AVALON RARE METALS' UNIVERSITY OUTREACH INITIATIVE

Ian M. London
Mandeep Singh Rayat

William Mercer
Avalon Rare Metals
Toronto, Ontario, Canada
mrayat@avalonraremetals.com

Abstract – Avalon Rare Metals Inc., a mineral exploration and development company with a primary focus on developing rare earth element and rare metal projects, launched its University Outreach Initiative in 2011.

A scarcity of engineers in North America familiar with rare earth process engineering and a lack of rare earth element course material at Canadian universities were key motivating factors for the launch of the Outreach Initiative. Through this Initiative, the Company has been proactive in educating students about science and engineering issues related to rare earth elements, by means of lectures, sponsored course projects, and sponsored participation at conferences and symposia. All projects had a sustainability dimension.

This paper details seven undergraduate engineering projects and three graduate research projects initiated by Avalon at a total of seven different universities. The paper also provides recommendations to university engineering and science programs to ensure graduating students can build and play contributing roles in the emerging rare earth supply chain sector.

Keywords: rare earth elements ('REEs'), engineering education, company perspective

Social responsibility and environmental stewardship are cornerstones of Avalon's vision, plans and operations. At Avalon, sustainability initiatives also underlie its commitment to earning its social license to operate, enhancing its risk management profile, satisfying customers' growing requirements for sustainable supply chains, and meeting growing investor preference for companies which incorporate sustainability in their plans. Sustainability considerations, therefore, are integrated into all engineering decisions and work at Avalon.

As REE production and the technology sectors which are enabled by REEs continue to develop, Avalon has been proactively engaging and training highly qualified persons in the university system. Under its *University Outreach Initiative*, Avalon has actively participated in undergraduate engineering programs through providing curriculum content, delivering lectures and championing capstone design projects, in an effort to raise awareness of the emerging opportunities and technical challenges in the rare earth and clean technology sectors. Avalon has also supported graduate research programs in earth sciences, environmental sciences, mining and metallurgical engineering, supported by internships and participation in industry and academic forums. Avalon has supported eight graduate students involved in research relating to the Nechalacho project.

1. INTRODUCTION

Avalon Rare Metals Inc. ('Avalon') is a mineral exploration and development company, with an advanced stage project known as the Nechalacho Rare Earth Elements Project. The Rare Earth Elements (REEs) are critical materials in advanced technology applications, including emerging technologies in renewable energy, hybrid and electrical vehicles, and energy efficient technologies. These clean technologies, however, can truly only be deemed 'clean' if the metals and alloys that form components of these technologies are mined and processed in a sustainable manner.

2. DEVELOPING TALENT – A COMPANY PERSPECTIVE

As Avalon is embarked upon its journey towards sustainability, we continually look to the future. Given the limited course material on REEs in North American universities, one of the opportunities for Avalon is to enhance the availability of trained and experienced employees to design, build, operate and finance rare earth mines and process plants. Avalon's journey is also about encouraging innovation and the entrepreneurial spirit among students to create cutting edge technologies that leverage REEs.

In early 2011, Avalon launched an ambitious program under the banner *University Outreach Initiative*. The primary objectives of this outreach initiative are (1) to build and enhance the talent pools needed to design, improve and operate facilities; (2) to encourage and enable the needed science, engineering and business talent pools to strengthen Canada's emerging downstream processing and rare earth applications supply chains; and (3) to engage broad audiences of undergraduate science, engineering, and graduate level business students, and faculty, around issues surrounding rare earth elements.

Avalon's university outreach initiatives in 2011 and 2012, specifically related to engineering, are outlined in the following sections.

