SHORT COMMUNICATION

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Cr-V-manganospinels in metamorphic rocks, Lake Baikal, Russia

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MANGANOSPINELS — manganochromite $(Mn,Fe)(Cr,V)_2O_4$, and vuorelainenite $(Mn,Fe)(V,Cr)_2O_4$, are very rare minerals. Manganochromite was first described by Graham (1978) from the Nairne pyrite deposit, South Australia. Manganese vanadium spinel was first reported by Long *et al.* (1963) as an unnamed mineral in their study of karelianite from Outokumpu. Later it was found at the Sätra pyrite deposit by Zakrzewski *et al.* (1982) and named after Yrjö Vuorelainen, discoverer of the Outokumpu manganese vanadium spinel. As may be seen in Fig. 1, a number of spinel grains from Sätra have a manganochromite composition. Until recently only one other occurrence of manganochromite had been noted, that in the Burkhala meteorite, by Yaroshevsky *et al.* (1989). During a recent investigation of quartzite-schists sampled by the author from Baikal, a Cr-V-manganospinel was identified (Boronichin *et al.*, 1990). In this communication new chemical data for the Baikal manganoan spinels are reported.

The Cr-V-manganospinels were discovered in kyanite-sillimanite-cordierite schists on the west shore of Lake Baikal, 4 km south of the Maloye More Strait. The quartzite-schists form a part of a layered metamorphic sequence (Olkhon series) consisting of calciphyres, marbles, quartzites and pyroxene-amphibole schists. All the rock varieties and especially the quartzite-schists are enriched in graphite (the carbon content is up to 10 wt.% in pyrrhotite- and pyrite-rich layers). The Cr and V contents are somewhat elevated in all the metasediments of the Olkhon series, but particularly in graphitic quartzites and quartzite-schists (up to

TABLE 1. Chemical composition of rock samples studied

Sample	PO451	PO643	PO1474	PO1845
SiO_2	69.84	69.20	65.42	70.10
TiO_2	0.92	0.84	1.01	0.99
Al_2O_3	11.85	11.44	13.05	13.37
Fe_2O_3	0.80	1.40	4.05	0.60
FeO	0.60	0.81	0.43	2.51
MnO	0.01	0.01	0.02	0.03
MgO	1.02	1.13	1.31	1.25
CaO	2.50	1.71	1.52	1.08
Na_2O	1.96	2.73	1.37	2.56
K_2O	3.83	2.83	3.76	3.91
P_2O_5	0.09	0.08	0.07	0.08
CO_2	n.d.	n.d.	n.d.	n.d.
C	5.61	5.90	3.13	0.91
S	0.56	0.52	2.89	0.30
H_2O	0.34	0.81	1.51	2.00
Total	99.93	99.41	99.54	99.69
Cr, ppm	600	500	2900	2900
V	700	600	400	310

Analyses were performed at the Irkutsk Institute of Geochemistry by XRF (petrogenic components), quantitative spectral (Cr and V) and chemical (volatile components) methods.

TABLE 2. Microprobe analyses of spinel

Analyses	1	2	3	4	5	6	7	8	9	10
TiO_2	0.12	0.01	0.16	0.05	0.12	0.03	0.08	0.44	0.60	0.57
V_2O_3	5.89	8.82	10.32	13.44	15.84	18.97	20.00	24.29	30.11	39.33
Cr_2O_3	64.24	60.00	59.43	54.89	52.62	48.73	49.44	43.78	37.52	28.42
FeO	12.00	12.18	13.84	12.37	11.86	12.74	10.48	9.73	10.12	9.92
MnO	7.76	11.79	9.90	12.52	13.19	13.54	15.73	19.15	18.84	20.27
MgO	4.56	2.47	3.69	1.88	2.22	2.24	0.91	–	–	–
ZnO	5.79	4.89	2.94	4.94	4.01	3.22	3.96	2.88	2.97	2.32
Total	100.36	100.16	100.28	100.09	99.86	99.49	100.60	100.27	100.16	100.83

