DEVELOPING A NEW PROCESS DESIGN FOR THE SOUTHWESTERN OREGON INDUSTRIAL MINERAL BEARING PLACER SYSTEM VIA PRACTICAL STUDY OF THE UNIQUE DEPOSITION, MINERALOGY, AND DRY TAILING REQUIREMENTS

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Introduction

Oregon Resources Corporation (ORC), an industrial minerals mining company, is currently engaged in the development of a new process design that will allow the unique paleo-beach placer deposits of southwestern Oregon to be mined efficiently and economically, creating an additional domestic source for chromite, garnet, and zircon.

Engineering design has been guided by the variable geology and mineralogy of the paleo-beach placer deposits as well as the need for a dry tailing scheme that resolves a lack of water resources at the placer locations and at the same time eliminates the need for slurry settling ponds, typical of paleo-beach placer operations in North America.

Metallurgical study of the placer material was grouped into four distinct samples based on marine terrace deposition, geological facies, and mineralogy. Because the metallurgical samples represented the extremes likely to be encountered in all future Oregon paleo-beach placer ores, the process design is highly dynamic and will successfully adjust to meet the production needs.

Water availability at the mining area is seasonal and will not support a typical placer operation's water requirement needs for heavy mineral concentration. For this reason, ORC has developed a plan to construct the ore processing facilities near Coos Bay, where a municipal source of water is available. Raw ore will be transported from the mining sites approximately twenty miles one way to the processing facility with return loads hauling tailings back to the active pit. The need to haul dry tailings, return dry material to the pit for reclamation, and limit the amount of water being purchased from the municipality has driven the design of a unique water reclamation system.

Background

Location and Access

Economic concentrations of "black sand" or heavy mineral (minerals with specific gravity greater than 2.85) have been recognized and studied in marine placers from Coos Bay to the mouth of the Rogue River, a distance of approximately 75 miles along the southern Oregon coast (Hornor, 1918; Griggs, 1945)(Figure 1).

ORC will begin mining existing reserves approximately 20 miles south of Coos Bay in a region known locally as Seven Devils. Ore will be trucked north to the processing site near Coos Bay via use of existing county and state roads, including U.S. 101.

The available facilities at the processing site include highway, rail, municipal water and electricity, natural gas, and a deep water port. At the time of this writing, the rail line had been abandoned, but was being pursued by the International Port of Coos Bay. It is anticipated that this will be serviceable at some time in the future.

History

The southern Oregon marine placers have garnered the interests of miners since 1852, when present day beaches were exploited for gold. The beach deposits were small and irregular in nature and were easily washed away by the major storms the coast endures during the winter months (Hornor, 1918).

In the 1920's, deposits at the beach were followed upstream to their paleo-beach terrace origins (Pardee, 1934). These terrace placers were mined, but with little success, as the cost of mining and processing was greater than at the present day beach deposits.

The greatest effort to understand and delineate the paleo-beach terrace placers came during World War II. As the need for a domestic source of steel hardening

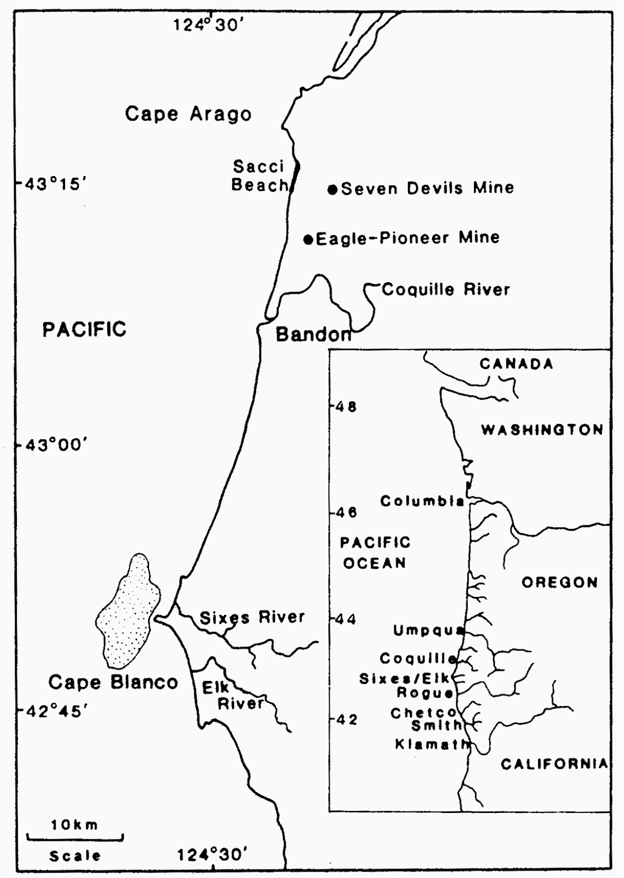

Figure 1. Location map of southern Oregon with major sediment source rivers (Peterson et al., 1987).

chromite was evident, the heavy mineral bearing placers of southwestern Oregon provided just that. The U.S. Geological Survey, under guidance from the Oregon Department of Geology and Mineral Industries, began exploration drilling of the paleo-beach terraces in 1940 (Griggs, 1945). This work was part of the investigation of strategic mineral deposits and would ultimately supply much needed chromite for the war efforts.