3. UNIVERSITY OUTREACH PROGRAM

3.1 University of Waterloo, Nanotechnology Engineering

Avalon introduced first-year Nanotechnology Engineering students at the University of Waterloo to the properties and applications of REEs. Through the Introduction to Nanotechnology course requirement, Avalon sponsored the "*Grand Rare Earth Nanotechnology Challenge*", where teams of three or four students were asked to identify future applications that would utilize a rare earth element that was expected to be in surplus, or a solution to reduce the demand for a specific rare earth element that may be in short supply. Given eight weeks, the teams were asked to address the underlying science, environmental issues and anticipated commercial opportunities. In December 2011, each team submitted a written report and presented their ideas before their peers and Avalon representatives. In support of the project, Avalon also delivered a one-hour lecture on the chemistry and physics of rare earth elements to the freshman class of 110 students enrolled in this highly competitive undergraduate program.

3.2 University of British Columbia, Mining Engineering

An Avalon Mining Engineer delivered a presentation to UBC Engineering students on design criteria for mine ventilation and occupational health and safety. The assignment to the class of 25 students was to determine the total ventilation system head loss and fan power requirements for Avalon's Nechalacho Rare Earth mine. The students were also introduced to the rare earth elements and their use in a variety of clean technology and more traditional applications.

3.3 McGill University, Materials Engineering

In January 2012, as part of their fourth year capstone design course in Process and Materials Design, Materials Engineering students conducted technical, environmental and economic assessments of various known REE resources around the world. Each team was also instructed in project management techniques and mentored by an experienced Projects Manager, provided by the internationally respected management, engineering and development consultancy Hatch Ltd. The teams' findings and presentations were adjudicated by McGill Faculty, a PhD candidate, and representatives from Hatch and Avalon in April 2012.

Avalon has also initiated a multi-year research project on rare earth beneficiation processing.

3.4 University of Toronto, Chemical Engineering

As part of their final year Chemical Engineering Plant Design project, three teams of six fourth-year students designed different variations of Avalon's hydrometallurgy process for the recovery of REEs. Over the course of 12 weeks, the teams researched technical data and designed alternative process and plant schemes, complete with project economic and environmental assessments. Avalon provided the overall project objectives, preliminary design considerations and regular oversight. The teams presented their final projects to Avalon and the Chemical Engineering faculty in December 2011.

Given the students' limited experience in this field and the scarcity of published materials in English on rare earth hydrometallurgy, Avalon consulting engineers were quite impressed by the plant design reports and presentations—so much so that the Company hired two graduating students from this program as Junior Chemical Engineers.

In addition to the plant design project, Avalon also delivered a two-hour guest lecture to the second year Applied Chemistry I - Inorganic Chemistry class, attended by approximately 100 students. Under the banner "*What are the Rare Earths and How Chemistry Brings them to Life*", students were introduced to the REEs, their current applications, the chemistry that underlies their unique properties such as magnetism and luminescence, and processing parameters. The discussion also touched on developing the downstream infrastructure to support rare earth processing and materials manufacturing within Canada, rare earth recycling, environmental regulations, human resource needs, and the utilization of rare earths in clean technologies.

3.5 University of Toronto, First Year Engineering

In November 2012, Avalon led a series of three seminars on rare earths for first year engineering students

at the University of Toronto as part of the required Engineering Strategies and Practice course. The seminar sessions, under the banner *Rare Earths – What they are, Applications and the Opportunity for Canada*, distributed over three days, were each two hours in duration. Twenty-one students, from a variety of engineering disciplines, participated in the seminar series. Students were assigned assorted readings on rare earths from the public domain and scientific literature in advance of the program.

In the final seminar session, students were invited to make three-minute informal presentations on a particular application of rare earths they found most exciting—topics as diverse as the use of rare earths in novel cancer treatment to powering lasers for future space travel were presented. Select comments written by students in a post-seminar survey included:

“I am now aware of rare earths and their applications in every day life”

“I really enjoyed learning about rare earths as it would not have been something I would have taken notice in until it appeared in upper year course materials (if at all)”

“I learned about the importance of rare earths in today's technology-driven society and the significance of the current state of the industry.”

