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Physical Separation Technology
External Newsletter

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More out of ore

Contents

Separation Solutions

Geologic Age and Minerals Sands Deposits: Youth versus Maturity... impacts on processability

Historically, most commercial mineral sands deposits are hosted in Quaternary-aged sedimentary shoreline sequences located on modern day beaches or within close proximity to the coastline. Older (inland) deposits exist, but due to the degree of lithification/induration and burial, have not been as extensively developed although some exceptions are known. It is expected that the older deposits will become increasingly important in the supply of mineral sands products. (*Deposits of fluvial/alluvial nature, such as the Sierra Rutile and Irshansk Ukraine deposits, are not reviewed.*)

Quaternary-aged deposits

Mineral sands provinces hosting this style of deposit include:

- South Eastern USA deposits in Florida and Georgia
- South Western and East coast Australian deposits
- South Africa, Mozambique, and Madagascar deposits
- South West and East Coast Indian and Sri Lankan deposits
- Coastal Brazilian deposits

Most often, these deposits are composed of medium to fine-grained, well-rounded, unindurated sand, although local cementation by iron oxides, clay and/or humates are possible.

With competing land use issues, high land values and environmental constraints the industry is pursuing more and more older deposits. These are usually Tertiary aged deposits, typically located inland of the modern-day coastline.

Tertiary-aged deposits

Mineral sands provinces/regions hosting these deposits include:

- Inner-coastal plain deposits of Virginia and North Carolina USA
- Lakehurst, New Jersey USA district
- Murray and Eucla basins of Australia
- Tertiary aged shoreline deposits in the belt stretching through Ukraine, Russia and Kazakhstan

These deposits are frequently buried by younger sediments, and consist of more deeply weathered minerals that often affect the HM assemblage by dissolution of less stable HM and leucoxenization of the ilmenite. Often, oxides can be reprecipitated or reincorporated in other minerals (for example the increase in U and Th oxides in altered ilmenites). Although not a rule, many of the Tertiary-aged sand deposits are finer-grained than their Quaternary-aged counterparts.

Mesozoic/Paleozoic-aged deposits

Older Paleozoic and Mesozoic-aged sedimentary rock deposits are known, but often the degree of lithification/induration precludes economic development.

Mineral sand provinces hosting these deposits include:

- Cretaceous Western interior seaway deposits of USA and Canada.
- McNairy Sand formation in the Mississippi Embayment of Southern USA
- Karoo Basin deposits in South Africa

As with the Tertiary-aged sands, many of the Mesozoic sands are finer-grained in nature and buried by younger sediments and rocks. Cementing material can include iron oxides and carbonates but often authigenic TiO_2 materials can also form cements.

As crushing/grinding can be required, the requisite cut-off grades would be higher, resulting in smaller and more isolated economic deposits.

To combat this increase in fines, companies are advancing traditional technologies like advanced rare-earth roll separators that are more suited for materials <75µm.

No matter the age of the deposit, testing is key to determine the feasibility of processing.

Comparison of deposit ages and processing issues

Attribute	Young deposit	Old Deposit	Processing significance
Heavy Mineral (HM) assemblage	Often light and trash HM	Often garnets and other iron bearing "light" HM removed providing a more "mature" HM suite	• Light heavies (can include leucoxene) can interfere with zircon product quality and lower recoveries of valuable HM. • Important to focus on valuable heavy minerals and not total heavy minerals. • Exclude, as much as possible, the light HM in the gravity circuit. Can benefit by using combined techniques such as spirals and density separators. • Propensity exists for older deposits to produce more contaminated products thus necessitating testing each discreet part of the deposit through to final product.
Ilmenite alteration	Typically lower (*not always if there is an intermediate source*) 45-55% TiO_2	Usually higher 55-65% TiO_2	• Ilmenite deposits with lower TiO_2 content are easier to concentrate using magnetic separation. • Radioactive levels in ilmenite typically increase with increasing TiO_2 content. • Fractionation using rare-earth magnets to produce different ilmenite qualities is ideal.
Induration/coatings	Usually negligible	Can be deeply stained/coated	• Heavy duty scrubbing may be required with tenacious material. • Cementing material can be ferruginous, carbonate or sometimes TiO_2 itself. • Attritioning is critical. • Water attritioning is not always sufficient. • May require acid or alkali reagents. This is especially critical with rutile zircon separation. HT efficiency tests should be used to determine best/adequate attritioning and location of attritioning circuit. • Grinding may form fines that are subsequently lost in processing. • May pose difficulties correlating in-ground contents with metallurgical recoveries.
Heavy Mineral (HM) grade	Low to high	Necessarily high	• No real correlation of HM grade and age except that of an economic association in that older/deeper indurated deposits may require higher cut-off grades. • Higher grade deposits may allow simpler gravity flowsheets and MSPs due to corresponding relative drops in "light" heavy minerals.
Grain size	Med to fine grained	May tend towards fine side	• Careful design of flowsheet is needed to ensure recoveries of fine valuable HM. Lower throughputs on spiral circuits. • Classification is critical to assist in recovery of ultra fines. • Necessity for new generation magnetic and electrostatic separators. • Possibility of applying enhanced gravity concentrators
Slimes	Usually low <5%	Often high up to 20-40%	• Desliming is critical to PCP and MSP performance. • Slimes handling and rehabilitation of slime and sand mixtures important

