E R A•M I N 2

RESEARCH & INNOVATION PROGRAMME ON RAW MATERIALS
TO FOSTER CIRCULAR ECONOMY

ERA-MIN Joint Call 2014 Results:

Summary Reports

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Joint Call 2014 results: Summary Reports

Thirteen ERA-MIN funding agencies, **ADEME (France), ANR (France), DST (South Africa), FCT (Portugal), MINCYT (Argentina), MINECO (Spain), NCBR (Poland), OTKA (Hungary), SGU (Sweden), TEKES (Finland), TUBITAK (Turkey), UEFISCDI (Romania) and VINNOVA (Sweden),** committed together a total of €7.87 million of national/regional public funds to support their national/regional participants in the selected transnational R&D proposals submitted to the **second ERA-MIN Joint Call 2014.**

21 full proposals were submitted in total from 83 participants. Out of the 21 proposals, 16 passed the eligibility check. After evaluation and ranking, 7 transnational projects, involving 38 organisations, were finally selected for funding: project acronyms **AMDREY, BOFLUX, ENVIREE, EXTRAVAN, NewOres, RAREASH and StartGeoDelineation**. The total project funding was €5.43 million, being the total costs of €8.57 million. The total success rate of the Joint Call 2014 was 33,3% (7 funded/21 submitted proposals). When considering the 16 eligible proposals the success rate increases to 43,75 %.

The **scope** of this second Joint Call 2014 was needs driven research on **"Sustainable Supply of Raw Materials in Europe"** with the following main topic areas:

1. Primary resources,
2. Secondary resources (recycling),
3. Substitution of critical materials.

The sub-topics "Extraction" and "Recycling of mining and smelting residues" are covered in 4 out of 7 funded projects (Figure 1).

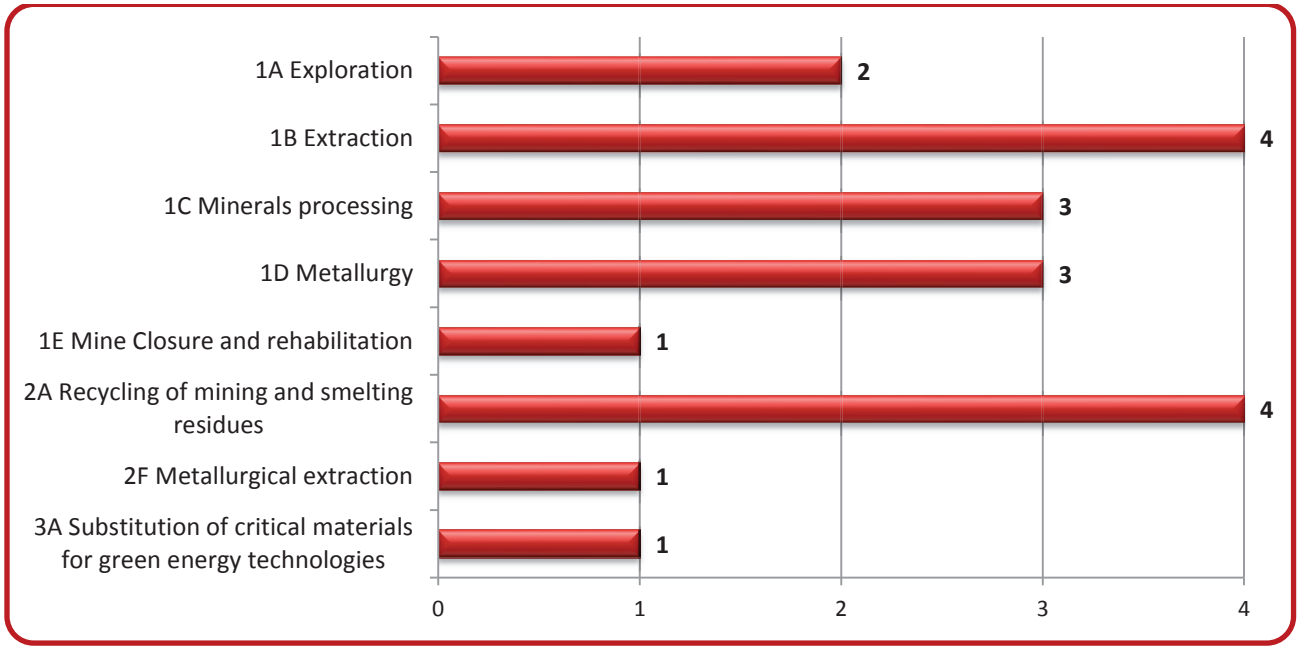


Figure 1 - Distribution of sub-topics addressed in the 7 funded projects.

The type of organisation with the highest participation in the 7 funded projects was public research organisation, representing 34%, followed by higher education institution with a participation of 32% (Figure 2).

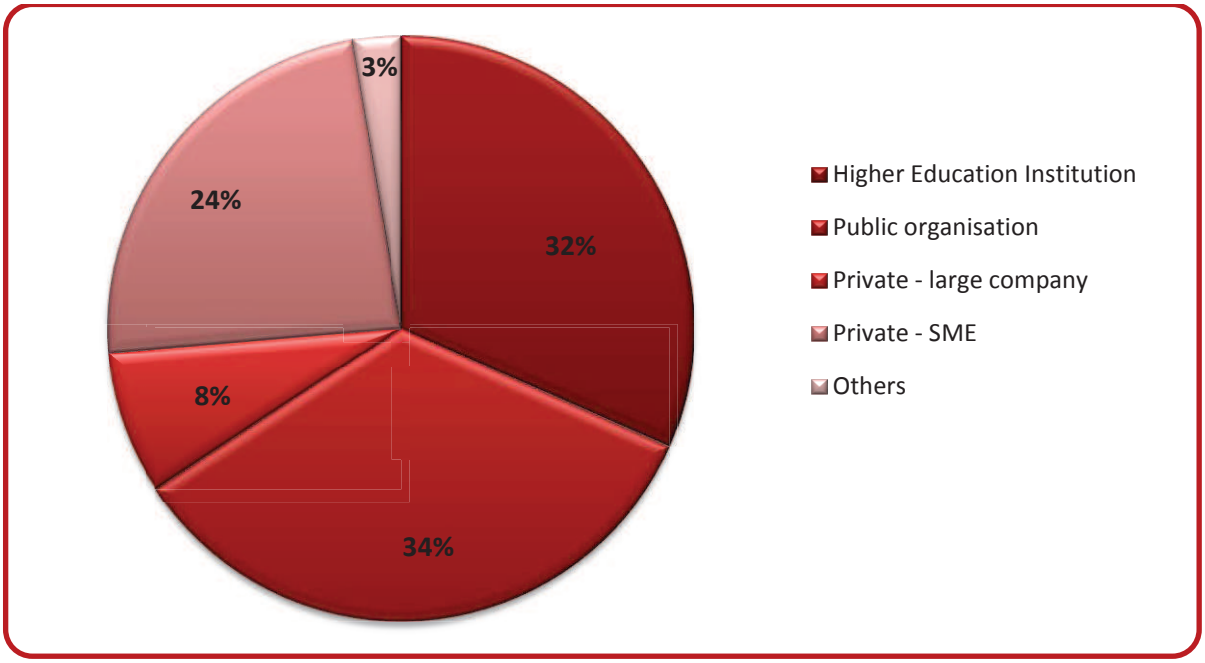


Figure 2 - Distribution of types of organisations in the 7 funded projects.

