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Economic analysis of the Ring of Fire chromite mining play

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This paper has been commissioned by MiningWatch Canada to undertake a preliminary review of the economic issues surrounding chromite mining in the Ring of Fire mining area of northern Ontario. There is no experience with chromite mining or ferrochrome production in Canada, and none of the over 35 mineral exploration companies involved have carried out technical studies that look at the economic viability of their claims. As a result, this economic analysis is a work in progress that raises more questions more than it provides answers. The paper is organized as follows:

- Chromite characteristics, uses and environmental concerns
- Chromite and ferrochrome processing
- Supply, prices and markets
- Key issues regarding Ring of Fire economics:
    - Power requirements
    - Rail-line
    - Ferrochrome prodcution facility
    - The companies
    - Taxation and government subsidies
    - Water management
    - Shipping and peak oil
    - Sustainability
    - Feasibility of the mine projects

Kemi Chromite Mine, Finland

Chromite characteristics, uses and environmental concerns

Chromium is a chemical element with the symbol Cr. It is a bluish, hard, lustrous metal with a very high melting point (1857°C)[1]. It is odourless, tasteless and malleable. It has high corrosion resistance. It has unique magnetic properties; at room temperature and below it shows antiferromagnetic properties.[2] Exposed to air, it reacts with oxygen and forms a thin protective oxide surface layer that prevents rusting

Although many minerals contain chromium in low concentrations, the only commercial ore mineral is chromite, an iron chromium oxide ($FeCr_2O_4$). [3] Chromite is found in peridotite from the Earth's mantle. It also occurs in layered ultramafic intrusive rocks and in metamorphic rocks such as serpentine, and corundum.[4]

Because of its corrosion resistance and hardness, chromium is combined with iron and nickel to form stainless steel and/or super steel alloys; 94% of chromium is used for this purpose.[5] Its other uses are chrome electro-plating and refractory uses. Some chromium is still used in paint as it changes colours in combination with other elements. It is sometimes used for leather tanning, and as a dietary supplement, although these uses are falling into increased disrepute because of the toxicity of their by-products.

The most common and stable form of chromium is trivalent CR(III) which is not generally considered toxic. Another form of chromium - hexavalent chromium CR(VI) is, however, highly toxic. It is a powerful oxidant at low or neutral pH. It is produced industrially by the oxidative roasting of chromite with calcium or sodium carbonate. It is generally believed that Cr(VI) is only created by human agency.[6] The relationship between Cr(III) and Cr(VI) depends on pH and oxidative properties of the environment. Ground water has been known to contain up to 39µg/L of total chromium of which 30µg is present at Cr(VI).[7]

Residues from mining and processing chromite are often toxic, not only because of the presence of Cr(VI) but because of the reagents and other waste materials in overburden and wastes. Abandoned and closed chromium production sites require long-term monitoring, containment and clean-up.[8] Cr(VI) is particularly toxic when inhaled and it can cause severe damage to the lungs, kidneys, liver and blood cells. It is also carcinogenic.[9]

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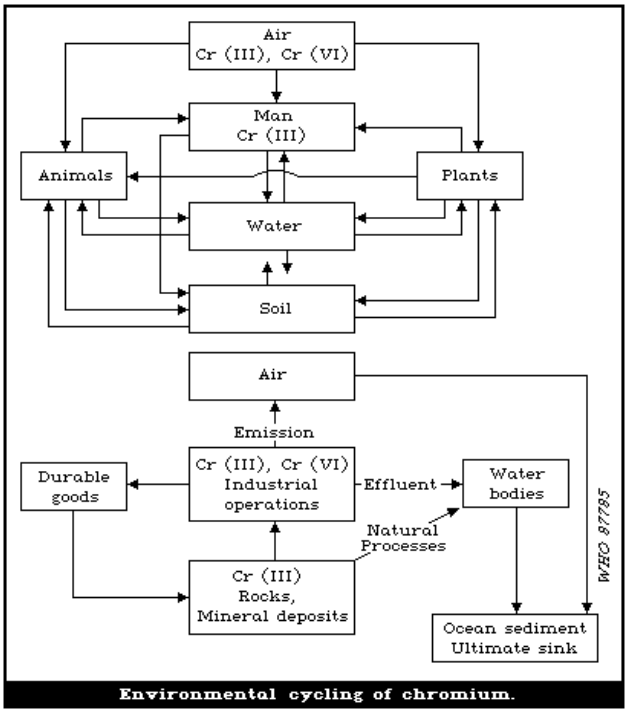
[1] The Element Chromium. *The Periodic Table.* http://www.periodic-table.org.uk/element-chromium.htm
[2] Chromium, *Wikipedia*, http://en.wikipedia.org/wiki/Chromium and
Chromium, *The Encyclopaedia of Earth*. http://www.eoearth.org/article/Chromium
[3] Chromite, *Absolute Astronomy*. http://www.absoluteastronomy.com/topics/Chromite
[4] ibid.
[5] http://www.roskill.com/reports/steel-alloys/chromium
[6] Chromium, *Wikipedia,* http://en.wikipedia.org/wiki/Chromium
[7] A. R. Gonzalez, K. Nhung'u, A.R. Flegal. Natural Occurrence of hexavalent chromium in the Aromas Red Sands Aquifer, California *Environmental Science and Technology* 39 (15):5505-5511 2005.
[8] J.S. Geelhoed, et al. Processes Determining the Behaviour of Chromium in Chromite Ore Processing Residue Used in Landfill, *Land Contamination and Reclamation*, 7(4), pages 271-279. 1999.
[9] OSHA Fact Sheet. 2006. *Health Effects of Hexavalent Chromium*. www.osha.com. See also, Pellerin, Cheryl and Susan M. Booker. "Reflections on Hexavalent Chromium". *Environmental Health Perspectives*, Volume 108, Number 9. September 2000. Pages 403-407.