Structural formulae based on 4 oxygens with total Fe as FeO

1. $(Fe_{0.360}Mn_{0.236}Mg_{0.244}Zn_{0.154})_{\Sigma 0.994}(Cr_{1.824}V_{0.170}Ti_{0.003})_{\Sigma 1.997}O_4$
2. $(Fe_{0.373}Mn_{0.366}Mg_{0.135}Zn_{0.132})_{\Sigma 1.006}(Cr_{1.736}V_{0.259})_{\Sigma 1.995}O_4$
3. $(Fe_{0.418}Mn_{0.303}Mg_{0.198}Zn_{0.078})_{\Sigma 0.997}(Cr_{1.695}V_{0.299}Ti_{0.004})_{\Sigma 1.998}O_4$
4. $(Fe_{0.380}Mn_{0.390}Mg_{0.103}Zn_{0.134})_{\Sigma 1.007}(Cr_{1.596}V_{0.396})_{\Sigma 1.992}O_4$
5. $(Fe_{0.364}Mn_{0.410}Mg_{0.121}Zn_{0.109})_{\Sigma 1.004}(Cr_{1.526}V_{0.466}Ti_{0.003})_{\Sigma 1.995}O_4$
6. $(Fe_{0.393}Mn_{0.423}Mg_{0.123}Zn_{0.088})_{\Sigma 1.024}(Cr_{1.420}V_{0.561})_{\Sigma 1.981}O_4$
7. $(Fe_{0.321}Mn_{0.498}Mg_{0.050}Zn_{0.107})_{\Sigma 0.976}(Cr_{1.432}V_{0.588}Ti_{0.002})_{\Sigma 2.022}O_4$
8. $(Fe_{0.300}Mn_{0.599}Zn_{0.079})_{\Sigma 0.978}(Cr_{1.279}V_{0.719}Ti_{0.012})_{\Sigma 2.010}O_4$
9. $(Fe_{0.312}Mn_{0.600}Zn_{0.081})_{\Sigma 0.993}(Cr_{1.096}V_{0.892}Ti_{0.017})_{\Sigma 2.005}O_4$
10. $(Fe_{0.304}Mn_{0.630}Zn_{0.063})_{\Sigma 0.997}(Cr_{0.824}V_{1.157}Ti_{0.016})_{\Sigma 1.997}O_4$

Analyses 1–6 — sample PO1474, 7 — PO643, analyst: L.F. Suvorova;
Analyses 8–10 — sample PO451, analyst: V.A. Boronichin.

3500 ppm Cr and 1000 ppm V). They contain many rare Cr-V-minerals including eskolaite (Cr_2O_3), karelianite (V_2O_3), schreyerite ($V_2Ti_3O_9$), olkhonskite[1] ($(Cr,V)_2Ti_3O_9$), berdesinskiite (V_2TiO_5) and Cr-V-manganospinels. The bulk chemical compositions of spinel-bearing rocks are given in Table 1.

The manganospinel occurs in trace amounts, as small (usually <100 μm) black, euhedral crystals with a metallic lustre. Occasionally, larger crystals (up to 0.5–1 mm) can be found.

Electron-microprobe analyses (Table 2) have been done with a JCXA-733 using pyrope, sphalerite, chromite, ilmenite, synthetic V_2O_5 and $MnFe_2O_4$ as standards. The atomic proportions have been calculated on the basis of four oxygen atoms in the spinel formula taking Fe, Mn and Zn as divalent, and V and Cr as trivalent.

The chemical composition of the spinel is constant within single grains but varies significantly between separate crystals, especially between those from different layers. The most significant variations are those for V_2O_3 (5.45–39.33 wt.%), Cr_2O_3 (28.42–65.83 wt.%) and MnO (1.76–20.52 wt.%). As can be seen from Fig. 1, the Baikal manganospinels fall mainly within the manganochromite and chromite fields, and only three analyses correspond to vuorelainenite. Both the manganochromite and the vuorelainenite differ from the examples from Nairne, Sätra and Outokumpu manganospinels in having a higher Fe/Mn ratio.

An increasing Cr/V ratio in Baikal spinels is accompanied by an increase of the (Fe+Zn+Mg)/Mn ratio to form a continuous isomorphous series between chromite, manganochromite and vuorelainenite. As shown in Fig. 1, the spinel composition varies greatly even within the same sample. Such a wide compositional range is evidently due to chemical variations in the thin alternate layers of quartzite-schists: spinels from more graphitic layers contain more V and Mn, whereas those from less graphitic, kyanite-bearing layers are more chromian and ferrous. This appears to reflect the initial uneven distribution of Cr and V in the sediments which was inherited through regional metamorphism because of the extremly low mobility of these elements.