In terms of country participation, 8 out of 11 countries participating in this Joint Call funded at least two national/regional organisations of the funded projects (Figure 3).

Figure 3 - Geographical participation in the 7 funded projects.

All funded projects involved 69 young researchers which represents the 36% of researchers participating in these projects (Figure 4).

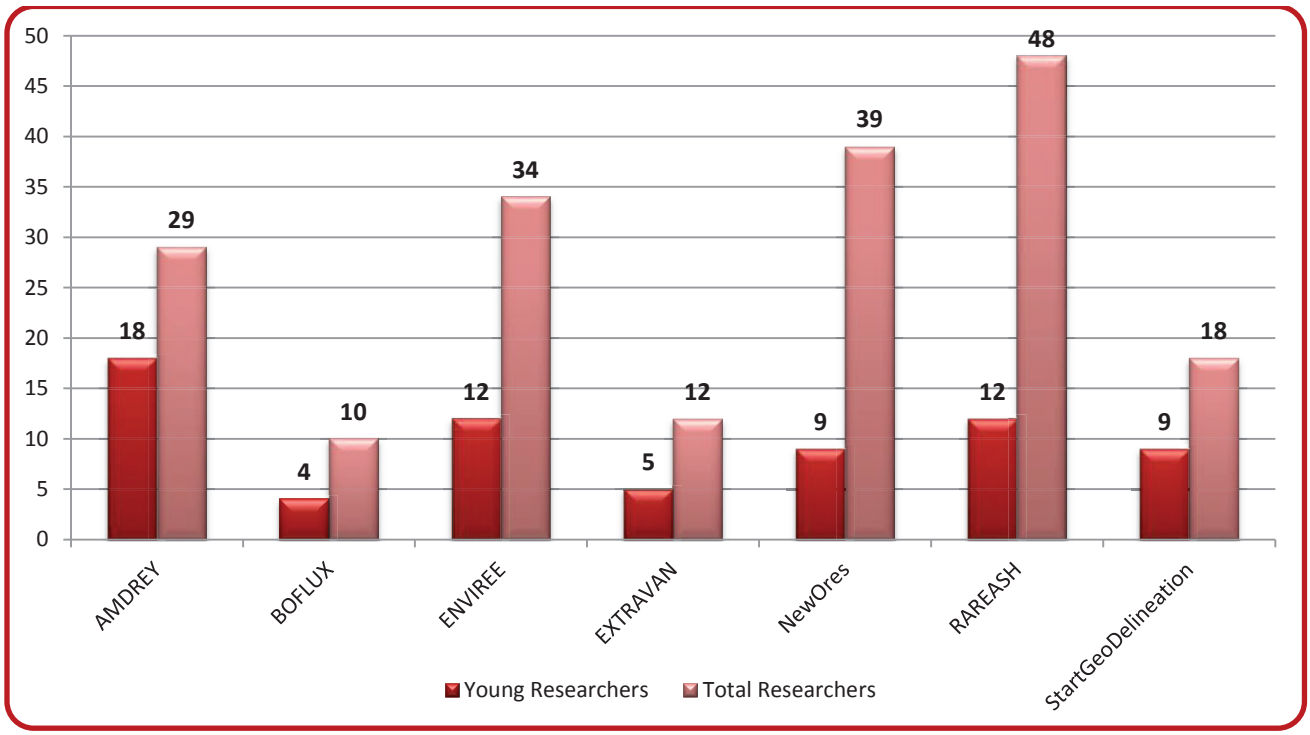


Figure 4 – Young and total researchers participating in the 7 funded projects.

It is highlighted mentioned that 44% of the researchers involved in these funded projects are female which represents a good indicative of gender balance (Figure 5).

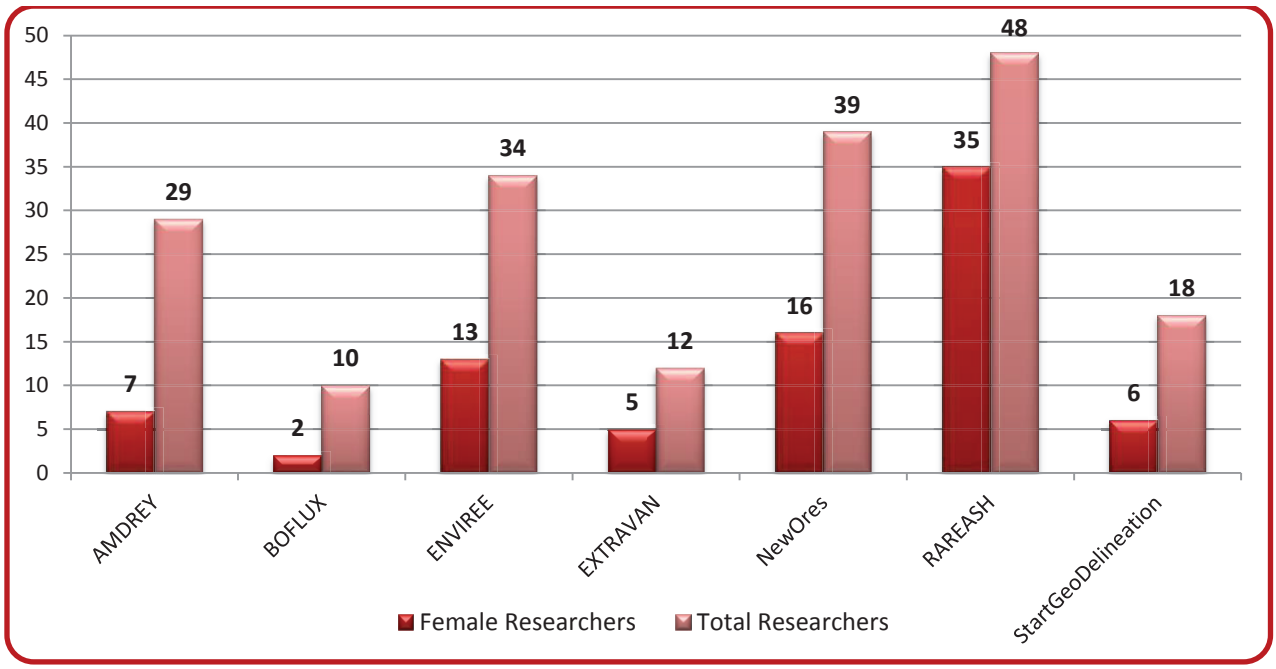


Figure 5 - Female and total researchers participating in the 7 funded projects.