The first mining efforts began in 1943 by the Humphreys Gold Corporation and the Krome Corporation (Griggs, 1945). Black sand concentrates averaging roughly twenty five percent Cr_2O_3 were produced at the mining sites via wet gravity processes and trucked to the Defense Plant Corporation's separation plant near Coquille, Oregon, where the black sand was further concentrated to approximately forty percent Cr_2O_3.

Humphreys Gold Corporation developed and utilized the revolutionary helical spiral separator for the purpose of concentrating the heavy mineral of the Oregon paleo-beach placers (Allen, 1943). Today, this methodology is still utilized in hundreds of mining applications from placer mining to coal processing.

Geology

Regional Geology

As with any marine placer deposit, one must understand the source of the economic minerals, the transport mechanisms, segregation and depositional systems, and preservation of the deposits.

The heavy mineral of the southwestern Oregon placers are sourced from the metamorphic and ultramaphic rocks of the Klamath Mountains (Twenhofel, 1943). The Klamath Mountains are located in southwestern Oregon and northwestern California. Within the metamorphic and ultramaphic terrain exist alpine-type podiform chromite deposits. Several small operations have attempted to exploit these deposits with little success, given the podiform variability (Libbey, 1963).

Several major rivers including the Chetco, Rogue, Elk, Sixes, and the Coquille drain from the Klamath Mountains to the Pacific Ocean (Kulm et al., 1968). Mineral grains in currently identified paleo-beach placer deposits have been chemically analyzed with ion microbe analysis to demonstrate that their sources are indeed the existing rivers whose watersheds begin in the Klamath Mountains and in the regions of the alpine-type podiform chromite deposits (Peterson et al., 1986).

Once the sediments reach the Pacific Ocean, predominant longshore currents transport the sediments northward. Headlands along the paleo-coastline reduced the energy of the currents and allowed for the preferential removal of dense particles according to Stokes Law (Peterson et al., 1986). Currently, deposits of heavy minerals are forming off the coast of southern Oregon, following the same mode of deposition adjacent to prominent headlands (Cape Blanco) (Kulm at al., 1968). Another characteristic of the Oregon coast is the fierce storms and high energy wave action that occurs along the beaches. This high energy environment is sufficient to segregate the dense from light minerals and is amplified during storm events.

Finally, once the economic heavy minerals are in place and concentrated, the deposit must be preserved. Such industrial mineral placers around the world typically show preservation via high sea level stands and subsequent regression, leaving behind the coastal remnant. The Trail Ridge deposit, which stretches from Florida to the Carolinas, represents such a depositional model. Economic heavy minerals have been mined from this ridge since the late 1940's to present. It is suggested by Peterson, et al. (1986) that the southern Oregon paleo-beach terraces were formed by a transgressive sequence that encroached approximately five kilometers inland from the present-day beach followed by regression, high sea-level stand, and a subsequent progradational beach forming sequence, thus forming the overall geomorphology of the region into a stair-step sequence leading down to the present day beach (Peterson et al., 1987).

Terrace Geology

Although several terraces exist, ORC's operation currently is developing reserves within the Seven Devils and Pioneer terraces (Figure 2).

The Seven Devils terrace has been suggested to be 124,000 years old (Pleistocene) (Adams, 1984). The terrace has been uplifted to an elevation of 75 to 85 meters above present sea level and is inland five kilometers, roughly parallel with the current beach. The Seven Devils terrace can be traced from approximately seven miles south of Cape Arago to Cape Blanco to the south, a distance of approximately fifty kilometers. Griggs (1945) suggests that the terrace is truncated to the east by normal faulting, leaving a sharp contact between the terrace sands and an older Tertiary mudstone (weathered to clay in most areas). To the west, the terrace is eroded by the subsequent formation of the younger Pioneer terrace (Figure 3).

Peterson, et al. (1987) interpreted stratigraphic sections studied within the Seven Devils terrace to represent a transgressive sequence. Deposition on the Seven Devils terrace represents the nearshore to inner shelf deposition of the transgressive sequence. Exploration drilling by the Krome Corporation and ORC indicate the presence of additional tensional faulting in the nearshore environment that increased the thickness of the sediment package. As a result, typical nearshore orebodies (North and South Seven Devils) have mineralized sand depths from surface to maximum of thirty meters, while averaging fifteen meters. Typical of the nearshore deposition, the delineated reserves are characterized by a basal conglomerate of well rounded rocks and agates overlaying the weathered Tertiary mudstone (Baldwin et al., 1983 and ORC drilling). Coarse sands overlay the conglomerate and include some of the highest concentrations of heavy minerals, in some cases up to ninety five percent. These higher grade units typical reflect lags created under high energy storm sequencing. Upsequence, a general fining upwards exists, representing the transgressive nature of the ocean. Heavy mineral concentrations are recorded throughout the entire sequence, but there is no doubt that as the transgressive sequence progressed and energy shifted from high breaker/swash zone to seaward energies, segregation and concentration waned. In stark contrast to the lower zones of deposition, the upper zones typically contain two to ten percent heavy mineral. Authigenic clays derived from feldspars and other weathered minerals exist within the deposits and represent ten to fifteen percent of the ores within the nearshore environment. Bioturbation does exist in the form of branching tubes very typical of nearshore environments (Hunter, 1980).

