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GEOLOGIC REPORT NO. 19

Geology of Part of the Amphitheatre Mountains, Mt. Hayes Quadrangle, Alaska

By

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GEOLOGY OF PART OF THE AMPHITHEATRE MOUNTAINS
MT. HAYES QUADRANGLE, ALASKA

by Arthur W. Rose

ABSTRACT

Reconnaissance geologic mapping in the Amphitheatre Mountains north of the Denali Highway shows that basalt and andesite flows, silicic tuffs and tuffaceous sediments, and andesite agglomerate of the Triassic(?) Amphitheatre formation are intruded by gabbro, granite, and peridotite. Some of the gabbro appears to occur as a thick layered sill or lopolith; other gabbro and diabase occur as sills in the tuffs and tuffaceous sediments. In general the sediments and sills dip gently northward.

A layer of mafic gabbro about 150 feet thick contains about 22% iron in magnetite and ilmenite. A magnetic concentrate contained 47% iron and 11.1% TiO_2. Stream sediment sampling detected several copper anomalies which deserve follow-up.

INTRODUCTION

Geochemical analyses of stream sediments collected in 1964 showed weak to moderate anomalies for copper, lead, zinc, and molybdenum in part of the Amphitheatre Mountains just north of the Denali Highway and about 10 miles west of the Richardson Highway at Paxson (Rose and Saunders, 1965). In 1965, seven days were spent in the Amphitheatre Mountains collecting additional geochemical samples in the vicinity of the anomalies and mapping geology. One day was spent in the area near Landmark Gap (figure 2), in the Mt. Hayes A-5 quadrangle just west of the area shown on figure 1. Considerable snow was present on the north side of the range, so the geologic map is still incomplete. Except for a few sharp valleys and steep slopes, outcrops are not common in the area, especially in the higher parts, and much of the mapping is based on frost-heaved blocks.

ROCK UNITS

Amphitheatre Formation

Basalt and Andesite

The basalt and andesite unit consists mainly of massive fine-grained dark green basalt, locally containing plagioclase phenocrysts. Minor amounts of medium gray-green porphyritic andesite with a fine-grained to aphanitic groundmass is also present. Individual flows can rarely be recognized. Amygdules of chlorite and other minerals are sparsely developed in some zones. This is the same rock as described under the heading "Amphitheatre basalt" in the Paxson area (Rose and Saunders, 1965, p. 4).

Silicic tuff and tuffaceous sediments

The tuff and tuffaceous sediments are typically hard, siliceous, and light gray to buff. Locally, bedding is observed in units 1/8 to 1 inch thick defined by changes in grain size and composition. The grain size ranges from fine to coarse sand, with a silica cement that is difficult to distinguish from the grains. Minerals present include quartz, feldspar, and chlorite. Calcite cement is present in some localities. A pyroclastic origin for at least part of these rocks is inferred from the hard siliceous matrix plus the association with volcanic rocks.

In the area near Landmark Gap, tuffs like those described above are interbedded with a thick sequence of coarse-grained massive andesitic or dacitic tuff. One limestone bed about 10 inches thick was found in the tuffs of this area.

Diabase and tuffaceous sediments

The area just south of Sugarloaf Mountain is composed of thin zones of siliceous to andesitic tuff and tuffaceous sediments, mostly well-bedded, separated by more extensive masses of diabase which are believed to be sills. In addition to tuffaceous sediments like those described above, subordinate amounts of andesite or basalt tuff, black siliceous argillite, black slaty pyritiferous shale, and thin recrystallized limestone are present. Fine pyrite is present in most of the tuffs and tuffaceous sediments, but is especially abundant in one black shale unit.

Diabase appears to form about 75% of the unit. It is fine - to medium-grained, with skeletal pyroxene grains up to several millimeters in size locally present. In all cases where a contact could be found, the diabase was conformable with the tuffaceous sediments and appeared to be a sill. However, some diabase may have originated as thick flows or dikes. A thin section of a typical specimen indicates an original composition of about 35% labradorite and 65% augite, plus traces of magnetite-ilmenite and pyrite. Partial alteration of augite to actinolite has occurred. The subhedral feldspars are partly enclosed in coarser skeletal augite.

