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Geochemical signatures of mineral deposits and rock types as shown in stream sediments from the Chugach and Prince William terranes, Anchorage quadrangle, southern Alaska

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INTRODUCTION

A reconnaissance geochemical and mineralogical survey was conducted in the Anchorage quadrangle between 1982 and 1985, as part of the Alaska Mineral Resource Assessment Program (AMRAP). The Anchorage quadrangle contains parts of three different lithotectonic terranes: the Peninsular, Chugach, and Prince William. The geologically distinct Peninsular terrane covers the northern and western part of the Anchorage quadrangle, and it is discussed separately in another paper (Madden and Tripp, 1987). The geologically similar Chugach and Prince William terranes cover the southeastern part of the quadrangle. Because of their geological similarity, these two terranes were geochemically interpreted together.

The Chugach terrane is bounded by the Knik-Border Ranges fault system to the north and by the Contact fault to the south. Between its fault boundaries, the terrane consists of a landward unit of metamorphosed melange called the McHugh Complex and a seaward unit of metaflysch called the Valdez Group. Seaward from the Valdez Group, across the Contact fault, lies the Orca Group of the Prince William terrane. The Orca Group is lithologically similar to the Valdez Group (Nelson and others, 1985).

In the Chugach and Prince William terranes, we collected samples of -80-mesh stream and glacial-moraine sediments at 735 sites and the heavy-mineral fraction of these sediments at 644 of these sites. Samples of sediment and of the nonmagnetic fraction of heavy-mineral concentrate were analyzed for 31 elements using a semiquantitative emission spectrographic method (Grimes and Marranzino, 1968). In addition, stream and glacial-moraine sediments were analyzed for As, Cd, and Zn by atomic absorption. The resulting geochemical data consisted of a set of sediment data and a separate set of heavy-mineral-concentrate data (Arbogast and others, 1987). These two geochemical data sets were transformed into logarithms and interpreted using factor analysis. Factor analysis was used to simplify the data, define meaningful geochemical associations, and determine the areal locations of these associations. The results from factor analysis were compared with the mineralogy of the samples.

R-MODE FACTOR ANALYSIS OF GEOCHEMICAL DATA

The method of R-mode factor analysis, with varimax rotation, showed associations of trace elements in each of the two data sets. These associations of elements are grouped in factors, which may be related to particular types of rocks and mineral deposits. Factor analysis showed which suites of ore-related elements occur and where in the quadrangle these suites are significant. This analysis is an interpretation, but not a unique solution. These data could be recast differently by adding or subtracting elements, using an oblique rather than varimax rotation, or using non log-transformed data.

Table 1 lists five significant factors and factor loadings derived from R-mode factor analysis of the sediment data. The most significant factors all have eigenvalues greater than one. Their factor loadings indicate the correlation between an element and a factor, and their factor scores are recomputed values for each sample. The factor scores are related to areas sampled in this reconnaissance survey, as discussed below.

The elements which load strongly into factor 1 are Mn, Cr, Sc, Mg, Co, and V. These elements define a mafic association of greenstone and minor ultramafic rocks in the McHugh Complex (Clark, 1973) of the Chugach terrane, and areas potentially exposing mafic volcanic rocks or shale in the Valdez Group of the Chugach terrane and the Orca Group of the Prince William terrane in the following areas: (1) Girdwood gold-mining district (fig. 1), (2) an area southeast of Whiteout Peak, (3) the east side of Lake George Glacier, (4) Grasshopper Valley, (5) Serpentine Glacier, (6) Eliot and Harvard Glaciers, (7) upper Marcus Baker Glacier, (8) Powell Glacier, (9) upper Meares Glacier, (10) north and east of Miners Lake, and (11) Kadin Lake. Some of these areas may expose mafic volcanic rocks in the Valdez Group, such as those mapped in the adjoining Valdez quadrangle (Winkler and others, 1981). In the first six of these areas, chalcopyrite was seen in the heavy-mineral-concentrate samples, which suggests a potential for copper-sulfide mineralization. Such mineralization occurs to the south of the Anchorage quadrangle in areas where mafic volcanic rocks are found (Nelson and others, 1984). This type of mineralization also occurs far away from exposures of mafic volcanic rocks in the Valdez Group in Lynx Creek (Paige and Knopf, 1907).

Factor 2 shows high loadings for B and Zn, which occur in areas that may expose relatively clay-rich metasedimentary rocks in the Valdez and Orca Groups in the following areas: (1) the area northeast of Anchorage; (2) upper Coal Creek; (3) locally in the Metal Creek drainage in Cottonwood Creek, Paradise Creek, and the canyon north of Paradise Creek; (4) southeast of Whiteout Glacier; (5) east of Lake George Glacier; (6) upper Eagle River; (7) the canyon east of Crow Creek in the Girdwood area; (8) Glacier Fork; and (9) east of Miners Lake. In all except the first two areas, sphalerite and barite were seen in the heavy-mineral concentrates suggesting potential for Zn-rich massive sulfides.