From the International Program on Chemical Safety[10]

> Almost all the hexavalent chromium in the environment arises from human activities. It is derived from the industrial oxidation of mined chromium deposits and possibly from the combustion of fossil fuels, wood, paper, etc. In this oxidation state, chromium is relatively stable in air and pure water, but it is reduced to the trivalent state, when it comes into contact with organic matter in biota, soil, and water. There is [a natural] environmental cycle for chromium, from rocks and soils to water, biota, air, and back to the soil. However, a substantial amount (estimated at 6.7 x 10^6 kg per year) is diverted [by human and natural processes] from this cycle by discharge into streams, and by runoff and dumping into the sea. The ultimate repository is ocean sediment



Environmental cycling of chromium.

[10] Environmental Health Criteria 61, International Programme on Chemical Safety, published under the joint sponsorship of UNEP, ILO and WHO, Geneva 1988. *1.1.2. Sources of chromium, environmental levels and exposure.* http://www.inchem.org/documents/ehc/ehc/ehc61.htm

Chromite and ferrochrome processing

Most chromite extraction is through open pit mining operations. As with any open pit operation inflows of water have to be managed and controlled, and overburden, waste rock and the ore have to be removed. Then ore is then crushed to release the chromite. Usually a "jaw crusher" is employed. Initial processing of chromite sorts ore into "lumpy" ores and fines, and uses heavy media or gravity separation of finer ores to remove gangue or waste materials and to produce upgraded ores or concentrates. Magnetic separation and froth flotation techniques have also been applied in some cases. "Lumpy ore" requires little beneficiation and is effectively quarried. In order to be considered "lumpy ore", the chromite must have a grain over 6mm, so that it can be fed directly to the ferroalloy smelter[11].

The Big Daddy Deposit in the Ring of Fire may be as much as 100% lumpy ore. [12] Micon estimated that the Big Daddy Massive Chromite Domain contains an indicated resource of 16.3 million tonnes averaging 40.66% chromium oxide (Cr_2O_3), and an additional inferred resource averaging 39.09% Cr_2O_3. By comparison, Outkumpu's Kemi Mine in Finland has ore reserves of 41.1 million tonnes averaging 24.5% Cr_2O_3. [13] It should be noted that indicated and inferred resources have not been analyzed for economic viability.[14]

Before the chromite can be used for steel making, it has to be converted to ferrochromium. The International Chromium Development Association[15] provides a description of the process of producing ferrochromium alloys from chromite. (see a further description in Appendix A) Chrome ore in various sizes is typically charged into a submerged AC electric arc furnace and reductants (coke, coal and quartzite) are added. The smelting process is energy intensive, requiring up to 4,000 kWh per tonne of material. Slag is separated from the liquid ferrochrome and tapped into ladles for further processing. Liquid ferrochrome is then poured into moulds and after cooling crushed into sizes as required by the customers. Crushed ferrochrome is railed to final customers or harbours for shipment.

[11] There are two Micon International Limited Technical Reports, both preliminary assessments: one for Spider and KWG on the Big Daddy chromium deposit dated March 30, 2010 and one for Noront on the McFaulds Lake Eagles Nest Project dated September 9, 2010.I refer to them in the references as Micon Big Daddy and Micon Noront. This reference is from Big Daddy, page 98.
[12] KWG Press Release, January 19,2011 "Big Daddy Drilling begun, passes test for lump ore."
[13] Micon. Big Daddy. Page 87
[14] Micon, BigDaddy, page 10.
[15] Explanation and diagram courtesy of http://www.icdachromium.com/chromium-ore-processing.php

Supply, markets and price

Chromium is the 21st most abundant material in the earth's crust and geologists estimate that there are about 12 billion tonnes of chromite in the world that could be mined[16]. "This is enough chromium ore to meet world demand for hundreds of years into the future."[17] In addition, scrap metal that contains chromium can be recycled as an alternative, more environmentally responsible source.

About 45% of the mined chromite ores in the world are produced in South Africa[18]. Kazakhstan, India, Russia and Turkey are also substantial producers, and Finland, Iran and Brazil produce smaller amounts. The world's largest producer of ferrochrome is Xstrata in South Africa (45%) with seven operating chromite mines and six others that are not operating. [19] Other top chromite producing companies are (in alphabetical order) Anglo Platinum Ltd, Aquarius Platinum Ltd, Merafe Resources Ltd and Outokompu OYJ.[20]

Fourteen percent of all chromite is consumed in the USA, but there is almost no domestic production .The Stillwater Mine produces chromite but does not market it, and a small new mine in Oregon is about to go into production.

The price of chromite is determined, not by metal exchanges like the London Metals Exchange, but by negotiation between individual buyers and sellers.[21] It is confusing (to say the least) to sort out the price of raw chromite from processed ferrochromium and processed chromium.

In 2007, in the midst of the huge steel and metals commodity boom, a USGS presentation to the Metal Powder Industries Federation in Denver on the price of chromium and other metals[22] said the following:

> The chromium industry's production capacity expansion to meet sustained stainless steel demand was delayed by antiapartheid policies and dissolution of the Soviet Union, an event that reduced demand, and put chromium-containing materials on the market [recycled stainless steel scrap] until 1994 as stocks in the former Soviet Union were sold off. It took until 1995 for world demand to catch up with installed capacity as indicated by the price increase in that year. ...In 2003, the price of chromium rose 40% following two consecutive years of strengthening of the South African rand, which rose 24% against the U.S. dollar in 2003 alone. ...The rising cost of ferrochromium production and a strengthening South African rand, along with increased demand for

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[16] J. Papp. USGS. *Mineral Commodity Summaries,* January 2010 Chromium, page 43
[17] Eoearth.org/article/Chromium. The USGS estimates that there are 12 billion tonnes of mineable ore.
[18] Mbendi Information Services. World Chromite Mining- Mining and Production http://www.mbendi.com/indy/ming/chrm/p10010/htm
[19] http://www.wikinvest.com/stock/Xstrata_(LON:XTA)
[20] http://www.infomine.com/commodities/chromium.asp
[21] Micon. Big Daddy, page 101

[22] John F. Papp, Lisa A. Corathers, Daniel L. Edelstein, Michael D. Fenton, Peter H. Kuck, and Michael J. Magyar. *Cr, Cu, Mn, Mo, Ni, and Steel Commodity Price Influences, Version 1.1*. http://pubs.usgs.gov/of/2007/1257/

ferrochromium and limited supply of stainless steel scrap, caused the price of ferrochromium to reach historically high levels in 2004.

