Fiscal Year 2018/2019 Annual Report

Florida Industrial and Phosphate Research Institute

Laboratory Demonstration of Packed Column Jig System for Mosaic Respresentatives

Approved by the Phosphate Research and Activities Board

September 20, 2019

Index **Page**

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Florida Industrial and Phosphate Research Institute

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Patrick Zhang, Ph.D., Research Director, Mining and Beneficiation

Gary Albarelli, MLS, Director of Information Programs

Executive Director's Message – Dr. Terry Parker

This fiscal year FIPR Institute has undergone a change in leadership that will direct the Institute's operation and focus going forward. Florida Polytechnic University President Randy Avent appointed University Provost Dr. Terry Parker as FIPR Institute Executive Director in August 2019. This highlights the University's recognition that FIPR holds a vital strategic position within the University and its commitment to support and foster the Institute's role as an international center of excellence.

This comes at a time when the Institute's Strategic Priorities for the next five years need to be formulated. As a first step, I have appointed Dr. James Mennie, Assistant Professor of Business Analytics at Florida Polytechnic to serve as Business Director for the Institute. Dr. Mennie has been tasked with assessing current business operations and to develop a strategic plan for the coming years. Dr. Mennie brings expertise in business analytics that will be brought to bear in addressing all FIPR business operations to include funding, budgeting, personnel, facilities and project management. The goal is to have FIPR become a self-sustaining concern, not wholly reliant on its portion of the Phosphate Severance Tax.

During the past year, FIPR's research into separation of dolomite using the packed column jig has shown great promise. The laboratory unit has demonstrated effective separation and a pilot-scale unit will be installed at Mosaic's South Pasture mine later this year to determine effectiveness at that scale. The ability to sustainably demonstrate this technology could expand phosphate resources in Florida by 100%. In addition, many of the world's other phosphate deposit exhibit dolomite contamination and could be potential customers for this technology.

FIPR's participation as a key partner with the U.S. Department of Energy's Critical Materials Institute has established the Institute as the leader in rare earth element research into recovery from phosphate processing streams. We hope to capitalize on this position through additional research and business opportunities.

The Institute's role within the University has been further solidified during the past year. FIPR was instrumental in laying out the Program Course of Study that was approved by the Florida Board of Governors. The new Environmental Engineering Bachelor of Science degree program at the University is designed to collaborate closely with FIPR to provide long term, real-world projects for project-based learning throughout the curriculum. Faculty and students in the program will have the resources, experience and connections of the Institute available to support their research.

The Institute's Outreach Program has continued to be leveraged to promote STEM knowledge to K-12 students in central Florida. This outreach has exposed prospective University students to the great opportunities available to them through this program of excellence. Also, in the past year FIPR's library has assumed all interlibrary loan service for University students, faculty and staff. It is our full intention to keep this integration effort moving ahead as part of the greater effort to bring FIPR and Florida Poly together.

Financial Report

FIPR Institute's research and operation are funded through the Phosphate Research Trust Fund. This trust fund receives its income from a portion of the severance tax paid to the state for each ton of beneficiated phosphate rock concentrate and pebble (not dry) as measured coming off the belt at the washer of each beneficiation plant.

Since the Institute's inception in 1978, the severance tax rates, distribution, and associated fees have varied greatly, as has the rate of mining. This has, in turn, resulted in widely variable rates of income for the Phosphate Research Trust Fund. The distribution to the Institute's trust fund has varied from 5% to 12.5% of the collected tax during our history. The distribution was 5.6% for this fiscal year, and the tax rate was $1.80 per ton of rock severed.

The FIPR Institute's Executive Director provides a summary of expenditures and the trust fund balance at public meetings of the Institute's Phosphate Research and Activities Board. A more detailed summary is included herein.

Trust Fund Balance

July 1, 2018	$7,146,732
June 30, 2019	$6,943,938

Operations

Income	
Gross Severance Tax	$1,711,826
LESS Fees to Dept. of Revenue	($113,404)
Net Income	$1,598,422
PLUS Interest	$161,287
Total Income	$1,759,709
Expenses	
Research	($218,393)
Internal Operations[2]	($1,744,109)
Total Expenses	($1,962,502)
Change in Trust Fund	($202,794)

[1]Per Section 211.3103, F.S.

