UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Geochemical signatures of mineral deposits and rock types as shown in stream sediments from the Peninsular terrane, Anchorage quadrangle, southern Alaska

By

Dawn J. Madden[1] and Richard B. Tripp[1]

Open-File Report 87-129

[1]DFC, Box 25046, MS 973, Denver, CO 80225

1987

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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 Chugach and Prince William terranes were interpreted together and discussed in another paper (Madden and Tripp, 1987). The geologically distinct Peninsular terrane covers the northern and western parts of the Anchorage quadrangle and it is discussed below.

The Peninsular terrane is bounded by an unnamed shear zone to the north of the Anchorage quadrangle (Csejtey and others, 1978) and by the Knik-Border Ranges fault system to the south (fig. 1). The terrane contains bedded volcanic and sedimentary rocks (Early Jurassic to Tertiary), plutonic rocks of the Talkeetna Mountains batholith (Early Jurassic-Tertiary), and metamorphic rocks (Paleozoic? to Jurassic) mapped by Csejtey and others (1978).

In the Peninsular terrane, we collected samples of -80-mesh stream- and glacial-moraine sediments at 562 sites and the heavy-mineral fraction of these sediments at 524 of these sites. Each sample of sediment and of the nonmagnetic fraction of heavy-mineral concentrate was analyzed for 31 elements using semiquantitative emission spectrography (Grimes and Marranzino, 1968). In addition, stream- and glacial-moraine sediments were analyzed for As, Cd, and Zn by atomic absorption spectroscopy; and the mineralogy of heavy-mineral concentrates was studied. The resulting geochemical data consisted of two sets of geochemical data derived from analyses of (1) a set of stream and glacial-moraine sediments and (2) a set of heavy-mineral concentrates (Arbogast and others, 1987). These two geochemical data sets then were transformed into logarithms and interpreted using factor analysis. The results from factor analysis were compared with the mineralogy of samples.

R-MODE FACTOR ANALYSIS OF GEOCHEMICAL DATA

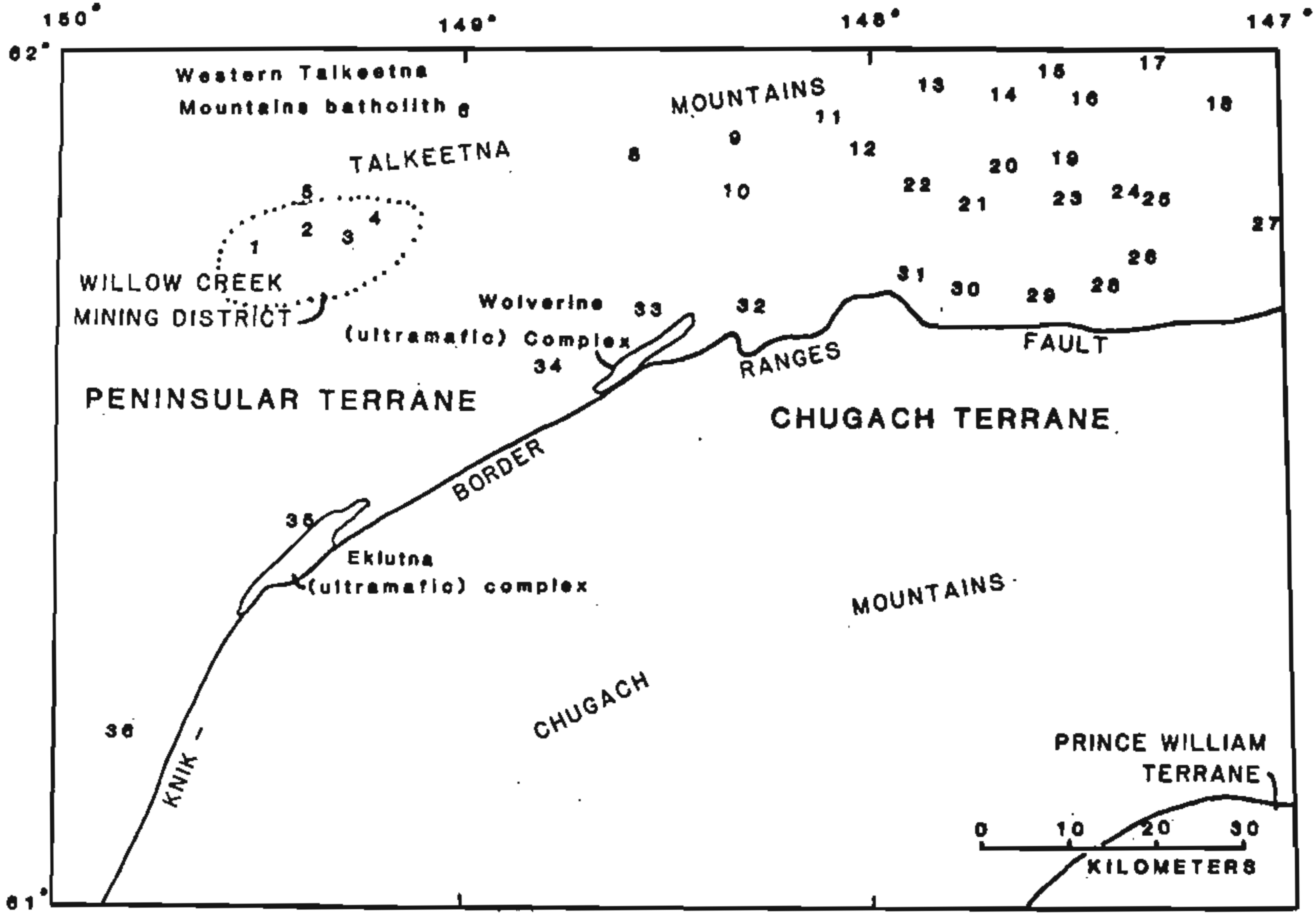
The method of R-mode factor analysis, with varimax rotation, showed associations of trace elements which occur in each of the two data sets. These elements are grouped in factors which are related to particular types of rocks and mineral deposits. Factor analysis was used primarily to see which suites of ore-related elements occur and where in the quadrangle these suites are significant.