During the 1991-2006 time period, South African chromite ore and ferrochromium smelter production capacity more than doubled while that of other countries declined. Kazakhstan and India became the second and third leading chromite ore producers. Indian chromite ore and ferrochromium production capacity also expanded while that of Albania, Croatia, Japan, Zimbabwe and other countries decreased.

Chromium consumption by the leading consumers (China, Germany, Japan, and the United States) shows that China moved from the least amount of consumption to the greatest amount during this time period and was the only leading consumer that substantially increased its consumption. Percent change shows that chromium price changes are similar to China's consumption changes. Chromium consumption growth was driven throughout the time period by stainless steel production growth in Asia; growth in Taiwan in the early part of the time period; growth in Korea and India throughout the time period; and growth in China that started in 2000 and dominated the end of the time period. China's growth rate was more than double that of any of the others.

The Economics of Chromium was published by Roskill in early 2009[23] and made the following important points:

- Around 94% of global chromite production is destined for use in the metallurgical industry, for the production of ferrochrome, with the remainder produced for use in the foundry, chemical and refractory sectors.
- Around 70% of global chromite production is consumed domestically in ferrochrome production in the country of origin.
- Three countries dominate output of ferrochrome. In 2008, South Africa, Kazakhstan and India accounted for around 67% of total world production
- Chinese production has started to increase rapidly. At around 1.5Mt in 2008, Chinese ferrochrome production has grown at an annual average rate of 28% per year, for the period 2002 to 2008.
- The stainless steel industry is by far the largest consumer of ferrochrome. Until the beginning of the downturn in the global economy, stainless steel production had shown large increases.
- Demand in developing countries such as China and India helped global output increase at an annual average rate of 5.4% for the period 2000 to 2007, with China alone accounting for over 60% of this rise in global stainless production.
- Any changes to supply have a large impact on the price.

[23]Roskill Information Services. *The Economics of Chromium*, 11th edition 2009 http://www.roskill.com/reports/steel-alloys/chromium

After the report was written, the 2008 financial crash had a major effect on chromium markets. Roskill then reflected:

> "The onset of the economic downturn from mid-2008 has seen demand for chromium plummet, with prices following a similar path. Ferrochrome consumption fell by 3.5% in 2008, in year-on-year terms, as major Asian and European consumers reduced orders to a minimum in an attempt to run down inventories, as demand from end-users declined sharply...
>
> Export prices for ferrochrome have fallen by 68% for the ten months to May 2009, as demand from stainless steel, the main end-use for ferrochrome, has collapsed. In response to weakening demand and falling prices producers have cut production, in some cases ceasing operations all together. Around 70% of world ferrochrome production capacity was suspended in the first quarter of 2009, with the Xstrata-Merafe joint venture operating at 20% of capacity since December 2008, while Samancor Chrome suspended all production in the first quarter of 2009."[24]

In 2010, the industry was once again bullish, anticipating considerable increase in demand. Xstrata, the world's largest chromium producer, is building a 4.9 billion rand ($710 million) smelter in South Africa to feed demand for the stainless steel ingredient.[25] The sustainability of this new economic growth over the long-term is highly questionable.

The following chart[26] shows what happened to **refined chromium** prices between November 1, 2005 and December 2010.

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[24] Roskill Information Services. Double-Digit Falls in Ferrochrome and Chromite Demand in 2009. June 3, 2009. http://www.roskill.com/reports/chromium

[25] C. Lourens and R. Bonorchis. Xstrata Approves $710 Million Smelter; Merafe May Join. *Bloombert* Oct 20, 2010. http://www.bloomberg.com/news/2010-10-20/xstrata-partner-merafe-to-decide-by-year-end-on-whether-to-build-smelter.html

[26] http://www.infomine.com/chartsanddata/chartbuilder.aspx?z=f&g=127648&dr=15y show

Raw chromite ore fetches considerably less than refined chromium on the market, and is subject to massive price fluctuations. Table 18-6 in the Micon Big Daddy Report showed 2010 prices for metallurgical grade chromite ranging from $180/tonne to $395/tonne, depending on grade.[27]

South African chromite miners have been selling raw ore to China at prices significantly below what other producing countries have been getting. Mining Weekly reported in March of 2010 that "China bought the 2.9-million tons [of raw chromite ore] from South Africa at the comparatively low average price of $215/t including cost, insurance and freight (CIF), compared with the $360/t CIF it paid for raw ore from India - 67% more. China also paid 35% more for the raw ore it bought from Turkey." [28] South Africa's ability to produce ferrochrome from its chromite ores is restricted by an inadequate power supply.

The price and market for chromite is intimately tied to the fate of the steel industry. Historically, most North American steel plants have been centred around the Great Lakes on both the US and Canadian sides of the border. The steel industry in North America has been in decline for decades, since the price of oil went up in the 1970s, with the growth of inexpensive steel production capacity in other parts of the world, and with the rise of globalized corporations that move products between their subsidiaries.

[27] Micon. Big Daddy. page 102
[28] M. Creamer. South Africa exporting more raw chrome ore at low prices. *MiningWeekly*. March 5, 2010 http://www.miningweekly.com/article/south-africa-exporting-more-raw-chrome-ore-at-low-prices-2010-03-05

Writing for Credit Agricole on the website www.consensuseconomics.com, Magne and Frecaut, presented the following analysis of steel industry prospects.