Andesite agglomerate

The mountain about 2 miles southeast of Sugarloaf Mountain (location of triangulation station Tangle) consists largely of agglomerate and some tuff containing rounded to subangular fragments of andesite up to several inches in size. The andesite of the fragments typically contains sparse plagioclase phenocrysts set in an aphanitic green groundmass. The matrix of the agglomerate appears to be finer-grained material of the same composition, and may include some devitrified glass, along with small fragments of andesite altered to chlorite, epidote, calcite, and other minerals.

Inter-relations of units in the Amphitheatre formation

The massive basalt at the eastern end of the map area is continuous with the thick (more than 2000 feet) section of basalt exposed on Paxson Mountain just to the southeast (Rose and Saunders, 1965). Basalt on Sugarloaf Mountain appears lithologically identical. The latter basalt grades downward through several hundred feet of andesitic tuffs and flows into the tuffaceous sediment and diabase sequence. The existence of the fault east of the tuff-diabase sequence is questionable, but no tuffs or tuffaceous sediments were found to the east of this fault. Most exposures near geochem samples 41 and 42 are andesite agglomerate and few exposures are basalt or diabase. The fault is shown as the most likely alternative, but it is possible that the difference in rock type results from facies changes near a volcanic vent. The relations of the basalt north of the agglomerate are not clear.

Tuff and gabbro south of the agglomerate appear to underlie the agglomerate, and may correlate with similar tuffs in the central part of the map area. Alternatively, this tuff and gabbro may correlate with the tuff-diabase unit to the west, with a facies change instead of a fault between the agglomerate and the upper part of the tuff-diabase unit. The questionable andesite agglomerate east of the main body of agglomerate is underlain by black siliceous argillite, and this in turn by gabbro and buff to gray siliceous tuff. These relations further suggest that the siliceous tuffs and gabbros of the central part of the area may underlie the agglomerate, but detailed correlation of units was not possible.

About 40 miles to the west in the drainage of Clearwater Creek, Moffit (1912) describes Triassic limestone associated with "banded slates, black slates, red-weathering slates or shales, graywackes or fine tuffs, tuffaceous conglomerates and diabase flows or intrusions" which overlie basalt or greenstone. The tuffs, tuffaceous sediments, limestone, and basalt of the map area are tentatively considered Triassic on the basis of similarity to the rocks described by Moffit, and other relations previously described by Rose and Saunders (1965). However, a Permian age is also possible for some of the rocks, and the diabase sills probably correlate with the gabbro described below.

Gabbro and mafic gabbro

Gabbro and mafic-rich gabbro form a large proportion of the central and eastern part of the map area. The gabbro varies noticeably in grain size, composition, and texture. The major part of the gabbro is medium-grained (about 1-2 mm) and contains augite (diallage) and plagioclase (mostly An 55-65, Ango in one sample) with accessory magnetite-ilmenite. Minor alteration of plagioclase to saussurite and augite to actinolite is common. Some zones show very distinct foliation defined by preferred orientation of plagioclase and slight compositional layering. The observed foliation has shallow to moderate dips to the north and south.

A zone in the central part of the gabbro complex, shown as mafic gabbro, is considerably darker in color and finer grained (1/2 - 1 mm). At least part of this zone consists of norite (orthopyroxene and plagioclase, Table 1, sample 5E241A) and local areas approach pyroxenite in composition. Some gabbro with both clinopyroxene and orthopyroxene is also present. One zone (discussed further under economic geology) contains between 25 and 30% magnetite.

The foliation and the compositional variability suggest that at least part of the gabbro complex is a differentiated sill or lopolith. The gabbro in the north-western part of the complex almost certainly occurs as thick sills separated by tuff units. However, the trend of some contacts, and the lack of persistence of some distinctive lithologies suggests that multiple intrusion, faulting, and other processes have operated in addition to layering from crystal settling or other processes of differentiation.