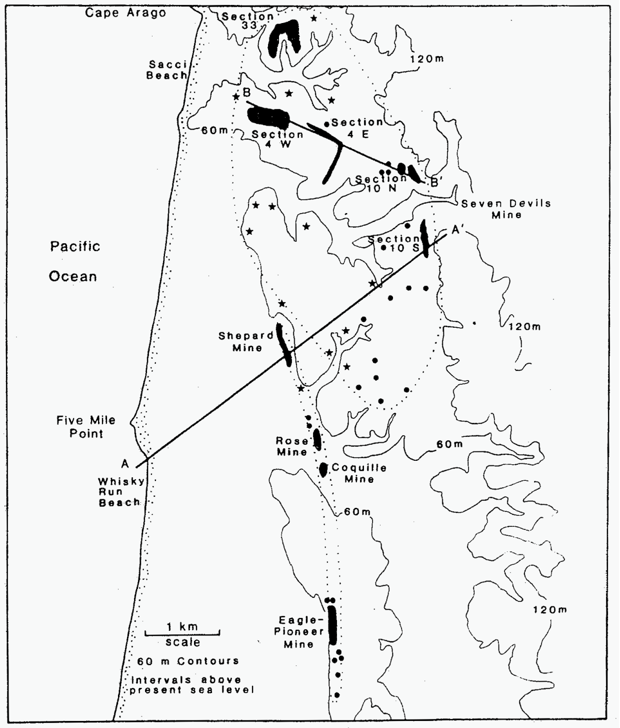

Figure 2. Detailed map of study area with deposits. Cross section A-A' depicted (Peterson et al., 1997 with supporting data from Griggs, 1945).

West of these deposits on the Seven Devils terrace, ORC has further delineated the Westbrook (Sec. 4E), West Bohemia (Sec. 4E), and Section 33 deposits. These deposits are shallow in nature, located at or near surface to maximum depths of nine meters and averaging six meters. As is the case with the previously described North and South Seven Devils deposits, the western deposits along the Seven Devils terrace demonstrate a transgressive sequence as suggested by Peterson et al. Similarities include the sequencing from basal Tertiary mudstones/clay and conglomerate unconformity followed by coarse sand deposition with higher concentrations of heavy mineral continuing upsection to lower energy sands. The primary difference between the two sets of deposits being the total depth of the deposited package of sand. The North and South Seven Devils deposits are narrowly bounded by north-south trending faulting, whereas the westward reserves on the Seven Devils terrace are broad, laterally continuous representations of full scale beach deposition and transgression.

The Pioneer terrace is the younger of the two terraces in which ORC has been delineating reserves. The age of the terrace is approximately 103,000 years old and