> "From a pre-crisis peak of 121.1m tonnes in May 2008, world steel production plummeted to a low of 81.7m tonnes in December that year. It has since recovered, but remains below its level two years earlier. Because steel production in rich countries fell much more than in countries like China, the latter increased its share of global output. In May 2008 China produced 38% of the world's steel; by August 2009, its share had soared to 49%. Since then, steel production in other countries has recovered too, causing China's share of world output to slip to 45% in July. But China's dominance of the global steel industry is not under threat. In July it produced more than five times as much steel as Japan, its closest rival.
>
> "The slowdown in the commodity price cycle predicted by many analysts for "after the Beijing Olympic Games" did indeed take place and, in just a few months, turned into a downturn of unprecedented violence and scale. It has affected all sectors, even though their fundamentals continue to differ significantly....In our view, only a major wave of plant closures and a very significant reduction in world capacity would be capable of rebalancing supply and adapting it to actual demand, which was probably significantly overestimated (particularly in China in the euphoria of preparing for the Olympic Games).... Based on an initial purely theoretical analysis, we think it would be necessary to reduce production capacity by between 200 million tonnes and 300 million tonnes. Obviously such major restructuring would require governments to respond to the situation and implement support measures.
>
> In conclusion, for us the steel industry has entered a major crisis period, characterised by a very significant structural supply surplus and prices that are too low for most companies. The length of the crisis will naturally depend on an improvement in economic conditions."[29]

[29] P. Magne and G. Frécaut, *Steel: The End of the Commodities Super Cycle* Crédit Agricole, Paris. May 20, 2009. http://www.consensuseconomics.com/News_and_Articles/Steel_Prices401.htm

Key issues regarding Ring of Fire economics

Power Requirements.

Electricity requirements for the production of ferrochromium are very high, often coming to more than 1/3 of the cost of production.[30] Electric arc furnaces use up to 360-400 kWh of power per tonne. The furnaces are so energy intensive they often require the building of new dedicated power plants. World-wide, most of the power used for ferrochrome production currently comes from coal.

Outokumpu, the Finnish chromite mining company estimates that electricity costs (including the ferrochrome smelter and the Kemi Mine) are 31% of their ferrochrome production costs, with an additional 28% of costs for other energy.[31] These energy costs are drastically lower if the only activity is milling the ore on site. As an example, the Bloom Lake Iron Ore Mine estimated the average cost of crushing and processing iron ore at US$4.18/tonne concentrate (less than 20% of the total cost of production of the iron ore). On the other hand, shipping ore that is minimally processed is much more costly – because the weight and bulk are greater. [32]

All the players in the Ring of Fire have expressed concerns about power availability and price for their projects. In April 2010, Moe Lavigne, KWG's VP of exploration and development, told *Northern Ontario Business* that their project, including a mine, concentrator, ferrochrome smelter, and rail would cost $2 billion. He went on to say:

> "…the issue with an electric arc furnace is that it consumes a huge amount of electricity and one of the issues will be where do we get the electricity cheaper?...It's a simple financial decision. It makes more sense business-wise for us to save a billion dollars a year by building a plant somewhere else." [33]

For the Big Daddy deposit, Lavigne pegged an acceptable power cost at 4 cents a kWh.[34] At present, Ontario residential consumers are paying anywhere from 5.1 to 9.9 cents per kWh.[35] Wes Hanson, Noront CEO is also blunt. He told *Northern Life in* November that the project will "require a substantial government investment."[36]

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[30] Hatch Associates. *CIS Ferroalloys Industry:Current Profile and Future Potential*. 21st International Ferro-alloys Conference. 15 Nov. 2005. Slide 26

[31] K. Kaituei. *Ferrochrome investment-self-sufficiency and future growth Capital Markets Day 2010*. Sept. 22, 2010. Outokumpu. www.ouitokumpu.com. slide9

[32] Consolidated Thompson Mines April 2009 Technical Report, Bloom Lake Mine

[33] Northern Ontario Business. *Power, First Nation Cooperation Key to developing Ring of Fire mine*. Northern Ontario Business, April 19, 2010.

[34] Northern Ontario Business. *Power, First Nation Cooperation Key to developing Ring of Fire mine*. Northern Ontario Business, April 19, 2010.

[35] http://www.ieso.ca/imoweb/siteShared/demand_price.asp?sid=bi

[36] I. Ross. *Sudbury Mining suppliers well placed to benefit from Ring of Fire. Republic of Mining*, Dec1, 2010. http://www.republicofmining.com/2010/12/01/sudbury%E2%80%99s-mining-suppliers-%E2%80%98well-placed%E2%80%99-to-benefit-from-ring-of-fire-by-ian-ross/

Rail-line

In order to access the chromite deposits in the Ring of Fire, a 340 km rail-line will have to be built from Nakina to the site. KWG has already claim-staked the rail-bed along a conveniently located esker, although mining claims should not constitute a rail right of way. The companies have hired consulting firm Krech Ojard & Associates to do a technical study of the proposed rail line. Since the location is an enormous swamp, crossed by a number of major rivers, the engineering will be complicated and construction costly.

Ontario Northland Transportation Commission –with considerable experience in the region - has expressed strong interest in the rail line. The ONTC maintains 1100 kilometres of track from North Bay to Moosonee and from Calstock to Hearst. They've built spurs in the past to mines in northeastern Ontario [37] The company is losing $7-9 million in freight with the closure of the Kidd Met smelter in Timmins. When ONTC built a new spur into the Agrium phosphate mine near Kapuskasing in 1999 – more than a decade ago - the cost per kilometre was about $1 million.[38] They say that adding a major bridge can cost as much as an entire section of new track. Doing structural work on their quarter-mile-long bridge spanning the Moose River will cost between $18 million -$20 million over five years.[39]

Recently, Consolidated Thompson Mines had to strengthen an existing 500 km rail line from Wabush, Labrador to the St. Lawrence and build an additional 31 kilometre line to their new iron mine. Capital costs for only the rail upgrades came in at over $176 million (almost double the original estimate). In addition they anticipate an operating cost for rail transport of $11.87 per tonne mined.[40] In December 2010, heavy rains washed out sections of the railbed which took more than two weeks to repair.[41]

It should be noted that since Cliffs Natural Resources purchased Consolidated Thompson on January 11, 2011, for $4.5 billion, they now own a railway company. BL Railway, which operates in Newfoundland and Labrador was created by Consolidated Thompson in 2008.