Table 1 lists four 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 Fe, V, Ti, Y, Sc, Cu, Co, Mn, and Mg. This suite of elements suggests a mafic-rock source, with potential for Cu mineralization. Using factor scores, the suite of elements can be related to various geologic units. Factor-1 scores are high in a number of units, as follows: (1) Jurassic gabbronorite in the northern Chugach Mountains; (2) ultramafic and gabbroic rocks of the Wolverine Complex of Carden and Decker (1977); (3) a heterogeneous unit mapped as quartz diorite along the Kings River; and (4) mafic Tertiary volcanic rocks of the northern margin of the quadrangle, between the Chickaloon River and Caribou Creek. In

Figure 1.--Generalized lithotectonic terrane map of the Anchorage quadrangle, after Silberling and Jones (1984). Also shown are the Wolverine Complex of Corden and Decker (1977) and the informally named Eklutna complex of Clark and Greenwood (1972).

1. Willow Creek
2. Craigie Creek
3. Independence mine area
4. Fishhook Creek
5. upper Purches Creek
6. upper Kashwitna River
7. northeastern, upper Kings River
8. Kings River
9. Chickaloon River
10. Puddingstone Hill area of lower Boulder Creek
11. Boulder Creek
12. East Boulder Creek
13. Chitna Creek
14. Caribou Creek
15. Flume Creek
16. Alfred Creek
17. Table Mountain
18. Eureka Roadhouse
19. Inoceramus Creek
20. Fortress Creek
21. Dan Creek
22. Hicks Creek
23. Sheep Mountain
24. Trail Creek
25. Knob Lake-East Fork area
26. Middle Creek
27. Nelchina Glacier
28. Rusaw Creek area
29. Matanuska Glacier
30. Glacier Creek
31. Gravel Creek
32. Coal Creek
33. Carpenter Creek
34. Wolverine Creek
35. Eklutna
36. Anchorage


150°
149°
148°
147°
62°
61°
Western Talkeetna
Mountains batholith
TALKEETNA
MOUNTAINS
WILLOW CREEK
MINING DISTRICT
Wolverine
(ultramafic) Complex
PENINSULAR TERRANE
CHUGACH TERRANE
RANGES
FAULT
BORDER
KNIK -
Eklutna
(ultramafic) complex
CHUGACH
MOUNTAINS
PRINCE WILLIAM
TERRANE
0 10 20 30
KILOMETERS
1
2
3
4
5
6
8
9
10
11
12
13
14
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addition, scattered high factor scores occur near mafic Tertiary sills and dikes exposed within strata of Jurassic through Tertiary age. High factor-1 scores occur near known Cu mineralization on Sheep Mountain and near Rusaw Creek. Mineralization in these areas is discussed briefly in Cobb (1979).

Factor 2 characterizes Zn-rich stream sediments from the Talkeetna and Matanuska Formations. The sources for the Zn may include shaly layers in the two formations, small mafic intrusions in some of the drainages, and/or local mineralization. High scores in the Talkeetna Formation occur in the Chickaloon River and in Boulder, East Boulder, and Hicks Creeks; and high scores in the Matanuska Formation occur in Caribou Creek, and in the Table Mountain-Eureka Roadhouse and Knob Lake-East Fork areas. All of the above areas show evidence for mineralization in the composition of their panned, heavy-mineral concentrates (Tripp and Madden, unpublished data), except for the Table Mountain-Eureka Roadhouse area. To the southwest, near Eklutna, an isolated, high, factor-2 score occurs. This high score may reflect local Cu-Pb-Zn mineralization in Jurassic(?) metavolcanic rocks on Mount Eklutna (Cobb, 1979). In addition to showing information about the Zn content of the Peninsular terrane itself, the distribution of high scores for factor 2 also shows that the southern part of the terrane contains detritus derived from upstream in the more Zn-rich metasedimentary rocks of the Chugach terrane.