These projects have produced 79 publications (Annex I), 5 patents/licenses and 1 start-up (Annex II) as well as created 17 permanent jobs and 63 temporary jobs.

New industrial collaborations have been created through the funded projects and the continuation of these collaborations have been strengthened, being very important the role developed by the industrial sector in the funded projects. Underline the creation of the Ferrovan start-up.

Project AMDREY

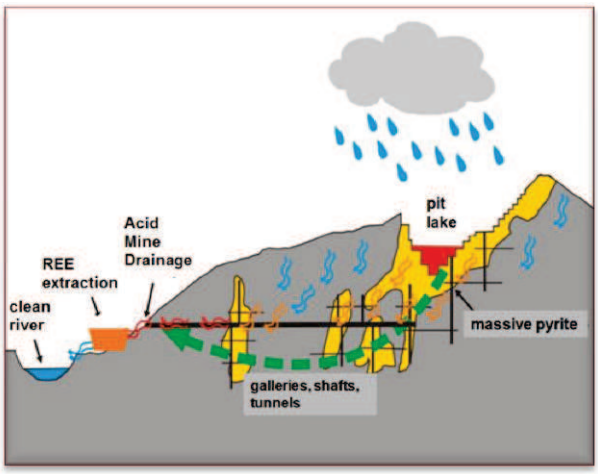
Extraction of Rare Earth Elements from Acid Mine Drainage

Sub-topic: Recycling of mining and smelting residues (incl. historical dumps and tailings)
Project Coordinator: CSIC (Spain)
Consortium partners:
Oy Chemec Ab (Finland); ICSM (France); UFS (South Africa); UHU (Spain).

Project total funding: 830.140 €
Project total costs: 972.500 €
Duration: 24 months (2016-2018)

SUMMARY and RESULTS:

Acid Mine Drainage (AMD) is commonly considered an environmental pollution issue. However, Rare Earth Elements (Scandium, Yttrium and Lanthanides) concentrations in AMD can be several orders of magnitude higher than in naturally occurring water bodies. With respect to shale standards, the REY distribution pattern in AMD is convex and enriched in intermediate and valuable REY. Traditional AMD remediation systems are based on the reaction of AMD with a base, such as lime or limestone, generating a large amount of iron and aluminum-rich sludge. The main objective of the AMDREY project was to characterize and recover REE from the treatment sludge and thereafter investigate the efficiency of some chemical separation techniques.



A main outcome of AMDREY project is to link the 100% recovering of REE in the sludge of AMD treatment. Thus, in active neutralization plants with lime or sodium carbonate, precipitation of the iron oxyhydroxide schwertmannite occurs at pH below 4 with no REE scavenge. On the contrary, the equivalent aluminum mineral basaluminite precipitates as neutralization progresses to pH 6.5. Practically all REE are retained in basaluminite. The same behavior is observed in passive remediation systems consisting of AMD circulating through a permeable substrate of limestone. There, schwertmannite and basaluminite successive fronts precipitate as the AMD is neutralized by calcite. The accumulation of REE in the treatment wastes is especially relevant in the Phalaborwa Industrial Complex (PIC) in South Africa. There, the waste rock dumps are composed mainly of carbonatite-material, with high REE content. Therefore, this alkaline material becomes an attractive solution to not only neutralize the acid drainage, but also to enrich them in REE. The results of AMDREY have demonstrated that commercial calcite, commonly used in treatment systems can be replaced by carbonatite (mining by-product), which will decrease costs dramatically.

Further studies need to be performed in order to characterize the REE-enriched wastes and its feasibility as a marketable product. Two chemical separation processes have been evaluated based on different technological systems based on “green chemistry” rules. Liquid/liquid extraction using solvating agent such as TODGA is efficient to recover selectively REE (Nd=Y>Gd>La >> Fe, Al, Mg, Ca) but the main drawback is the need to increase the concentration of H_2SO_4 until 7.5M. With respect solid-liquid systems with no solvent, one of the synthesized resin seems to be an efficient candidate to the treatment of AMD with high extraction (>90%) and stripping (>80%) behavior. First attempts to biorecovery have also been tested by means of investigating the metal resistant mechanisms of two bacteria. *Clostridium sp.* was able to reduce and accumulate Eu^{2+} intracellularly, whereas *Thermus scotoductus* SA-01 accumulated Eu extracellularly using two different strategies. The results have significant implications for REE biorecovery, probably as nanoparticles for *Clostridium sp*. and as insoluble carbonates for *T. scotoductus* SA-01. Rather than extracting REE from wastes, another objective of AMDREY was to extract REE straightforward from the AMD. Thus, the work led by Chemec Oy used the vegetal-based adsorber CH Collector to remove scandium from AMD. A pilot plant mounted in the Tharsis area (SW Spain) removed up to 81% Sc from the acidic waters without any pH control.

The main constraint of recovering REE from AMD is the low annual tonnage of the ore. Compiling all the acid drainage produced in an entire region, such as the Iberian Pyrite Belt, a total annual reserve of 70 to 100 t REY_2O_3, with an average rate of 0.23% REY_2O_3 is obtained. The rate is in the lower range of those compiled for currently working mines and prospects. The annual reserves are less than 0.05% of the world annual production. However, despite the low rates and annual production expected for the IPB, the natural processes that generate AMD are expected to continue for centuries or thousands of years. In this sense, the IPB could function as a giant heap leaching process of regional scale, in which rain and oxygen act as natural driving forces with no energy investment. Furthermore, as the main objective of AMD treatment is to remove acidity and pollutants, the benefits for water reserves and ecosystems are obvious. Therefore, recovery from AMD can be considered a small but environmentally friendly and renewable source of REE.

