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The Emma Bell deposit, Siskiyou Co., California: A possible low-grade source of chromite

by

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Abstract

The Emma Bell chromite deposit in Siskiyou County, California contains over 5 million tons of dunite averaging about 4 percent Cr_2O_3. Chromite is not evenly disseminated throughout the dunite, however. For the most part the deposit consists of many chromite-rich bands in sharp contact with, and separated by, common dunite containing 1 to 2 percent accessory chromite. Electron microprobe and petrographic analysis of accessory chromite shows that it is fine grained (average grain size 0.14 mm), generally lower in Cr_2O_3, and has a lower Cr/Fe ratio than segregated chromite. In addition, unusual patchy zoning is exhibited by some accessory chromite. These patchy zones are extremely rich in iron ($>$60 percent total iron oxide).

The negative factors such as the fine-grained nature of the accessory chromite and high iron content compared to segregated chromite, could be overcome by the very large tonnage in the deposit.

Introduction

The Emma Bell deposit is one of the Seiad Group of deposits (Wells and Cater, 1950) located in the folded and metamorphosed Seiad ultramafic complex of Medaris (1966) which is in Siskiyou County, California, about 11 km north-northeast of the town of Seiad Valley (Fig. 1). The complex lies in the western Paleozoic and Triassic belt of Irwin (1964) and is probably part of a disrupted ophiolite in the Klamath Mountains. For a more extensive description of the local geology of the area and the petrology of the Seiad ultramafic complex the reader is referred to the following: Barrows (1969), Irwin (1964), Medaris (1966), Wells et al. (1949), and Wells and Cater (1950). For the purposes of this report it is important to note that the complex, as described by Medaris (1966), consists of two tabular ultramafic masses separated by a thin wedge of metasedimentary rocks. The western ultramafic mass is dominantly harzburgite whereas the eastern body is dominantly dunite and contains most of the known chromite deposits in the complex, including the Emma Bell (Fig. 2).

Although the Emma Bell (a.k.a. the Stanton deposit) has yielded less than 500 tons of chromite during mining in the 1950's, more recent work including mapping and some drilling has indicated that the Emma Bell deposit as a whole may be a low grade source of chromite.

Ophiolites such as the Seiad ultramafic complex contain two main varieties of ultramafic rocks, harzburgite and dunite. Dunite is the favored target for low-grade metallurgical chromite deposits because accessory chromite in it commonly contains more than 40% Cr_2O_3 with low Al_2O_3 (<20%). On the other hand accessory chromite in harzburgite generally contains 20-40% Cr_2O_3 with Al_2O_3 also between 20 and 40%, which makes it unsuitable for metallurgical use (Lipin, 1983).

The eastern ultramafic mass containing the Emma Bell deposit is predominantly dunite. If the average chromite content of the dunite is one percent, by volume, then a block $100m^3$ would contain 40,000-50,000 tons of chromite, depending upon its specific gravity. The dunite occupies about 8.5 km^3 (Fig. 2). Therefore, the chromite potential is very large.

This report will address the petrographic and chemical characteristics of the Emma Bell deposit in order to assess its suitability as a low-grade source of metallurgical chromite.

Acknowledgements

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Characteristics of the Emma Bell Deposits

Figure 3 shows the extent of the Emma Bell deposit and its relation to the Seiad Creek and other deposits to the south. The Emma Bell deposit, as described by Cornwall (1981) extends discontinuously for over 1220 m northwest-southeast and ranges in thickness from 3 to 60 m. The lenses of chromite dip 45° NE to near vertical. Drilling by the U.S. Chrome Company indicates that mineralization is discontinuous down dip but persists in some places to about 100 m. The deposit consists of schlieren, disseminated lenses with about 25 to 50% chromite and some lenses of >50% chromite. The average thickness of the chromite-rich lenses and schlieren is only a few centimeters. The lenses are separated by dunite with 1-2% chromite. However, in some places along strike the chromite-rich layers are rather closely spaced.

