Mineral Commodity Report 3 — Chromium

by Tony Christie, Bob Brathwaite, and Mike Johnston

Institute of Geological and Nuclear Sciences Ltd

Symbol	Cr
Atomic no.	24
Atomic wt	52.00
Specific gravity	7.19
Valence	6, 3, 2
Melting point	1890˚C
Boiling point	2482˚C
Crustal abundance	100 ppm
Preferred analysis method	plasma atomic emission spectroscopy
Routine detection limit	1 ppm

Discovery and Origin of Name

Chromium was discovered by the French chemist Louis-Nicolas Vauquelin in 1797 and isolated as a metal a year later. Chromium ores were first mined in Norway in 1820. Stainless steel, the current major end use of chromium, was developed in 1900.

The name chrome is derived from the Greek *chroma* for colour, on account of the brilliant colours of its compounds.

Major Ores and Minerals

Chromite is the only commercial chromium ore. It is a mineral of the spinel group and has the ideal formula $FeCr_2O_4$. Magnesium may replace iron and aluminium, and aluminium may replace chromium and therefore natural chromite is a complex mineral and has the general formula $(Fe,Mg)O(Cr,Al,Fe)_2O_3$. Pure chromite contains 67.9% Cr_2O_3 but natural chromite rarely contains more than 50% Cr_2O_3. Chromite ore and concentrates are generally marketed in grades based on Cr_2O_3 content.

Ultramafic rocks have a high concentration of chromium, typically about 1000 to 3000 ppm, compared with an average crustal abundance of about 100 ppm.

Properties

Chromium, a member of Group VIb in the transition metals of the periodic table, is a hard, steel-grey metal that takes a high polish. When pure, it is ductile, but even small amounts of impurities render it brittle. Chromite is an isometric mineral and is octahedral when found in crystals, resembling magnetite, but because crystals are rare, the typical form is massive. Chromite is iron-black to brownish black in colour, has a metallic to sub-metallic lustre, a hardness of 5.5 and specific gravity of 4.6.

Formation

Chromite crystallises from mafic and ultramafic magmas and collects as masses formed by early crystal settling, by late gravitative liquid accumulation, or by liquid injection. Two main types of primary deposits are distinguished: stratiform and podiform. The stratiform deposits form extensive layers within pyroxenite-norite zones of stratified mafic-ultramafic complexes and are remarkably uniform in thickness and grade, in some places over tens of kilometres. Podiform deposits occur as irregular pods or lenses within peridotites, especially dunites, of ophiolite belts, and vary widely in size and grade. Weathering of the stratiform and podiform deposits produces detrital chromite in alluvial and beach sands.

Uses

The main use of chromium is for alloying with iron to produce steels that have high strength and hardness, with resistance to oxidation and breakdown at high temperatures. Stainless steel typically contains 18% Cr and 8% Ni. Special chrome alloys, such as stellite, using also W, Mo and Co, yield hard, high-speed tool steel. Nichrome and chromel, consisting largely of Ni and Cr, are used for heating coils because they have low electrical conductivity and resist corrosion, even at red heat.

Chromium's bright colour and resistance to corrosion make it ideal for plating plumbing fixtures, automobile bumpers and decorative pieces. Chromium is also used as a refractory to protect furnace linings, in dyes, tanning, bleaches, pigments, and as an oxidising agent in the chemical industry.

Price

The average price for chromium (99% Cr), quoted by the London Metals Exchange during 1992, was about US$2.90 per pound (0.45 kg), whereas South African chromite ore (friable lumpy basis 44% Cr_2O_3) sold for about US$62 per tonne and Turkish ore (lumpy, 48% Cr_2O_3) sold for US$170 per tonne.

World Occurrence and Production

Known chromite resources are dominated by the Bushveld and Great Dyke stratiform complexes in South Africa and Zimbabwe, and the podiform deposits in Kazakhstan (formerly part of USSR). Significant resources (>10 million tonnes of ore) are also present in the podiform deposits of Turkey, India, Finland, Phillippines, Albania and Brazil.

Annual world production of chromite ores and concentrates is about 10 to 13 million tonnes (10.6 Mt in 1992; Coope 1993).