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[37] I. Ross. Study begins on Northern Ontario's Ring of Fire Railroad. *Republic of Mining*. June 2010. http://www.republicofmining.com/2010/06/17/study-begins-on-northern-ontario%E2%80%99s-ring-of-fire-railroad-%E2%80%93-by-ian-ross/

[38] "Agrium invested more than $70 million to establish the mine and build the mill and the rail spur. The railway spent $22 million on the spur line to move the reserve of 22 million tonnes for the next two decades." http://www.northernontariobusiness.com/Regional-News/timmins/Phosphate-mining-potential-near-Hearst-%289-01%29.aspx

[39] Ibid.

[40] Consolidateed Thompson Iron Ore Company. *Annual Information Return.Fiscal Year ended December 31, 2009.* Page 32.

[41] Consolidated Thomspon Iron Ore Mines website.

Ferrochrome production facility

There is substantial interest from municipalities like Timmins and Thunder Bay in hosting a ferrochrome smelter, because of the jobs that would be generated and property tax revenues they might enjoy. Value-added production of ferrochrome would also increase potential economic benefits at the provincial level. It is not clear, however, if a processing plant in Ontario would be the companies' preferred option. Tom Laughren, the Mayor of Timmins, says that the "underlying cost structure in Ontario makes processing prohibitive."

A smelter will require rail and or port access, public willingness to sacrifice the environment, competitive electricity costs and a tax and benefit regime that is attractive to industry. Ontario is in competition with Quebec, which has very low industrial electricity costs, because of the hydroelectricity projects on the Cree lands of northern Quebec. Section 91 of the Ontario Mining Act requires minerals to be refined within Canada, though an exemption can be granted by the Minister who also can define the degree of processing required.

In 2010, Timmins lost the Xstrata Kidd Metallurgical plant, and with it 640 jobs. The Kidd Met smelter in Timmins is owned by Xstrata, the world's largest chromite miner, which has shown no interest to date in the Ring of Fire play – although the Xstrata labs have been carrying out metallurgical analysis for KWG. The site's processing facilities would have to be substantially overhauled if not entirely rebuilt to process chromite however basic infrastructure is in place and there is strong support from local politicians[42]. As an indication of the cost of such a facility, the new Xstrata-Merafe smelter in South Africa will cost $710 million.

This summer, the province gave $225,000 for Timmins to spend on a feasibility study to outline the Met Site's assets, environmental concerns and marketing opportunities. The chair of the CAW union local, Ben Lefebvre, said in June that "the infrastructure at the site won't last beyond the end of the year, as the frost will likely lay waste to the equipment as it goes unused through the winter months". Although discussion has taken place with Cliffs, it would be at least five years before anything could be built in Timmins.[43]

The companies

None of the companies involved in the Ring of Fire are experienced chromite miners. KWG, Noront and the Cliffs Natural Resources subsidiaries[44] (Spider and Freewest) are all exploration companies. Cliffs itself has no chromite mining experience; neither has it operated a ferrochrome smelter.[45]

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[42] C. Romain. Minister tries to calm fears for Ring of Fire, Vows ore won't go to China. *Timmins Daily Press*. Jan. 12, 2011. www.timminspress.com/ArticleDisplay.aspx?e=2924802

[43] N. Stewart. *Timmins Looks past Kidd Met Closure.* Northern Ontario Business, June 11 2010 www.northernontariobusiness.com/Industry-News/mining/Timmins-looks-past-Kidd-Met-closure.aspx

[44] Cliffs purchased 100% of Spider October 7, 2010, 100% of Freewest January 27, 2010, 100% of Wabush February 1, 2010, 100% of Consolidated Thompson(Bloom Lake) January 11, 2011.

[45] Cliffs Natural Resources website www.cliffsnaturalresources.com

Cliffs Natural Resources mines iron ore in Brazil, Australia, Minnesota and Labrador. Coal, essential for coke and power plant fuel, is mined by Cliffs in West Virginia and Alabama. Cliffs recently purchased, for $4.5 billion – at $17.25 a share, Consolidated Thompson Iron Mines (January 11, 2011), a company with less than a year of experience operating an iron ore mine. Consolidated Thompson had a very well connected Board, including Brian Tobin as CE0, and Goldcorp's Kevin MacArthur; it had been able to get permitting for the Bloom Lake iron mine in record time.

Perhaps of most significance for northern Ontario, with the purchase of Consolidated Thompson, Cliffs Natural Resources has cemented relationships with purchasers in China:

> In July 2007, the Consolidated had entered into a distribution agreement with Worldlink Resources Limited, a China-based integrated trading company, for the supply of iron ore concentrates. In December 2007, the distribution agreement was expanded to a seven-year term as Worldlink committed to purchase 7.0 million tonnes of iron ore concentrate per year. Worldlink is a trading company engaged in the import and export business of iron ore, coal and other dry bulk commodities and has been marketing in China since 2000, including having joint ventures with two Chinese steel mills. By providing long-term mineral resources, Worldlink has built consolidated marketing channels and relationships with major steel customers in China.[46]

The company intends "to apply our expertise in open-pit mining and mineral processing to chromite ore resource base that could form the foundation of North America's only ferrochrome production operation."[47] With the purchase of Consolidated, they have now announced a major company re-organization[48], focusing on sales to Asia.

There is no doubt that they want to develop a chromite mine in northern Ontario, assuming they can make money doing it. However, it will not be economic for the company to do it unless there is very substantial public investment in infrastructure like rail-lines, electrical subsidies, First Nations compensation and training.

KWG Resources is a mineral exploration company, not a mining company. It started out as a diamond exploration company, and currently owns "Debuts Diamonds Inc. ("DDI"), a wholly-owned subsidiary which holds all the Company's diamond exploration properties. KWG controls the MacFadyen Kimberlites and other contiguous exploration properties that are all adjacent to the De Beers Victor Diamond Mine".