Resource Estimate

Resource estimates for the Emma Bell are based upon field observations and drilling information. The Emma Bell has been divided into three units (Fig. 3), the Upper Emma Bell, the Lower Emma Bell, and the Tail. Sixteen drill holes in the Upper and Lower Emma Bell indicate a total of over 5 million tons averaging about 4 percent Cr_2O_3, 90 percent of which is under 10 percent Cr_2O_3 (Table 1). The estimate does not include the Tail for which there is no subsurface information. However, from surface exposures, resources in the Tail would also be low grade; that is, about 90 percent of the tonnage probably contains less than 10% Cr_2O_3. Clearly the Emma Bell is a very low grade deposit.

The grade and tonnage estimate in this report is potentially misleading because it may give the impression that the chromite is evenly distributed throughout the Emma Bell deposit. Actually, the majority of the chromite is concentrated in discrete layers or lenses within zones referred to as schlieren chromite. Schlieren chromite zones consist of subparallel, high grade bands (45-50 percent Cr_2O_3) bounded by common dunite containing 1-2 percent Cr_2O_3. The high grade layers are generally well defined and vary in thickness from 2 to 10 cm. Typically, a 1 m zone of schlieren chromite averages 9 thin (4 cm) layers of high grade chromite (averaging 45 percent Cr_2O_3) separated by 60-70 cm of common dunite (averaging 1 percent Cr_2O_3). Therefore the average Cr_2O_3 content of the 1 m zone would be about 17 percent Cr_2O_3. The schlieren zones are generally less than a meter wide and are in turn separated by several meters of common dunite. Thus a typical 10 m section of core contains 8 meters of common dunite with 1 percent Cr_2O_3 and 2 zones of schlieren ore (1 m each) averaging about 17 percent Cr_2O_3 with the overall Cr_2O_3 content averaging about 4 percent. These examples are generally the occurrences encountered which result in the large tonnages of about 4 percent Cr_2O_3.

Traditionally only high grade chromite ore has been mined (+25 percent Cr_2O_3) and the lowest grade mined in the Coast Ranges from the same type of rock is at the Grau Mine in Tehama County, California, at about 10 percent Cr_2O_3. Over a three year period during the second world war, this ore was processed to produce 44 percent Cr_2O_3 concentrates with a 3.1 to 1 Cr/Fe ratio; however, mill recovery averaged only 40 percent. During this same period, ore form the Pilliken Mine in El Dorado County, California averaged 7 percent Cr_2O_3 and was processed to produce 38 percent Cr_2O_3 concentrates with a 2.0 to 1.0 Cr/Fe ratio and a mill recovery of 52.2 percent (McMillan, 1941). Because the Emma Bell deposit mostly comprises accessory chromite, it is important to determine possible differences between the properties of the common accessory chromite and less-common segregated chromite.

Segregated versus accessory chromite

Grain size and chemical composition of accessory chromite are important factors in evaluating the minability of any possible low-grade deposit. Cornwall (1981) pointed out that the average size of disseminated chromite is 0.14 mm whereas the diameter of segregated chromite is commonly larger (up to 3.5 mm). Grain size measurements by the authors have confirmed the size versus concentration relationship noted by Cornwall. Therefore, crushing to about 180 mesh would be necessary to separate the fine grained accessory chromite from the silicate gangue.

The composition of the accessory chromite differs markedly from segregated chromite (Fig. 4 and Table 2). Accessory chromite is lower in Cr/Fe and Cr_2O_3 than segregated chromite. The metallurgical industry pays premium prices for chromite with high Cr_2O_3 and high Cr/Fe ratios. Thus the accessory chromite in the Emma Bell deposit, which accounts for most of the resources, is not as desirable as the segregated chromite, although it is still suitable for metallurgical use.

One other potentially troubling aspect of the Emma Bell accessory chromite is the unusual compositional zoning (Table 3 and Fig. 5). The bright areas of the chromite grains (Fig. 5) are significantly iron rich (FeO=26-29 percent, Fe_2O_3=19-49 percent, Cr_2O_3=19-49 percent). These compositions are not suitable for metallurgical use and about 10 percent of the accessory chromite grains studied exhibit this type of zoning. Therefore a detailed and systematic study of accessory chromite compositions and textures is needed at the Emma Bell deposit in order to properly assess the possible effect of the zoning on the economic potential.

