	113 43.62	MEM	Sapphire Mtns	Kmgs	mg	34.6	0.6			2.61	2.62	1.0
79cw037	46 10.26	113 45.78	SKP	Sapphire Mtns	Kmgs	mg	15.7	0.9			2.60	2.62	2.1
80d1013	46 11.52	113 43.50	MEM	Sapphire Mtns	Kmgs	mg	18.5	2.2			2.59	2.61	2.1
b1151a	46 15.06	112 7.92	JEF	Boulder Bath	Kmgd	mg	398.4	13.7	59.9	224.4	2.66	2.68	1.6
79cw046	46 12.12	113 43.92	MEM	Sapphire Mtns	Kmgs	mg	22.6	1.9			2.61	2.63	1.6
79cw050	46 10.92	113 41.82	MEM	Sapphire Mtns	Kmgs	mg	5.0	124.6			2.56	2.60	3.3
79cw045	46 9.54	113 45.96	SKP	Sapphire Mtns	Kmgs	mg	69.4	1.1			2.65	2.66	1.7
79cw044	46 10.98	113 44.94	SKP	Sapphire Mtns	Kmgs	mg	18.1	11.3			2.58	2.61	2.7
79cw051	46 9.42	113 40.74	MEM	Sapphire Mtns	Kmgs	mg	13.7	0.4			2.60	2.61	1.9

Tabulation of rock properties from data file rocksort.dat from Butte 1° x 2° Quad., MT

