CLIFFS CHROMITE – A NORTH AMERICAN INTEGRATED PRODUCER

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ABSTRACT

In early 2010, Cliffs Natural Resources acquired the largest known resources of chromite in North America. The deposit, located in the Ring of Fire in Canada, is world-class in size and quality. Cliffs has been pursuing the development of these resources since acquisition. The project has completed a pre-feasibility study based on the construction of an open cast mine, transportation corridor and a ferrochrome smelter. Preliminary capital estimates from the pre-feasibility study suggest a total capital expenditure range of $2.7 - $3.6 billion, with first production by mid 2017, with a positive project Net Present Value. The project is based on an open pit mine producing about 4 million tons of ore per year, a chromite gravity concentrator and associated infrastructure, including a housing and accommodation complex, located adjacent to the mine producing 2.3 million tons per year of concentrate as lump, chips and fines at an average grade of 43% Cr_2O_3 *and chrome to iron ratio of 1.85. The project requires the development of an integrated transportation system consisting of a 340 km all weather road and a material transload facility for rail loading to facilitate concentrate distribution. The ferrochrome processing facility is designed to produce 560 000 tons of high carbon ferrochrome per year with an average grade of 57.6% Cr. The ferrochrome facility, based on rotary kiln pre-heating technology combined with DC smelting furnaces and the granulation of final product, is currently planned to be situated north of the town of Capreol within the City of Greater Sudbury. The project is being designed to the highest environmental and social standards possible with particular emphasis on energy conservation and long term sustainability. This paper will provide information on the proposed design and technology selection with a focus on energy conservation as well as a general project update.*

KEYWORDS: *Chromite, ferrochrome, cliffs, Canada, DC furnace, rotary kiln.*

1. PROJECT OVERVIEW

Cliffs Natural Resources, an international mining and natural resources company, is currently engaged in the evaluation and development of a chromite project located in the province of Ontario, Canada. The project represents a significant investment in Northern Ontario and Canada in general. Cliffs, driven by the core values of social, environmental and capital stewardship, believe that the Black Thor deposit represents a massive potential benefit to all stakeholders.

Cliffs has a proud history of providing value to various stakeholders across three continents and over 160 years. We believe that the development of the Ring of Fire chromite deposits represent a continuation of the company’s ability to unlock value for all stakeholders in a new and exciting mineral rich area of the world.

In 2010, Cliffs acquired the largest known chromite deposits in North America and began immediately with developing plans for unlocking this resource. The deposits, located in the Ring of Fire, are some 500 km northeast of Thunder Bay and centered on McFauld’s Lake. The deposits are currently undergoing significant exploration and have so far found to contain mineralisation of chromite, nickel and platinum group elements. Cliffs owns the Black Thor deposit which is the basis for this project.

Cliffs intends to develop an integrated project consisting of three major units:

1. An open pit mine and concentrator at the deposit location in the Ring of Fire.
2. An integrated transport system consisting of an all weather road and transload facility to allow the transport of materials from the mine site to the CN transcontinental railway line near Nakina.
3. A ferrochrome production facility located near Capreol in the City of Greater Sudbury.

Key project locations within Ontario

The project will be producing both chromite concentrate and high carbon ferrochrome for sale to international markets with expected production slated to start in 2017. Direct employment created across the various sites will be approximately 1200 positions during operations.

Cliffs completed a pre-feasibility study in early 2012 which provided capital and operating estimates as well as finalised the selection of major process components. The business case presented in the prefeasibility study allowed for the further development of the project through a feasibility study, currently underway, as well as continuing to engage various bodies to obtain various environmental and regulatory approvals that are required for project execution.

2. PROJECT DETAILS

2.1. Geology

The Black Thor deposit is located in the Ring of Fire geological formation in the McFauld's lake region of Northern Ontario is a world class chromite deposit. The deposit has been through numerous rounds of geological drilling and is currently NI 43-101 compliant in accordance with Canadian regulations.

