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FINDS SERVES THE WORLD'S FERTILIZER INDUSTRY AND INDUSTRIES USING RELATED TECHNOLOGIES.

Fertilizer Markets

Corn

Corn prices on the Chicago Board of Trade leveled out during the last quarter at about $4.40 per bushel, well below their previous peaks (Figure I, page 4). In February, the USDA forecast that U.S. farm income this year would decline 27 percent from last year's record high. Consequently, crop land values could fall significantly over the next several years after rising steeply between 2005 and 2013. However, USDA data shows that the average farm debt-to-asset ratio is lower today than at any time in the past (Figure II, page 4).

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Ochoa Sulfate of Potash Feasibility Study

By Arthur J. Roth

IC Potash Corporation (ICP) recently released results of the Ochoa Project feasibility study that SNC-Lavalin completed in January. This article summarizes the results for the project, which is located in southeast New Mexico near the Texas border. An introductory article about Ochoa was published in *FINDS* last year.[1] The feasibility study concluded that the proposed project is economically viable, has the capacity and reserves to produce over 714,000 tons of Sulfate of Potash (SOP) per year for at least 50 years, and should move forward. Table 1 (page 14) summarizes the financial results.

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The Shale Revolution

The U.S. shale revolution has lowered natural gas prices in North America to levels not seen in years and is also depressing oil prices. Other countries are eager to follow suit, but the U.S. has two distinct advantages. Its population density is relatively low and its property owners own the sub-surface mineral rights. However, overseas shale fields will be producing gas and oil sooner or later, lowering the production costs of ammonia, methanol, and petrochemicals.

In Europe, the UK is leading the nascent shale gas industry because it has significant shale deposits and because the British government supports fracking. David Cameron, the prime minister, is seeking a way to spread the new wealth equably and bring the UK a little closer to the U.S. model. France's extensive investment in nuclear power has reduced its appetite for gas-fired power generation.

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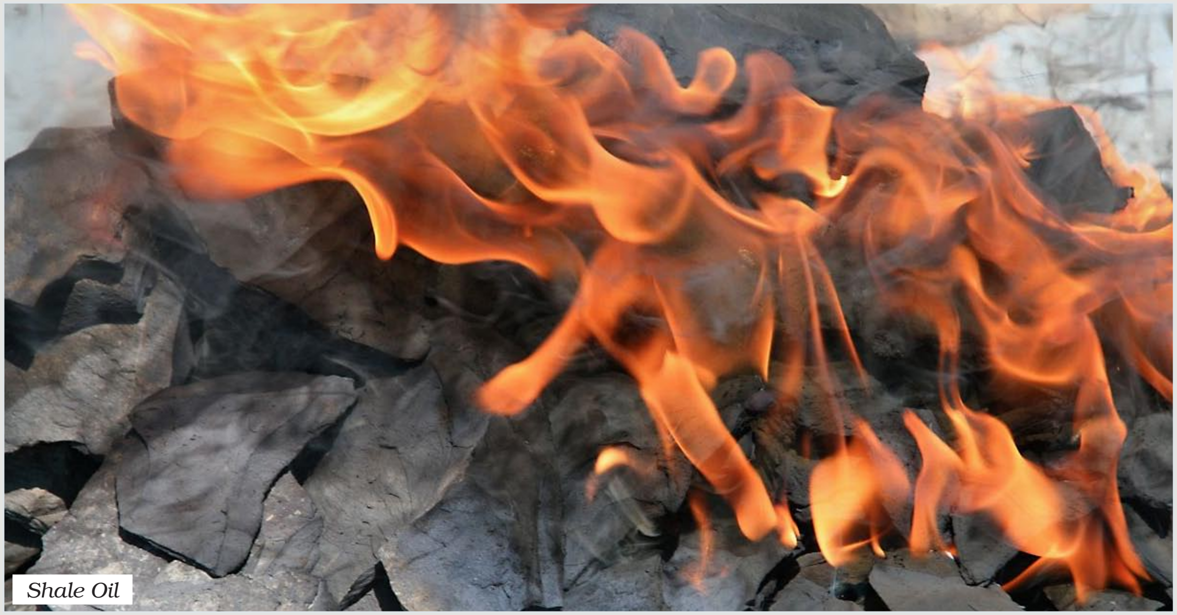

Shale Oil

OCHOA SULFATE OF POTASH ...(Cont. from cover)

Table 1

Full Equity Basis (i.e., No Debt)	Before Tax	After Tax
Capital Cost	$1,018.0 million	$1,018.0 million
Operating Cost per Ton SOP at Steady State	$ 195.0	$ 195.0
Internal Rate of Return (IRR)	17.8 %	16.0 %
Net Present Value (NPV), 8% Discount Factor	$1,502.3	$1,018.9
NPV, 10% Discount Factor	$ 942.7	$ 612.0
Payback Period	–	5.4 years

The financial model covers approximately three years of construction and commissioning beginning in the second quarter 2014 and continuing through the second quarter 2017, followed by 50 years of operation. SOP production is estimated at 48 percent of annual capacity in 2017, with full capacity expected in 2018. No inflation or escalation factors were applied to cash inflows and outflows in the financial model.