Factor 3 (Zr, Ba, Y) defines felsic intrusive rocks and the younger sedimentary rocks derived from them. The intrusive rocks include the Cretaceous and Tertiary tonalite and adamellite of the Talkeetna Mountains batholith; the Cretaceous trondhjemite which cuts the Knik-Border Ranges fault system in upper Wolverine Creek (Pavlis, 1982); and the younger, Tertiary felsic dikes and plugs intruding Jurassic through Tertiary strata. High factor-3 scores in the Talkeetna Mountains batholith are accompanied by high scores in the younger, Tertiary sedimentary deposits of the Arkose Ridge Formation. These deposits may have been derived from the batholith (Winkler, 1978).

Factor 4 (Ni, Cr, Mg, Co, Cu, Sc, B) characterizes ultramafic and very mafic igneous rocks as follows: (1) the chromite-bearing Wolverine Complex and the informally named Eklutna (ultramafic) complex of Clark and Greenwood (1972), (2) the serpentinite in the schist and mafic dikes in plutonic rocks in the Willow Creek gold mining district, (3) unmapped, mafic rocks within Jurassic amphibolite and quartz diorite of the Talkeetna Mountains batholith; and (4) the Tertiary mafic sills and dikes intruding strata as young as Tertiary in age.

Table 2 shows factor loadings for six heavy-mineral-concentrate factors. The elements loading strongly in factor 1 (Co, Ni, Cu, Fe, Zn, Pb, Ba, As, Mg, Cr, Ag, B) reflect a mixture of sulfide minerals and minerals from mafic rock types. High factor-1 scores occur in numerous areas as follows: (1) Alfred Creek, (2) Caribou Creek, (3) Hicks Creek, (4) the bend in Boulder Creek, (5) lower Inoceramus Creek, (6) Knob Lake-East Fork area, (7) Puddingstone Hill, (8) Chitna Creek, (9) Fortress Creek, (10) Dan Creek, (11) Middle Creek, (12) Trail Creek, (13) northeastern Kings River, (14) Chickaloon River, (15) Carpenter Creek, and (16) Wolverine Creek. The first four areas contain arsenopyrite, chalcopyrite, sphalerite, and galena in heavy-mineral concentrates; the first fifteen areas are anomalously high in ore-related elements (Cu, Pb, Zn, As) in the heavy-mineral concentrates. This suggests potential for base-metal mineralization in these areas. High scores in the last two areas reflect heavy minerals such as copper and chromite from rocks in the Wolverine Complex.

The elements which load strongly into factor 2 (V, Ca, Mn, Mg, Cr) reflect a mafic to ultramafic rock assemblage contributing chromite, olivine(?), pyroxenes, and/or amphiboles to the streams. The highest factor-2 scores cluster together in areas exposing the Jurassic gabbronorite which lies between the Nelchina and Matanuska Glaciers. In addition, high scores occur (1) near smaller, Tertiary-aged, mafic sills and dikes in the Talkeetna, Matanuska, and Chickaloon Formations; (2) in the undivided volcanic rocks of Tertiary age which overlie the Jurassic and Cretaceous units on the northern margin of the quadrangle; (3) in the amphibolite-quartz diorite of the Talkeetna Mountains batholith; and (4) locally in the southern part of the Cretaceous and Tertiary tonalite of the Willow Creek gold mining district. In the last area, high factor-2 scores may reflect dikes of diabase within the tonalite (Ray, 1954).

Factor 3 (Au, Ag, Y, Pb, Zn, As) defines areas having potential for lode and/or placer gold mineralization. High scores for factor 3 occur in the following areas, some of which were previously unreported: (1) Alfred and Flume Creeks, (2) Inoceramus Creek, (3) East Fork-Knob Lake area, (4) Caribou Creek, (5) Boulder Creek, (6) Chickaloon River, (7) Willow Creek, and (8) Hicks Creek. In the first seven areas, gold was seen in heavy-mineral concentrates; in the last area no gold was seen, but galena, sphalerite, and arsenopyrite were found. These minerals commonly occur in gold-bearing veins in the Willow Creek gold mining district. High scores in South Fork, the eastern side of the Matanuska Glacier, and Glacier, Gravel, and Coal Creeks probably reflect detritus from upstream in the more Au- and Ag-rich Chugach terrane.