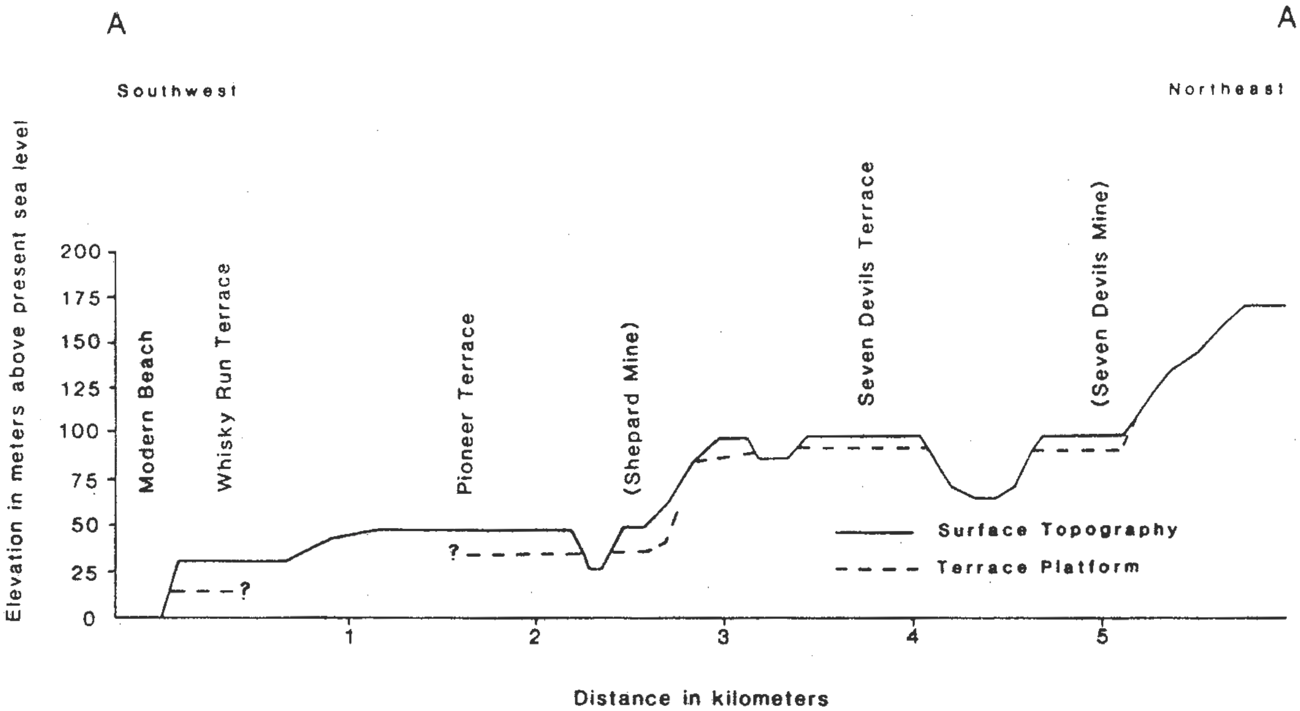

Figure 3. Generalized cross section of the southwestern Oregon paleo-beach terraces (Peterson, et al., 1987).

represents a progradational beach sequence formed at high sea-level stand (Adams, 1984). The stratigraphic sequence of the Shepard deposit, the only reserve currently delineated by ORC on the Pioneer terrace, is similar to that of the Seven Devils terrace deposits and generally represents deposition at what would be the final stages of the transgressive sequence (Peterson et al., 1987). A basal conglomerate of well rounded rocks and agates exists above an unconformable layer with the same Tertiary mudstone encountered on the Seven Devils terrace deposits, followed by a nearshore/swash zone depositional sequence of coarse sand and higher concentrations of heavy mineral. Once again, this higher energy zone served to concentrate the heavy mineral during periodic storm and wave events. Upsection is found the same fining upward sequence along with lowered concentration of heavy mineral resulting from lower energy environments associated with the transgressive sequence. The Pioneer terrace deposit differs from the previous terrace deposits in that it is capped by aeolian dune sequences that represent the end of transgression and the early stages of beach progradation (Peterson et al., 1987). While this aeolian sand does contain heavy mineral, it is not in economic concentrations within the Shepard deposit study area.

Mineralogy

Economic minerals from the southern Oregon paleo-beach placers currently being marketed by ORC include chromite, garnet, zircon. Other recoverable minerals include ilmenite, magnetite, staurolite, kyanite, sillimanite, rutile, leucoxene, gold, and platinum (Hornor, 1918 and Griggs, 1945). Not only do the total concentration of these economic minerals vary with depositional facies, there is also a degree of variability found in overall assemblage between the Seven Devils and Pioneer terraces. Constant among all of the terraces, however, is the degree of sphericity and rounding as well as the overall sizing and sorting (Hoyt, 2006).

The deposits located on the Seven Devils terrace (North and South Seven Devils, Westbrook, West Bohemia, West Section 10, and Section 33) contain higher concentrations of chromite and zircon in the heavy mineral fraction (specific gravity greater than 2.85) than does the Shepard deposit located on the Pioneer terrace. Full ore reserve (not metalurgical bulk sampling) analysis performed by ORC indicates that concentrations of chromite within the Seven Devils terrace ranges from approximately 33 to 43 percent, in contrast to only 23 percent on the Pioneer terrace (Drew, 2008). The same can be said of zircon, which averages between 1.5 and 2.9 percent within the Seven Devils terrace and only 1.4 percent on the Pioneer terrace. Alternatively, the Pioneer terrace shows greater percentage of garnet, at 12.6 percent versus 4.6 to 9.8 percent on the older Seven Devils terrace (Drew, 2008). This differences in mineral assemblage reflects the differing sources supplying the system at the time of deposition. Peterson, et al. (1986) has shown several unique river sources supplied the deposition at varying stages of terrace development, yielding the shifts in mineralogy.

Constant throughout both the Seven Devils and Pioneer terrace deposits is the general physical nature of the heavy mineral. The chromite, garnet, and zircon sand grains from the southern Oregon paleo-beach placers are highly rounded and moderate to highly spherical (depending on original crystal form) (Hoyt, 2006). The grains have also experienced a high level of sorting by the wave action of the Pacific Ocean, yielding very consistent products.

Process Design

Bulk Sample Selection and Preparation

A total of four bulk samples for metallurgical test work and plant design were collected by the ORC team (Table 1) and delivered to Outotec (USA) Inc. for characterization. Criteria for selection included marine terrace deposition, geological facies, and mineralogy. Upon selection, the bulks were collected using existing drillhole samples.

To accomplish the goal of creating a set of bulk samples that best represented the known mineable resources, the ORC team divided the Seven Devils from the Pioneer terrace deposits. Based on previous work by Griggs (1945) and Peterson, et al. (1987), the mode of depositional (facies) changes present between both terraces and the mineral sourcing variability present at the time of deposition was enough to warrant concurrent metallurgical investigation of the two terraces.

Table 1. Bulk sample location and mineral information. SH=Shepard, WB=Westbrook, S7D=South Seven Devils, N7D=North Seven Devils deposit.