Granite

The granite is exposed in the western part of the gabbro area. It is a light gray-fine-grained granite containing sparse needles of hornblende and minor biotite. A thin section indicates a composition of 35% quartz, 45% perthitic microcline, 10% albite, 5% hornblende, 5% biotite, and accessory sphene, apatite, and epidote. The quartz tends to occur as grains up to about 0.5 mm in diameter partly enclosing smaller subhedral to angular microcline. Minor amounts of coarser-grained rock are present. Most likely the granite is a differentiate of the gabbro, although exposures are not adequate to prove this. The age relative to the peridotite and dunite is not known.

Peridotite and dunite

Several bodies of peridotite and dunite occur in the large gabbro intrusive. The two larger peridotite intrusives with north-south elongation are mainly serpentinized dunite. The body about a half mile north of the Denali Highway is relatively unaltered dunite with minor pyroxenite. The northeasterly trending body southeast of sample point 33 is peridotite or very mafic-rich gabbro (sample 5E231, Table 1).

The peridotite and dunite clearly intrude the gabbro, but have been found only within it, suggesting either a genetic relation or a common structural control for the ultramafics and the gabbro feeder.

STRUCTURE

In general, the bedded rocks and sills dip northward at 20-25°. They are cut by several faults trending north-south, and are interrupted by the large mass of gabbro in the eastern part of the area. Some agglomerate which appears to dip south may reflect primary depositional flow layering.

ECONOMIC GEOLOGY

Locality 1

A band of rusty-weathering "gabbro" crosses the bottom of the valley at this point. The "gabbro" contains about 28% magnetite as anhedral grains averaging 0.7 mm in size, in a matrix of labradorite and augite (sample 5E241B, Table 1). The magnetite-bearing gabbro appears to be a layer in the mafic gabbro, with a dip of about 42° to the north. The layer is 100-150 feet thick, and is exposed for a length about 500 feet in the valley bottom. At the limits of exposure the magnetite-bearing rock passes under glacial deposits with no indication of a change in thickness. An analysis of a chip sample across the zone showed 22.1% acid soluble iron, and 0.15% copper with no gold or silver. A magnetic concentrate separated from the sample contained 47.1% total iron, 11.1% TiO_2, 0.16% S, and 0.02% P. The high titanium content suggests that ilmenite forms about 20% of the magnetic concentrates. The base of the magnetite-bearing layer grades into normal gabbro containing minor orthopyroxene (sample 5E241, Table 1) over a distance of about 1 foot. The over-lying rock is mafic gabbro, but the contact was not observed. The magnetite zone is most likely a layer formed by differentiation of the mafic gabbro magma.

Locality 2

Sparse float of mafic gabbro containing disseminated chalcopyrite and pyrrhotite was found at this location. An assay showed 0.16% nickel, 0.15% copper and no gold or silver.

About 1/4 mile south, a copper-stained quartz vein about 1 foot wide cuts fine-grained mafic gabbro with local pyroxenite patches. The vein strikes N10W and dips vertically. Several small pits have been dug on the vein.

Locality 3

Minor amounts of copper staining were noted in basalt float in this vicinity. Tiny veins of chalcocite were noted in one piece of basalt. Epidote appears to be relatively abundant in this area suggesting a genetic similarity to similar copper occurrences on Paxson Mountain (Rose and Saunders, 1965).

Locality 4

Black shale and calcareous black shale at this point contain abundant pyrite, including lenses of almost massive pyrite up to 1/2" thick. Analysis of a chip sample (5E266) showed only 35 ppm copper, 105 ppm zinc, 20 ppm lead, and 9 ppm molybdenum.