3.6 Western University, Chemical and Mechanical Engineering

Avalon's Nechalacho Rare Earth Element deposit is located in Thor Lake, Northwest Territories. As with most projects in the North, the base case project design relies on diesel generators for power. Avalon is interested in adopting alternative energy technologies which would help reduce a full reliance on diesel at this site. The reasons for this are many, including the high cost of diesel (particularly when it needs to be transported to the Northwest Territories), expected increases in price faster than average inflation, mitigating environmental risks and possible future carbon tax or some other levy for producing carbon dioxide. Avalon considers that it is both economically and environmentally responsible to investigate renewable power sources to reduce its dependence on fossil fuels.

Fourth year Chemical and Mechanical Engineering students were asked to design alternative energy systems that would achieve this goal as part of their capstone design projects. One Chemical Engineering Team designed a biomass cogeneration plant which would use wood pellets to produce steam which would then be used to generate electricity. A second Chemical Engineering

Team designed a biodiesel plant (as opposed to regular diesel). One Mechanical Engineering Team proposed a combined wind and diesel solution, whereas a second Mechanical Engineering Team investigated the potential storage solutions for excess energy generated by wind power.

3.7 University of Toronto, Engineering Science, Energy Systems Major

As discussed above, Avalon is interested in investigating the potential for alternative power supplies either supplemental to or replacing diesel power.

A similar challenge to that presented at Western University was presented to fourth year Engineering Science students specializing in Energy Systems as part of their capstone design course. This group of students analyzed potential alternative energy systems using their backgrounds in energy systems design. Each group selected a system based on their analysis of the system's ability to meet power demand requirements, including their evaluation of economic, environmental and social outcomes. Of the four groups three proposed a biomass power plant fueled by wood pellets, while one group proposed a system which used a combination of wind, battery storage, and diesel.

3.8 Graduate Research Initiatives

Avalon also actively supports graduate student research, driven primarily by specific technical questions, rather than general outreach. In some cases, the topics were raised by Avalon to the professor, and in other cases, the professor or graduate student approached Avalon.

To date, the research efforts are focused on Earth Sciences and Metallurgy. Earth science theses at the University of Windsor and McGill University are focused on the nature and formation of the Nechalacho Deposit. In the process of these investigations, fundamental knowledge of the mineralogy of the deposit is developed, which is a very important input into the understanding of the behaviour of mineralization during processing.

Processing research is taking place at both Western University and McGill University, with very specific projects relating to recoveries during flotation processes.

Finally, thesis work that straddles the boundaries between Earth Sciences, Environment and Metallurgy is underway at Queens University. This research is addressing elements of the possible mine tailings, and the behaviour of rare earths in the natural environment in the vicinity of the Nechalacho Deposit.

Success with graduate research is not solely through support of the specific thesis work. Avalon has adopted a broader approach, with an annual Earth Science

Workshop—one of the most important mechanisms to spread the knowledge of the research. These full one-day Workshops provide Avalon, student geologists, and professors from multiple institutions, with the opportunity to make presentations, exchange ideas and debate the science of the Nechalacho Deposit. The annual workshop was taken successfully to a higher level in December 2012 by including metallurgy graduate students and professors, thus creating a wider spectrum of ideas for debate. This enabled earth scientists and metallurgists to explore the boundaries between their disciplines.

It goes without saying, that in addition to broadening the collaboration among academia, the company's geologists and metallurgists benefit through this key professional development event.

3.9 Company Sponsored Extra-Curricular Activities

In addition to Avalon's role in sponsoring engineering and science-related course projects, the Company has also been active in sponsoring student activities which challenge students to think about how resource extraction and processing can be done in a sustainable manner. This includes the Company's recognition that the emerging REE industrial sector can only benefit with business and policy related perspectives being integrated into finding and implementing solutions.

A primary example is Avalon's sponsorship of the Schulich School of Business International Case Competition. Avalon sponsored this competition in 2011 and 2012, both of which had resource extraction and sustainability themes. Avalon representatives also participated as judges in both years.