Summary

Surface examinations plus drilling have delineated over 5 million tons of chromite resources at about 4 percent Cr_2O_3 in the Emma Bell deposit. The most important problem in mining the low-grade chromite for metallurgical use would be the fine-grained nature and relatively high iron content of the accessory chromite. However, the very large tonnage might overcome the adverse characteristics.

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Table 1.-- Resource estimates for the Upper and Lower Emma Bell units.

Cumulative Indicated Resources			Noncumulative Indicated Resources		
Cut off (% Cr_2O_3)	Metric Tons	Percent Cr_2O_3	%Cr_2O_3	Metric Tons	Percent Cr_2O_3
0	5,400,000	4.1	<1%	1,200,000	0.5
1	4,100,000	5.2	1-2%	1,100,000	1.4
2	3,000,000	6.5	2-3%	1,000,000	2.3
3	2,000,000	8.6	3-5%	900,000	3.9
5	1,100,000	12.5	5-10%	500,000	6.7
10	500,000	18.3	10-20%	300,000	11.4
20	300,000	26.5	<20%	300,000	26.5

Table 2.-- Electron microprobe analyses of some massive and accessory chromites.

	MASSIVE				ACCESSORY			
Sample #:	1-79:59	79-1:11	79-1:62	1-78:108	79-7:147	14-79:59	79-1:82	1-78:94
Cr_2O_3	57.80	60.15	59.50	58.85	56.28	56.29	54.92	55.82
Al_2O_3	9.94	9.30	9.86	8.96	9.97	9.60	9.66	9.05
[1]Fe_2O_3	4.20	2.59	2.89	4.79	3.40	4.26	3.64	5.63
FeO	14.97	17.27	17.35	16.25	21.31	20.48	22.58	20.30
MgO	11.94	10.54	10.76	11.25	7.63	8.39	6.76	8.60
NiO	0.10	0.05	0.06	0.09	0.15	0.00	0.02	0.10
TiO_2	0.26	0.25	0.31	0.28	0.28	0.27	0.29	0.25
SiO_2	0.09	0.00	0.00	0.00	0.00	0.11	0.15	0.22
ZnO	0.14	0.07	0.01	0.02	0.11	0.06	0.00	0.09
MnO	0.44	0.42	0.43	0.37	0.51	0.55	0.63	0.46
Total	99.88	100.62	100.82	100.85	99.64	99.99	98.65	100.53
Cr/Fe	3.398	3.065	3.018	3.187	2.324	2.419	2.140	2.419

[1] Fe_2O_3 Calculated assuming spinel stoichiometry

Table 3.-- Composition of some Fe-rich zones in accessory chromite grains.

Sample Number:	79-1:82	13-79:84.5	79-1:84.5	79-7:147
Cr_2O_3	18.78	26.05	48.92	48.94
Al_2O_3	1.48	0.72	0.23	0.09
[1]Fe_2O_3	49.02	43.05	19.71	19.02
FeO	29.37	26.87	26.18	26.49
MgO	1.66	2.92	3.78	3.14
NiO	0.02	0.34	0.00	0.17
TiO_2	0.15	0.26	0.65	0.89
SiO_2	0.22	0.19	0.18	0.00
ZnO	0.00	0.20	0.02	0.30
MnO	0.43	0.52	0.86	0.83
Total	101.13	101.12	100.53	99.87
Cr/Fe	0.56	0.85	1.64	1.63

[1]Fe_2O_3 Calculated assuming spinel stoichiometry

Figure 1.-- Map of California showing general location of Emma Bell deposit, Siskiyou County.

Figure 2.-- The Seiad Ultramafic complex: simplified map of bedrock geology, h: harzburgite, d: dunite and peridotite, lh: lherzolite, g: granulite, a: amphibolite, ms: marble and metasedimentary rocks, gsc: greenschist.

Figure 3.-- Locations of Upper, Lower and Tail Emma Bell deposit and their relationship to other deposits in the area

Figure 4.-- Compositional differences between segregated and accessory chromites.