2.2. Mine Infrastructure

The remote and undeveloped location of the mine and concentrator site requires extensive investment in infrastructure to allow for the operation of the mining and beneficiation complex required by the process. This requires that all utilities and services required for not only the mine and process plant but also to support a full operational staff must be generated locally and brought up the Integrated Transport System (ITS) as the only supply link. The mine and concentrator are designed to be self sufficient with a fly in, fly out labour force. The plant will include a power generation station, accommodation complex, water management infrastructure, mine process related buildings and the concentrator process plant. The northern location requires that all these facilities be enclosed and able to operate in Arctic weather conditions.

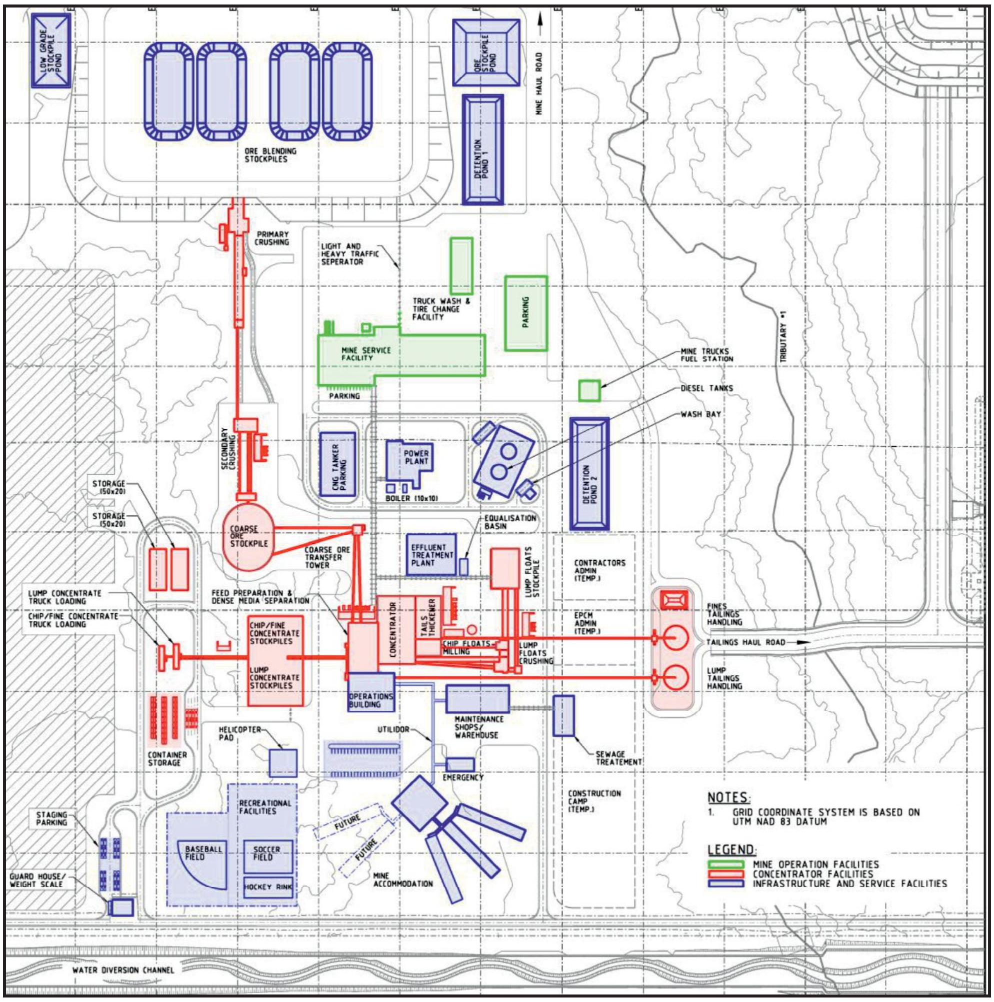
As a result of Cliffs ongoing commitment to reducing its carbon footprint the electrical generation on site will be performed with compressed natural gas. The total power requirement is expected to be approximately 20 MW. The excess heat from the power plant will assist in the heating of facilities and the process plant. Diesel will be maintained on site for the fuelling of haul trucks and as an emergency backup power source. The accommodation complex will house the workforce which is expected to be in the region of 450 – 500 during operations and as high as 1200 during construction. The development of a fully functional air strip capable of allowing the landing of large transport planes is critical to the safe and effective operation of the facility.