[2]"Internal Operations" includes staff salaries and benefits, and expenses for the Education Program, Library, and Laboratories. The Institute's Research Directors and technicians spend most of their time directing or conducting research. The remaining staff deliver information and education services to the public and schools, or provide office support within the Institute. Since "Internal Operations" also includes research done by the FIPR Institute staff, the portion of the annual income expended on research is substantial. Of the amount that is approved by our Board for specific research projects ("Research" in the summary table), the largest shares typically go to universities and private firms. Their research is conducted under the direction of the Institute.

Auxiliary Funds (Not from the Severance Tax)

According to Florida Statutes 1004.346 enacted in 2012, the FIPR Institute may also secure funding from grants and other available sources, enter into contracts, and provide consulting services. Revenue from these sources is deposited into an auxiliary account.

Auxiliary Account Balance

July 1, 2017	$661,972
June 30, 2018	$603,363
Income	
Consulting	$29,431
PLUS Interest	$14,129
Total Income	$43,560
Total Expenses	($102,168)
Change in Auxiliary Account	($58,609)

Awards and Grants (Not from the Severance Tax)

Critical Materials Institute (CMI) Account

Expenses	$136,635
Reimbursements	($136,635)
Change in CMI Account	$0

The overall financial status for FY 2018-2019, which combines the Trust and the Auxiliary Funds, was $7,808,704 as of July 1, 2018. The final amount, as of June 30, 2019, is $7,547,301; showing a net decrease of $261,403.

Information Program

Furthering the Institute's goal of complete integration with University operations, in the past year FIPR Institute's library has assumed all interlibrary loan service for University students, faculty and staff. FIPR staff has presented guest lectures to students in University courses, as well as giving presentations to community groups and at conferences. The Institute has also provided information-related input required for accreditation of University degree programs. At the start of the fall semester 2019 FIPR hosted the meeting of the Data & Business Analytics Department.

Investigation into approaches for digitizing FIPR library material is ongoing. Scope of the effort has been determined and it is proposed that there be both internal and public facing databases. The internal portion would serve as a knowledge base of phosphate information collected throughout the Institute's life. The public facing portion would be attached to the library's catalog within the State University System. In most instances, the digitized version will replace the physical copy of the item.

The Institute is also participating in the committee to revamp the University website, providing valuable input to directly design content. Again, the aim is for the interface between FIPR and the University to be seamless.

A key role continues to be providing guidance on environmental issues. Specifically information on environmental impacts related to phosphate mining and phosphogypsum utilization to local, state, federal and international groups. FIPR also provides authoritative responses for a wide range of phosphate-related inquiries to stakeholders, namely government, industry, NGO's, academia and the public on a daily basis. The Institute's role as an independent, unbiased resource places it in a unique position with substantial value to stakeholders.

K-12 Education/University Outreach Program

The FIPR Institute's Education Program continues to evolve to meet the needs of Florida's educators, the community and the University. The Education Program, under the direction of Education Outreach Coordinator, Indira Sukhraj, is fully integrated within the University's Community Outreach Program. STEM lessons developed at FIPR are used in the program to engage students and prepare them for further education and careers in high-tech fields. Lessons are always-hands on and emphasize critical thinking and problem solving. The Education program can be broken down into three categories: K-12 and Community Outreach, Professional Activities and University Activities.

1. **K-12 and Community Outreach**: involves interacting with K-12 students and teachers in Florida classrooms, as well as informally at community events that also involve the public. The Outreach Program has direct contact with K-12 students by going into schools upon request and teaching hands-on lessons in the classroom. Other requests include exhibiting at a STEM or STEAM night hosted by a K-12 school. The Outreach Program exhibits at community events geared towards K-12 hosted by community partners including Bok Tower Gardens and Circle B Bar Reserve. All activities are created by the Outreach staff and are STEM based, focusing on soft skills, such as critical thinking, problem solving and teamwork. To be most effective, each interaction is individually planned based on the details of the request. Most requests place an emphasis on engineering, technology, sustainability, environmental science and geology (rocks/minerals/fossils). Outreach staff had approximately seventy outreach interactions in 2018-2019 fiscal year.