SAMPLE ID	LATITUDE	LONGITUDE	QUAD.	PHYSIOGRAPHIC LOCATION	MAP UNIT	ROCK TYPE	MAGNETIC SUSCEPT.	REMANENT INTENSITY	MAGNETIZATION INCL.	MAGNETIZATION DECL.	DENSITY DRY	DENSITY WET	POROSITY %
79cw052	46 8.70	113 41.58	MEM	Sapphire Mtns	Kmgs	mg	12.3	1.0			2.59	2.61	2.4
e0191a	46 12.06	112 59.34	ANA	Flint Creek Range	Tgl	mg	51.0	3.8			2.58	2.56	2.2
e0187a	46 12.42	113 0.00	ANA	Flint Creek Range	Tgl	mg	2.0	0.1			2.60	2.61	1.4
e0076a	46 3.60	113 9.90	MEV	Anaconda Range	Tmgh	mg	44.0	16.4			2.60	2.62	2.1
e0134a	46 2.34	113 10.50	MEV	Anaconda Range	Tmgh	mg	86.8	8.1			2.61	2.62	1.5
e0073a	46 5.10	113 4.08	MHA	Anaconda Range	Tmgh	mg,bm	35.3	-1.0			2.60	2.62	1.9
e0014a	46 17.58	113 0.66	POL	Flint Creek Range	Kbmp	mg,bm	35.7	-1.0			2.66	2.26	1.0
b0348	46 15.60	113 53.52	WIM	Sapphire Mtns	Kps	py	3645.5	3777.0			3.44	3.44	0.0
b0500a	46 4.26	113 15.48	STL	Anaconda Range	Kgd	qmd	196.0	10.1	69.8	307.5	2.78	2.80	2.2
e0072b	46 4.98	113 4.62	MHA	Anaconda Range	Kqds	qmd	10.2	76.9			2.78	2.79	1.0
b0733	46 44.82	113 37.32	RAV	Garnet Range	Ybo	qtz	1.4	0.8			2.63	2.64	0.5
b0638	46 54.84	113 52.14	BLP	Garnet Range	Ybo	qtz	-1.0	-1.0			2.55	2.58	2.3
b0702b	46 49.02	113 20.52	ELM	Garnet Range	Ygr	qtz,f	13.6	0.4	41.4	6.1	2.64	2.66	2.0
b0694	46 45.48	113 30.60	MIR	Garnet Range	Ym	qtz	-1.0	-1.0			2.62	2.63	0.9
11508b	46 4.50	113 22.92	CAR	Anaconda Range	Yms2	qtz,f	-1.0	-1.0			2.63	2.64	1.2
80d1041	46 3.96	113 43.26	WHR	Sapphire Mtns	Yms2	qtz	36.8	-1.0			2.64	2.66	2.4
b0270	46 8.46	113 54.96	GIP	Sapphire Mtns	Yms2	qtz,f	2.0	0.4			2.60	2.61	1.0
b0278a1	46 2.88	113 31.50	MOL	Sapphire Mtns	Yms2	qtz,ironst	0.0	0.1			2.59	2.63	3.4
b1583	46 45.72	112 29.70	GRB	Swan Range	Yms1	qtz,f	0.0	0.0			2.51	2.56	4.4
b0278a2	46 2.88	113 31.50	MOL	Sapphire Mtns	Yms2	qtz	0.0	1.3			2.62	2.64	1.2
12215	46 33.60	113 43.80	RAV	Sapphire Mtns	Yms3	qtz,ar	-1.0	-1.0			2.70	2.70	0.6
b0669	46 55.50	113 32.40	POT	Garnet Range	Yms	qtz,f	2.4	0.0	1.5	187.2	2.64	2.65	0.8
b0593	46 28.08	113 49.74	SAS	Sapphire Mtns	Yms2	qtz	-1.0	-1.0			2.58	2.60	2.4
b1073	46 32.04	113 27.90	BEA	John Long Mtns	Yms3	qtz	5.0	7.7	-5.4	130.3	2.66	2.67	0.7
79cw099	46 4.08	113 43.32	WHR	Sapphire Mtns	Yms2	qtz	15.1	-1.0			2.65	2.67	1.6
b0751	46 44.94	113 29.04	BEA	Garnet Range	Ypi	qtz	2.4	0.5	-30.9	85.7	2.62	2.63	1.9
b0649	46 58.74	113 33.00	POT	Garnet Range	Ysn	qtz,f	3.1	0.3	1.6	14.0	2.65	2.70	4.8
b0643	46 59.40	113 36.24	POT	Garnet Range	Ysn	qtz,f	1.5	1.5	-33.7	7.6	2.57	2.61	4.6
b1081	46 1.20	112 49.14	ANA	Boulder Bath	Tlv	rhy	167.1	432.6			2.33	2.44	11.4
b1097	46 0.66	112 56.58	ANA	Boulder Bath	Tlv	rhy,tu	10.6	537.5			2.06	2.25	19.0
b1755	46 35.70	112 55.68	GAR	Garnet Range	Kcc	sils,li	0.0	0.0	7.8	286.5	2.66	2.70	4.0
b1478	46 48.24	112 0.36	RAM	Swan Range	Yg	sil	0.0	0.0	-84.3	77.0	2.62	2.65	3.2
b0967	46 17.94	113 25.68	ANC	John Long Mtns	Yh	sil	3.0	0.1	-15.9	246.0	2.62	2.64	2.8
b1434a	46 46.92	112 56.64	HEV	Garnet Range	Ym	sil	6.0	1.0	-54.6	15.6	2.62	2.68	5.9
b0940	46 35.82	113 24.48	BEA	John Long Mtns	Ym	sil	1.0	0.2	81.6	100.0	2.61	2.62	1.2
b0630	46 42.48	113 58.80	CLM	Sapphire Mtns	Yms3	sil	2.9	8.5			2.42	2.55	13.0
b0625	46 38.64	113 51.84	CLM	Sapphire Mtns	Yms3	sil	2.5	8.4			2.63	2.65	1.9
b0367	46 33.36	113 46.20	CLM	Sapphire Mtns	Yms3	sil(ho?)	3.1	9.8			2.71	2.71	0.0
b1284	46 47.10	113 0.90	CHL	Garnet Range	Yms1	sil	0.0	2.0	-5.3	27.0	2.56	2.62	5.3
b1584a	46 45.66	112 31.50	NEM	Swan Range	Yms3	sil	6.8	1.5	-15.3	52.7	2.54	2.61	6.5
b1485	46 49.80	112 4.44	RAM	Swan Range	Ys	sil	0.0	0.5	5.3	113.3	2.66	2.69	2.4
bL150	46 54.30	112 15.78	WIL	Swan Ramge	Ys	sil	0.0	0.9	52.7	216.9	2.65	2.67	2.8
b1535	46 54.42	112 5.22	SHC	Swan Range	Ys	sil	0.0	0.4	-29.1	168.3	2.66	2.68	1.8
b1426	46 50.46	112 51.72	NEL	Swan Range	Ysn	sil	0.0	2.2	-18.7	144.8	2.62	2.64	2.6
b0543	46 20.10	113 25.74	ANC	John Long Mtns	Ysn	sil	2.3	2.8	-33.7	41.4	2.65	2.67	1.2