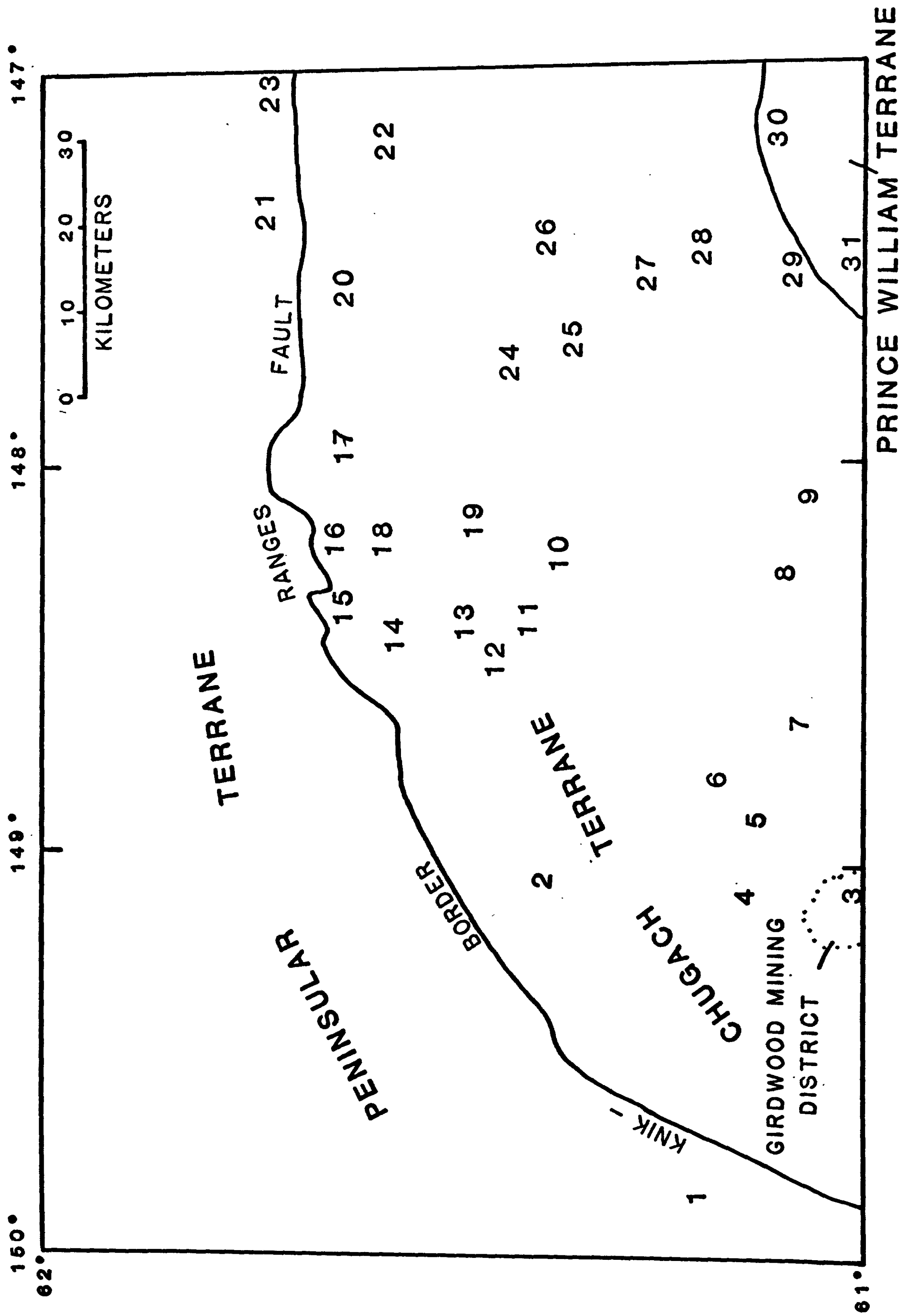
Factor 3, with high loadings for Zr, Cu, Fe, Y, Mg, Co, Ti, As, Pb, and Ba, reflects a mixture of lithologies including igneous intrusions (Zr, Ti), mafic volcanic rocks (Fe, Mg, Co, Y), and sulfide mineralization (Cu, As, Pb, Ba). Plots of factor scores show high values clustered in the north-central outcrop area of the Valdez Group in areas with known igneous intrusions and known or suspected mineralization. These areas are in Metal Creek, upper Grasshopper Valley, Gravel Creek, Marcus Baker Glacier, and southernmost South Fork, where this factor corresponds with samples containing ore-related sulfide minerals (arsenopyrite, galena) and gold in their heavy-mineral concentrates. Only Metal Creek previously was known as a placer mining stream.