2.3. Mine Operations

The Black Thor deposit will be operated as an open pit mining operation delivering between 4 and 5 million tons per year of run-of-mine ore to the plant crusher. Operations are based on a standard drill and blast arrangement with hydraulic shovels and haul trucks for extracting the ore and overburden. The current mine design points to a life of mine of 27 years and an average Cr_2O_3 grade of 30% delivered.

2.4. Concentrator Operations

The concentrator has been designed to produce 2.4 million tons of concentrate at an average Cr_2O_3 grade of 43%. The flow sheet uses a combination of physical separation equipment to maximise both chromite recovery and mass yield. Due to the remote location of the site and the associated transport costs for the concentrate the flow sheet has been optimised to ensure as high as possible recovery. This resulted in the inclusion of a rod mill circuit to regrind the coarse tailings for reprocessing. Although the flow sheet is not dissimilar to other producers the size of the facility will make it one of the largest individual chromite concentrators in the world.



Cliffs Chromite Mine and Concentrator Site Plan

2.5. Integrated Transport System (ITS)

The integrated transport system is a critical component of the project and consists of a new 340 km all weather gravel road that links the mine and concentrator site to a transload facility located on the Canadian National mainline at Cavell. It represents the key artery whereby concentrate is moved out of the mine area and supplies are moved in. The transload facility is designed to handle both lump and fine concentrates and to appropriately move this material from trucks to rail cars for transport to either a Canadian port or to the Ferrochrome Processing Facility. Both road and the transload facility are designed to be able to handle approximately 7000 tons per day. All of the material moved between mine site and transload facility will be transported in sealed half-height twenty foot equivalent (TEU) intermodal containers. The containers provide several advantages over standard bulk transport.

- The containers are sealed and as a result limit any potential environmental effects.
- Due to the remote location containers represent a cheaper capital investment per ton of storage than large civil structures.
- The potential to backhaul supplies on the same trucks.
- As the containers operate within a closed transport loop they provide accurate tracking and shipping control over the large and integrated supply chain. This assists in lowering overall safety stockpiles and limiting working capital.

The material destined for the Ferrochrome Processing Facility will not be transferred from the truck and placed on rail cars without opening the container. This allows for cheap, efficient and traceable transfer of materials. Each containers contents and weight are known. This allows the furnace facility unprecedented quality control. Material bound for export will be emptied from the containers and stored in covered stockpiles on site before being loaded into bulk gondola cars for transport to the selected ports.

2.6. Ferrochrome Production Facility

The ferrochrome production facility (FPF) is located on a site north of the town of Capreol within the municipality of Sudbury. The site was selected due to the established skills based located in the Sudbury basin combined with large and well established infrastructure with particular focus on electrical grid capacity. The Hanmer substation within the Sudbury area is fed with a 500 kV line allowing for the significant fault protection required to connect a facility of this size. Proximity to the Canada National mainline and the previously disturbed nature of the site were also critical factors.

The facility is designed to produce 560 000 tons of High Carbon Ferrochrome (HCFeCr) per year utilising ore only from the captive mine. This will make the Cliffs FPF one of the largest ferrochrome facilities in the world. The chromite concentrate will be delivered in intermodal containers on unit trains from the transload facility. Four unit trains are required per week. The facility is able to handle both fine and lump material with an inline crusher installed to reduce the ore in size as required. Additional raw materials are sourced from North America and delivered by rail in bottom dump cars.