SAMPLE ID	LATITUDE	LONGITUDE	QUAD.	PHYSIOGRAPHIC LOCATION	MAP UNIT	ROCK TYPE	MAGNETIC SUSCEPT.	REMANENT INTENSITY	MAGNETIZATION INCL.	MAGNETIZATION DECL.	DENSITY DRY	DENSITY WET	POROSITY %
b1457a	46 52.86	112 39.66	LIN	Swan Range	Ysn	sil	0.0	-1.0			2.55	2.62	7.0
b0631a	46 40.20	113 57.06	CLM	Sapphire Mtns	Ywm	sil	3.5	0.0	36.7	237.1	2.51	2.59	7.4
b0476a	46 17.88	112 39.12	DEL	Deer Lodge Valley	Kbv	ss,fe	34.2	58.3	16.9	305.8	2.60	2.64	3.4
b1376	46 32.40	113 5.52	DRU	Flint Creek Range	Kbvl	ss,li	-1.0	-1.0			2.59	2.59	0.9
b1741a	46 37.56	112 59.64	GAR	Garnet Range	Kc	ss,fe	5.9	0.2	-12.5	228.7	2.61	2.65	4.0
b1747a	46 41.04	112 56.40	GAR	Garnet Range	Kk	ss	0.0	0.0	-65.4	152.2	2.62	2.66	4.2
b1745	46 41.40	112 58.62	GAR	Garnet Range	Kk	ss,fe	0.0	0.0	24.8	234.6	2.50	2.57	7.0
b0313a	46 14.97	113 53.22	GIP	Sapphire Mtns	Kps	sy	0.0	0.0	-51.7	91.7	2.44	2.52	8.6
b0313a1	46 14.94	113 53.22	GIP	Sapphire Mtns	Kps	sy	17.6	-1.0			2.65	2.68	2.6
b1132a1	46 4.56	112 42.78	BUN	Boulder Bath	Tlv	vobr,r	0.0	0.1			2.33	2.44	10.5

ACKNOWLEDGEMENTS

The authors acknowledge the assistance received from Gordon Johnson and Richard Reynolds in making the facilities of the petrophysics laboratory available and their instruction in the use of the equipment.

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Appendix A

List of abbreviations used for rock types on the Butte 1° x 2° quadrangle, Montana

arg	argillite
and	andesite
and,tu	andesite, tuffaceous
clsh	calc-silicate, hornfels
clsh,m	calc-silicate, hornfels, magnetite
dac,b	dacite, breccia
dac,p	dacite, porphyritic
dac,tu	dacite,tuffaceous
dio	diorite
do	dolomite
gab	gabbro
gd	granodiorite
gd,b	granodiorite, biotite
gd,bh	granodiorite, biotite and hornblende
ho	hornfels
lmg	leucomicromonzogranite
ls	limestone
ls,si	limestone, siltly
mar	marble
mg	monzogranite
mg,bm	monzogranite, biotite and muscovite
py	pyroxenite
qmd	quartz monzodiorite
qtz	quartzite
qtz,ar	quartzite, argillaceous
qtz,f	quartzite, feldspathic
qtz,ironst	quartzite with iron staining
rhy	rhyolite
rhy,tu	rhyolite, tuffaceous
sil	siltite
sil(ho?)	siltite (or hornfels ?)
sils,li	siltstone, limey
ss	sandstone
ss,li	sandstone, limey
ss,fe	sandstone, feldspathic
sy	syenite
vobr,r	volcanic breccia, rhyolitic

Appendix B

List of geologic map unts appearing in table 1, from Wallace and others, 1986.