Chromium is produced from chromite in several ways. Chromite is roasted with soda ash (Na_2CO_3) to form sodium dichromate ($Na_2Cr_2O_7$) which is then reduced by heating with coke to form green chromic oxide (Cr_2O_3). In the Goldschmidt, or thermite, process the chromic oxide is intimately mixed with aluminium and heated. The chromic oxide is reduced to chromium metal, 97 to 99% pure, the reaction producing a large quantity of heat.

An alternative method obtains pure chromium by reduction of the chromic oxide by either carbon or silicon in an electric arc furnace. By electrolysis of either chrome alum or chromic acid solutions, a deposit of approximately 99.8% metallic chromium can be obtained at the cathode.

Ferrichrome, a mixture of chromium and iron used in the manufacture of chrome steel, is obtained by the treatment of chromite with coke in an electric furnace.

New Zealand Occurrence, Production and Imports

No chromite is currently mined in New Zealand: all our chromium requirements are imported, amounting to approximately 200 tonnes (t) of chromite ore annually. However, chromite has been mined in the past and between 1859 and 1902 about 6000 t of chromite, at a grade of 20-54% Cr_2O_3, were mined in east Nelson at Dun Mountain, Croisilles Harbour and D'Urville Island (Figures 1, 2 and 3). Mining was in three distinct periods: in the 1860s for manufacture of dyes, in the 1880s for use in tanning and in about 1900 for steel manufacture. The known remaining resources of chromite are very small and in some of the deposits the chromite has detrimentally high concentrations of iron or aluminium.

The chromite occurs in podiform type deposits associated with a belt of ultramafic rocks (Dun Mountain Ophiolite Belt of Permian age) in the South Island and in small peridotite and serpentinite bodies near North Cape, Wellsford and Piopio in the North Island.

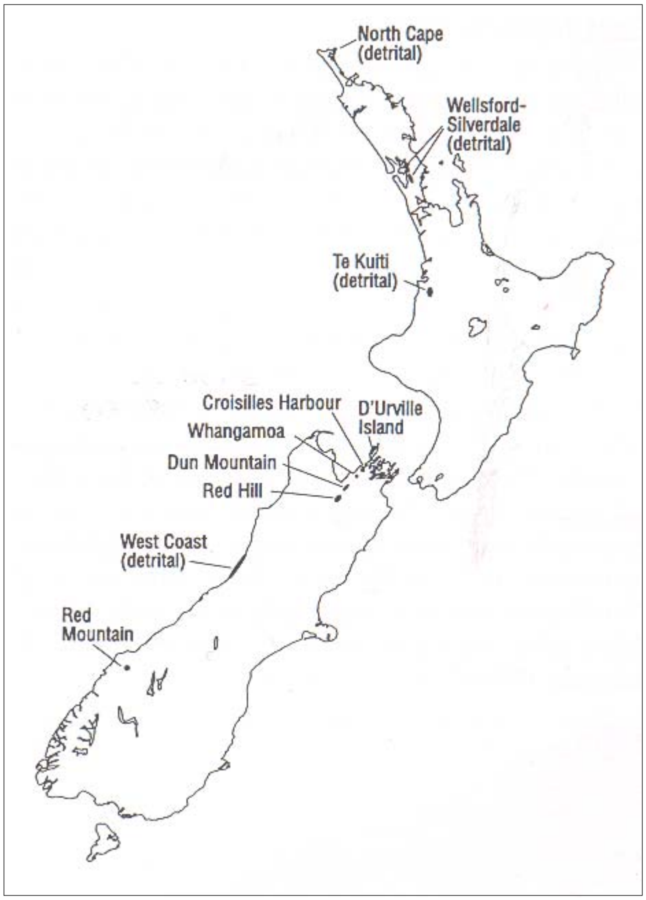

Figure 1: Location of chromite deposits in New Zealand.