Figure 5.-- Photos showing the unusual Fe-rich zones, light areas, in some accessory chromite grains

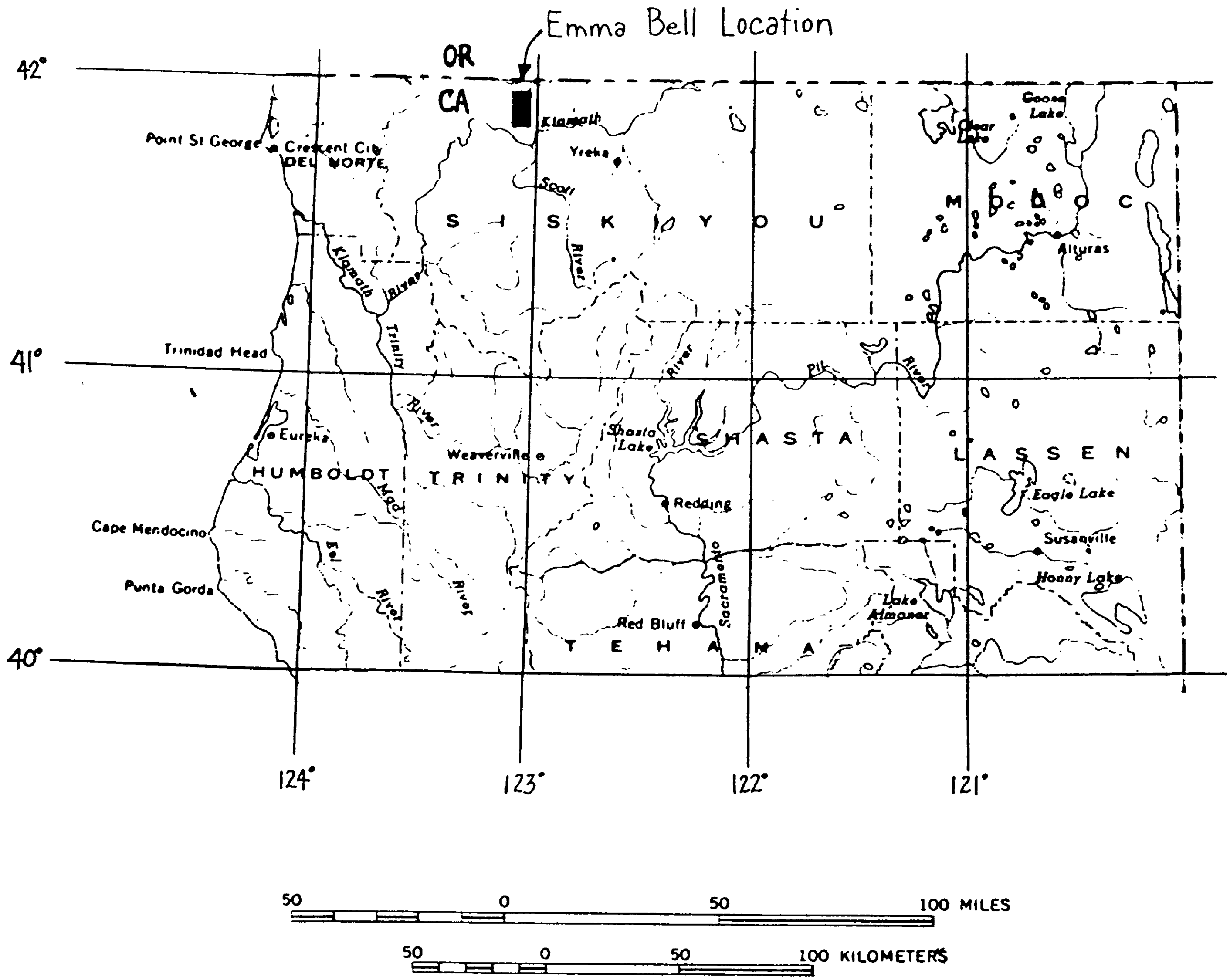
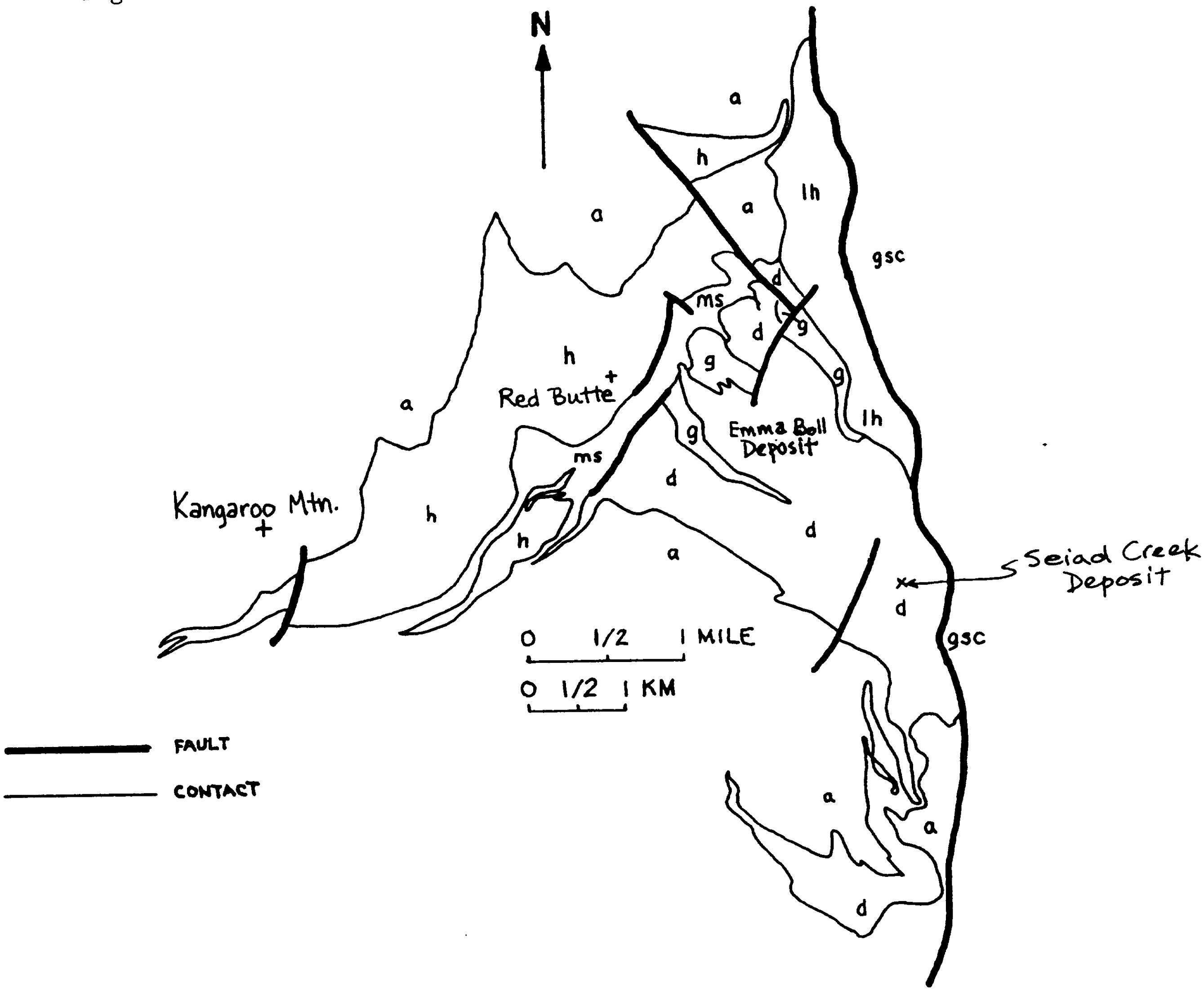