KWG owns [49] 26.5% of the Big Daddy chromite deposit in the Ring of Fire. The company also claim staked a potential 340 km railline from the deposits to Nakina, along an esker. Mining

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[46] Consolidated Thompson. Op cit. Page 5

[47] Cliffs Natural Resources Inc. *Notes to unaudited financial statements* Sept. 30, 2010, page 17.

[48] *Cliffs Natural Resources Inc. Announces Global Reorganization: Worldwide Realignment of Commercial, Operating and Administrative Functions Designed to Leverage Global Scale and Improve Production Efficient* Jan 21, 2011. http://www.mfrtech.com/articles/9482.html

[49] KWG. Management Discussion and Analysis, Dec 2010. Page 4. www.sedar.com

claims do not leagally constitute a Right of Way. They also hold Net Smelter Return royalty agreements on the nearby Black Thor and Black Label deposits. The company created wholly-owned subsidiary Canada Chrome corporation to manage the rail-line interests. " A number of off-balance sheet financing alternatives are being pursued to fund the first phases of consultation, assessment and construction of this transportation corridor."[50] In June 2010, there was a struggle with Cliffs over a proposed amalgamation between KWG and Spider Resources. In the end, Spider became a wholly owned subsidiary of Cliffs. [51]

There are almost forty exploration companies active in the region, but most are unlikely to develop a mine.

The Noront Eagle One project is a proposed underground nickel and PGM mine in the Ring of Fire region, projected to last for eleven years. Like chromite, it is a bulky and expensive material to transport, and so, unlike gold, is not conducive to air transport. An underground mine and mill will also have extensive power requirements for which the company proposes a diesel power plant at Webequie with a transmission line to the site. The mine also will need a winter road to Webequie, a slurry line from the site to a load-off in Webequie and a reinforced road south to smelters.[52] An underground mine in the swampy environment will probably require either drainage or freeze walls, and will therefore be more expensive. The management of tailings - which the company intends to eventually put back underground – will be very challenging.

It is unlikely that this mine will be able to go ahead unless the infrastructure is supplied by some source other than the Company's own financing, and even then, it will be marginal. Recently, investors appear to agree, as the shares of Noront are in freefall.

Taxation and government subsidies.

The companies concerned have been accumulating substantial tax asset pools during their exploration activity. By August 2010, Spider had over $20 million in deferred exploration costs[53]. Noront's deferred exploration expenditures in October 2010 came to almost $97million.[54] KWG had accumulated $30,596,595 in deferred costs and exploration expenses by the end of September 2010.[55] Even if the chromite mining project does not go ahead, the Canadian Income Tax Act (section 66) allows Cliffs to use the Canadian Exploration credits from Spider and Freewest to offset the profits from Wabush Mines and Bloom Lake (which are both turning a profit).

Canada' s tax incentives are considerable for mining exploration and development. As an example, because KWG has set up its rail-line interests as Canada Chrome, a separate subsidiary, Canada Chrome exists as a separate legal person and can have a completely separate balance sheet from a parent company. This enables a parent or a partner company to make use of losses

[50] Ibid.
[51] KWG news releases posted on www,sedar.com June-July 2010.
[52] Micon - Mcfaulds Lake p. 11
[53] Spider Resources. Interim Financial Statements June 30 2010. Page 10.
[54] Noront. *Management Discussion and analysis for the quarter ending October 31, 2010.* Page5
[55] KWG, MD&A, Dec1010. Page 16.

from that operation as they wish: deducting losses from the parent balance sheet if they need tax write-offs, or allowing the subsidiary sink further in debt or go bankrupt. KWG CEO Frank Smeenk is quoted in the *Sudbury Mining Solutions Journal*: "The attractiveness of a project financing vehicle using tax incentives available in Canada and having a partner like KWG is that Cliffs' financial metrics aren't affected by this huge capital cost, so we're finding a sympathetic hearing in Cleveland."[56]

In Ontario, Ring of Fire mines will qualify as "northern Ontario remote mines" and will enjoy a ten year tax holiday from paying any mineral royalties (the Mining Tax). If First Nations succeed in negotiating a royalty sharing agreement with the province, they must be careful that it is based not on a percentage of the mining tax, but on a share of gross revenues.

All companies have been demanding enormous government interventions to assist Ring of Fire development: building an all weather road, paying the lion's share of a railroad to the mine site, lower power rates, transmission lines and possibly new power sources, contribution to the development of a new ferrochrome smelter, etc. They will also expect governments to pay for training for First Nations and others to be able to take on jobs. The 2010 provincial budget announced a $450 million Northern Industrial Electricity Rate Program (NIERP), $45 millionin new project based skills training program for Aboriginals and Northern Ontario residents, the appointment of a Ring of Fire Co-ordinator and the $1.2 billion in infrastructure development to strengthen Northern communities [57]

The Micon Study of the Eagle One project (accurate to within ±50%) states: "this estimate assumes that certain proportions of the off-site capital costs will be borne by other stakeholders potentially including the provincial and federal governments and other mining companies with interests in the ROF." [58] Later the study admits that it assigned only 25% of the all season road, 50% of the power line and 50% of the winter road costs to Noront.[59]

The high capital costs of mine development would also ensure that they do not show a profit for income, or mining tax purposes for a number of years, and will pay little or no mining and income tax during the life of the mines.