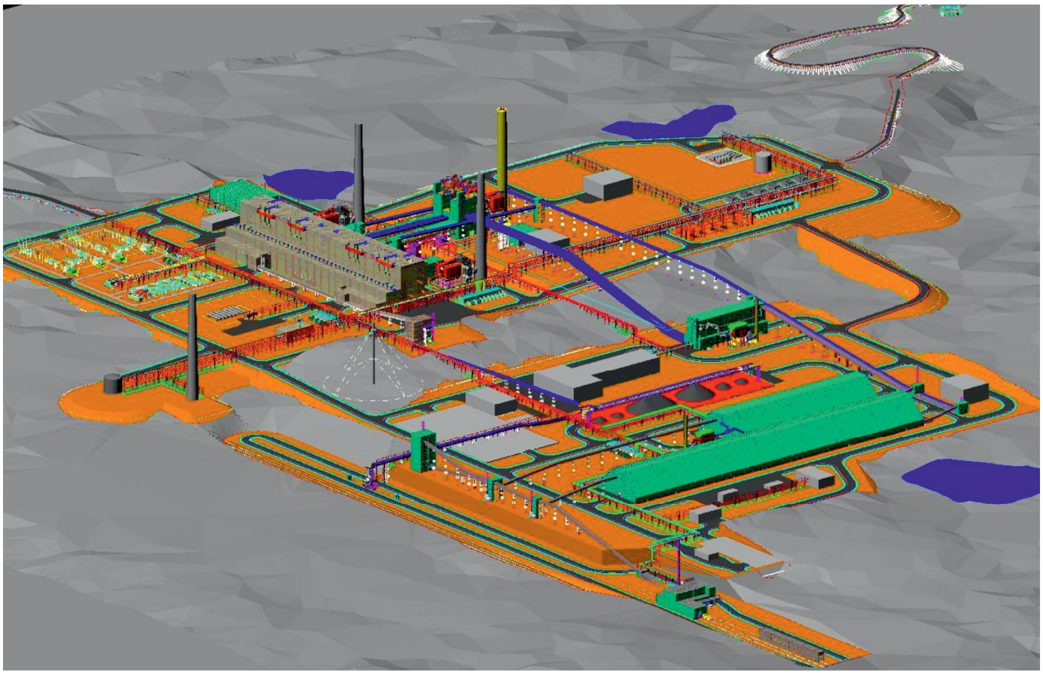
The raw materials will be stored in a combination of covered un-heated storage and containers. Due to the potential for residual service moisture to result in the freezing of the ore in the containers during shipment a rail thaw shed fired with LPG has been included.

The primary processing equipment at the facility consists of two carbon monoxide fired kilns feeding four 65 MW direct current open arc furnaces. The kiln calcine is transferred between kiln and furnace bin at approximately 650°C via an automated calcine transfer system. Each kiln is designed to feed two furnaces but can feed all four furnaces at a reduced furnace production rate.

The furnaces are circular single electrode DC furnaces with one slag and two metal tapholes. Slag is granulated directly from the furnace taphole and pumped for dewatering/storage at the tailings facility. Metal is tapped from one of the two tapholes into a 60 tons ladle eight times per day. The metal filled ladle is transported via overhead crane to a granulation station where the liquid metal is granulated, dewatered, dried and sized according to client requirements before being stored in a dedicated building. The final metal is loaded into rail cars for export to the various customers via either coast or directly to customers in North America.

During pre-feasibility Cliffs engaged heavily in evaluating the various process options for the Ferrochrome Production Facility. Cliffs wanted to be in the highest quartile for quality and the lowest quartile for cost. As a result of this and our commitment to the environment Direct Current (DC) furnace technology combined with the pre-treatment kilns has been selected as the most appropriate technology. The benefits associated with the technology are:

1. Higher overall chrome recovery.
2. Lower cost carbon inputs to DC smelting and no metallurgical coke use.
3. Better environmental control and lower hexavalent chrome creation.
4. Pre-heating and calcination of furnace feed resulting in lower overall energy consumption and associated costs.
5. Lower overall capital costs than competing technology.