Project BOFLUX

Characterisation of the impact, boron addition has on the physical and smelting properties of chromite slag

Sub-topic: Metallurgy
Project Coordinator: Mintek (South Africa)
Consortium partners:
Ab Etiproducts Oy (Finland);
Siyanda Chrome Smelting Company Pty Ltd (South Africa)

Project total funding: 221.925 €
Project total costs: 269.500 €
Duration: 24 months (2015-2017)
Website:
http://www.mintek.co.za/technical-divisions/pyrometallurgy-pdd/boflux/

SUMMARY and RESULTS:

BOFLUX, funded via ERA-MIN, is a joint project between Mintek, EtiProducts, and Siyanda Chrome Company which aimed to explore the potential benefits of using colemanite as an alternative fluxing agent for chromite smelting. This report is presents at a high level the main outcomes and conclusions of the work.

Laboratory-scale smelting tests were conducted at Mintek over the course of two years. The work included evaluation of a variety of boron-containing materials to replace or partly replace conventional fluxes. The laboratory test results indicated that colemanite had the best outcomes. The tests confirmed that addition of boron lowers the liquidus of the slag and smelting can be done at 1650°C, lower than conventional smelting temperatures. The grade of the final product improved by approximately 1 to 2.5 % Cr units, depending on the grade of the ore smelted. The test work was supplemented by modelling work through which various flowsheets were developed and evaluated for suitability. The study focused on South African chromite concentrates, assessing the impact of using various grades of colemanite, analyses and samples provided by EtiProducts.

EtiProducts can supply a wide range of grades and part of the objective was to establish whether any significant benefits can be demonstrated for a one type of colemanite over any other.

The main conclusions from the study can be summarised as follows:

- No significant benefits were demonstrated between the various types of colemanite ores which EtiProducts can supply. Colemanite products that would be suitable for chromite smelting of South African chromite ores would need at least 30% B_2O_3 and 25% CaO with a maximum SiO_2 content of 8% (on an uncalcined basis). Most products in the EtiProducts range meet these requirements.
- Replacing conventional fluxes with colemanite appears to offer an opportunity for process intensification (increased chrome production for the same power input). The benefits are marginal for smelting process without pre-treatment of the colemanite (calcining). Pre-heating of the ore and colemanite is thus highly recommended.
- Tests with lower grade chromite concentrates resulted in only marginal metallurgical improvements. Modelling work and mass and energy balance calculations showed the same trends as the test work. Benefits are most significant South African metallurgical grade chromite.
- The flowsheet scenario with the most potential for process intensification includes provision for pre-heating feed and calcination of colemanite; here the benefits when compared to conventional processing is significantly higher than any other scenario evaluated. Pre-heating of chromite ore is not a direct benefit of BOFLUX. The benefits presented by addition of colemanite must always be weighed against the cost of replacing conventional fluxes with colemanite. The BOFLUX results highlighted that the cost of the colemanite will need to be similar to that of conventional fluxes.
- Some of the BOFLUX benefits may not be directly measurable through a test work based study that focused on the metallurgical impact. However, it is worth highlighting that lower operating temperatures can lead to increased longevity of refractories and tap-holes, which can improve cost and efficiency of a commercial smelter significantly. Reduction of maintenance downtime, even relatively small reductions, could outweigh any process intensification benefits associated with the increased throughput for example. This may ultimately be the primary selling point for colemanite, especially for chromite smelter that is currently operating with smelting temperature in excess of 1800°C

The BOFLUX project demonstrated successfully that process intensification appears to be possible by replacing conventional fluxes (quartzite and/or limestone) with colemanite, however further technoeconomic and sensitivity studies should be undertaken to evaluate the cost of replacing conventional fluxes with an imported product.

The technical outcomes of the work conducted under the BOFLUX project added to the scientific knowledge and directly resulted in additional research beyond the original scope of the project.

Project ENVIREE

ENVIronmentally friendly and efficient methods for extraction of Rare Earth Elements from secondary sources

Sub-topic: Extraction, Minerals processing, Mine closure and rehabilitation, Recycling of mining and smelting residues (incl. historical dumps and tailings)

Project Coordinator: Chalmers (Sweden)

Consortium partners:
BRGM (France); CEA (France); KIT (Germany); PIPAS (Norway); AGH UST (Poland); R.O.T. (Poland); EDM (Portugal); IST-ID (Portugal); AICU (Romania); CGS (South Africa)

Project total funding: 1.822.371 €
Project total costs: 2.481.175 €
Duration: 40 months (2015-2018)
Webpage: www.enviree.eu

SUMMARY and RESULTS:

The ENVIREE project aimed at strengthening the REE supply within Europe by addressing exploitation of specific secondary sources. The purpose was to study innovative approaches in processing (beneficiation, leaching and separation) of identified materials and to provide economic and environmental assessment of the tested methods. ENVIREE was a highly multidisciplinary project with competences ranging from analysis techniques using e.g. Mössbauer to the more visual knowledge-based mineralogy in the field, and in size from molecule level to ton scale. This wide scope made the initial work challenging when several disciplines, each with their own science language were to agree on what to do and how. In addition to these more technical works there was also an extensive training and education activity.

Large sampling scheme implemented within ENVIREE did lead to a very useful information on REE content of different mine wastes in different countries and although only three samples were selected for further treatment the analysis of the remaining ones can serve as a basis for further research and potential exploitation depending on REE prices and demand in the future. The base for the analysis was that the samples were grinded and homogenised before the actual analysis was made using neutron activation analysis, X-ray fluorescence and inducted coupled plasma mass spectrometry analysis. The most REE rich residue was the one from New Kankberg in Sweden with about 500 ppm REE content. For the selected samples from Portugal and Sweden efficient beneficiation techniques were developed and applied proving that the REE content in the ultimately treated material could be increased by orders of magnitude thus increasing the potential market efficiency of the following selective separation scheme. The basic techniques used here were gravimetry for the Portuguese samples increasing the concentration from 52 to 284 ppm and flotation techniques for New Kankberg increasing this content to more than 5000 ppm. Not surprisingly the dominating REE were lanthanum, cerium and neodymium.

For the separation CYANEX based systems were used for e.g. the New Kankberg beneficiated samples. This was tested in lab scale and a small pilot test was run. The DGA based systems did not show enough promise for further development. Also some complete novel ligands were tested successfully but due to limited supply not used for upscaling. Other techniques such as hollow fibres and ionic liquids were tested in smaller scale with promising results but not developed further to pilot plant scale. All in all the separation schemes developed clearly showed the technical feasibility of the techniques adopted in ENVIREE.