Samples showing high scores for factor 4 (Be, Ba, Pb, Y) are distributed mostly in the southeastern outcrop area of the Valdez Group and in the Orca Group, rather than in the northwestern outcrop area of the Valdez Group. The factor-score plots suggest that there is a geochemical difference between rocks in the northwestern outcrop area of the Valdez Group (between the McHugh Complex and the crest of the Chugach Mountains), and the southeastern outcrop area of the Valdez Group and the Orca Group.

Factor 5 (Cd, Zn, As) defines areas of Zn-rich sediments in the northern outcrop area of the Valdez Group between the Matanuska and Nelchina Glaciers, and from Metal Creek to upper Gravel Creek (especially in Grasshopper Valley and the area north of Marcus Baker Glacier), Eklutna Lake, locally along the Eagle River, Yale Glacier, east and northeast of Miners Lake, and east of Wells Bay. Most of the samples having high scores in the stream sediments do not contain ore-related minerals or high Cd, Zn, or As in their concentrates. This suggests that the high Cd, Zn, and As occur only in the clay-size fraction of sediment. This stream-sediment factor could reflect the lithology of the metasedimentary rocks, or the weathering products of sphalerite from mineralized zones. The types of mineralization in the Chugach and Prince William terranes are discussed by Nelson and others (1984).

Figure 1.--Generalized lithotectonic terrane map of the Anchorage quadrangle, after Silberling and Jones (1984).

1. Anchorage
2. Eklutna Lake
3. Crow Creek
4. upper Eagle River
5. Whiteout Peak
6. Whiteout Glacier
7. Lake George Glacier
8. Serpentine Glacier
9. Mount Curtin
10. Knik Glacier
11. Glacier Fork
12. Metal Creek
13. Paradise Creek
14. Cottonwood Canyon
15. Metal Creek Glacier
16. upper Coal Creek
17. Gravel Creek
18. upper Grasshopper Valley
19. Marcus Baker Glacier
20. Matanuska Glacier
21. lower South Fork
22. Powell Glacier
23. Nelchina Glacier
24. Mount Marcus Baker
25. Eliot Glacier
26. Harvard Glacier
27. Yale Glacier
28. Meares Glacier
29. Miners Lake
30. Kadin Lake
31. Wells Bay



147°
148°
149°
150°
62°
61°
0 10 20 30
KILOMETERS
PENINSULAR TERRANE
CHUGACH TERRANE
PRINCE WILLIAM TERRANE
KNIK - BORDER RANGES FAULT
GIRDWOOD MINING DISTRICT
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Table 2 shows the loadings for seven significant heavy-mineral-concentrate factors. Factor 1 (Co, Ni, Fe, Cu, As, Pb, Zn, Ag) scores are high in the following areas: (1) the Girdwood gold mining district, (2) Metal Creek, (3) upper Grasshopper Valley, (4) snowfields southeast of Knik Glacier, (5) locally on Harvard, Yale, and upper Meares Glaciers, (g) Mount Curtis, (7) east of Miners Lake, (8) Marcus Baker Glacier, and (9) a large area in the northeastern outcrop area of the Valdez Group between Mount Marcus Baker and the Nelchina Glacier. In the first seven areas, samples contain arsenopyrite, chalcopyrite, sphalerite, and galena. The presence of these minerals suggests that there is potential for base-metal mineralization in the above areas, either in gold-bearing veins or in massive-sulfide occurrences.

Factor 2 shows high loadings for Mg, Mn, Cr, Ca, V, Sc, and La. High factor scores are clustered in the northern and western outcrop area of the Valdez Group. In contrast, scores are low in the Orca and southeastern Valdez Groups. This distribution (like stream-sediment factor 4) suggests that a geochemical boundary within the Valdez Group occurs near the crest of the Chugach Mountains, with more mafic strata lying to the north and northwest. Northwest of the boundary, the strata contain more mafic minerals. The northwestern area includes the McHugh Complex, which is rich in Mn and includes mafic and ultramafic rocks, and parts of the Valdez Group. Mafic rocks in the McHugh and the Valdez may be contributing mafic minerals such as olivine, pyroxene, and amphibole to provide Ca and Mg in these samples.