GEOCHEMISTRY

The locations of stream sediment samples collected in both 1964 and 1965 are shown on figures 1 and 2. Analytical data are presented in Table 2. Samples collected in 1964 from the Sugarloaf Mountain area (samples 23, 25, 26, 27, 30, 34, 35, 37, 43, 46) were weakly to moderately anomalous in a variety of metals. Seven of these anomalous localities were checked in 1965. Only weak anomalies or background values were found in the new samples. In addition, reanalysis of sample 37 gave much lower results. It appears that analytical problems or contamination may have been responsible for most of the increment over background in these samples, but some weak anomalies remain. In addition, two 1965 samples (41 & 49) are moderately anomalous in copper. Some possibility of small base metal deposits therefore remains. Analyses of rock chips to check on background trace metal content for the area are listed in Table 3. A relatively high content of copper is present in many of these samples and may be reflected in the weak copper anomalies in the stream sediments. Three samples of pyrite-rich sediments and volcanics do not show any unusual amounts of base metals (samples 5N40, 5N40A, & 5E266).

Nickel values are anomalous for samples 9, 13, 15, and 16, but this probably results from the high nickel content of the ultramafic rocks in the vicinity rather than a nickel deposit. A copper anomaly would be expected from any copper-nickel deposit associated with the ultramafics, but no such anomaly is recognized, although too few samples have been taken to the north to completely rule out this possibility.

On figure 2, sample 66 is distinctly anomalous in copper, zinc, and possibly molybdenum, and sample 67 is weakly anomalous in copper. Considering that only 220 ppm copper are present in stream sediments (collected by the writer in 1965) on Discovery Creek about 1/2 mile below the K-M prospect and mine dump (Chapman & Saunders, 1954) these anomalies on Landmark Lake deserve follow-up.

SUGGESTIONS FOR PROSPECTING

The grade of iron and the titanium content of the magnetite-rich gabbro as given by the one analysis quoted under locality 1 are not particularly encouraging by present standards for iron ore. However, a rapid magnetic survey seems justified to determine the extent of the magnetite-rich zone, which may become larger under the glacial cover. Some additional sampling also seems desirable as the high titanium content may be restricted to only part of the zone.

Additional stream sediment sampling and prospecting in the Landmark Gap and Sugarloaf Mountain areas should be done to trace down the anomalies in samples 66, 67, 41, and 49.

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Mukherjee, N.R., and Mark Anthony, L., 1957, Geochemical Prospecting: University of Alaska, School of Mines Bulletin 3, 81 pp.

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Sample No.	5E222	5E223	5E228	5E231	5E241	5E241A	5E241B	4AR174
Plagioclase	50%	50%		12%	40%	55%	17%	28%
% An	90	65		55?	68	67	60	55
Olivine			3	40(B)				
Augite (diallage)	29	20	15	18	46	15	37	55
Orthopyroxene				6(B)	7	30		
Hornblende				3				
Biotite				1				
Actinolite	15	30			2			5
Chlorite	3				2		3	2
Serpentine			75	13				
Epidote	3			5			16	10
Magnetite-ilmenite		tr	7	2	3	tr	28	
Pyrite	tr		tr				tr	
Grain size(mm)	0.4-2	1-4	(A)	(B)	0.5-2	1-2	0.5-1	
Name	Gabbro	Gabbro	Peridotite	Peridotite	Gabbro	Norite	Magnetite-rich gabbro	Gabbro

(A) Originally about 80% olivine in 1 mm grains in a matrix mainly of coarse augite.

(B) Fo_{95} in olivine, about En_{80} in orthopyroxene, subhedral olivine and plagioclase about 1 mm enclosed in coarse pyroxene.

Compositions determined by visual estimates in thin sections, except sample 241B, which was estimated by point-counting methods. Plagioclase in samples 222 and 223 and olivine and orthopyroxene in sample 231 determined by universal stage measurements.