Trv	Rhyolitic volcanic rocks (Oligocene and Eocene)
Tav	Andesitic volcanic rocks (Oligocene or Eocene?)
Tvg	Basaltic, andesitic, and latitic volcanic rocks and dikes (Oligocene? and Eocene)
Tlv	Lowland Creek Volcanics (Eocene)
Tbv	Basaltic volcanic rocks (Eocene?)
Kcc	Carten Creek Formation (Upper Cretaceous)
Kc	Coberly Formation (Upper Cretaceous)
Kbv	Vaughn Member of the Blackleaf Formation (Lower Cretaceous)
Kbv1	Lower part of Vaughn Member of the Blackleaf Formation
Kk	Kootenai Formation (Lower Cretaceous)
Mm	Madison Group (Lower Mississippian)
Djm	Jefferson and Maywood Formations (Upper Devonian)
DCs	Devonian and Cambrian formations
Crh	Red Lion and Hasmark Formations (Upper Cambrian)
Cmw	Silver Hill Formation and Flathead Quartzite, Western lithofacies (Middle Cambrian)
Ypi	Pilcher Quartzite (Middle Proterozoic)
Ygr	Garnet Range Formation (Middle Proterozoic)
Ym	McNamara Formation (Middle Proterozoic)
Ybo	Bonner Quartzite (Middle Proterozoic)
Yms	Mount Shields Formation (Middle Proterozoic)
Yms3	Member Three of the Mount Shields Formation (Middle Proterozoic)
Yms2	Member Two of the Mount Shields Formation (Middle Proterozoic)
Yms1	Member One of the Mount Shields Formation (Middle Proterozoic)
Ymsc	Carbonate lithofacies in upper part of Member One of the Mount Shields Formation (Middle Proterozoic)
Ysn	Snowslip Formation (Middle Proterozoic)
Yh	Helena Formation (Middle Proterozoic)
Yh1	Lower Member of the Helena Formation (Middle Proterozoic)
Ywm	Middle Member of the Wallace Formation (Middle Proterozoic)
Ye	Empire Formation (Middle Proterozoic)
Ys	Spokane Formation (Middle Proterozoic)
Yg	Greyson Formation (Middle Proterozoic)
Kmlm	Leucomicromonzogranite porphyry of the Sapphire batholith (Cretaceous)
Kgds	Porphyritic and equigranular hornblende-biotite granodiorite of the Sapphire batholith (Cretaceous)
Kmgs	Porphyritic and equigranular muscovite-biotite monzogranite of the Sapphire batholith (Cretaceous)
Tmgh	Biotite-muscovite monzogranite of Hearst Lake stock (Tertiary)
Kqds	Hornblende quartz diorite, granodiorite, quartz monzodiorite, and diorite of Storm Lake stock (Cretaceous)
Kbmp	Porphyritic muscovite-biotite monzogranite of Mt. Powell batholith (Cretaceous)
Kgdr	Hornblende-biotite granodiorite of Royal stock (Cretaceous)
Kgdp	Hornblende-biotite granodiorite of Philipsburg batholith (Cretaceous)
Kgp	Medium-grained granite porphyry (Cretaceous)

Kmgd	Porphyritic biotite-hornblende monzogranite and granodiorite of Boulder batholith (Cretaceous)
Tqmm	Hornblende-biotite granodiorite of Maysville stock (Tertiary)
Tgl	Biotite monzogranite stock of Lost Creek
TKgb	Gabbro, and diorite plugs, sills and dikes (Tertiary or Cretaceous)
Kqmd	Hornblende-biotite granodiortie of Dalton Mountain stock (Cretaceous)
Kqmo	Hornblend-biotite granodiorite of Ogden Mountain stock (Cretaceous)
Kgdg	Porphyritic hornblende-biotite granodiorite of Garnet stock (Cretaceous)
Kgdm	Hornblende-biotite granodiorite of Miners Gulch stock (Cretaceous)
Kdp	Diorite porphry and equigranular diorite (Cretaceous)
Kps	Pyroxenite, leucosyenite, and hornblende syenite of Skalkaho Mountain stocks (Cretaceous)

Appendix C

List of three-letter abbreviations used for identification of 7.5- or 15-minute topographic quadrangles from which samples were collected.

ALG	Alder Gulch	MAM	Marcum Mountain
ANA	Anaconda	MIR	Mineral Ridge
ANC	Antelope Creek	MOC	Moose Creek
BEA	Bearmouth	MOL	Moose Lake
BLP	Blue Point	MEM	Mount Emerine
BFL	Burnt Fork Lake	MEV	Mount Evens
BUN	Butte North	MHA	Mount Haggin
CAR	Carpp Ridge	MPO	Mount Powell
CHL	Chimney Lakes	NEL	Nevada Lake
CLI	Clinton	NEM	Nevada Mountain
CLM	Cleveland Mountain	PIP	Pikes Peak
COG	Corley Gulch	POL	Pozega Lakes
DEL	Deer Lodge	POT	Potomac
DRU	Drummond	RAM	Rattlesnake Mountain
ELL	Elliston	RAV	Ravenna
ELM	Elevation Mountain	SAS	Sawmill Saddle
ELP	Elk Park	SHC	Sheep Creek
FBL	Fred Burr Lake	SKP	Skalkaho Pass
FIN	Finn	STL	Storm Lake
GAR	Garrison	STP	Stemple Pass
GEL	Georgetown Lake	SWG	Swede Gulch
GIP	Gird Point	WHP	Wild Horse Parks
GRB	Granite Butte	WHR	Whetstone Ridge
HEV	Helmville	WIL	Wilborn
JEF	Jefferson City	WIM	Willow Mountain
LIN	Lincoln		