2. **Professional Activities:** FIPR Outreach staff lend our expertise and gain more knowledge in areas related to STEM, FIPR and Florida Poly. Science and Engineering Fair encourages talented young scientists and engineers to ask questions and find answers. To foster this love of science and engineering the Outreach Program lends our expertise as judges and mentors. Our staff is involved in every level of Science and Engineering Fair from the individual school level to International Science Fair. Staff serve as category judges, category captain, category co-chair, mentors and qualified scientists. Staff also attend symposium sessions at the INTEL International Science and Engineering Fair for professional development. Professional partnerships have also resulted in our involvement. Texas Instruments has been a partner for several years, including on campus sessions at Florida Poly for Outreach STEM Days.

   Outreach staff attend conferences to lend expertise. This year presentations were given at the Florida Association of Science Teachers (FAST) Annual Conference and the 2018 National Science Teachers Association (NSTA) Conference on Science Education: A National Priority. Outreach Staff also serve on professional committees including Polk Vision's Talent Pipeline, STEM consultant for Texas Instruments, and serve on the Internal Review Board (IRB) for Polk Regional Science Fair and internal committees at Florida Poly.

3. **University Activities**: involve collaboration with other university departments and students in outreach and using our expertise to teach Florida Poly students. Faculty and staff at the University reach out to the Outreach Program when they receive requests from K-12. Outreach staff also collaborate with university departments to immerse K-12 students in Florida Poly culture. Outreach collaborates with the Admissions Department

in several ways. Admissions gets requests for hands-on activities from groups that have reserved campus tours. Admissions contacts Outreach to design and facilitate a hands-on activity for K-12 students. Outreach also teams up with Admissions when exhibiting at community and educational events. Admissions talks about requirements and campus details, while Outreach shows what we do at Florida Poly through demonstrations and hands-on activities. Outreach is currently working with Admissions to create designated STEM Days to be held on campus.

Outreach works with individual faculty and staff requests when an event involves K-12 students. Outreach is also working with the office of Economic Development and Board Management to focus on Diversity and Inclusion for students at Poly and K-12 students. This collaboration has resulted in becoming part of the Central Florida STEM Alliance and more involved with student diversity and inclusion organizations at Florida Poly. THRIVE is another organization Outreach collaborates with. THRIVE's goal is to engage female students, faculty, staff and anyone at Florida Poly who is interested in encouraging STEM. Through this collaboration, we have mentored students from PACE School for Girls, co-hosted International Women's Day and hosted a series of Lunch and Learn events at the IST.

Outreach also relies on Florida Polytechnic student involvement. The Presidential Ambassadors are a group of students that represent the university. They facilitate activities when Outreach hosts events on campus for K-12 students. The Presidential Ambassadors have also created their own presentations for school groups. Florida Polytechnic students have also been invited to serve as judges at the Polk Regional Science and Engineering Fair and the Florida State Science and Engineering Fair. Students that hear about the Outreach program through the Introduction to STEM course volunteer to help at events held on campus. They also speak to prospective students about their personal Poly experience.

The Outreach program is very STEM intensive and our staff participates in continuous professional development. The Introduction to STEM (IDS 1380) course is a required course for all entering freshman. This is a foundation course to prepare students for their Poly career. The course is project based and has undergone curriculum updates to meet ABET standards. This course exposes students to skill-building but also introduces real-world application that Outreach staff bring from experience through professional activities. This course introduces the idea of applied STEM, mathematical methods, problem solving, technical writing, teaming and leadership, oral presentations, professional practice and responsibility, professional ethics, social, economic and environmental concerns, real world application and information literacy in STEM.

The Outreach Program continues to fulfill the requests of Florida's teachers, students and the community through meaningful partnerships and collaborative efforts. These relationships are creating a bigger impact on the K-12 students and community we interact with. Our staff are scheduled to speak at and attend STEM-focused conferences and are becoming more involved with integrating Florida Poly students in the University's outreach efforts.

Indira Sukhraj Named 2019 ISEF Co-Chair

Florida Polytechnic University Faculty-Student Research Program

The FIPR-funded program that allows Poly faculty to address an applied research problem in their field of expertise continued this year. The program's principal goal is to engage students as research assistants to develop research skills to creatively address real-world problems. Gary Albarelli, FIPR Director of Information Programs, oversees projects funded under this program. The following project yielded promising results and afforded the students involved to present at prestigious conferences and attain their first publication in a scholarly journal.