To further show the potential profitability for both environment and economy, studies and environmental analyses were made for selected processing scenarios making it possible to guide future prospectors in this field. It was clear that even for the very rich samples from New Kankberg there were clear benefits to treat the material at the same place as the original mining activities for energy conservation. For the reclamation of the mining sites it was shown that the remaining material for the New Kankberg material could be stored on the surface and used as a soil substrate in land reclamation. The situation for the more sulphur-rich residue from the Covas site there was a need for neutralisation processes before the material could be used for reclamation purposes, which gives a negative impact for the overall, holistic system evaluation.

Last but not least the training and education work within ENVIREE has been highly successful with practical field trips combined with theoretical courses in all the scientific areas included. This gave the participating younger scientists a unique possibility to broaden their competence and thus lay the foundations for a more holistic approach to not only mine waste use but also to potential use in primary material recovery.

Project EXTRAVAN

Innovative extraction and management of vanadium from high vanadium iron concentrate and steel slags

Sub-topic: Extraction, Minerals processing, Metallurgy, Recycling of mining and smelting residues (incl. historical dumps and tailings), Metallurgical extraction

Project Coordinator: MEFOS (Sweden)

Consortium partners: FERROVAN (Finland); BRGM (France)

Project total funding: 829.912 €

Project total costs: 1.203.234 €

Duration: 26 months (2014-2017)

SUMMARY and RESULTS:

The EXTRAVAN aimed at developing novel technologies for production of vanadium in Europe based on V-bearing iron ore and V-bearing steel slag existing in the Nordic countries. EXTRAVAN focused on two major technological approaches. Route A is a "roasting-leaching" route including a novel approach for roasting of V-slag with very high vanadium content. This technology has been developed and demonstrated during the EXTRAVAN project. The industrial partner has contributed additional 35 000 € to make this pilot testing possible. The vanadium yield achieved is as high as 97%. All technical steps from high V-slag to roasting, leaching, AVP precipitation, V2O3 and V2O5 preparation, FeV making have been demonstrated in various scale with a very high overall vanadium yield. The results of the project have been an important and crucial part of the project development of MKOY (FERROVAN). The second focus (Route B) in the EXTRAVAN was development of a new approach for vanadium extraction using spent PVC waste stream as the chlorination agent. BRGM has demonstrated the concept capability in laboratory scale. High process flexibility has been demonstrated and a high V-recovery yield has been achieved.

The technological achievements include a special roasting approach for high V-containing slag for the FERROVAN process aiming for a high overall vanadium recovery yield demonstrated in large pilot scale and a carbo-chlorination approach using spent PVC waste demonstrated in laboratory scale.

The scientific achievements include:

- A PhD thesis work (Mikael Lindvall, Swerim/Royal Institute of Technology (KTH), Sweden).
- A Master thesis work (Martin Berg, KTH).
- Two publications concerning "roasting-leaching" and optimized conditions for vanadium extraction (published).
- Two publications on the PVC roasting approach (to be submitted by BRGM).
- Over 10 presentations at various international conferences, seminars and workshops including those arranged by ERAMIN (Stockholm/Berlin).

The main conclusions are as follows:

- The technical feasibility of the whole chain of Route A – "reduction – selective oxidation – roasting – leaching/precipitation – FeV making" has been completely demonstrated.
- The roasting, leaching, vanadate and V2O5/V2O3 preparation and FeV-making steps are successfully developed and proved in this project including a novel high temperature roasting (HTR) process has been developed. The innovation will shorten the roasting time by a factor of about 10. The vanadium recovery yield of the HTR roasted V-slag was up to 97%.
- A novel oxy-chlorination process for direct roasting of high V-bearing BOF steel slag has also been demonstrated in laboratory scale with an overall vanadium recovery of up to 95%. In this process Cl-bearing wastes like PVC waste streams could used as the energy source and reagent. Further verification of this concept in larger scale is needed and recommended.

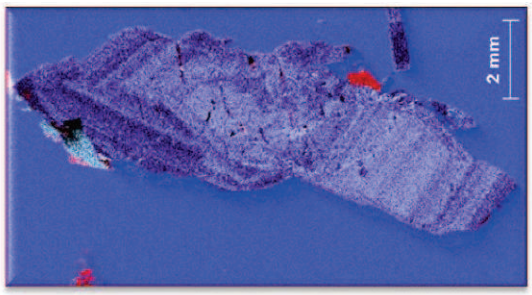
Project NewOres

Development of New models for the genesis of Rare Metal (W, Nb, Ta, Li) Ore deposits from the European Variscan Belt and valorization of low grade and fine grained ore and mine tailings

Sub-topic: Exploration, Extraction, Minerals processing, Metallurgy
Project Coordinator: GeoRessources-CNRS-Université de Lorraine (France)
Consortium partners:
Université d'Orléans (France); FCUP (Portugal); FFCUL (Portugal); LNEG (Portugal); Sojitz Beralt Tin & Wolfram S.A. (Portugal)

Project total funding: 451.343 €
Project total costs: 1.818.244 €
Duration: 48 months (2015-2018)

SUMMARY and RESULTS:



A new vision of the W-Sn, Nb-Ta concentration processes for better industrial choices in exploration, exploitation and ore processing: NewOreS is a project devoted to the development of new models of ore deposition relevant to the W-Sn (Nb-Ta-Li) mineralisations, and intends to propose new exploration guides for this type of mineralization, by building i) a fully comprehensive model for the behaviour of metals duringcrustalmagmatic events, and ii) by understanding the behaviour of these metals at the hydrothermal stage, and the factors controlling metal deposition thanks to a more precise reconstruction of the pressure-temperature evolution.

One of the major targets was Panasqueira which represents the largest W deposit in Europe linked to a series of granite intrusions. One of the main goal was the development of exploratory mapping of particular mineral chemistry features aiming at the assessment of possible compositional zonings that may provide clues about the superposition of ore-forming processes (eventually controlled by distinct sources and structures). The results gathered show that: (1) the western and eastern sectors of the mine display contrasting features recognised at different scales and impacting both the metallogenic model for the Panasqueira system and the ongoing short range exploration surveys. On the basis of the relative abundance of various mineral phases (namely, coarse-grained muscovite, topaz, tourmaline, cassiterite and wolframite), the influence of at least two distinct metal sources may be inferred, both recording a similar geochemical evolution: the early stages of mineral infillings in the western sectors suggest the prevalence of B F(±P)-rich fluids, while in the eastern sectors the fluids involved in these initial stages would have been more enriched in F(±P±B). Accordingly, cassiterite (along with topaz) is much more abundant in the western sectors of the mine, as the exploitation works carried out in the last years have also shown. A third different source of fluids and metals, possibly centred at Vale de Ermida (to the NW), can be glimpsed if differences in the relative abundance of Bi, As, Sb (and Ag) mineral phases are considered.