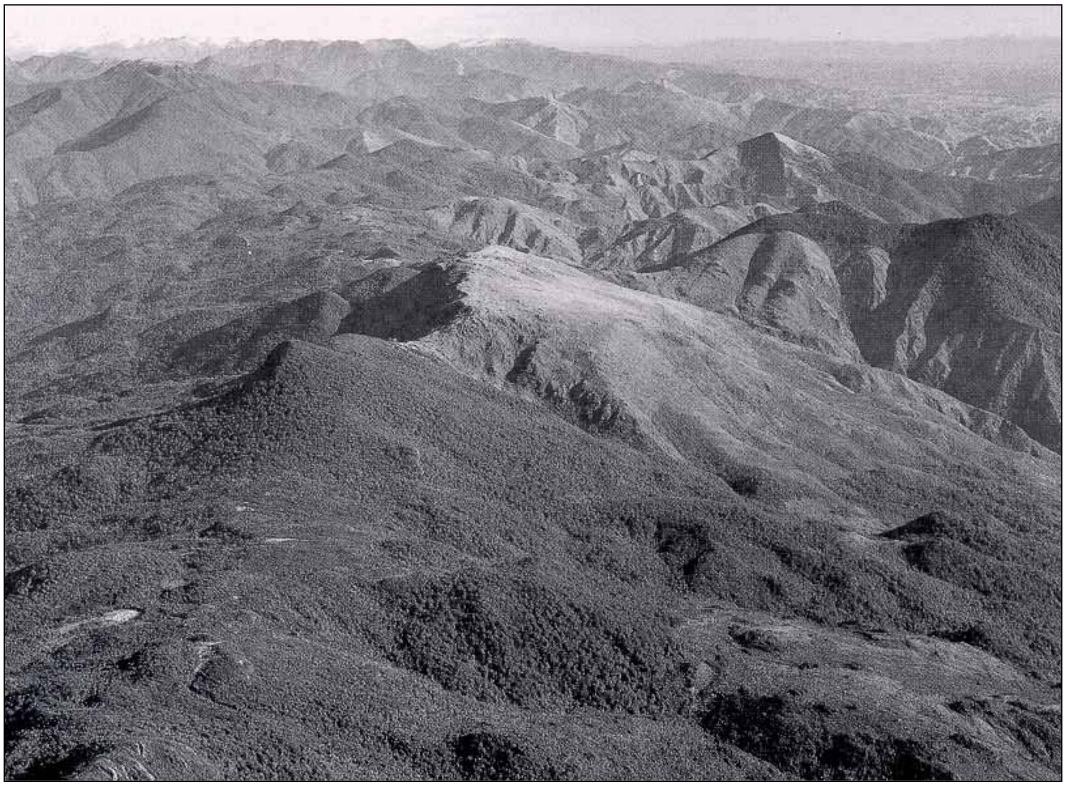

Figure 2: Dun Mountain (centre) area of east Nelson from which almost all of New Zealand's chromite was produced (Photo: Lloyd Homer).

Other chromium-bearing minerals found in New Zealand include fuchsite (chrome mica) and uvarovite $Ca_3Cr_2(SiO_4)_3$, and their locations were listed by Railton & Watters (1990), however they are of no economic importance.

East Nelson area

Chromium and copper were prospected in the Dun Mountain Ophiolite Belt ("Mineral Belt"), particularly on Wooded Peak in the Dun Mountain area from the 1850s (Figure 2). Prospecting concentrated on chromite following the discovery of chromium compounds which could be used as pigments, particularly those green in colour. The deposits worked were typically of small size, and production in most cases did not exceed several hundred tonnes. About 5000 t were extracted from Wooded Peak between 1859–1866, at grades between 20 and 54% Cr_2O_3 (Officers of the New Zealand Geological Survey 1970). Small tonnages were also extracted in the early 1860s from loose blocks near Croisilles Harbour and from *in situ* lenses in the Serpentine and Hacket valleys. Mining collapsed due to low prices for chromite brought about by oversupply on the English market, disruption to the English cotton industry from the American Civil War, the discovery of aniline dyes, and the depletion of the higher grade and readily accessible deposits in east Nelson (Johnston 1987).

The deposits in the area between Dun Mountain and Lee River, particularly along the Dun Mountain Railway, were the most important. Other localities include Jackson Creek, Old Maungatapu Track, the head of Roding River, Chromite Creek, Serpentine valley, Miner Stream, Mt Starveall and Little Ben Nevis (Bell *et al.* 1911).

Mineralisation typically occurs as lenticular masses, pods, and layers of chromite within serpentinised dunite and harzburgite, disseminated grains within dunite and harzburgite, and as complete blocks of chromite in the Patuki (Old Maungatapu Track) and Croisilles (Mt Starveall) melanges (Johnston 1981). The best grades were obtained in Chromite Creek and Serpentinite River. The largest known deposits that were not mined are those at Jackson Creek, where the biggest lens is 4.3 m thick, and traceable for 27.4 m. Grades averaged 21.8–34% Cr_2O_3.