In November 2011 Avalon led a seminar at the Canadian MBA Leadership Conference, facilitating a discussion with and among 29 MBA student leaders from nine business schools across Canada. The seminar was framed under the banner "*What can the next generation of Canadian business leaders do to better leverage the nation's abundant natural resources?*" Using Canada's emerging rare earths production capability and the complex backdrop of international trade, technology, supply chain and economic development related to this sector, the delegates discussed strategies around entrepreneurship, public policy development, industry-government-academic partnerships, research, development and building the talented workforce within Canada.

As a result of these initiatives, Avalon was invited to chair the inaugural Rare Earth Elements Symposium at COM 2012 - the annual Conference of Metallurgists, an event organized by the Metallurgy and Materials Society, a constituent society of the Canadian Institute of Mining, Metallurgy and Petroleum (CIM). Prior to this

Symposium being convened, graduate students, faculty and industry technical specialists involved in rare earth processing research lacked a dedicated forum to discuss the results of their work. The inaugural Symposium attracted significant international attention with 44 papers from 10 different countries presented in 2012. Avalon was invited (a repeat performance) to chair the Rare Earth Symposium at COM 2013, to which 55 papers and five poster presentations from 16 countries, from academia and industry, are to be presented in October 2013. The scope of these papers range from mineralogy studies, through beneficiation, hydrometallurgy, separation and material science. Sustainability related topics such as the recovery of rare earth elements from electronics, recycling and radioactive materials management will also be presented.

4.0 OUTCOMES AND OBSERVATIONS

Avalon's overall experience with university departments, professors and students has been very positive, and it is only a beginning. The Company's academic engagements have achieved the primary goal of introducing students to rare earth element properties, applications, and challenges associated with extraction.

Avalon representatives have noted, however, that university faculty members tend to focus on graduate research, where there is subject flexibility and, after all, that is how the granting system works. Undergraduate studies tend to be more structured in terms of curriculum requirements. Avalon continues to seek a better balance between undergraduate and graduate initiatives, however, sometimes this balance is not easy to strike.

Undergraduate level initiatives allow the company to reach a broader group of students. Some of these students may decide that they desire to work as an engineer for a rare earth-related mining or downstream processing company. Such initiatives give undergraduate students the opportunity to learn about an industrial sector which normally would not be covered in their regular course material.

Others may wish to pursue graduate studies related to rare earths. Graduate students of course solve real and detailed technical problems.

Avalon has also noted that there is an interesting difference in its interactions with MBA programs versus its dealings with engineering programs. The Company's interaction with MBA students has largely been driven by student clubs and not by specific courses, as is the case with engineering programs. Undergraduate technical course requirements are by their nature structured with specific content requirements. These can be limiting at times. There may very well be a role for student-led engineering clubs to engage with companies and host case competitions and seminars.

It may also be beneficial for engineering faculties to cultivate internal subject champions, like one for REE-related processing and applications, to interact with companies and position projects in the appropriate courses. In addition, the internal champion could and should interact with faculty in other departments and seize on opportunities to make these projects interdisciplinary, as the challenges facing the rare earth sector requires complete solutions with input and expertise of individuals from different backgrounds.

5. CONCLUSION

Avalon has actively tried to engage faculty and students as part of its University Outreach Initiative. Students have shown an enthusiastic interest in learning more about rare earths, and there is clearly value in expanding this further as Canada leverages its natural resources to build solid downstream supply chains. As experienced across freshmen to senior year classes, students found the material helpful and stimulated their learning experience early on. Incorporating rare earths in engineering curricula, including the unique properties, material science and demands of future applications, as early as first year, is highly recommended.

To achieve a larger long-term impact, rare earth element chemistry and process engineering needs to be formally introduced into undergraduate chemical engineering courses. The combination of course work in REEs, and projects and internships sponsored by companies in the sector will ensure that graduates have the background to meet the industry's talent needs. This would also serve as a foundation for increased graduate-level REE-related research.

Finally, interdisciplinary (cross-departmental) solutions are essential for complete engineering solutions. As such, engineering departments should seek opportunities to develop interdisciplinary design courses.

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