Ore genesis: from field studies and in situ metal analysis in minerals to conceptual and numerical modelling. From province to magmatic body and fault scale, methodology consisted in coupling: i) field studies with systematic analyses of ore mineralogy and relative chronology, as well as trace elements in ore minerals, ii) paleofluid studies with precise reconstruction of pressure-temperature-fluid composition evolution, iv) dating of the main fluid events, fluid flow reconstruction based on mineral textures, followed by mass and heat transfer modelling. The targets are various parts of the Hercynian chain, especially i) NW Massif Central (France) with representative examples of rare-metal enriched granite bodies, and pegmatites mineralized in Sn-W-Li-Nb-Ta deposits (Puy-les-Vignes and St Sylvestre pegmatites) and ii) Iberia (Portugal) with the Argemela granite, and the Panasqueira deposit (Portugal). A mineralogical and numerical modelling approach to interpret the geometry and constrain the fluid circulations (directions, velocity) in the deposit has been applied to Panasqueira. At Argemela, the structural and geophysical constraints have shown that the intrusion is a pipe-like body. The mechanisms of the magmatic-hydrothermal transition have been characterized and illustrate as a rare example of deposition of Mn-rich wolframite deposited from magmatic fluids. A new ore deposit model is set up for Panasqueira deposit. Contrary to most recent interpretations, the deposit appears to be a focus of fluid flow and large convection cells implying metamorphic fluids and little evidence of true magmatic fluids probably mixed and/or buffered quickly by the host rocks. The overall system is linked to a major and deep zone of partial melting and successive magmatic pulses are necessary to explain the huge complexity and duration of the W-Sn (Nb-Ta) ores, in association with exhumation of the belt and subsequent changes in fluid pressure , and the amounts of other brought metals (Cu, Zn). Same conclusions concern French Massif Central.

Ore processing and mine tailings: The processing of low grade and fine-grained ores has been attempted for the recovery of copper from tailings from already mined deposits, in particular from Panasqueira, but appears rather difficult due to the ore oxidation after storing in waste piles. Thus, the processing of low grade and fine-grained ores and tailings from Panasqueira wastes has been attempted for the copper by flotation, but Cu exploitation from mine tailings remains difficult. Besides successive upgrading of eluvial Sn ores have been obtained successfully on the Bejanca ores.

Project RAREASH

Assessment of Possible Recycling Directions of Heavy & Rare Metals Discovered from Combustion Waste Products

Sub-topic: Recycling of mining and smelting residues (incl. historical dumps and tailings), Substitution of critical materials for green energy technologies

Project Coordinator: CPMTE/UPB (Romania)

Consortium partners:

ADW (Poland); GIG (Poland); LIPOR (Portugal); UP (Portugal); CEO (Romania); UCB (Romania)

Project total funding: 805.327 €

Project total costs: 859.803 €

Duration: 44 months (2015-2018)

Website: http://upb-cpmte.ro/rareash-project/

SUMMARY and RESULTS:

The project aimed to demonstrate by a detailed fundamental and applied investigation the technically feasible alternative for strategic metals production as Heavy and Rare Metals (HRM) consisting of Lanthanides and Gallium, Strontium, Rubidium, Yttrium and Wolfram by utilizing fresh and reuse landfilled fly ash and bottom ash as a source soft (pulverized) rock.

The proposed approach, with a very limited experience in Europe and even worldwide, demonstrated innovative methods/technologies to develop metal recovery processes and transform wastes into high-grade and valuable metals with various applications, creating the possibility for a fast and low-cost access to strategic metals and a widespread saving of EU primary mineral resources.

The project achieved results will be used as an initial basis for the advanced, waste-less and environmentally safety utilization of various ashes to obtain concentrates, high purity reactives, metals and metallic salts, and adsorbents, metal and oxide nanoparticles, scale controlled and functionalized as well as solar collectors precursors potential manufacturing to be used in high-tech and environmental purposes.

The characterization of Oltenia bottom ash, Polish coal ashes and LIPOR ashes was one of the main aims of the project together with the metals extraction. In this sense the characterization tasks were fully accomplished and a much better insight on the characteristic of theses ashes towards their use as a secondary source of rare and heavy metals is an achievement of the project. Resuming:

(i) it was found that Oltenia bottom ash is a potentially promising source of REY. However, Gd seems to be the most promising element, especially in the 0.090–0.125mm and < 0.063mm size fractions;

(ii) it was found that for Polish samples the prospect for recovery are four elements (cerium, lanthanum, scandium, neodymium), which account for a total of 77% of the total rare earth elements contained in the examined waste. Coefficients of variation of these elements are in the range of 6% to 11%. The average content of such rare earth elements as scandium, lanthanum, cerium, praseodymium, neodymium, and dysprosium is higher than in the earth's crust.

(iii) in LIPOR fly ash between 75% and 85% of the samples mass is concentrated in the >75 µm size fractions, and the <25 µm fraction is always less than 2%. The insoluble residue corresponds to approximately a 20% of the fly ash and does not vary with time. The chemical analysis of this fraction shows that its major compounds are chlorides, sulfates and CaO. However, Pb value was also high (783 ppm).

The LIPOR bottom ash size fraction < 2mm shows high concentration of Mo, Cu, Pb, Zn, Cd, Sb, In, Zr, and Sn in relation to the Upper Continental Crust, whereas the fly ash shows high concentrations of Mo, Cu, Pb, Zn, Cd, Sb, W, In, Bi, Zr, Sn, and Se in relation to the Upper Continental Crust. Meanwhile, major, minor and trace elements do not present high variations with time.

Derivative scientific objectives:

The Oltenia bottom ash not used for metals extraction has a promising potential to be recycled in making ceramic composites.

It was found that in coal fly ash and bottom ash from Romania and Poland, several morphotypes did not fit into the general fly ash classifications, unless grouped together as “undifferentiated inorganics”. However, many of these morphotypes not only have distinctive petrographic patterns but are also characterized by a chemical assemblage dominated by Ca, Mg, and P. Therefore, the following nomenclature are proposed: “calcispheres”, “calcimagnesiaspheres” and “magnesiaspheres”.