Water management

Since the Ring of Fire is in the James Bay lowlands, one of the world's largest wetlands water management requirements will be enormous: it will be necessary to engineer massive drainage and pumping systems or to use freeze walls in order to mine. Wes Hanson of Noront said that : "It's not uncommon to see your diamond drilling contractor standing up to their waists in water,

[56] N. Tollinsky. Ontario Ring of Fire Chromite Operator Still to be determined. *Sudbury Mining Solutions Journal*. March 2010. http://www.sudburyminingsolutions.com/articles/News/03-10-Chromite-mine-operator-still-to-be-determined.asp
[57] http://www.fin.gov.on.ca/en/budget/ontariobudgets/2010/bk_northern.html
[58] Micon, Noront page 6.
[59] Micon, Noront page 11

finishing a hole."[60] In similar conditions, the Victor Mine, McArthur Mine and Aquarius Mine were forced to use the "freeze wall" method in order to keep water out of their mines. This greatly adds to the cost of production, and can have serious effects on aquifers and the water table.
The difficulty of managing tailings and waste rock over the long term in an environment that is saturated with water will be enormous. Writes Norm Tollinsky: "It makes sense to locate the concentrator where the furnace is to bypass the engineering challenges associated with tailings management in the swampy terrain of James Bay."[61]

In addition, Micon has indicated in the Big Daddy study that the aggregates needed at the mine site and to build a base for the railroad may not be available. In this case, they would have to be brought in, at great cost.

Shipping costs.

Although rates for ore shipments are negotiated on a contract by contract basis, the Baltic Exchange[62] provides in depth market analysis and information to its 500 members about going shipping rates and conditions. Currently, bulk carrier shipping costs from Asia to Europe are at an all time low, because of the flooding of coal mines in northern Australia. [63] This situation is unlikely to continue indefinitely, and shipping costs will rise as production resumes. Rising fuel prices, the inevitable result of peak oil, will combine with the increased demand for shipping to substantially increase costs in the medium term.

Bloomberg provides this analysis:

> Marine fuel, known as bunker, cost $543.50 a metric ton on Jan. 14 in Singapore, a key refueling point, according to data compiled by Bloomberg. That's 30 percent more than in May and the highest since October 2008... Futures traders are anticipating higher oil costs through at least the next eight years, according to contracts traded on the New York Mercantile Exchange. Crude for next month traded at $91.34 a barrel late yesterday and changed hands at $96.50 for delivery a year after that, bourse data show. The largest ships burn 320 tons of fuel a day when traveling at full speed, according to Soren Andersen, vice president for vessel management at Maersk Line, the container unit of A.P. Moeller-Maersk."[64]

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[60] Noront CEO whets appetite of Sudbury mine suppliers. *Northern Ontario Business.* Nov. 30 2010. http://www.northernontariobusiness.com/Industry-News/mining/Noront-CEO-whets-appetite-of-Sudbury-mine-suppliers.aspx

[61] N. Tollinsky, N. Ontario Ring of Fire Chromite Operator Still to be determined. *Sudbury Mining Solutions Journal.* March 2010. http://www.sudburyminingsolutions.com/articles/Exploration/06-09-Chromite-discovery-sparks-excitement.asp

[62] Balticexchange.com

[63] A. Hollaway. Shipowners Increase Payments to Get Their Vessels to Atlantic. *Bloomberg.* Jan 11, 2011 http://www.bloomberg.com/news/2011-01-17/shipowners-increase-payments-to-get-their-vessels-to-atlantic.html

[64] A. Nightingale and K. Park. *Container Ship Rates Rising as Fuel Prices Slow Vessels: Freight Markets* Jan 19, 2011 http://www.bloomberg.com/news/2011-01-19/container-ship-rates-rising-as-fuel-prices-slow-vessels-freight-markets.html

Rising shipping costs will play a major role in markets for northern Ontario chromite or ferochrome. Over the past three decades, it has become more cost efficient for steel producers to ship bulk ores from Canada to smelters in Asia and South Africa than to refine it in North America. Rising shipping costs could alter the equation, making it more viable to refine metals in Canada, however the fastest growing markets are no longer in North America.

Sustainability.

There are a number of sustainability issues that need to be addressed in a full analysis of the chromite proposals. They are outside the scope of this economic analysis, but warrant further study. These issues include:

- Aboriginal sovereignty and consent;
- Distribution of benefits, costs and risks between communities;
- The ability (or inability) of our environmental protection systems to effectively monitor, manage and control emissions to air and water from chromite mining and processing operations;
- Impacts on ground and surface water from mining activities, including potential increases in mercury concentrations;
- The lack of comprehensive environmental assessment of mines in Ontario;
- The lack of cumulative effects assessment of mines and smelters; and
- Net green house gas emissions including loss of carbon capture in affected areas of the James Bay Lowlands[65], mining, processing and shipping.

Feasibility of the mine projects

At the time of writing, none of the projects have prepared a feasibility study or even a pre-feasibility study at this time, so there is really little to evaluate. The claims of massive finds are not yet even NI43-101 compliant reserves.

The Micon preliminary economic study of the Eagle One deposit indicated that the mine would barely be able to repay capital costs at current nickel prices – and that was with considerable "synergies" with governments and other mining companies. Joe Hamilton of Noront executives told Sudbury Mining Solutions in June 2009: *"You need something that will last for years to justify the the infrastructure up there and it looks like chromite is going to derive(sic) that... I don't think the global market is going to be able to support the required production rates without cratering the chromite price."*[66] It is hard to believe that major multinational companies like Xstrata will stand for a cratering of the price; it is more likely they would buy up the deposit just to prevent its being developed. Cliffs Natural Resources is trying to enter their league; it remains to be seen if they will be able to.