Samples showing high scores in factor 4 (Mo, Y, Pb, Mn) are clustered in plutons of the younger, more felsic, western part of the Talkeetna Mountains batholith. The area of high scores extends from Willow Creek northward to the Kashwitna River. High scores also occur locally in the older, Jurassic units (trondhjemite, amphibolite, quartz diorite) of the batholith, which are exposed in the Kings River and upper Chickaloon River drainages. Eastward from the Chickaloon River, high factor-4 scores occur near plugs of felsite in East Boulder, upper Caribou, and Alfred Creeks.

High scores in factor 5 (W, As) characterize tonalite and trondhjemite of the Talkeetna Mountains batholith, plugs of felsite, and mineralization on Sheep Mountain. The cluster of highest scores occurs in the tonalite (Cretaceous-Tertiary) in the Willow Creek gold mining district, in upper Willow, Craigie, and upper Purches Creeks, and in the creek northeast of Independence mine. Another cluster of high scores occurs to the north, in tonalite and older trondhjemite (Jurassic) of the batholith. To the east of the batholith, high scores occur near scattered outcrops of Tertiary felsite in the Knob Lake-East Fork area, and in Boulder, East Boulder, and upper Caribou Creeks. High scores occur on the northwest and southeast sides of Sheep Mountain, downstream from known Cu mineralization which contains anomalously high As, but lacks high W.

High scores for factor 6 (Sr, B, Ba, Fe, Pb, Mg, Ca, Zn) define the older generally more mafic, Jurassic-aged parts of the Talkeetna Mountains batholith, and parts of the Lower Jurassic, volcanogenic Talkeetna Formation. Factor-6 scores are low in the younger more felsic, western part of the batholith, in contrast to factor 4.

High scores for concentrate factors 1, 3, 5, and 6 occur in the southern part of the Peninsular terrane, in large drainages which originate in the Chugach terrane. These high scores reflect drainage from the Chugach terrane into the Peninsular terrane.

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 Peninsular terrane in the Anchorage quadrangle. For example, Au, Ag, and associated elements are relatively abundant in heavy-mineral concentrates in Alfred and Flume Creeks, Inoceramus Creek, the East Fork-Knob Lake area, Caribou Creek, Hicks Creek, Boulder Creek, the Chickaloon River, and Willow Creek. In addition to precious metals, associations of base metals occur in both the stream sediments and concentrates from the Talkeetna and Matanuska Formations along the Chickaloon River; Boulder, East Boulder, Hicks, and Caribou Creeks; near Table Mountain and Eureka Roadhouse and along East Fork near Knob Lake; and locally on Sheep Mountain.

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TABLE 1.--Factor loadings for the first six factors after varimax rotation of the stream- and glacial-moraine-sediment data. Total variance explained by the 4 factors equals 69 percent. Loadings less than 0.40 have been omitted.

Factors	1	2	3	4
Fe	.81	--	--	--
Mg	.54	--	--	.66
Ca	.45	-.62	--	--
Ti	.71	--	--	--
Mn	.55	--	--	--
B	--	--	--	.41
Ba	--	--	.81	--
Co	.63	--	--	.62
Cr	--	--	--	.87
Cu	.64	--	--	.44
Ni	--	--	--	.89
Sc	.64	--	--	.44
Sr	--	-.80	--	--
V	.74	--	--	--
Y	.66	--	.51	--
Zr	--	--	.81	--
Zn	--	.74	--	--
Percent of total variance of data explained by factor.	26.0	11.9	11.6	19.6

TABLE 2.--Factor loadings for the first six factors after varimax rotation of the heavy-mineral-concentrate data. Total variance explained by the six factors equals 65 percent. Loadings less than 0.25 have been omitted.

Factors	1	2	3	4	5	6
Fe	.78	--	--	--	--	.42
Mg	.39	.58	--	.47	--	.36
Ca	--	.74	--	--	--	.33
Mn	--	.68	--	.26	-.30	--
Ag	.30	--	.83	--	--	--
As	.41	--	.25	--	.55	--
Au	--	--	.90	--	--	--
B	.25	--	--	--	--	.70
Ba	.44	--	--	--	--	.69
Co	.82	--	--	--	--	--
Cr	.34	.56	--	-.42	--	--
Cu	.79	--	--	--	--	--
Mo	--	--	--	.75	--	--
Ni	.82	--	--	--	--	--
Pb	.48	--	.28	.39	--	.38
Sr	--	--	--	--	--	.76
V	--	.79	--	--	--	--
W	--	--	--	--	.82	--
Y	--	--	.28	.66	--	-.29
Zn	.55	--	.27	--	--	.26
Percent of total data variance explained by factor.	20.3	12.4	9.7	9.5	6.0	12.4