Project StartGeoDelineation

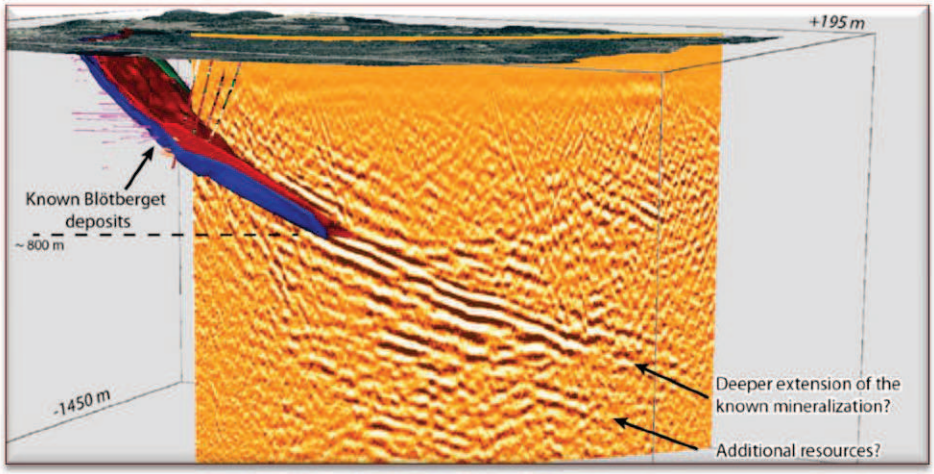
State-of-the-art geophysical and geological methods for delineation of mineral deposits and their associated structures

Sub-topic: Exploration, Extraction
Project Coordinator: UU (Sweden)
Consortium partners:
YARA (Finland); NIO (Sweden)

Project total funding: 471.707 €
Project total costs: 963.522 €
Duration: 43 months (2014-2018)

SUMMARY and RESULTS:

StartGeoDelineation project officially started in the beginning of December 2014 and ended in May 2018. The project approaches were tested in two geologically different environments: Siilinjärvi alkaline-carbonatite deposit in Finland and Blötberget iron-oxide deposit in Sweden. Two PhD students were employed and 3 MSc-BSc theses were produced. A number of short-term researchers worked in the project along with the senior scientists and explorationists from the partner companies. All these contributed to the acquisition of new data, revisiting existing data and new knowledge on the geology of the sites and ways to explore in a systematic manner cost-effectively. The project covered all aspects involved in mineral exploration ranging from data compilation and historical data gathering, rock physical property measurements (both laboratory and downhole), mineralogical and petrological studies to geochemistry and systematic geophysical surveys. Innovative solutions were also experimented in the project. In the Siilinjärvi, the focus was to mainly test the capability of landstreamer seismics for open-pit mine surveying and better understating of dyke emplacement through combination with magnetic property measurements and sample geochemistry. In Blötberget, depth extension, deep targeting and emplacement of the deposits were focused. New ways of geophysical data acquisitions for the first time attempted including landstreamer seismics for deep-targeting and UAV-based methods for higher-resolution targeting iron-oxide deposits. Over dozen of peer-reviewed high-quality journal publications and tens of conference abstracts were produced ensuring the efficient dissemination of the new knowledge from the project. StartGeoDelineation took part in all organized events by the sponsors and presented the work in progress. The successes of the project and the great network resulted in collaboration among the partners for a H2020 project, Smart Exploration, where StartGeoDelineation continuity is guaranteed for another three years.



ANNEX I:

❖ Project AMDREY:

Title	Link (doi or similar)
Recovery of Rare Earth Elements and Yttrium from Passive-Remediation Systems of Acid Mine Drainage.	Environmental Science & Technology, 50: 8255-8262, 2016
A geochemical approach to the restoration plans for the Odiel River basin (SW Spain), a watershed deeply polluted by acid mine drainage.	Environmental Science and Pollution Research, 24: 4506-4516, 2017
Quantification of proportions of different water sources in a mining operation.	The Science of the total environment, 619-620: 587-599 , 2017
The nanocrystalline structure of basaluminite, an aluminum hydroxide sulfate from acid mine drainage	American Mineralogist, 102: 2381-2389, 2018
Application of nanofiltration for recovery of rare earth elements from acidic waters: influence of transition elements, acidity and membrane stability.	Desalination, 430:33-44. 2018
Passive elimination of sulfate and metals from acid mine drainage using combined limestone and barium carbonate systems.	Journal of Cleaner Production 182, DOI: 10.1016/j.jclepro.2018.01.224
Geochemical behavior of trace elements in acid mine drainage controlled by basaluminite precipitation.	2nd European Mineralogical Conference, Rimini, Italy, September, 2016
REE Mineralogy of wastes from acid mine drainage treatment.	2nd European Mineralogical Conference, Rimini, Italy, September, 2016
Extraction of rare earth elements from acid mine drainage	2nd European Mineralogical Conference, Rimini, Italy, September, 2016
REE Scavening from Acid Mine Drainage By Basaluminite: preliminary studies.	ESRF User Meeting 2017. Grenoble, February, 2017
Acid mine drainage: a small but sustainable source of rare earth elements	2nd Conference on European Rare Earth Resources, Santorini, Greece, May, 2017
REE accumulation in residues from acid mine water treatment.	2nd Conference on European Rare Earth Resources, Santorini, Greece, May, 2017
Remediation of Highly Polluted AMD by passive technologies.	13th International Mine Water Association Congress, Lappeeranta, Finland, June 2017
Acid Mine Drainage, a possible source of Rare Earth Elements.	13th International Mine Water Association Congress, Lappeeranta, Finland, June 2017
Potencial económico de los drenajes ácidos de la Faja Pirítica Ibérica.	XXXVI Reunión de la Sociedad Española de Mineralogía , Oviedo
Rare Earth Element Adsorption onto Basaluminite	XXXVI Reunión de la Sociedad Española de Mineralogía , Oviedo
Rare Earth Elements retention onto basaluminite: understanding sorption mechanisms.	Goldschdmidt Conference, Paris, August 2017
Geochemistry of REE in Acid Mine Drainage: sorption onto basaluminite and schwertmannite.	American Geological Association Meeting, New Orleans, December 2017
Is basaluminite a mineral?	XXXVII Reunión de la Sociedad Española de Mineralogía , Madrid, Junio 2018
Partition of Scandium, Yttrium and Rare Earth Elements between Acid Mine Drainage and its evaporitic sulfates. Preliminary results	XXXVII Reunión de la Sociedad Española de Mineralogía , Madrid, Junio 2018
Acid Mine Drainage in the Iberian Pyrite Belt: geochemistry, passive remediation and valorization of wastes	Keynote in Symposium on Mines and Environment -2018 Rouyn-Noranda, Canada, June 2018
Lights and shades of passive remediation systems in the	Course on AMD Remediation Systems