Mining analyst Brent Cook shares this opinion:

[65] Ontario Nature estimates that "Ontario peatlands sequester carbon at a rate of 0.273 tonnes of carbon per hectare if left undisturbed. That adds up to 7 million tonnes stored each year. www.ontarionature.org

[66] Chromite discovery sparks excitement. *Sudbury Mining Solutions*. June 2009 http://www.sudburyminingsolutions.com/articles/Exploration/06-09-Chromite-discovery-sparks-excitement.asp

> The ferrochrome market is similarly supplied by a few major players and mineral districts. Approximately 45% comes from South Africa, 17% from Kazakhstan and 19% from India. According to the USGS, world resources total 12 billion tonnes of direct-shipping grade chromitite ore. Direct-shipping grade ore is greater than 38% Cr2O3 (chromite mineral) and a chrome to iron (CR/Fe) ratio of greater than 1.8. The International Chromium Development Association estimated that some 19 million tonnes of marketable chromitite ore were produced in 2006 and that the market was in oversupply. Through mid-2008 chromite demand and prices increased, however the commodities crash of late last year means demand has probably fallen nearly fifty percent. Indicative of the price and demand collapse, Xstrata's Merafe ferrochrome plant in South Africa is operating at 20% of capacity...
>
> You begin to see the problems an emerging new nickel-chrome-PGE province will face. The new province would immediately have to compete on an economic basis with already developed mining districts hosting virtually unlimited resources. In addition to the mine development costs including roads and power, the project would have to consider the trade off costs between a new smelter in Canada vs. shipping the ore to one of the operating smelters owned by someone else. For major mining companies or investors to finance what is likely to be billions of dollars in exploration and development costs they will need to see very high returns to offset draining this swamp in the middle of nowhere.
>
> The fact that the two major nickel-chrome-PGE districts can conceivably ramp up production to meet increased demand puts them in ultimate control of the metal prices. The advantage offered by the McFaulds Lake area is that it could provide a third and politically stable supply of nickel-chrome-PGE. The go-ahead factor will be the discovery of a world-class high-grade deposit that puts the economic evaluation over the top and threatens the existing nickel-chrome-PGE market.[67]

A threat of increased chromium supply on the market from Cliffs will likely bring the large ferrochrome competitors in to the play such as Xstrata and Anglo-American. Whether they decide to let the project proceed or close it down will be determined by their own interests; not the interests of the environment, Ontario or the affected First Nations.

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[67] B. Cook. 2010. *The Ring of Fire McFaulds Lake area play - Draining a swamp.* http://www.resourcestockdigest.com/company_specific_commentary/index.php?&content_id=198

Appendix A - Ferrochrome Production

From the website of the International Chromium Development Association
http://www.icdachromium.com/chromium-ore-processing.php

Most of the world's production of chromite (95%) is used in the metallurgical industry in the form of ferrochromium alloys. The alloys are produced by high temperature reduction (smelting) of chromite. They are essentially alloys of iron and chromium with much lesser amounts of carbon and silicon, the amounts depending upon the grade or type of alloy, and impurities such as sulphur, phosphorous and titanium. The conversion of chromite to ferrochromium alloys is dominated by electric submerged arc furnace smelting with carbonaceous reductants, predominantly coke, and fluxes to form the correct slag composition. The electric current is 3-phase alternating current (AC) and the furnaces have three equally spaced consumable graphite electrodes in a cylindrical, refractory-lined container with a bottom tap-hole.

Characteristics of the submerged arc furnace for smelting chromite include:

1. Relatively easy to control provided the charge is well sorted to maintain a permeable overburden which will allow easy escape of the gases produced.
2. Self-regulating with power input determining the rate of consumption of charge (overburden)
3. Some pre-heating and pre- reduction of the overburden by the hot ascending gases.

Submerged arc furnaces can be open, semi-closed or closed with correspondingly better thermal efficiency and the ability to make use of the energy in the off-gases from the closed furnaces.

In the early days of high-carbon ferrochromium production, the furnaces were supplied with high-grade, lumpy chromite from countries such as Zimbabwe but with the increasing demand from the 1970s, other countries, South Africa in particular, commenced production from their lower-grade ores. The alloy produced from these ores became known as charge chrome because the chromium content was lower and the carbon content, and in particular the ratio of C:Cr, was very much greater than in high-carbon ferrochromium. This did not suit the stainless steelmakers who required as little carbon as possible entering their melts for each chromium unit and who were, therefore, having to use larger amounts of the more costly low-carbon ferrochromium to compensate. However, the situation changed radically with the advent of the argon-oxygen decarburising (AOD) and vacuum-oxygen decarburising (VOD) processes. These processes enabled the steelmakers to remove carbon from the stainless melts without excessive oxidation and losses of chromium.

A more advanced attempt to overcome the problem of ore fines was the introduction of DC arc, or plasma, furnace technology. The DC arc furnace uses a single, central hollow graphite electrode as the cathode, with an electrically conducting refractory furnace hearth as the anode. The furnace operates with an open bath, so there is no problem with overburden, and the chromite fines, together with coal and fluxes, are fed directly into the bath through the hollow electrode. The furnace has a closed top. Some of the advantages of DC arc furnace operation are:

use of fine ores without agglomeration, use of cheaper reductants and greater choice of reductants, higher chromium recoveries, deliberate changes in the charge composition are reflected rapidly in the slag or metal, and closed top operation allows furnace off-gas energy to be used.

Another approach to friable ores has been to pelletise them, after further grinding if necessary, with binder, reductant and fluxes and pass them through a rotary kiln where they are hardened (sintered), pre-heated and pre-reduced to a degree before charging to a submerged arc furnace.

A further development in treating ore fines by kiln pre-reduction used unaglomerated chromite fines and low cost coal, with fluxes, as the feed to the kiln. Self agglomeration of the fines was achieved close to the discharge from the kiln where the charge becomes pasty in a high temperature zone of approx. 1,500ºC. Very high degrees of reduction were achieved (80-90%) so that the downstream electric furnace (DC arc) became essentially a melting furnace.

A more recent approach, and one which is being installed by more plants, is again by pelletising. Pellets are produced with coke included and these are sintered and partly pre-reduced on a steel belt sintering system. From there, the pellets are delivered to pre-heating shaft kilns that are sited above submerged arc furnaces and which operate as direct feed bins, making use of the off-gas heat from the furnaces. Lump ore, coke and fluxes are also directed to the feed bins.

In addition to the technologies already discussed, there have been various other approaches to smelting chromite. These include rotary hearth sintering and pre-reduction of pellets, and fluidised bed pre-heaters for chromite fines.

Some intensive development work has been carried out in Japan upon entirely coal/oxygen based smelting processes using no electrical energy, sometimes referred to as smelt-reduction processes.