	Bulk Sample ID			
	SH	**WB**	**S7D**	**N7D**
Drillhole Samples	83	358	470	172
Total Bulk Weight (lbs)	1,634	2,351	8,248	5,190
Terrace Represented	Pioneer	Seven Devils	Seven Devils	Seven Devils
Deposits Represented	Shepard	Westbrook West Bohemia Sec 10, 33	South Seven Devils	North Seven Devils
% Heavy Mineral (sg > 2.85)	62.3	21.9	43.4	34.8
% Chromite	14.5	10.3	18.9	11.9
% Garnet	10.1	1.0	6.0	1.7
% Zircon	1.2	0.6	1.8	1.2
% Epidote/Clinozoisite	30.5	12.3	18.6	20.9
% Staurolite	1.5	0.4	0.3	0.7
% Ilmenite	1.0	1.1	4.3	0.5
% Leucoxene	0.5	0.5	0.3	0.8
% Rutile	0.2	0.2	0.5	0.4
% Magnetite	0.0	0.1	0.4	0.1
% Misc. Light "heavies"	3.6	0.4	1.0	0.9

At the time of bulk preparation, only the Shepard deposit within the Pioneer terrace had been delineated and drilled out, thus the requirement for only one bulk sample. The Shepard deposit on the Pioneer terrace also represents the largest shift in mineralogical assemblage, specifically The Seven Devils terrace deposits, however, included multiple deposits delineated and drilled out by ORC. A total of three bulks were selected within the Seven Devils terrace on the basis of, first, location relative to the eastern boundary of deposition, a north-south trending normal fault scarp described by Griggs (1945) to be the equivalent of a sea cliff. The North and South Seven Devils deposits are located at the base of this scarp and are notably thicker in total sand deposition than the Westbrook, West Bohemia, and West Section 10 and 33 deposits. Secondly, the North and South Seven devils deposits were bulked separately based on the relative amount of lower grade, uneconomic sand deposited in the final stages of the marine transgression at maximum ocean depths. While both deposits would have contained such deposition, the South Seven Devils deposit was partially mined during WWII, thus removing the upper sections of deposition that is still preserved at the North Seven Devils deposit.

The Westbrook, West Bohemia, West Section 10, and Section 33 deposits are all part of the Seven Devils terrace transgressive sedimentary package that has been dissected by erosion and mass wasting. These deposits are represented by one bulk sample resulting from the drilling at the Westbrook deposit.

Bulk samples were collected by splitting five foot drillhole interval samples previously collected and warehoused by ORC. A small sample was retained, while the remainder was placed in 55 gallon drums. Samples for bulking were selected on the criteria that greater than or equal to four percent chromite be present *in situ*. This cutoff is typically considered by ORC to be of economic value. Interbedded lenses of less than four percent chromite were included in the sampling, thus representing the realistically mined deposit (Tables 2, 3).

Table 2. Bulk sizing, desliming, and oversize data.

	Bulk Sample ID			
	SH	**WB**	**S7D**	**N7D**
% Pit Oversize (4 mesh, +4.75 mm)	1.3	4.0	3.1	2.6
% Plant Oversize (-4, +18 mesh, -4.75, +1.0 mm)	2.1	6.1	4.8	4.0
% Slimes (-230 mesh, -63 µm)	6.7	14.8	14.0	14.8
% Passing Deslime to Gravity Circuit	89.9	75.1	78.1	78.6
Screen Analysis of Deslimed Gravity Circuit Feed	100.0	100.0	100.0	100.0
+20 mesh (850 µm)	0.0	0.1	0.0	0.1
-20, +30 mesh (600 µm)	0.2	2.7	0.8	0.4
-30, +40 mesh (425 µm)	0.7	8.4	1.9	1.1
-40, +50 mesh (300 µm)	5.6	28.3	6.9	8.1
-50, +70 mesh (212 µm)	26.6	29.4	29.1	41.2
-70, + 100 mesh (150 µm)	43.4	17.8	33.7	30.7
-100, +140 mesh (106 µm)	18.9	8.1	20.5	13.0
-140, +200 mesh (75 µm)	3.7	3.3	5.5	3.7
-200, +230 mesh (63 µm)	1.0	1.0	1.7	1.9

Table 3. Heavy mineral concentrate sizing from bulks.

	Bulk Sample ID			
Screen	**SH**	**WB**	**S7D**	**N7D**
+20 mesh (850 µm)	0.0	0.0	0.0	0.0
-20, +30 mesh (600 µm)	0.0	0.3	0.1	0.0
-30, +40 mesh (425 µm)	0.0	1.1	0.4	0.2
-40, +50 mesh (300 µm)	3.1	8.6	0.8	2.1
-50, +70 mesh (212 µm)	29.0	28.9	12.4	20.7
-70, + 100 mesh (150 µm)	39.5	34.3	39.4	39.3
-100, +140 mesh (106 µm)	16.2	11.8	29.8	26.4
-140, +200 mesh (75 µm)	12.2	13.9	16.2	10.9
-200 mesh (-75 µm)	0.0	1.1	0.8	0.5

Ore grade control

The sample characterization summarized in Tables 1, 2, and 3 were homogenous samples produced from a drill program undertaken in 1991 by ORC. The goal of the 1991 drill program was to verify the findings of previous drilling studies and not necessarily to define the vertical and horizontal economic pit boundaries. Subsequent exploration programs in 2007, defined vertical and horizontal economic pit boundaries. The most recent drill studies indicate that grade varies not only by deposit but also vertically within the same deposit. For example, the heavy mineral content of S7D can from vary from10% at the surface, to > 70% at the bottom of the deposit.