The deposits at Croisilles Harbour are blocks within the Patuki Melange and about 200 t (30.1–50.2% Cr_2O_3) were exported around 1900 (Morgan and Henderson 1919, Johnston 1987). Whangamoa, north of Dun Mountain, was prospected in 1880 following unsuccessful exploration for copper (Cox 1882, Johnston 1987). Trenches and drives did not locate the source of high grade chromite boulders lying on the surface which are derived from blocks in the Patuki Melange (Johnston

Figure 3: Chromite mines at the terminus of the Dun Mountain Railway, 1863. The mines produced over 5000 t of chromite ore between 1859 and 1866 (Photo: Alexander Turnbull Library).

1993). Detrital chromite in Lee River is derived from weathering of "Mineral Belt" serpentinites.

Chromite occurs in the serpentinite of the Dun Mountain Ultramafic Belt on D'Urville Island and some may have been mined (Williams 1974). A sample from Te Akau contained 38% Cr_2O_3 (Dominion Analyst 1940) and a detrital sample from Hapuka Point contained 42.80% Cr_2O_3 and 23.65% Al_2O_3 (Hutton 1950).

Chromite was reported by Henderson (1924) and Challis (1965) from the Red Hills in the upper Motueka Valley, about 50 km south of Dun Mountain. The chromite occurs as disseminated grains and layers up to 50 mm thick in dunite and harzburgite. Two analyses of chromite have given Cr_2O_3 abundances of 38.01% and 39.51%.

West Nelson

Henderson (1923) reported a chromite-bearing band 30 to 60 cm wide in a zone of platy serpentinite, 120 m south of Asbestos Creek in the upper Takaka Valley. Small chromite-rich layered segregations are present in the ultramafic zones of the Cobb Igneous Complex of probable Middle Cambrian age (Hunter 1977). The chromite segregations are enriched in platinum (up to 1100 ppb Pt; Stegman 1987).

Westland and Northwest Otago

Chromite is widespread in ultramafic rocks throughout the southern segment of the ophiolite belt, occurring as disseminated crystals, masses, pods, layers parallel to crystal lamination, and fissure-form chromite–serpentine bands (Mutch 1965). Podiform chromite segregations occur at Red Mountain and on Serpentine Saddle. Some segregations are up to 1 m thick and extend for several metres, and although the total amount of chromite present is significant, it is widely disseminated (Mackenzie 1984b).

Turner (1930) reported chromite layers 1–3 mm thick, locally with over 80% chromite, in dunite at the head of a stream that drains into Woodhen Creek near Martyr Hill. During 1982–84 CRA undertook a survey of the Dun Mountain Ophiolite Belt to assess the potential for chromite as well as precious and other base metals. Although chromite-rich laminae, similar to those noted by Turner, were seen, rock chip sampling revealed Cr_2O_3 contents of less than 20% (Mackenzie 1984b).

MacKenzie (1984a) noted relict chromite associated with disseminated pyrrhotite–pentlandite–chalcopyrite mineralisation and magnetite in serpentinite, and also reported rock assays (JBL Ltd) of up to 0.1% Cr and 5.2% Cu for massive sulphide from an unspecified locality in the Kokatahi River catchment.

Detrital Chromite

Small amounts of alluvial chromite are found in most streams draining the ultramafic belt and on the beaches north of Jackson Bay, but no anomalously high concentrations have been encountered.

Hunter (1975) noted the presence of detrital chromite in the Lockett Conglomerate west of the Cobb Dam and, on the basis of chemistry, suggested the material was derived from the Takaka Igneous Complex (Cobb Igneous Complex).

Potential and Prospectivity

The potential for discovery of chromite deposits of significant size in the Dun Mountain Ophiolite Belt appears to be limited, as indicated from the small size and discontinuous style of the lenses worked last century, and their confinement to the cumulate part of the ultramafic rocks which are largely preserved in the Dun Mountain area. No significant chromium mineralisation has been reported from the Pounamu Ultramafics in Westland but there may be some potential for small deposits in these rocks.

Future Trends

Chromium is expected to remain in demand for use in steel alloys, and to a lesser extent in industrial chemicals. South Africa, Zimbabwe and Russia currently produce about half of the annual chromite production. If their share of production is not increased, and current production rates continue, the known resources in most other countries will be exhausted in the next 20 years.