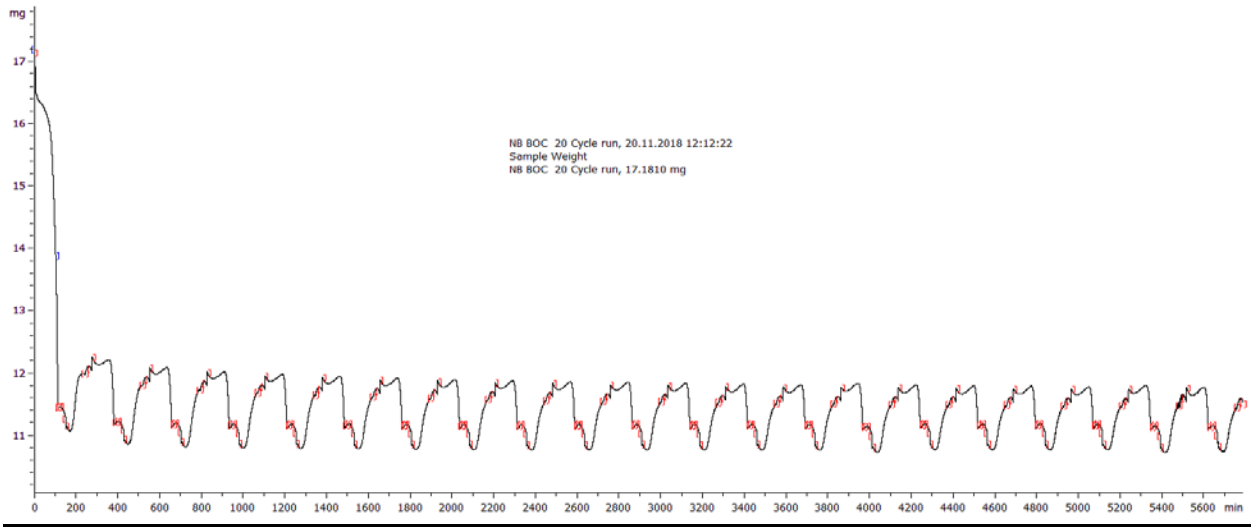
Florida Polytechnic University students McBenJoe Charles and Dominic Dodson at Google Headquarters after presenting their FIPR-funded research

Feasibility Studies of Dolomites from Phosphatic Pebble for Thermochemical Energy Storage and CO_2 Sequestration. Budget: $54,857; Faculty Investigator: Dr. Sesha Srinivasan. Three student researchers have been engaged in the research.

The objectives of this study are: to utilize dolomitic phosphate pebble to facilitate the calcination-carbonation cycle for thermochemical energy storage, and to investigate the potential for this system as a Carbon Capture and Sequestration (CCS) system. The hypothesis is that impurities present in the dolomitic pebble would avoid a sintering phenomenon that has occurred in prior work using pure dolomite, which inhibits repeated carbonation-calcination cycling.

High-dolomite pebble samples furnished by the FIPR Institute were ball-milled under various conditions to increase particle surface area to allow for increased sites for carbonation. Samples were subjected to repeated cycles of calcination and carbonation

and mass changes were measured using thermogravimetric analysis. Steady-state cycling was successfully demonstrated in support of the project's hypothesis.



Thermogravometric analysis plot demonstrating steady-state calcination-carbonation cycling

The success of this project could open the possibility of converting the rejected dolomite output of another FIPR research project, the packed column jig (see below) into a valuable resource that could be utilized as an energy storage medium.

FIPR Institute Research

FIPR Institute research projects are either conducted in-house or by various universities and private companies using Institute funds. FIPR Institute Research Directors serve as Contract Managers for all projects. Projects that were completed or ongoing during the fiscal year are described in the following text.

The Institute's projects that are funded by the Phosphate Research Trust Fund are directed at solving real-world problems identified with the mining and processing of phosphate rock in Florida in which the public has a substantial interest. Summaries of the Institute's research are described by title, funded organization, and a brief description of the objectives and accomplishments.