Table 2. Analyses of stream sediments, Amphitheatre Mountains

All analyses in parts per million (ppm) except Field test in milliliters of of dithizone solution

Map No.	Sample No.	Copper	Zinc	Lead	Molybdenum	Nickel	Field Test
1	S25						2
2	S26						2
3	S37						1
4	W68	10	35	10	3		1
5	S36						1
6	S35						1
7	S34						1
8	S33						1
9	S32	70	70	20	3	225	1
10	S31						2
11	S27						2
12	S28						2
13	5N12	85	95	5	2	240	6*
14	5N10	35	60	<5	1	70	2*
15)	5N11	95	90	5	2	200	3*
16)	S30	125	100	0	3	350	8
17	S29						2
17a	S24						2
18	S23						1
19	S22						2
20	S45						1
21	S44	45	65	0	2		11
22)	5N26	80	165	5	2	130	10
23)	S81	130?	400?	30?	5		4
24)	5N27	65	140	5	3	120	8
25)	S84	80	125	15	4	80	1
26	S83	85	170	5	3	50	1
27)	S82	130	80	15	4	60	2
28)	5N25	95	120	10	2	100	1 (2*)
29	S21						2
30	S80	200?	400?	20	10	120	1
31	S20						2
32	S19						2
33	S18						2
34	S79	70	130	10	3	90	3
35	S88	75	300?	10	7	80	2
36	5N35)	125	150	10	4	120	12 (5*)
37	S87°)	165	220	15	7		20
38	5N38	70	185	15	14	80	12 (5*)

Table 2 - Continued

Map No.	Sample No.	Copper	Zinc	Lead	Molybdenum	Nickel	Field Test
39	5N18	80	160	10	3	120	8 (3*)
40	5N46	130	125	10	3	120	10 (3*)
41	5E275	265	140	10	3	120	6*
42	5E274	65	125	10	3	90	2*
43	S85)	120	80	10	3	85	1
44	5N29)	130	130	5	3	130	4
45	5N30)	175	140	5	2	170	6
46	S86)	140	80	10	3	115	1
47	5E273	100	115	10	3	90	3*
48	5N54	105	75	10	3	90	4*
49	5N53	290	130	5	2	130	17*
50	S76	110	50	10	5	85	1
51	S75	75	80	0	4	50	1
52	S74	40	35	10	3	80	1
53	S73	60	65	5	4	170	1
54	S77	75	80	5	3	55	2
55	S38						1
56	S17	45	40	5	3	190	5
57	S39						2
58	S71	15	25	0	2	55	1
59	S72	45	50	15	3	50	1
60	5E221	55	90	5	2	80	
61	5E211	75	120	5	3	80	
62	5N1	75	120	5	3	100	
63	5N2	90	120	10	3	80	
64	5N3	70	90	5	2	70	
65	5N4	90	165	10	3	90	
66	5N5	200	270	10	5	130	
67	5N6	150	135	5	2	120	
68	5N7	110	105	5	2	100	

* Analyzed after sieving and drying.

° Reanalyzed in 1965 by Rocky Mountain Geochemical Laboratories.

) 1964 samples re-collected in 1965

? Indicates possible contamination or analytical error.