Optimized flowsheet development for concentrators and MSPs, including attritioning, slimes handling and rehabilitation of sand/clay tailings, and water recovery becomes even more important as older deposits are tapped for supply.

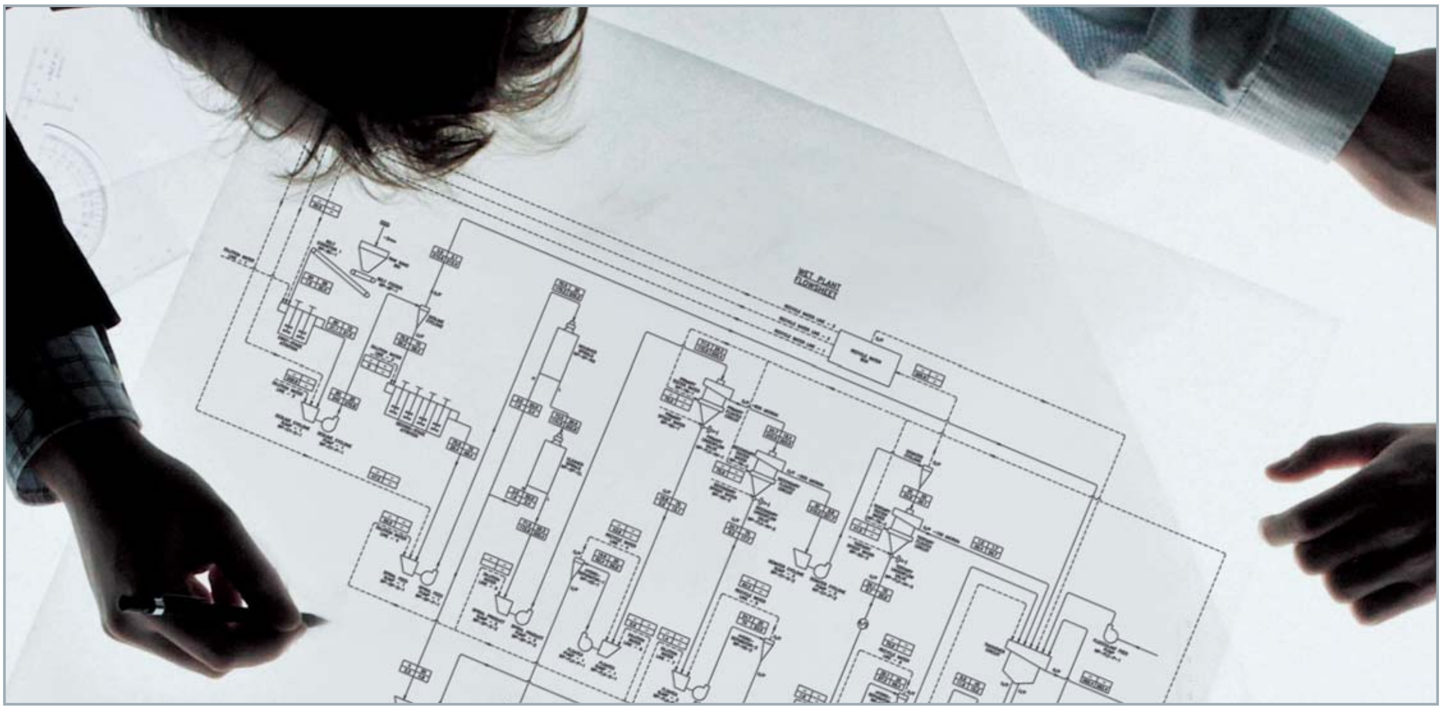
Laboratory facilities, like this one in Perth, Australia, will be critical to testing deposits and developing flowsheets.

Conclusion

Pre-Quaternary age (inland) deposits will become sources for an ever-increasing proportion of mineral sands production. These buried, more deeply stained, coated, indurated and clay-rich deposits will require careful flowsheet development. This will include detailed characterization and geo-metallurgical range testing of the samples in order to understand and predict metallurgical recoveries and qualities of the products. There is the propensity for these older deposits to produce more contaminated products. This indeed necessitates testing of each distinct part of the deposit, through to final products, to determine any special marketing issues inherent in the ore body.