1. ***Recovery of Rare Earths and Uranium from Phosphate***
   FIPR Institute and the Critical Materials Institute

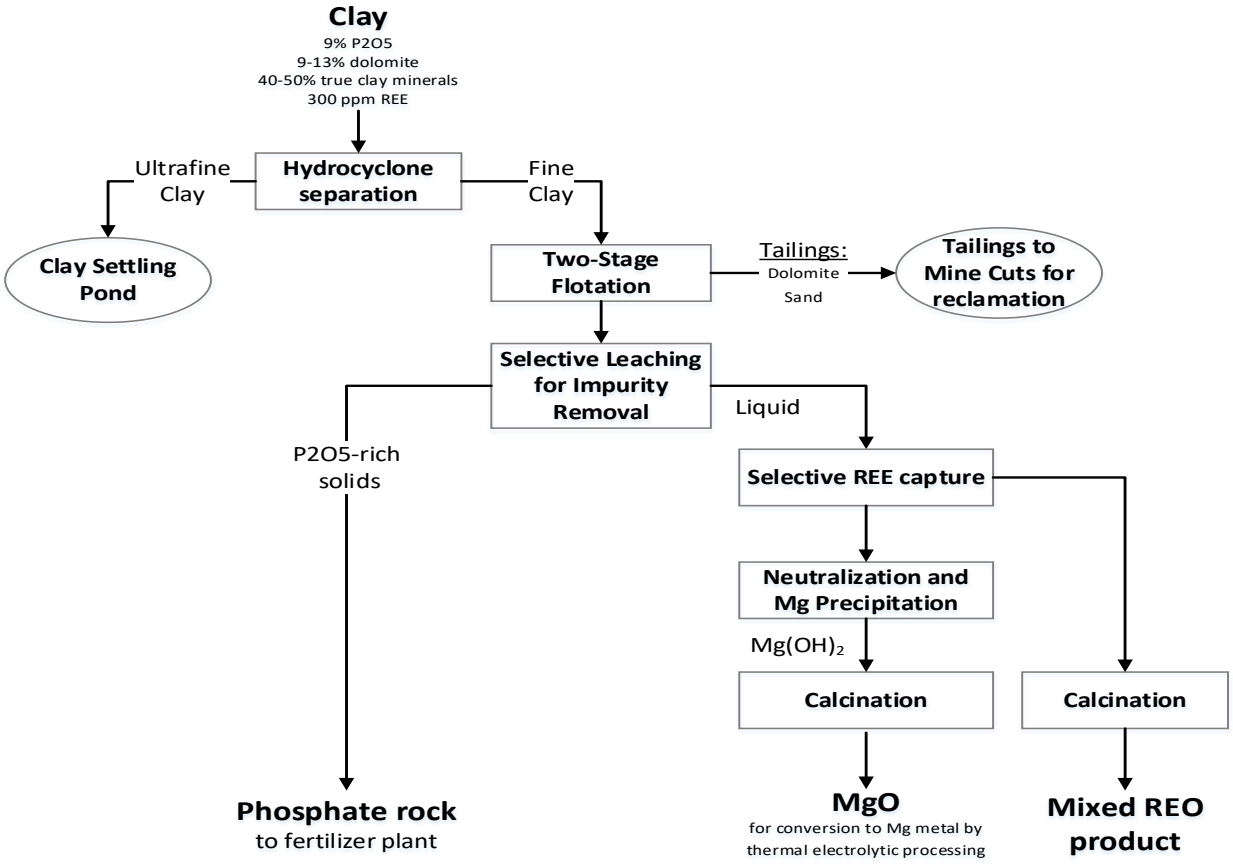
   In early 2013, the US Department of Energy (DOE) awarded $120 million to the Critical Materials Institute (CMI) to establish a new Energy Innovation Hub. CMI focuses on developing and commercializing advanced technologies to secure the national supply for critical materials, particularly rare earth elements (REE). The FIPR Institute is undertaking the project on recovery of Uranium and REE from phosphate mining and processing products as well as byproducts. All CMI members are shown in the figure below.

CMI member universities, national laboratories, and industry partners.

During CMI Phase 1 (July 1, 2013 to June 30, 2018), the FIPR Institute hosted four annual workshops that reviewed progress of all member teams researching the recovery of REE and uranium from phosphate rock. The workshops also reviewed

characterization of ten phosphate process streams for REE occurrence and content, and technically feasible flowsheets for REE recovery from phosphoric acid, phosphate rock, flotation tailings, phosphoric acid sludge and phosphogypsum.