Emma Bell Location
OR
CA
42°
41°
40°
124°
123°
122°
121°
Point St George
Crescent City
DEL NORTE
Klamath
Yreka
Scott
S I S K I Y O U
M O D O C
Goose Lake
Clear Lake
Alturas
Klamath River
Trinity
Trinidad Head
River
Pit
River
Eureka
Weaverville
Shasta Lake
S H A S T A
L A S S E N
HUMBOLDT
T R I N I T Y
Redding
Eagle Lake
Cape Mendocino
Mad
Susanville
Eel
River
River
Sacramento
Honey Lake
Punta Gorda
Lake Almanor
Red Bluff
T E H A M A
50 0 50 100 MILES
50 0 50 100 KILOMETERS

Figure 1.

Figure 2.


N
a
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Red Butte
lh
Emma Boll Deposit
g
ms
d
Kangaroo Mtn.
h
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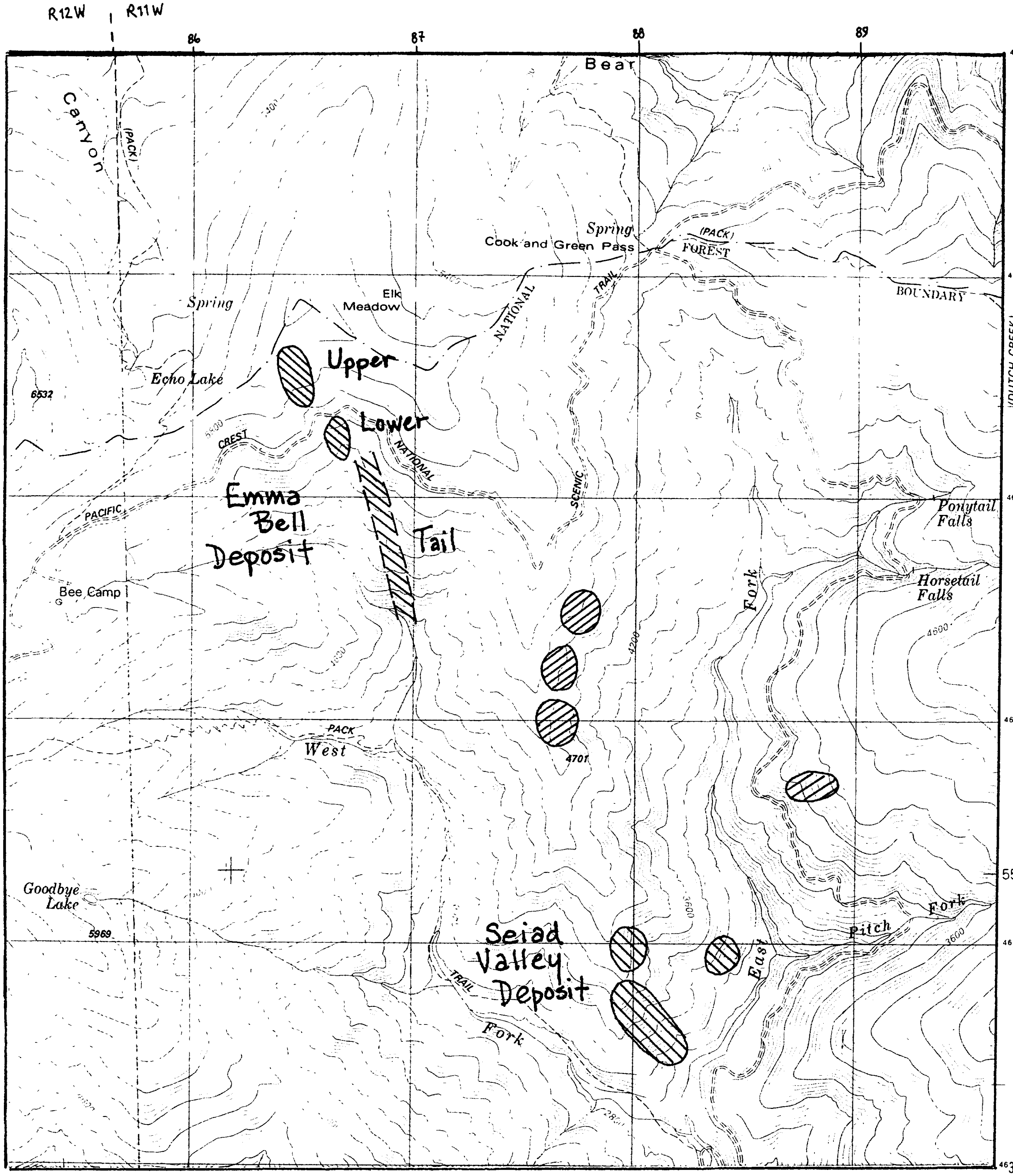
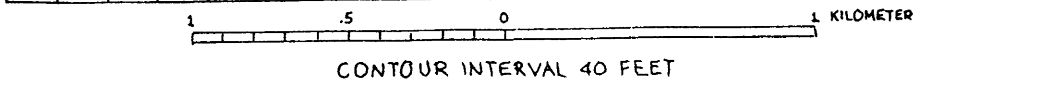
a
Seiad Creek Deposit
d
0 1/2 1 MILE
gsc
0 1/2 1 KM
FAULT
CONTACT
a
a
d