Cliffs Ferrochrome Production Facility

The kilns utilise the CO gas generated within the furnaces as primary fuel and provide the furnace with a pre-heated, calcined and de-volatilised charge. Cliffs believes that this flow sheet will provide a significant operating advantage in terms of energy consumption and overall costs. The design estimates the electrical consumption of the smelting process is expected to be below 3.4 MWhrs/ton.

2.7. Efficient Technology in Action

Cliffs has searched for efficient and innovative ways to make the project safer, cleaner and cheaper for longer than any comparative operation. The push for efficiency is rooted directly in one of the company's core values: Creating Economic Value. Cliffs believe that they can create economic value by doing the right things correctly the first time, eliminating waste and inefficiency and by utilising breakthroughs in productivity and technology.

To this end the Cliffs Chromite project makes use of extensive technological innovations to ensure that our stakeholders and customers interests are maximised. As an integrated project spanning mining, transportation and processing Cliffs has found several work fronts that are amenable to the newest advances in technology and shared efficiency.

Ferroalloy smelting is always an energy intensive process. Cliffs has approached the project with a view to gaining greater efficiency in energy usage and reducing our overall energy footprint.

2.8. Energy

Cliffs fully recognise that ferroalloys are a large consumer of many forms of energy and are committed to reducing the energy impact and cost of all of our operations. The Cliffs project energy consumption footprint is made up of two major components – electrical energy at the Ferrochrome production facility and fossil fuels for sustaining the mining and remote operations at the mine and concentrator.

2.9. Fossil Fuels for Remote Operations

The mine and concentrator is isolated from any other infrastructure for several hundred kilometres. As a result all the fuel required for the operation of mining equipment and for the generation of electrical energy for the operation of the concentrator must be generated on. The expected total electrical requirement of the plant and associated infrastructure is approximately 20 MW. The facility also requires extensive heating during the winter months. Normally a facility of this nature would use diesel fired generators to provide electrical energy and to burn heavy fuel oil or diesel for heating. This presents several challenges for a site of this nature. The transport and storage of diesel volumes as required for a project like this is not without risk. Tanker trucks would have to be dispatched from Southern Ontario and would need to complete the final leg of their journey through a remote and environmentally pristine area including three provincial parks without incident. Although Cliffs has been unable to remove diesel as a source of fuel for mining operations the generation of electrical energy on site will be performed with compressed natural gas. The compressed natural gas offers several cost, energy and environmental advantages. The gas although offering less energy per unit volume than diesel is a viable option for this project for the following reasons:

- Gas can be easily piped and a nationwide framework is already in place allowing Cliffs to tap into this distribution network at the southern end of the ITS.
- Natural gas offers a lower carbon footprint and produces less deleterious substances than diesel.
- Natural gas removes the spillage risk to the environment as any spillage would be gaseous and not liquid resulting in a much lower water pollution risk.
- The natural gas offers a simple and effective energy source with a lower cost per unit energy.
- The North American gas market is projected to grow rapidly keeping prices for natural gas low.

The current design allows for a natural gas compression station located at or near the Transload facility which is within a short distance of the TransCanada Mainline. The gas will be compressed and packaged in steel or composite vessels containing 100 000 ft^3 of gas. The vessels will be transported by truck to the mine site and connected to the generator stations. The CNG will not be transferred between storage vessels on site but the vessels delivered by truck will become the site storage. The trucks and vessels thus form a virtual pipeline. Cliffs estimates that the use of natural gas over diesel will result in a lowering of the cost of electrical power generated at the facility by approximately 50%.