FIPR also joined the research program of CMI Phase 2, which began July 1, 2018 and will run through July 1 2023, with a new DOE grant of $100 million. During the first year of CMI Phase 2, FIPR evaluated the flowsheet below for recovery of REE, P, and Mg from phosphate clay. Both laboratory and pilot scale testing were conducted to remove clay particles from phosphate clay. X-ray analyses showed that some clay minerals are completely separated from non-clay minerals using a 2-inch hydrocyclone with about 60% recovery of the solids in underflow, with an additional 15% solids recovery achieved by cycloning the overflow from the 2" cyclone using a 1-inch cyclone.



Processing flowsheet for research to recover REE, P, Mg, and U from phosphate clay.

In Year 7 of CMI, FIPR, in collaboration with Oak Ridge national Lab, will focus on improving the economics of REE recovery from phosphoric acid sludge by recovering the phosphate in the sludge as a high-value phosphoric acid while achieving higher recovery of REE.

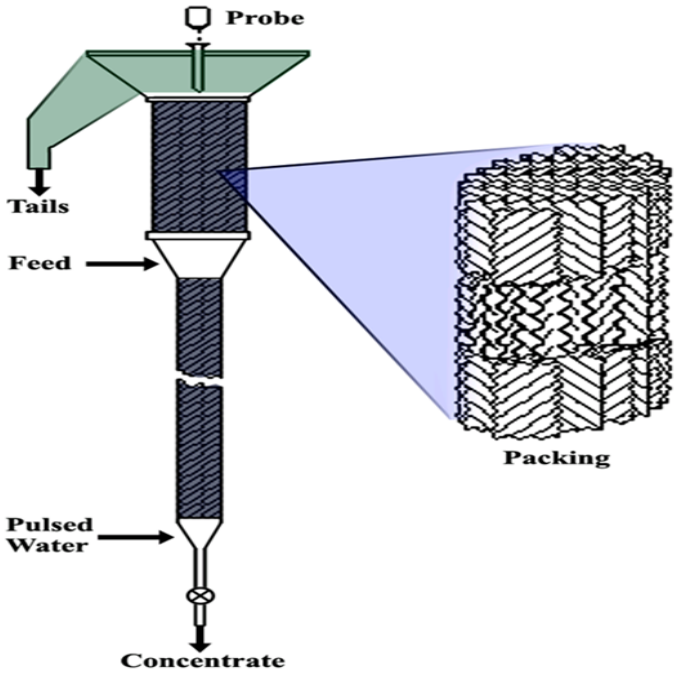
Research resulting from this grant has produced many publications in scholarly journals and conference proceedings.

2. *Removal of Dolomite from Florida Phosphate Pebble Using Packed Column Jig*

FIPR Institute

As the high-grade phosphate deposits deplete rapidly, the global phosphate industry now has to process phosphate ores with ever increasing contaminants, with carbonaceous materials (MgO and CaO) being the major problems. This issue is becoming pressing for the Florida phosphate industry as it mines further south and deeper. It was estimated that about 50% of the future phosphate resources would be wasted, if much of the high-dolomite deposits are bypassed in mining. The FIPR Institute has collaborated with worldwide experts in the field to address this issue. As a result, the industry is now offered two feasible options for partial solution to this problem. Option 1 provides three methods for reducing MgO content in the concentrate from the Crago process, including adding a dolomite depressant in the rougher flotation step, dolomite flotation of the cleaner concentrate, and scrubbing the cleaner concentrate in quartz sand. These methods could reduce MgO content in the final concentrate by 20-40%. Option 2 involves crushing and grinding of high-dolomite phosphate pebbles followed by dolomite flotation at slightly acidic pH using a new collector that does not require phosphoric acid as a phosphate depressant, achieving a final concentrate analyzing less than 0.9% MgO at about 87% P2O5 recovery.

Since early 2017, FIPR has been exploring the third option, a gravity separation technique using an innovative separation jig. The Packed Column Jig (PCJ) as a gravity separation device was patented by David Yang of Mineral Technologies International 20 years ago. Figure 1 shows the working principles of PCJ. PCJ offers the following unique features: 1) long, nearly unlimited separation zone; small footprint; 2) minimal water use; 3) no chemicals thus being benign to the environment; 4) high throughput; and 5) wide particles size range without limit on the fine side.