» John Elder - President, Jacksonville

The process of process development



Taking the time to test and develop a flowsheet before you build an operation is the best way to ensure a profitable process.

Tips and tricks to flowsheet development

Critical for both a new operation and when putting life back into an under performing, existing operation, accurate development of the process flowsheet of a minerals separation plant (MSP) is a must.

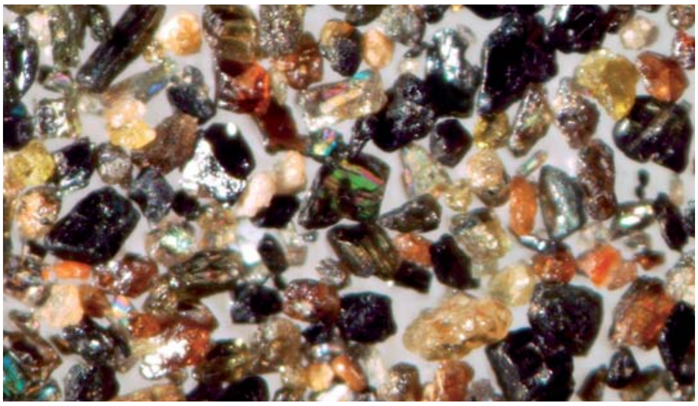
> Whether an operation is new or old; easy-to-process or running the tail end stockpile of fines; one thing is certain: The process flowsheet will make or break the operation.

As with most of nature, no two deposits are alike, and so no one processing plant can be mass produced. To turn raw materials into saleable products requires proper technology selection, tailoring and placement. In addition to yielding precise products a plant must fall within a budget, be environmentally sound and be capable of maintaining specifications throughout the life of the operation, no matter the variations in mineral suite from one end of a deposit to the next.

Though this may seem a daunting task, the best operation for each deposit can be easily discovered if you better understand the process of process development.

Before you begin:

1. **Do your homework on the feed sample**
   - Is the sample representative of the orebody, and not just an "easy to obtain" sample?
   - Ensure that you are working with representative material. If not, clearly understand the sample's origin, and any processing steps already being implemented on the material prior to receipt.
2. **Properly characterize feed**
   - Ensure your characterization work on the feed is performed with the proper sampling techniques.
   - Understand the size-range of the deposit.
   - Determine the nature of the deposit's valuable minerals.
3. **Define the process development guidelines**
   - What is the scope of testing?
   - Which component recoveries are important and how are they to be measured?
     Example: *In working with heavy minerals (HM), is overall HM recovery the right gauge, or does the trash, light heavy content warrant a VHM recovery approach?*
   - What are the final product goals?
     Example: *What are the needed product specifications? Do you need to perform simple chemical analysis or does your end-user require specific tests, such as: particle size distribution, mineralogic impurity reduction, etc. to meet an industry specific quality or requirement?*



Microscopic grain counts can often yield valuable information to help determine best processing methods.

Good general practices:

4. **Be consistent and accurate in your documentation**
   - Use good protocol to log and manage the flow of material through the process.
   - Keep weights, but for flowsheet purposes always translate back to % of head feed.
   - Keep retains.
5. **Don't assume**
   - Be cautious of making flowsheet assumptions based on prior experience and "typical flowsheets."
   - Consider alternatives and leave time for testing them - this is the only way to be sure the optimum flowsheet is defined.
   - Let the path finding testing and analysis guide the process.
   - Be cautious of preconceived notions when considering what equipment to place in a circuit.
     Example: *Magnetic separators - In some cases using a rare-earth drum seems like the logical choice, but tests reveal the rare-earth roll performs better, and vice versa.*
     Example: *Spiral selection - Don't discount a washwater spiral. They have proven effective on more than just fines or iron ore and may work better than a washwaterless model in some applications.*
6. **Be Practical**
   - Consider carefully where to place equipment in the flowsheet.
   - Put the more expensive process equipment steps as far back in the flowsheet as possible.
     Examples: *Only dry your minerals once! Consider using size and specific gravity differences to preconcentrate prior to grinding steps, such as for iron ore.*

As you test – keep in mind:

7. Start small

- Perform small, path finding tests before performing larger bulk runs. Use them to first determine the proper technology to utilize, then what model/configuration is best suited, and lastly, the best operating conditions for each step. Items you should consider, for example with a RER, would include: loading, roll speeds, magnetic configuration, feed point, etc.
- If needed, perform several small path finding tests that transcend the circuit you are considering, sometimes to the end of the flowsheet. These may be helpful in solving for separation challenges.
__Examples:__ Do you need to use a wet magnet? Where do you need to place the density separator in the gravity circuit? Should the high-tension electrostatic step come before magnetic separation in the dry mill?