The heavy mineral variations dictate the first design consideration, ore feed, grade control. Grade control will be accomplished via mining method. Mining will begin by establishing a low point at the edge of the deposit. Bull dozers will push diagonally through the vertical plane, taking slices of material from the entire vertical plane (top to bottom) with each push.

Grade control is especially important in the wet process. The wet process incorporates spirals where slurry is pumped to the top of the spiral and flows down the spiral in a corkscrew fashion. While descending the spiral, the minerals sort into distinct bands of materials of similar densities. Similar minerals are concentrated by splitters, which physically direct like bands of material onto the next processing step.

Feed grade should be made as consistent as possible in order to keep the width of the bands as uniform as possible. The position of the splitters is adjustable and the spiral circuit does have several reprocessing loops but the system would not be able to stabilize heavy mineral concentrate (HMC) recovery and grade with variations ranging from 10 to 80% (S7D). Figure 4 illustrates a typical spiral cross section. Dense materials, depicted by darker particles on the inside (right side) produce a distinct band. Stabilizing the feed grade produces a consistent band width of concentrate. The splitter would be positioned at the boundary between dense and non-dense material. Stabilizing feed grade, stabilizes band width and makes maximizing recovery and stabilizing HMC grade possible.

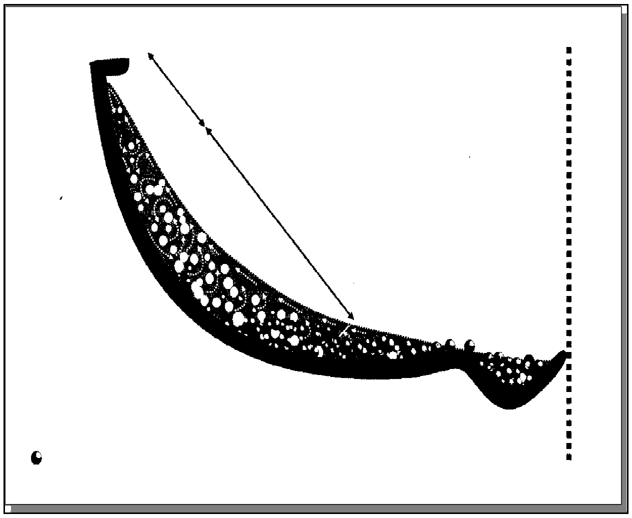

Figure 4. Typical spiral cross section

Ore and tailings transportation

Typically, wet concentrators are located close to the deposit to minimize transportation cost of getting ore to the wet concentrator and moving tailings back to the reclamation pits. Tailings are usually transported to reclamation areas via pumps moving slurry at 30-40 wt% solids.

The -230 mesh material (slimes), portion of tailings are usually difficult to dewater and for this reason tailings are frequently pumped to a series settling ponds where heavy equipment is utilized to work the coarse and fine material back together. Handling tailings this way is often difficult, as a series of collection ponds is usually required to allow the suspended solids enough time to settle, so the water fraction can be reused as process water.

Due to high ore grade, topography, zoning issues and lack of existing utilities and available process water at the mine site, both the wet and dry processing facilities are to be located separate from the mine site. The processing facilities will be located approximately 20 miles from the mine site.

Typical thickened tailings slurry (thickened surry at 40 wt% solids) could not be successfully trucked back to the reclamation site. Project success rests on ORC's ability to dewater tailings, so that it can be handled with standard, over the road, belly dump trucks.