Factor 3, with high loadings in Au, Ag, Bi, W, As, and Pb, indicates the areas that have potential for lode and/or placer gold. These areas are as follows: (1) Girdwood gold mining district; (2) Metal Creek drainage, especially Cottonwood Creek and a canyon north of Paradise Creek; (3) upper Grasshopper Valley, (4) Gravel Creek; (5) a glacier north of Marcus Baker Glacier; (6) upper South Fork, especially the west side of Powell Glacier and the area southeast of Sweden Peak; (7) locally on Harvard, Yale, and Meares Glaciers; and (8) northeast of Miners Lake. Samples from these areas contain gold and base-metal sulfide minerals.

The groups of elements in factors 4 (Sr, Ba, La) and 5 (Sn, Sb, Bi, Th, and Pb) reflect contributions from both metasedimentary rocks and from the granitic plugs and dikes in the Chugach terrane. The highest scores for factor 5 may reflect felsic anatectic melts and/or minor sulfide mineralization involving Sb, Bi, and Pb. However, factor 5 does not simply represent granitic rocks, because some of the highest scores occur in metasedimentary rocks that lack exposures of granitic intrusions.

Factors 6 (B, Ca, Bi) and 7 (Y, Sc, V, Cr) define areas of mafic rocks in the McHugh Complex, locally in the Valdez Group, and near gabbroic plutons in the Orca Group.

CONCLUSIONS

Factor analysis of geochemical data, supported by mineralogical study of heavy-mineral concentrates, shows combinations of ore-related metals which occur in certain areas of the Chugach and Prince William terranes in the Anchorage quadrangle. Some of these areas are new. For example, Au, Ag, and associated elements Pb, W, Bi, and As, are relatively abundant in heavy-mineral concentrates in the Girdwood area; locally in the Metal Creek drainage; in upper Grasshopper Valley; Gravel Creek; a glacier north of Marcus Baker Glacier; upper South Fork; locally on Harvard, Yale, and Meares Glaciers; and northeast of Miners Lake. In addition, base metals occur in the stream sediments and heavy-mineral concentrates from a number of areas. The base metals may occur in Au-bearing veins such as those mined in the Girdwood district, and/or as massive sulfides such as those described by Nelson and others (1984) and by Paige and Knopf (1907).

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TABLE 1.--Factor loadings for the first five factors after varimax rotation of the stream-sediment data. Total variance explained by the five factors equals 66 percent. Loadings less than 0.40 have been omitted.

Factors	1	2	3	4	5
Fe	--	--	.74	--	--
Mg	.53	--	.64	--	--
Ca	--	-.78	--	--	--
Ti	.54	--	.52	--	--
Mn	.74	--	--	--	--
As	--	--	.48	--	.55
B	--	.65	--	--	--
Ba	--	--	.45	.62	--
Be	--	--	--	.71	--
Cd	--	--	--	--	.82
Co	.52	--	.53	--	--
Cr	.66	--	--	--	--
Cu	--	--	.79	--	--
Ni	.40	--	.55	--	--
Pb	--	--	.47	.45	--
Sc	.62	--	--	--	--
Sr	--	-.76	--	--	--
V	.50	--	--	--	--
Y	--	--	.73	.40	--
Zr	--	--	.79	--	--
Zn	--	.46	--	--	.55
Percent of total data variance explained by factor	16.6	10.21	21.3	8.8	8.8

TABLE 2.--Factor loadings for the first seven factors after varimax rotation of the heavy-mineral-concentrate data. Total variance explained by the seven factors equal 70 percent. Loadings less than 0.25 have been omitted.

Factors	1	2	3	4	5	6	7
Fe	.91	--	--	--	--	--	--
Mg	--	.92	--	--	--	--	--
Ca	--	.64	--	--	.26	--	.40
Mn	--	.87	--	--	--	--	--
Ag	.37	--	.83	--	--	--	--
As	.64	--	.37	--	--	--	--
Au	--	--	.89	--	--	--	--
Ba	--	--	--	.79	--	--	--
Bi	--	--	.48	--	.55	--	--
Co	.92	--	--	--	--	--	--
Cr	--	.72	--	--	--	.38	--
Cu	.84	--	--	--	--	--	--
La	--	.36	--	.28	--	--	.40
Ni	.92	--	--	--	--	--	--
Pb	.61	--	.29	--	.41	--	--
Sb	--	--	--	--	.60	--	.26
Sc	--	.40	--	--	--	.81	--
Sn	--	--	--	--	.68	--	--
Sr	--	--	--	.85	--	--	--
V	--	.62	--	--	--	.53	--
W	--	--	.47	--	--	--	.32
Y	--	--	--	--	--	.89	--
Zn	.55	--	--	--	--	--	--
Th	--	--	--	--	--	--	.71
Percent of total data variance explained by factor.	19.7	13.9	9.2	6.9	6.7	8.8	4.9