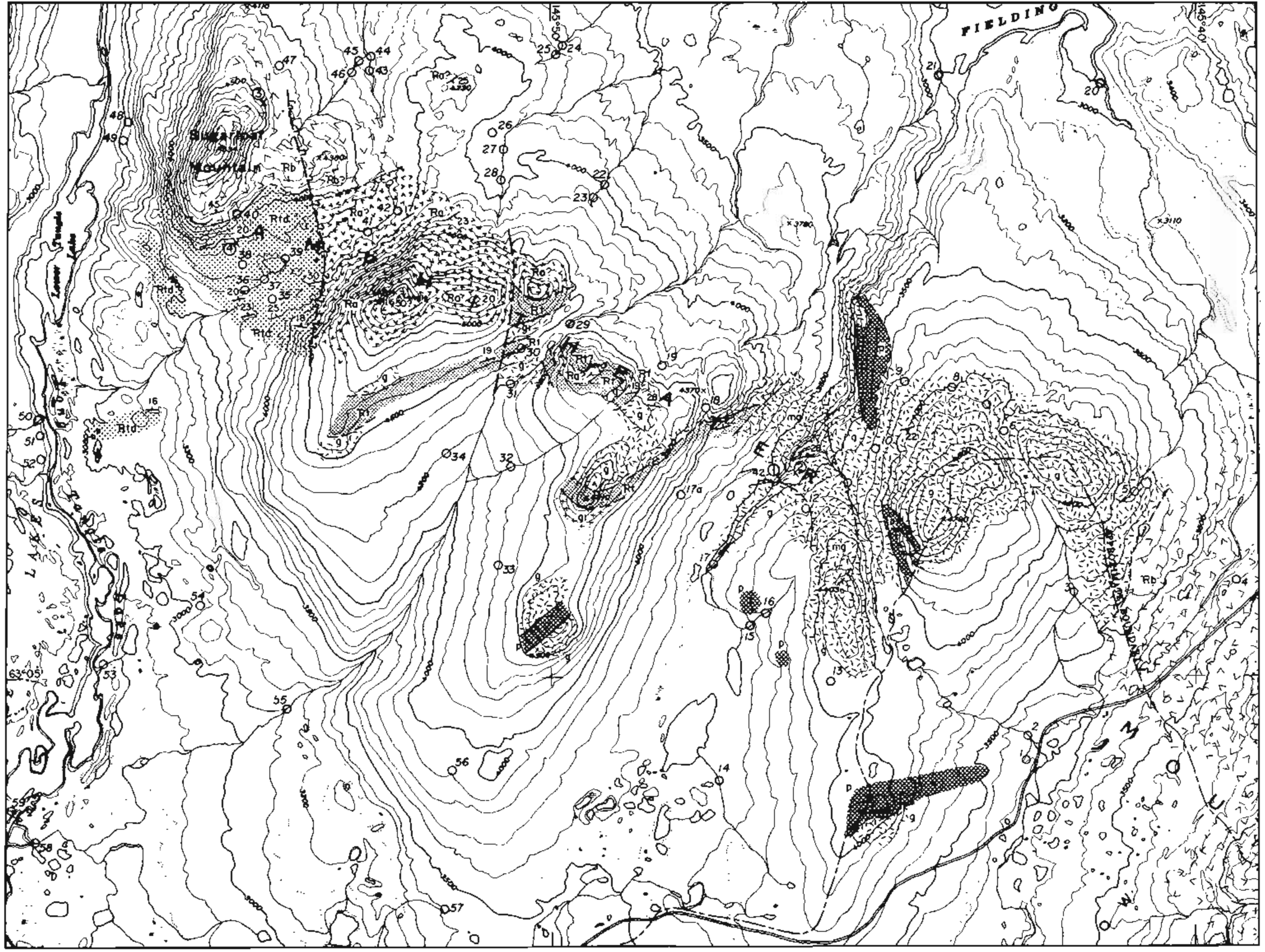
Analyses for copper, zinc, lead, molybdenum and nickel on samples prefixed 5N and 5E by Rocky Mountain Geochemical Laboratories, analyses on samples prefixed S and W by Division of Mines & Minerals laboratories (see Rose and Saunders, 1965).

Field analyses of samples prefixed 5E and 5N by readily extractable heavy metal procedure of Hawkes (1963); field analyses of samples prefixed S and W by University of Alaska procedure (Mukherjee and Mark Anthony, 1957).

Table 3 - Geochemical analyses of rock chips, Sugarloaf Mountain area

Sample No.	Rock Type	Copper	Zinc	Lead	Molybdenum
5N19	Porphyritic andesite agglomerate	170	50	10	3
5N21	Porphyritic andesite agglomerate	130	35	5	3
5N36	Porphyritic andesite agglomerate	100	55	5	3
5E255	Porphyritic andesite agglomerate	85	40	10	4
5N40	Andesite flow-pyritized	150	95	10	4
5N40A	Andesite tuff-pryitized	180	80	15	4
5E260	Silicic tuff	35	35	5	5
5E266A	Silicic tuff	175	80	10	3
5N36	Diabase	45	55	5	3
5E247	Diabase	170	65	10	3
5E266	Pyritic black shale	35	105	20	9

Analyses by Rocky Mountain Geochemical Laboratories. All values in parts per million.