The diesel fuel storage on site is limited to 5 million litres and is primarily for the mining vehicles and fleet. In the event of a natural gas supply chain disruption the mining fleet will be stopped and the electrical generators switched to diesel to maintain building heating and critical infrastructure while a solution is sought or personnel are evacuated. Natural gas represents a logical and effective solution to some of the challenges facing the mine and concentrator.

2.10. Energy Management at the FPF

Ferrochrome smelting is a highly energy intensive process. For the Cliffs Chromite project the approach is to maximise the efficiency of energy brought onto site in any form and recycle all energy once on site prior to release as waste heat of as low a quality as possible. The process is designed to reduce wherever possible the total energy requirement and to utilise more cost effective forms of energy where possible. Electrical power is supplied from the Ontario power grid via a dedicated double circuit 230 kV line. The other forms of energy brought to site are reductants such as coal and anthracite as well as supplemental liquefied petroleum gas.

The closed DC furnaces will produce in approximately 51 000 Nm^3/h of carbon monoxide rich off-gas at temperatures above 1000°C. This process gas represents approximately 153 MW of potential energy. This energy is available for several uses if it can be captured and redistributed. An economic evaluation was performed within the project to determine the appropriate form of energy reclamation. It was determined that at the expected electricity prices for the project the most advantageous use of the carbon monoxide was as a primary process fuel with any additional fuel being used for building heating and then finally being flared. No electricity generation is currently envisaged however the design is not restrictive in this regard. The plant design allows for the cooling and cleaning of the gas from each furnace via a spray cooler, low pressure venturi and a disintegrator scrubber. The cleaned gas from each furnace is mixed via a common header and compressed before being distributed as a fuel across the site.

The primary users of the carbon monoxide are the preheating kilns. Although the use of carbon monoxide for preheating is not a new concept and has been unsuccessfully tried before Cliffs, if successful, will become the first commercial ferrochrome operation to utilise rotary kilns to pre-heat the feed. Each kiln will require approximately 54 MW of fuel to provide the heat required which is equivalent to 18 000 Nm^3/h of process gas. This allows for the pre-heating of the feed to a kiln exit temperature of 850°C. The beneficial impact of the pre-heating on the electrical efficiency of the furnace cannot be overstated. Traditional submerged arc furnaces are able to produce ferrochrome at between 3.5 and 3.8 MWh/ton while a commercial scale DC furnace has traditionally operated at 3.8 to 4.3 MWh/t. Cliffs believes the preheating of the furnace feed to a kiln exit temperature of 850°C will result in the electrical power consumption of the furnace dropping to at least 3.3 MWh/t. This represents a direct reduction of between 15% and 30% in the electrical energy costs. This is a significant saving in a time when energy prices continue to climb. A secondary component is that as the production rate is largely a function of the installed electrical capacity of the furnace and the specific energy consumption of the melt, improved specific energy consumption not only lowers costs but increases production volume over a similarly sized furnace. This additional volume has a large affect on the overall economics of the project.

Cliffs has elected to utilise a hot transfer system between the kiln and furnaces, which results in a loss of temperature of approximately 100°C between kiln exit and furnace feed, to preserve the energy. The system consists of an automated crane and container system which transports the heated material in a sealed container from the bottom floor kiln discharge area to the top floor furnace bin area. The system is designed to be fully autonomous. Cliffs believes that the system designed for the facility utilises proven technology which will allow Cliffs to maximise the use of the various energy sources available and minimise heat losses throughout the integrated flow sheet.

3. SUMMARY

Cliffs Natural Resources is developing a unique world class integrated chromite project in Canada. Designed as an environmentally sensitive, socially responsible and long term sustainable business unit the Chromite Project incorporates best available technology for the mining, transport and smelting of chromite and ferrochrome. Key to the project's success is the fundamental energy management systems and efficiencies within the organisation.

4. REFERENCES

[1] Internal Cliffs Project Documents.
[2] Internal Hatch Project Documents.