Table 2 shows the sensitivity of after-tax IRR to capital, operating, and revenue assumptions.

Table 2

Input Variable to Financial Model	- 20%	-10%	Base Case	+10%	+20%
Capital Cost	19.3%	17.5%	16.0%	14.7%	13.6%
Revenue	11.3%	13.8%	16.0%	18.1%	20.1%
Operating Cost	17.8%	16.8%	16.0%	15.1%	14.2%

Capital Cost

The project's estimated capital cost is $1,018 million +/-15 percent. Table 3 summarizes the capital cost by major area.

Table 3

Estimated Capital Cost by Major Area	(millions)
Infrastructure and Development	$ 107
Process Plant	$ 527
Storage and Loading	$ 37
Total Direct Costs	**$ 671**
EPCM Services	$ 99
Construction Indirect	$ 22
Freight, Spares, and First Fills	$ 34
Total Indirect Costs	**$ 155**
Owner Costs	$ 80
Contingency	$ 112
Project Total	**$ 1,018**

Operations

Steady State Production, shown in Table 4 (page 15) , is the period from 2022 to 2065. Steady State years generally exclude major one-time costs that are included in years 2017 through 2021, such as start-up activities, equipment rentals, initial receding face expenditures, and inventory adjustments.

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OCHOA SULFATE OF POTASH ...(Cont. from page 14)

Table 4	**Estimated Operating Cost per Ton of SOP**
Steady State Production	714,400 Tons Per Year of SOP
Mining Cost per Ton	$ 78.0
Processing Cost per Ton	$ 108.0
General and Administrative Cost per Ton	$ 9.0
Total Operating Cost per Ton	**$ 195.0**
Percent of Operating Cost – Labor	24.8 %
Percent of Operating Cost – Electricity	24.5 %
Percent of Operating Cost – Natural Gas	20.7 %
Sustaining Capital per Ton per Year	$ 40.0

The plant is designed to operate for 7,900 hours annually. At full production, it should employ 400 people. Pilot test work by independent consultants and equipment providers projected an 82.2 percent K_2O recovery and an SOP product with a potassium content, or K_2O equivalent, of between 50.3 percent and 53.7 percent. Power costs are estimated at $0.035 per kwh; natural gas at $3.69 per mmBtu; and No. 2 diesel fuel at $3.95 per gallon.

Revenue Assumptions

My company, A.J. Roth and Associates, provided pricing estimates by grades and receiving locations for the study. The relevant SOP grades are standard, granular, and soluble. Upon full production of the estimated 714,400 tons per year, the product mix is projected to be 229,400 tons of standard SOP, 385,000 tons of granular SOP, and 100,000 tons of soluble SOP. A weighted average SOP FOB Jal, New Mexico, price of $636 per ton was used in the financial model. As reported in *Green Markets*, the average fourth quarter 2013 granular SOP price was $680 per ton for California delivery. Granular SOP prices historically receive an average premium of approximately $50 per ton above standard SOP. During the fourth quarter 2013, ICP estimated the soluble SOP price was $740 per ton for Florida delivery.

Mineral Resources and Mineral Reserves

The study identified measured and indicated resources of 1,018 million tons at an average grade of 83.9 percent by weight polyhalite. The resource was constrained by a minimum polyhalite thickness of four feet and a minimum resource grade of 65 percent polyhalite. Mineral resources that are not mineral reserves do not have demonstrated economic viability. Mineral resources are summarized in Table 5.

Table 5 — Mineral Resources (effective date May 31, 2013)

Category	Average Thickness (ft)	Resource Area (acres)	In-Place Tons (millions)	Polyhalite (wt %)	Equivalent K2SO (wt %) 7	Anhydrite (wt %)	Halite (wt %)	Magnesite (wt %)
Measured	5.2	26,166	511.7	84.5	24.4	4.02	3.27	7.94
Indicated	5.0	26,698	506.0	83.3	24.1	4.00	3.30	8.61
Total M&I	5.1	52,865	1,017.8	83.9	24.2	4.01	3.28	8.27
Inferred	4.8	15,634	284.0	82.6	23.9	4.11	3.37	8.82

In addition to defining the mineral resources and mineral reserves, the study specified a 50-year mine plan. Contained within the mine plan are approximately 182.4 million recoverable tons of proven and probable reserves containing 78.05 percent by weight polyhalite. Mining was constrained to a minimum polyhalite grade of 66 percent, as well as a minimum polyhalite thickness of four feet. A summary of these mineral reserves is listed in Table 6.

Updates to the mineral resources and mineral reserves estimates are based on ICP's Phase 3A exploration drilling program, which was a continuation of the exploration program included in a 2011 Pre-Feasibility Study (PFS). Industry best practices were followed for the exploration program. The investigations, interpretation of exploration information, and the quality assurance and quality control measures for the Phase 3A program are as reported in the PFS.

Over 70,000 feet of exploration drilling has been completed to date. Additionally, 855 petroleum wells were incorporated into the model (for stratigraphy correlation and bed thickness only) through geophysical logging. A higher minimum polyhalite grade (66 percent) was defined for the mineral reserves to ensure compliance with the mineral resource cutoff grade (65 percent) when developing mine projections.