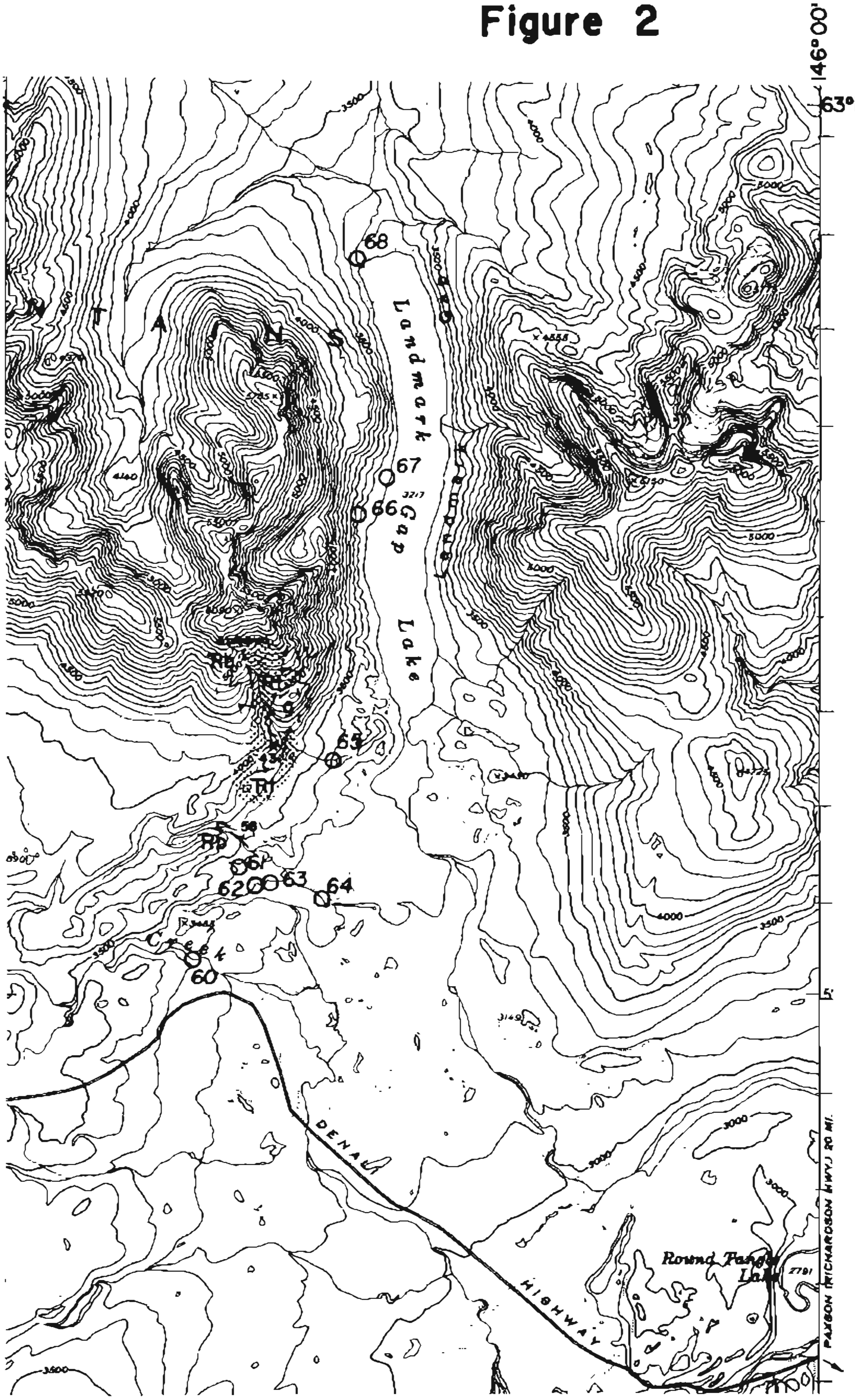


Geologic Map of part of the Amphitheatre Mountains

Base map from Mt. Hayes A-4 quadrangle
Geology by Arthur Rose assisted by David Bary

FIGURE 1

Figure 2



Mt. Hayes A-5
quadrangle

LANDMARK GAP AREA

For legend see Figure 1.

0 1 2 miles