Schematic illustration of PCJ working principles

FIPR has acquired a laboratory PCJ testing system with full computer control and has done some gravity separation tests for removing dolomite from Florida phosphate pebbles, achieving extremely encouraging results, A one-ton per hour pilot PCJ has been designed and fabricated for large scale demonstration of the technology.

In the laboratory jig separation tests, the pebble sample was crushed and ground, and screened into different size fractions prior to separation tests. From the computer interface, the following automatic control/adjustments can be made: water flowrate, separation zone (heavy bed), water pulsation frequency, system total air pressure.

Size range, mesh	% P_2O_5			%MgO			% P_2O_5	
	Head	Conc	Tails	Head	Conc	Tails	yield	recovery
-35+65	21.35	24.28	18.11	2.64	0.89	5.82	52.51%	59.72%
-65+150	19.77	21.31	13.85	3.37	1.16	7.88	79.36%	85.54%
-35+50	23.67	25.61	17.92	2.18	0.92	6.16	74.77%	80.90%
-20+35	25.65	27.94	22.38	1.76	0.53	3.37	58.81%	64.06%
-65+150	19.77	21.48	15.13	3.37	1.25	6.67	73.07%	79.39%

Initial Dolomite Separation Results Using PCJ

Separation of phosphate (dark) and dolomite (light) by packed column jig

These results on separation of dolomite from phosphate by gravity separation have never been achieved before using any devices. A lab demonstration was conducted for some Mosaic Managers and Engineers, who were impressed by both the results and simplicity of PCJ operation.

Laboratory Jig Separation Demonstration for Mosaic

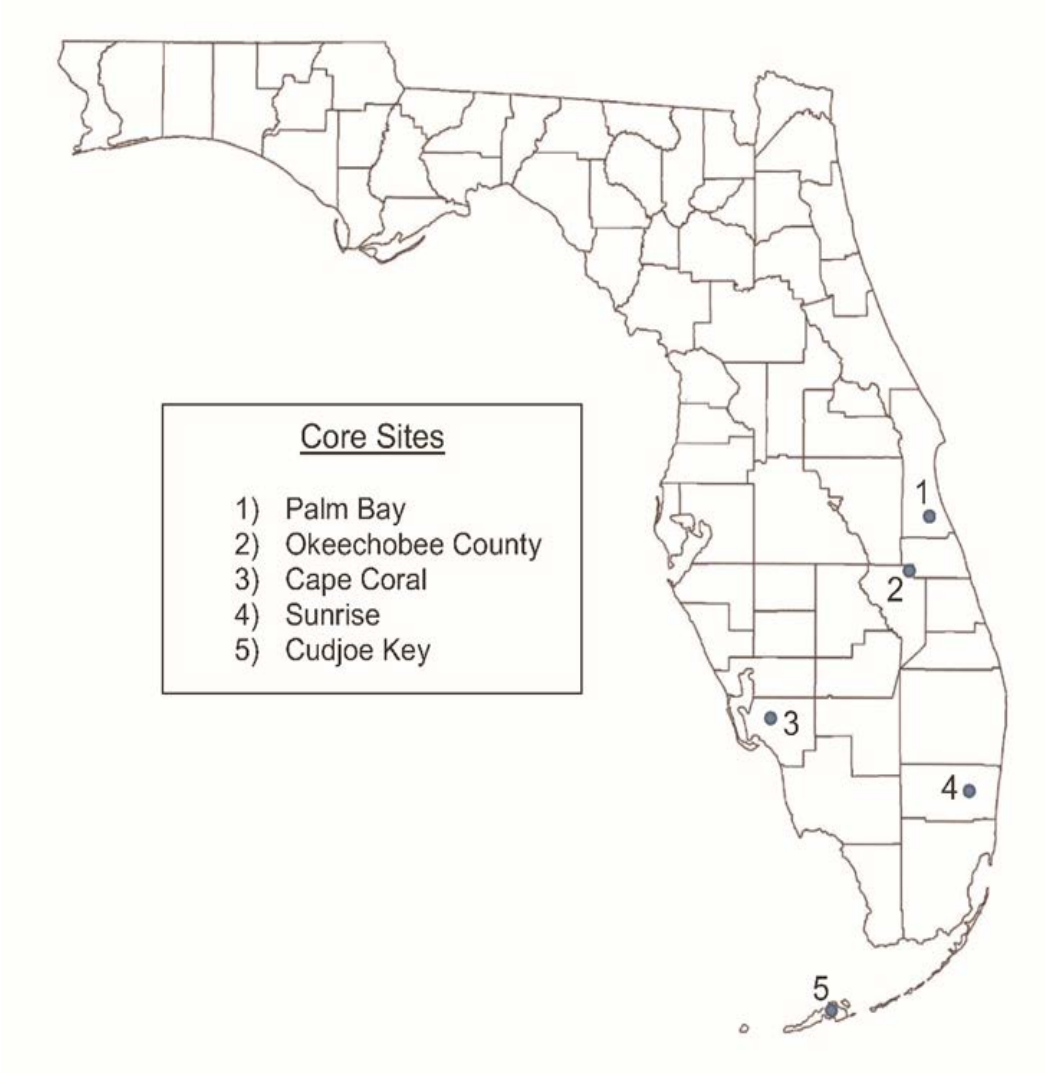
Given the demonstrated success of the laboratory system, the construction, assembly and installation of a pilot-scale system is underway. The system will be installed at a Mosaic mine facility in the coming fiscal year.