QUADRANGLE LOCATION

SCALE 1:24 000



CONTOUR INTERVAL 40 FEET

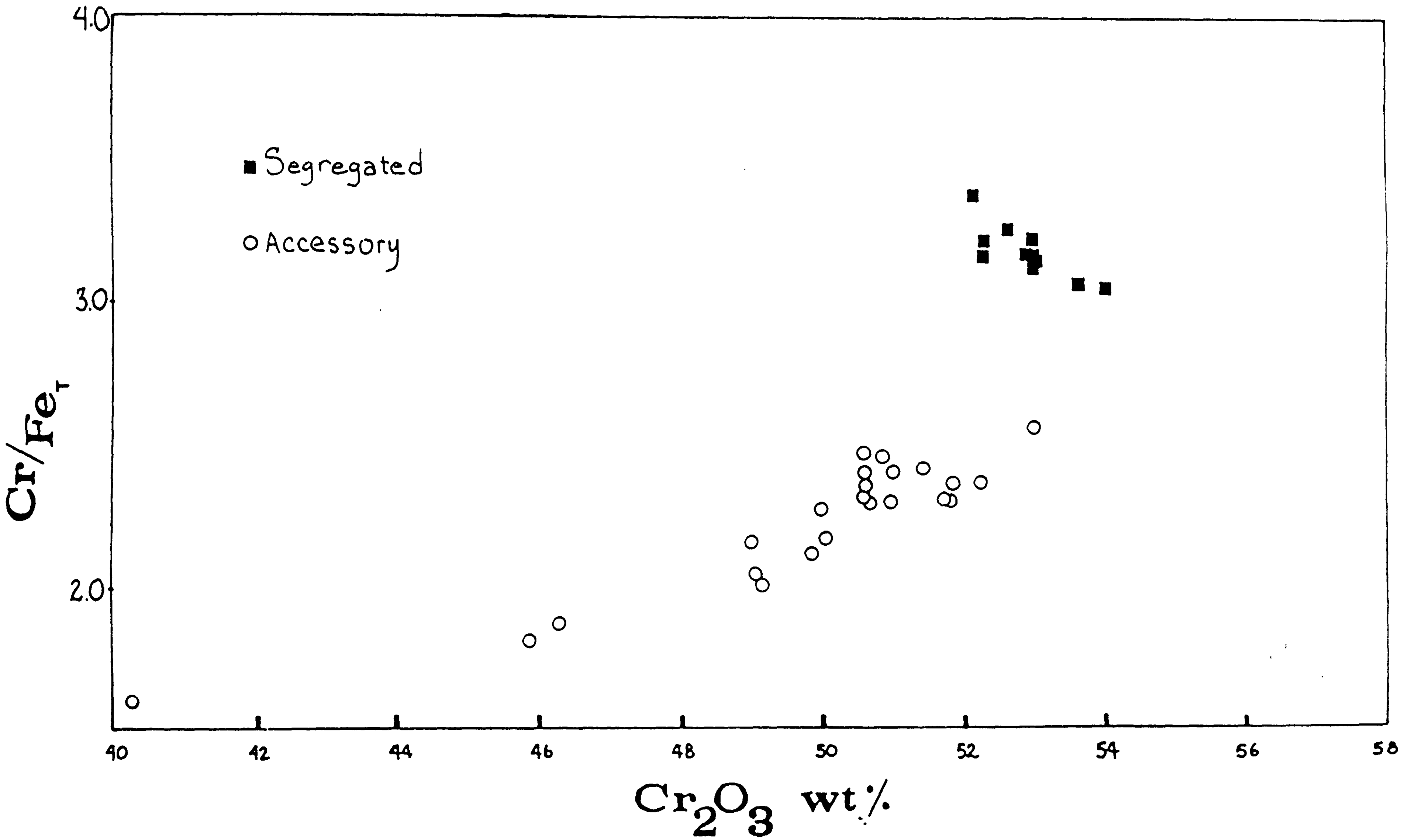
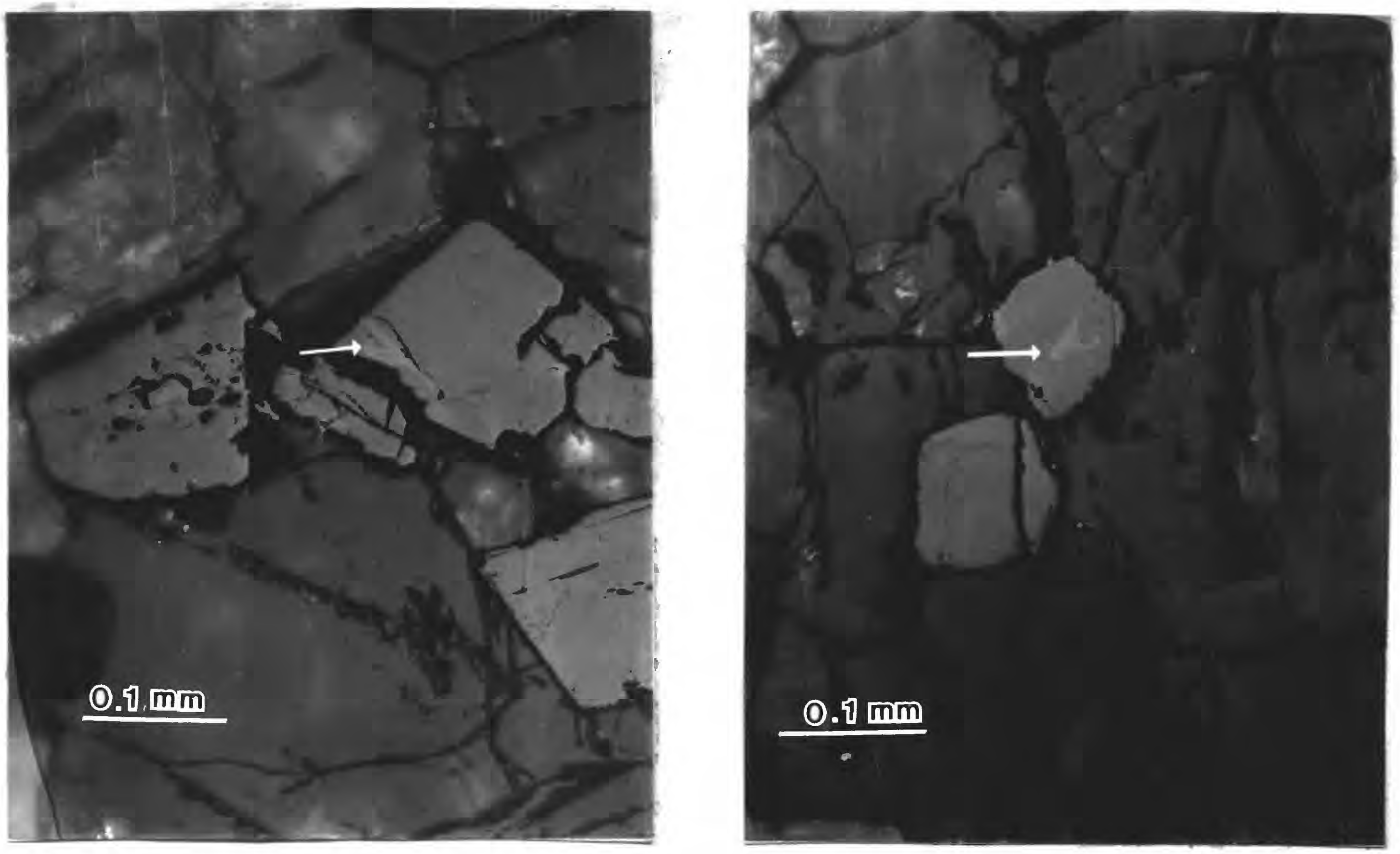

Segregated
Accessory
4.0
3.0
2.0
Cr/Fe_T
40
42
44
46
48
50
52
54
56
58
Cr2O3 wt%

Figure 4.



(a) (b)

Figure 5.