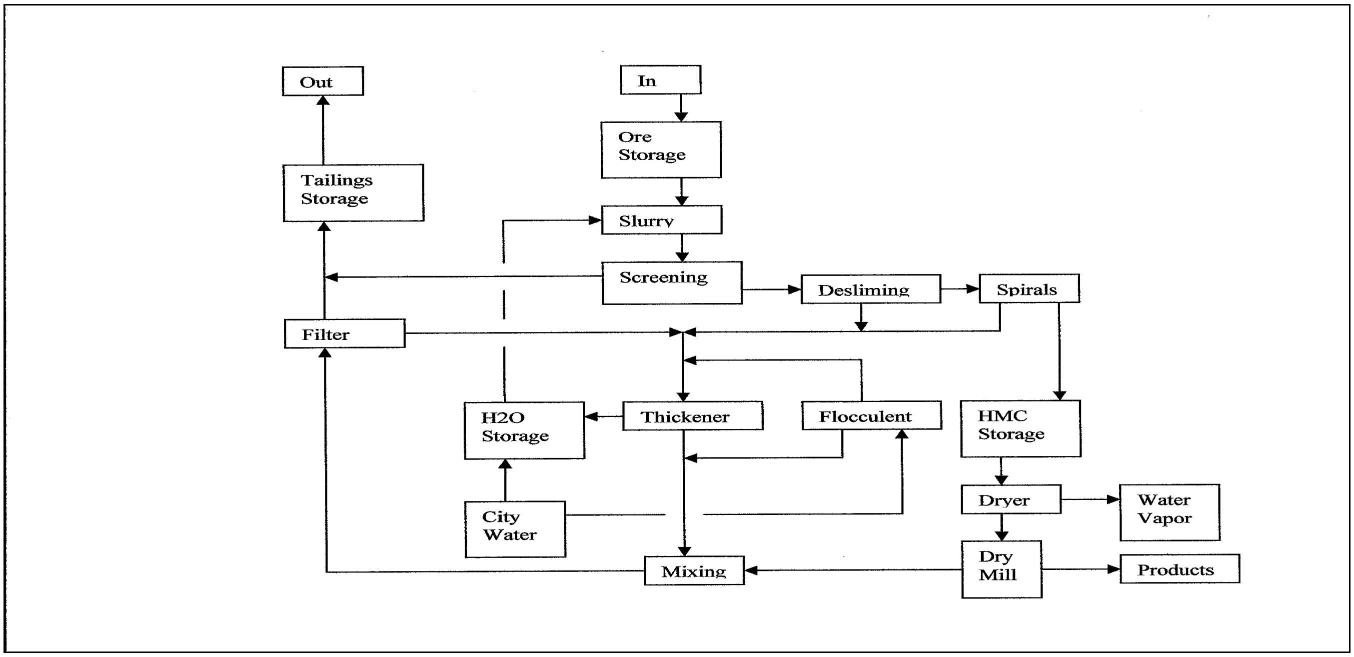

Figure 5. Process flow diagram

Tailings dewatering and process water treatment

ORC working together with FLSmidth Minerals has developed a unique solution to the problem of dewatering the tailings. The goal of the test work was to produce tailings which contained no free water, could be successfully transported, off loaded, and contoured immediately.

Sample characterization and flow sheet development test work by Outotec (USA) Inc. produced both fine and coarse tailings samples from each deposit. Dewatering testing at FLSchmidt commenced with sample characterization and a standard flocculent screening matrix. The fine material was not difficult to flocculate using any flocculent with high molecular wt., and low anionic charge density. Flow sheet development by Outotec, indicated the feed to the thickener would contain 7-10 wt% solids. Static 2000 ml cylinder tests were conducted using feed samples with 7-10 wt% solids, as expected, results were poor. Feed conditions with solids of 7-10 wt%, produced high flocculent dosage requirements, slow settling rates, poor supernatant clarity and low underflow densities (45-50 wt%). Subsequent tests were conducted where the feed solids were reduced to <5 wt%. Reducing the feed solids dramatically reduced floc. Consumption (on a, lb floc/ton dry solids, basis) and improved supernatant clarity, however settling rates and underflow densities were not dramatically improved. Next, coarse tailings were mixed with the fine tailings in ratios of 1:1 to 4:1 (coarse:fine) and then adjusted back to 5wt% and static 2000 ml cylinder tests repeated. The result of mixing coarse and fine material, diluting the feed, and using proper flocculent dosages was dramatic. The resulting flocculated particles were formed at nearly their ultimate density and settled very fast. Additionally, underflow densities of 65 wt% were achieved. The underflow was essentially a paste, so to be sure it could be pumped, rheology work was conducted. Yield stresses vs. solids concentrations were measured. Bingham yield stress values of ~100 Pa at 65 wt% solids were considered to be acceptable. Supernatant quality was also excellent, averaging 70-90ppm but never exceeding 130 ppm (very clean for process water at a mineral sands operation). Recovery at minerals sands operations often suffers with dirty process water. Fine valuable mineral and dirty process water often result in a smearing of the concentrate on the spiral and result in lower recoveries and HMC grades.

At 65 wt% solids the thickener underflow is not acceptable as a material for over the road transport in belly dump trucks. At 65 wt% solids the material is roughly the consistency of tooth paste and would fluidize in a moving truck and leak out the bottom, as a result, further dewatering is required.

Pressure filtration test were conducted unsuccessfully on underflow samples containing less than 1:1 coarse:fines ratios (very slow filtration, low cake solids). Pressure filtration test began to succeed as coarse:fines ratios approached 4:1, however so did vacuum filtration tests. Vacuum filtration has the advantage of being a continuous operation, does not require intermediate holding tanks, multiple units or a pug mill for breaking up cake. It was determined that by adding the coarse tailings produced by the dry mill, to the thickener underflow, followed by additional flocculent, that vacuum filtration would produce a dewatered tailing material suitable for transport and reclamation. Adding coarse material to the fines is not only crucial for thickener performance but also makes vacuum filtration possible. Adding the coarse material to the fines essentially produces a material which is porous overall. The coarse material provides pathways for the water to migrate, much the same as body aid would. By adding coarse tailings, vacuum filtration produced cake with a minimum of 82 wt% solids and no free water. The dewatered cake at 82%, resembles wet sand and passes paint filter tests. Tailings containing 82 wt% solids can be successfully transported and immediately contoured at the reclamation site.