Table 6 — Mineral Reserves (effective date January 9, 2014)

Category	Average Mined Thickness[2] (ft)	50-Year Mine Plan Mined Area (million sq ft)	ROM Mine Tons (millions)	Mining Recovery (%)	Polyhalite (wt %)	Equiv. K_2SO_4 (wt %)	Anhydrite (wt %)	Halite (wt %)	Magnesite (wt %)
Proven	5.9	246	125.0	47.1	78.42	22.66	11.29	3.66	7.79
Probable	5.9	113	57.4	64.8	77.20	22.31	11.60	3.65	8.30
Total P&P	5.9	359	182.4	51.5	78.05	22.55	11.39	3.66	8.08

As compared to the PFS, mineral reserves increased over 30 percent from 139.5 million tons to 182.4 million tons while maintaining similar polyhalite grades (79.39 percent in the PFS to 78.05 percent in the study). Measured and indicated resources (four-foot minimum thickness) increased from 983.8 million tons to 1,017.8 million tons.

Measured and indicated mineral resources exist to the north, east, and west of the 50-year mine-plan boundary and those resources should be economically mineable and extend mining operations beyond 50 years.

Environment and Permitting

ICP remains on schedule to receive a Record of Decision on its Environmental Impact Statement (EIS) in early April 2014. The schedule will allow construction to begin as planned. The Bureau of Land Management and its consultant are currently preparing to issue the final EIS once review comments are incorporated into the document. Publication of the final EIS is expected in February 2014.

In parallel with the EIS process, ICP also submitted an air quality permit application for construction to the New Mexico Environment Department's Air Quality Bureau. NMED AQB ruled the application administratively complete last December. The technical review should be complete by June 10. The assessment included in the permit application demonstrates that the project complies with air quality standards.

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OCHOA SULFATE OF POTASH ...(Cont. from page 15)

To date, the U.S. Army Corps of Engineers (Corps) has concluded no authorization from the Corps is required for construction and the New Mexico Office of the State Engineer has concluded that the ICP has full right to appropriate non-potable water from the Capitan Reef aquifer for mining and industrial use.

Mining

Room-and-pillar mining will extract ore from the deposit at a nominal rate of 3.7 million tons per year. Equipment selection includes state-of-the-art, high-horsepower, continuous mining equipment currently in use throughout the world in the coal, trona, and potash sectors. During the study, ICP performed linear cutting tests on the polyhalite core. A manufacturer of continuous mining equipment reviewed the test results, performed additional testing, and recommended the use of drum-type continuous miners.

The ore bed will be accessed via a 25-foot diameter, two-compartment mine ventilation and service shaft and a 12,000-foot, 8.5 degree slope. The 1,525-foot deep shaft will have an intake air compartment equipped with an emergency escape hoist and cage as well as electrical high voltage and communication cables. The second compartment will be used for return air and will contain fresh water and mine discharge water piping to prevent freezing during the winter months. General mine ventilation will be accomplished with dual 11-foot fans installed in parallel on the return side of the shaft. The slope provides flexibility to accommodate increased underground production as needed. Ore will be transported to the surface via a 60-inch slope conveyor with a capacity of 4,000 tons per hour.

The study recommends dual split super section (DSSS) mining methods. Parallel sets of main entries will be developed, each five to seven entries wide. Production panels will be developed up to 1,000 feet wide to accommodate the DSSS concept of operating two continuous miners side-by-side using a centrally located single belt conveyor. DSSS supports the use of common equipment such as section scoops, forklifts, and section conveyors. DSSS keeps both capital and operating costs as low as possible.

Surface Facilities

The plant will include several key unit operations to process a continuous stream of polyhalite ore from the mine into finished SOP products. The main process circuits include crushing and washing, calcination, leaching, evaporation and crystallization, and drying and granulation. In conjunction with the crushing phase, washing removes sodium chloride from the ore and ensures a high-quality, appropriately-sized feed to the calciner. Fluid-bed calciners provide precise temperature control and cause the ore to become readily soluble in water. A two-stage, counter-current leach circuit produces brine containing potassium and magnesium sulfates. This brine is fed to the evaporation and crystallization circuits where SOP is crystallized. Following crystallization, drying and granulation of the crystals produces the final product. Pilot plant operation confirmed that the process is technically and economically viable on a continuous basis. Portions of this process are covered by U.S. Patent 8,551,429, with other U.S. and foreign patents pending.

The SOP products will be trucked 22 miles to a rail-loading and truck-distribution facility. From this facility, ICP will have the ability to reach domestic rail and truck markets, as well as nearly any international dry bulk port facility in the Americas. Tailings management will include a variety of evaporation ponds and injection wells, in addition to a dry-stack gypsum storage facility. Deep saline water will be sourced from the Capitan Reef aquifer and treated, where necessary, through reverse osmosis. ■

[1]Sidney Himmel. "New Mexican Polyhlite: The Key to Producing High-Performance, Low-Cost Sulfate of Potash Fertilizer Products." *FINDS*, Vol. XXVIII, No. 1, page 1.