[1] The mineral has been recently approved by the Commission on New Minerals and Mineral Names of the International Mineralogical Association (Koneva *et al.*, 1994).

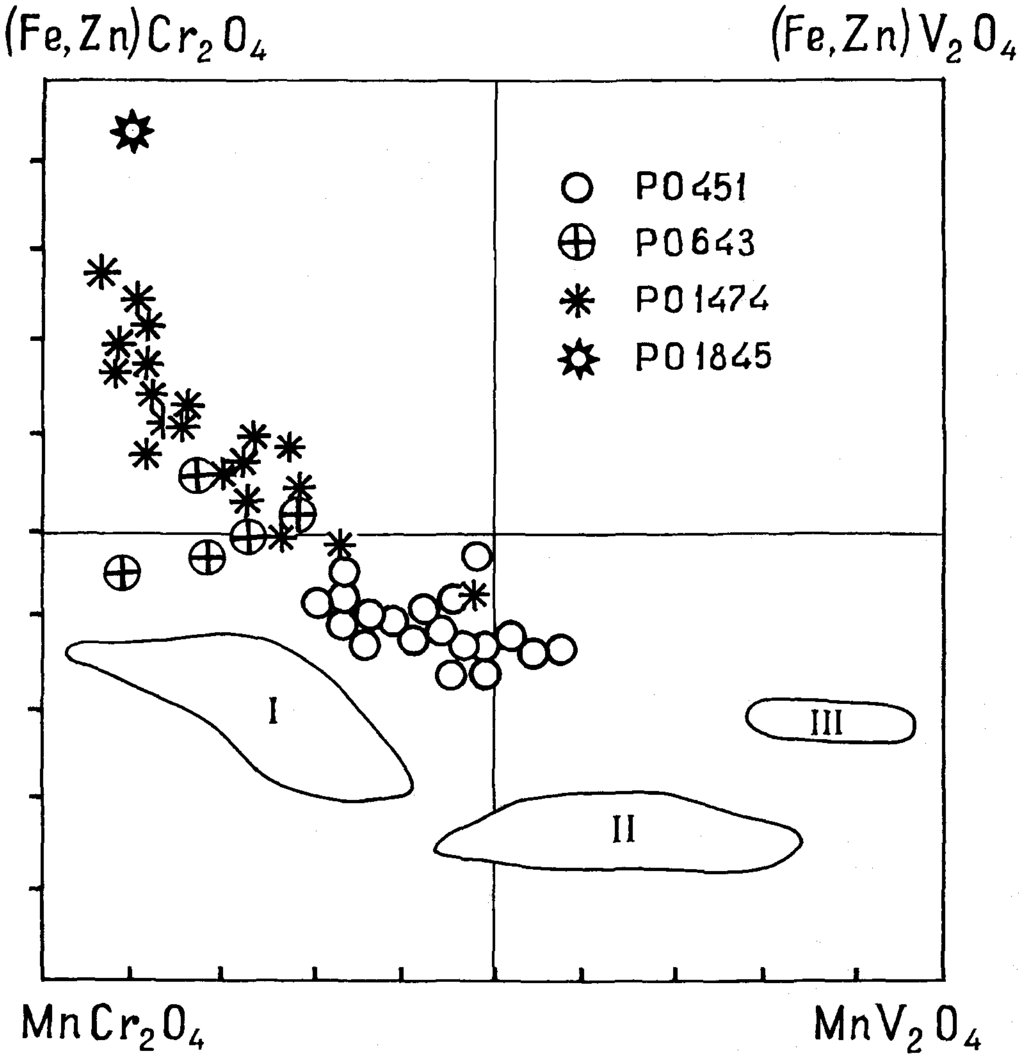

FIG. 1. Chemical composition of Baikal manganospinels in comparison with manganochromite. (I, Nairne; Graham, 1978) and vuorelainenite (II, Sätra; Zakrzewski *et al.*, 1982 and III, Outokumpu; Long *et al.*, 1963) in the field MnV_2O_4–$MnCr_2O_4$–(Fe,Zn)Cr_2O_4–(Fe,Zn)V_2O_4.

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