Chromite deposits mined for chromium do not have any by-product minerals and chromium is not mined as a by-product of mining any other mineral. There is potential for chromium to become a by-product of platinum mining in South Africa or a by-product of lateritic nickel mining.

Acknowledgements

David Skinner, Bill Watters, Alva Challis, and Bruce Thompson provided constructive reviews and comments on the manuscript and Jeff Lyall drafted the figure. The photographs were provided by Lloyd Homer and Alexander Turnbull Library. The Publicity Unit of Crown Minerals Operations Group, Ministry of Commerce provided funding and Roger Gregg is thanked for his support of the project.

References

Bell, J.M.; Clarke, E de C.; Marshall, P. 1911: The geology of the Dun Mountain subdivision, Nelson. *New Zealand Geological Survey bulletin 12.*

Challis, G.A. 1965: The origin of New Zealand ultramafic intrusions. *Journal of petrology 6:* 322–364.

Coope, B. 1993: Chromite. *In:* Bird, D. et al. eds, Metals & minerals annual review, volume 2 of Mining annual review, Mining journal pp 64–65.

Cox, S.H. 1882: Chrome deposits of Nelson. *New Zealand Geological Survey reports of geological exploration 14:* 1–10.

Dominion Analyst 1940: Chromite samples (Nelson District). Department of Scientific and Industrial Research, Dominion Laboratory, Institute of Geological and Nuclear Science Limited microfiche 659.

Henderson, J. 1923: Chrysotile asbestos in the upper Takaka district. *New Zealand journal of science and technology 6:* 120–123.

Henderson, J. 1924: The Motueka subdivision. *New Zealand Geological Survey annual report 18:* 4–6.

Hunter, H.W. 1975: Source of detrital chromite in northwest Nelson (note). *New Zealand journal of geology and geophysics 18:* 511–513.

Hunter, H.W. 1977: The geology of the Cobb Intrusives, Takaka valley, northwest Nelson. *New Zealand journal of geology and geophysics 20:* 469–502.

Hutton, C.O. 1950: Studies of heavy detrital minerals. *Geological Society of America bulletin 61:* 635–716.

Johnston, M.R. 1981: Sheet O27AC — Dun Mountain. Geological Map of New Zealand 1:50 000. Wellington, Department of Scientific and Industrial Research.

Johnston, M.R. 1987: High hopes, the history of the Nelson Mineral Belt and New Zealand's first railway. Nelson. Nikau Press.

Johnston, M.R. 1993: Geology of the Rai Valley area sheets O26 and O27BD. *Institute of Geological and Nuclear Sciences geological map 6.*

MacKenzie, I.F. 1984a: Final report on exploration licence 33-195, Whitcombe River, Westland: CRA Exploration Pty Ltd. Unpublished open-file mining company report, Institute of Geological and Nuclear Sciences Limited MR719, Ministry of Commerce M1398.

MacKenzie, I.F. 1984b: Final report on exploration licence 33-189, Olivine Range, Westland: CRA Exploration Pty Ltd. Unpublished open-file mining company report, Institute of Geological and Nuclear Sciences Limited MR732, Ministry of Commerce M1671.

Morgan, P.G.; Henderson, J. 1919: Chrome iron ore, mica, and tungsten ore in New Zealand. *New Zealand journal of science and technology 2:* 43–50.

Mutch, A.R. 1965: A prospector's guide to South Westland. *Department of Scientific and Industrial Research information series 44.*

Officers of the New Zealand Geological Survey 1970: Minerals of New Zealand (Part A: metallics 2nd Ed.). *New Zealand Geological Survey report 38A.*

Railton, G.T.; Watters, W.A. 1990: Minerals of New Zealand. *New Zealand Geological Survey bulletin 104.*

Stegman, C.L. 1987: Report on PL 31-1197 Asbestos Creek, northwest Nelson, New Zealand to May 1987: CRA Exploration Pty Ltd. Unpublished open-file mining company report, Institute of Geological and Nuclear Sciences Limited MR1005, Ministry of Commerce M1015.

Turner, F.J. 1930: The metamorphic and ultrabasic rocks of the lower Cascade valley, South Westland. *Transactions of the New Zealand Institute 61:* 170–201.

Williams, G.J. 1974: Economic geology of New Zealand. *Australasian Institute of Mining and Metallurgy monograph series No. 4.*