Figure 5 illustrates the approach to managing water and tailings. Fines from the desliming cyclones are combined with coarse tailings from the wet mill, filtrate from the tailings filter, conditioned with flocculent, diluted using supernatant (internal, not shown) and fed to the thickener. The thickener overflow is recycled to the process water tank. The thickener underflow is conditioned with additional flocculent and mixed with more coarse material from the dry mill, and dewatered on the horizontal vacuum belt filter. The oversize separated at the wet screen is added to the cake and stacked as dewatered tailings ready for transportation and reclamation.

Dewatering the tailings will make operations at the mine site much simpler. Because ORC will not place tailings by pumping slurry, there is no need for a complex system of tailings booster pumps. There will be no need to build and manage a series of settling ponds. The operating mine foot print will be very small (1 pit). ORC will be able mine and perform reclamation concurrently in the same pit due to the absence of water. The water make up requirement at the process facility is very small. The only paths to loose water at the process facility, is the difference in moisture contents of the feed and the tailings, and water vapor lost at the fluid bed dryers preceding the dry mill. The process water make up requirement is < 50 gpm.

Although not strongly related to water management, FLSchmidth Minerals is providing a third piece of equipment. Between the spirals and HMC storage blocks shown in Figure 5, a second horizontal vacuum belt filter will be utilized. The HMC dewatering filter will increase the solids content of the HMC from ~80 wt% solids, up to 95-98 wt% solids. Usually, HMC is stockpiled on a concrete pad and allowed to drain. Solids contents of 90-95 wt% are common with this method, depending on particle size distribution, process water viscosity, and drainage time. Filtered HMC containing half the water content of typical HMC is expected to require ~1/2 the fuel (less efficiency losses). Fuel cost savings at 2008 natural gas prices are expected to pay for the cost of the filter in ~1.5 years. Additionally, if stock piled HMC is low due to operational upsets, the dewatered HMC can be directly fed to the dryers without throughput or additional fuel requirement penalties.

Characterization and Circuit Development

Considerable effort was made by ORC and Outotec to develop a robust process design. The goal of the design work was to produce a process capable of producing 70,000 tons/year of high quality chromite foundry sand and subsequent secondary products (Garnet and Zircon).

Producing and characterizing representative samples for each deposit was critical for understanding the range of processing requirements necessary to reach design goals. Simply taking all the drill hole samples and combining them into one large sample for testing, would have resulted in a design not suited to any of the individual deposits

Table 1 demonstrates the wide variability of the presence heavy mineral, as well as finished products, by terrace as well as deposit. Table 1 illustrates that S7D contains almost twice as much HMC and chromite as WB. An inflexible design based on one deposit would have been inappropriate when mining in the opposite deposit. For this reason, the solids handling systems and wet plant capacity have an operating rage of 70 to 140 tph. Table 1 also illustrates that SH contains ~three times as much HMC as WB. A dry plant design based on an average HMC value would not have capacity required when processing ore from a deposit with a lot of trash heavy mineral, for this reason the dry plant is capable of operating 20-40 tph. The design process included a plant wide bottleneck analysis. The need for a bottle neck analysis can be seen in the garnet content shown in Table 1. If the solids handling capacity for garnet circuit were sized for WB the entire process could be either choked when not in WB or would result garnet being wasted, as the excess would simply thrown to tails because the capacity was not present to process it

The 1991 drill program utilized an “RC” drilling rig, for this reason, it is believed the pit and plant oversize will be grater than the values shown in Table 2. The design includes extra screen capacity for this concern.

Characterization results given in Table 2 demonstrate the need for a desliming circuit as slimes contents that high, would affect spiral recoveries as a result of the smearing effect previously mentioned.

A pilot scale test was conducted in August 2007. During the pilot test, 34 tons of finished chromite foundry sand was produced. The wet process was completed at ORC’s facility. The dry processing was completed at Hazen Research in Denver Co. Until the processing at

Hazen, was undertaken, the importance of the last two steps of the wet processing were not fully appreciated. Foundries require chromite contain less than 1.0 wt% clay coatings. Clay content is critical because it affects the binder requirement and mold strength. If foundries start with dirty chromite the binder requirement is higher and the mold's tensile strength is lower. The last two steps determined by bench scale testing at Outotec were attritioning of the HMC and final rinsing and grade control using a floatex hydrosizer. The attritioner liberates the clay coating on the HMC grains and the hydrosizer flushes it away while providing final grade control. When the pilot work was undertaken at Hazen, the exact pilot equipment to simulate the final steps in the wet process, was not available. The final steps were simulated using alternative equipment. The chromite produced was of unacceptable quality due to excessive clay content. Since the chromite produced was to be used for marketing purposes, it was vital that the material quality be representative of full scale production. Processing was halted until the appropriate equipment was available. The final material produced is low in clay (< 0.5 wt%), has a low binder requirement, produces strong molds and provides ORC a marketing edge over competitors.

Conclusion

Project development is not completed in linear, once through fashion. Each new finding hones understanding and guides future questions. The process is iterative and cumulative. Building on the work of others and completing new investigations has produced an understanding of the region's geology and mineralogy. Characterizing the mineralogy and building on past process investigations by conducting additional ones, has produced sizable representative product samples, as well as process flow sheets, and solid innovative engineering designs. Key to successful process design is specifying process capabilities to specific mineralogy and process challenges unique to the deposit.

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