8. Take your time

- Take time to test the conditions for each process step in order to best gauge performance ranges.

9. Does size matter?

- Particle size can greatly impact a process. The effects of a deposit's particle size-range should always be considered at the beginning of testing. Additionally, you might also need to reconsider particle size effects several times throughout the flowsheet.
__Remember:__ A simple sizing step, often overlooked, can be a great way to improve recovery through mass reduction of fractions that are void of valuable minerals. Often, final specifications for high purity silica sands can be made with a final screening step to remove trace feldspathic components.

10. Be thorough

- Perform plenty of path finding tests throughout the flowsheet development process. This will help you avoid making massive changes during large bulk sample runs.

From pathfinding to running larger bulk samples:

11. Sample!

- Take samples during bulk runs to confirm and validate (and occasionally improve) the path finding test results.

12. Scavenge first

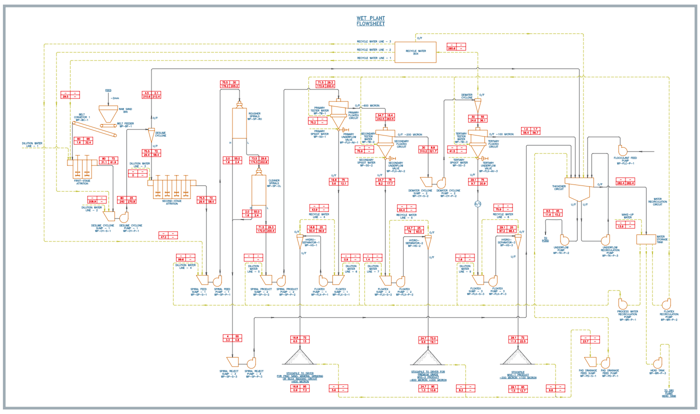
- Go down the scavenging "legs" of a flowsheet before moving on to the concentrating stages. This will allow scavenged material to be combined and moved forward, a better representation of true flowsheet conditions.

13. Fine tuning

- Often, the results obtained during bulk runs are better than path finding runs. This is because of several factors: process stabilization over time, temperature level consistency and minimization of short-term variables.
- This can force occasional flowsheet modifications from what was decided during path finding tests. That is to be expected: This is where you look for ways to simplify and fine tune the flowsheet.
- Your goal now is to further improve performance.

14. Consider middlings

- Where should you place your "mids" or "cat/dog streams?" If testing permits, make educated guesses on mids placement and include these streams in bulk runs when appropriate.



A test program ends with pulling together final mass balance and a recovery performance summary.

For more information on Outotec's testing facilities, or any physical separation technologies, visit www.outotec.com or call your local representative.

Wrapping Up:

15. Know your weight

- Prepare a mass balance for your test program using the percent of head feed as the main "mass tracking tool." This will eliminate confusion that could be created with weights removed during testing, i.e. your "retain" samples, stranded materials, mids streams, etc.

16. Model your flowsheet

- Excel or canned software is available. If a flowsheet is complicated (recirculating loads) or certain parameters are highly variable these can be good tools.
- Use testing data to develop adequate grade-recovery information to model the process.
- Validate the model, then use it to help answer process step sizing questions, check recirculating loads, and understand flowsheet robustness and areas of concern.
- Test the robustness of the flowsheet by evaluating other samples from the deposit to determine the effect of items, such as the ranges of particle size, mineralogy, etc., on grade and recovery.

17. The big picture

- The last step is to bring everything together. Present a flowsheet with final predicted mass balance and recovery performances.

Start with a strong foundation

Developing a proper process is not complicated if you only know what steps to take. By knowing your goals, taking your time during testing, and paying attention to the "finer" details, you can layout an operation to produce your required products at the level of production you desire.

With all said, there may still be areas that don't add up, or may be beyond your scope of capability on-site. For this, partnering early on with a reputable and knowledgeable laboratory can be the best investment you make. It is always better to start from a foundation based on thorough investigation than to build a plant destined to under perform.

» Peter Dunn - Business Development Director
Richard Beale - Laboratory Manger
(Both from the Jacksonville Physical Separation Office.)

Editor and layout:
Misty Dobbins - Communications Manager
Address: 6100 Philips Highway, Jacksonville, FL 32216 USA
Contact: Tel. +1 904 353 3681, fax +1 904 353 8705
E-mail: psdsales@outotec.com **Website:** www.outotec.com
Company: Outotec (USA) Inc.