3. *Leaching Study for Select Process and Non-Process Waters Relative to Future Disposal through a Deep Injection Well/Ardaman and Associates*

Although phosphogypsum stacking is neither cost effective nor environmentally sound, it has become an integral part of phosphoric acid manufacturing. It plays an important role in maintaining water balance. However, pond water treatment, either due to excessive rainfall or at stack closure, is extremely expensive and technically challenging. Double liming is the traditional method of pond water treatment, sometimes followed by reverse osmosis to further reduce conductivity and other contaminants. Pond water treatment cost ranges from $20 to $30 per thousand gallons, which translates to nearly 100 million dollars for a typical stack

closure. In the current pond water treatment and surface discharge practice, at least 5000 gallons of fresh water are used for every 1000 gallons of process water treated for dilution purpose to meet the requirement for conductivity. A typical PG stack system closure could require the treatment of over 3 billion gallons of process water, thus consuming 15 billion gallons of fresh water.

Under this project, eight source-waters were collected from various concentrate phosphate plants, with some partially-treated to obtain fourteen study waters, and eleven carbonate rock cores from five deep injection well sites located across Florida were used to extract seventeen horizontal core samples. The leaching tests were performed for 183 days to determine the potential change in hydraulic conductivity and water quality over the testing period. The results were favorable, and may have been more favorable if the influent was filtered just prior to permeation of the cores. These leaching tests indicate that using deep injection wells with carbonate formations to dispose of treated process and non-process waters may yield similar favorable results.



Location of Test Core Samples

4. ***Screening of a New Candidate Biological Control Agent of Brazilian Peppertree***
University of Florida

Brazilian peppertree (*Schinus terebinthifolius*) is a non-native, highly invasive shrub or small tree that infests thousands of acres of mined and unmined lands in Florida. The plant is not invasive in its native habitat in South America, indicating that its aggressive spread in Florida and elsewhere may be due to escape from its natural enemies. This suggests that importing Brazilian peppertree's natural enemies, such as certain insects, may help control the plant. The research has been testing the performance of two species of a leaf-gall-forming psyllid insect (*Calophya latiforceps and C. terebinthifolii*) on injuring Brazilian peppertree, testing the host specificity of the insect (attacking the target plant species, but not harming other plant species), and developing methods for rearing the insects.

Two insects were screened as possible biological control agents. Insects were imported to quarantine labs both in Florida and in Brazil, and researchers worked to rear them and assess their control performance and host specificity for Brazilian peppertrees.

Results of the research project include:

- a petition submitted to the USDA Animal and Plant Health Inspection Service (APHIS) requesting field release of *Calophya latiforceps* as a biological control agent on Brazilian peppertree has been approved;
- the next step will be testing the efficacy of release in the field.
- populations of *Calophya* species are being maintained at Fort Pierce for continued research and release.

Brazilian Peppertree with Leaf Damage from Calophya latiforceps.

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Please contact us for more information on the research or programs of the FIPR Institute.