Iberian Pyrite Belt	Symposium on Mines and Environment -2018 Rouyn-Noranda, Canada, June 2018
Use of alkaline mine waste as treatment for acid drainage.	Proceedings ISBN 978-3-86012-533-5 Drebenstedt, Carsten, Paul, Michael (eds).
Novel strategy to concentrate rare earth elements by neutralization of acid drainage from phosphogypsum stacks using carbonatites	ERES2017: 2nd European Rare Earth Resources Conference|Santorini|2017
New reductive interactions of REY by Thermus Scotoductus SA-01 and Clostridium sp.	ERES2017: 2nd European Rare Earth Resources Conference|Santorini|2017
Neutralization of Acid Drainage and Concentration of Rare Earth Elements Using Carbonatites; Results from a Bench Scale Experiment.	Proceedings: "ISBN 978-0-620-80650-3. Wolkersdorfer, Ch.; Sartz, L.; Weber, A.; Burgess, J.; Tremblay, G. (eds).
Biomineralization and bioaccumulation of europium by a thermophilic metal resistant bacterium	doi: 10.3389/fmicb.2019.00081

❖ Project BOFLUX:

Title	Link (doi or similar)
Fluxing of South African chromite ore with colemanite	M.W. Erwee; I.J. Geldenhuys; M.B. Sitefane; M. Masipa http://www.mintek.co.za/Pyromet/Files/2018Erwee-InfaconXV-SAIMM.pdf http://dx.doi.org/10.17159/2411-9717/2018/v118n6a15
Solid-state Reduction of South African Manganese and Chromite Ores: Effect of an organic binder and B2O3 – Solid-state Reduction of South African Manganese and Chromite Ores: Effect of an organic binder and B2O3	Herman Lagendijk, Kabwika Bisaka, Markus Erwee, Olive Makwarela IMPC 2016: XXVIII International Mineral Processing Congress Proceedings – ISBN: 978-1-926872-29-2

❖ Project ENVIREE:

Title	Link (doi or similar)
Możliwości pozyskiwania metali ziem rzadkich z odpadów poflotacyjnych i górniczych [In:] W kierunku gospodarki o obiegu zamkniętym - perspektywa przemysłu. (Eng.: Possibilities of acquiring rare earth metals from post-flotation and mining waste. Towards a circular economy - an industry perspective).	Kossakowska K., Grzesik K., Bieda B., Kozakiewicz R., 2017, Wydawnictwo IGSMiE PAN 2017. pp. 49–61. http://konferencja-pan.pl/wp-content/uploads/2017/04/monografia.pdf

❖ Project EXTRAVAN:

Title	Link (doi or similar)
The Effect of Al2O3, CaO and SiO2 on the Phase Relationship in FeO-SiO2 Based Slag with 20Mass% Vanadium	J. Sustain. Metall. DOI 10.1007/s40831-016-0088-y Published online: 16 September 2016 M. Lindvall, M.Berg, Du Sichen
Vanadium Extraction from Fe-V (2.0 Mass%)- P(0.1 Mass%) Melt and Investigation of the Phase Relations in the Formed FeO-SiO-Based with 20 Mass %V	J. Sustain. Metall. DOI 10.1007/s40831-017-0147-z Published online: 16 November 2017 M. Lindvall, J. Tikka, M.Berg, G. Ye& D. Sichen

❖ Project NewOres

Title	Link (doi or similar)
Michaud and Pichavant (2019) The H/F ratio as an indicator of contrasted wolframite deposition mechanisms	Doi: 10.1016/j.oregeorev.2018.10.015
Launay et al 2018 Deciphering fluid flow at the magmatic-hydrothermal transition: A case study from the world-class Panasqueira W–Sn–(Cu) ore deposit (Portugal).	Doi : 10.1016/j.epsl.2018.07.012
Carocci et al. : Rutile from Panasqueira (central Portugal): an Excellent Pathfinder for Tungsten Deposition	Doi: 10.3390/min9010009
Goncalves et al.: Using multifractal modelling, singularity mapping, and geochemical indexes for targeting buried mineralization: application to the W-Sn Panasqueira ore-system	Doi: 10.1016/j.gexplo.2017.07.008
Bobos et. al. Fe-, Fe,Mn- and Fe,Mg-chlorite: A genetic linkage to W, (Cu,Mo) - mineralization in the magmatic-hydrothermal system of Borralha, Northern Portugal. M ineralogical Magazine 189: 42-53	Doi:10.1180/minmag.2017.081.104

❖ Project RAREASH

Title	Link (doi or similar)
Assessment of landfilled Oltenia lignite bottom ash (Romania) as a source of rare earth elements.	International Journal of Coal Geology 201 (2019) 109–126 B. Valentim, A.T. Abagiu, L. Anghelescu, D. Flores, D. French, P. Gonçalves, A. Guedes, L.G. Popescu, G. Predeanu, J. Ribeiro, V. Slăvescu, C.R. Ward.
Spinels in the fly ash of power plant ostroleka (poland)	18th International Multidisciplinary Scientific GeoConference SGEM 2018, Vienna, 1-8 A. KLUPA, Z.ADAMCZYK
Petrographic and SEM/EDS characterization of bottom ash fractions obtained using magnetic separation equipment.	WSEAS TRANSACTIONS on ENVIRONMENT and DEVELOPMENT, Volume 14, London 26-28 october, 2018, 526-530, E-ISSN: 2224-3496 526. B.VALENTIM, P. GONÇALVES, A. GUEDES, L.G. POPESCU, G. PREDEANU.
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Capitalization of industrial wastes in economic circuit – a way to reduction the impact upon environment due to its storage	Fiability & Durability, "Academica Brâncuşi", Târgu Jiu, No 1/ 2018, 327-332. ISSN 1844 – 640X. L. G. Popescu, F. Grofu.
Ashes from bituminous coal burning in fluidized bed boilers as a potential source of rare earth elements	Mineral Resources Management, 2018, Vol.34, Issue 2, 21-36. Z. Adamczyk, J. Komorek, M. Lewandowska, J. Nowak, B. Bialecka, J.-k. Moszko, A. Klupa.
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Assessment of landfilled Oltenia lignite bottom ash (Romania) as a source of rare earth elements.	ICCP Program & Abstract Book. 69th Annual Meeting of the International Committee for Coal and Organic Petrology, September 3-9. 2017, Bucharest, Romania. Schriftenreihe der Deutschen Gesellschaft für Geowissenschaften Heft 92, 145-147. ISBN 978-3-510-49239-8. B. Valentim, A.T. Abagiu, L. Anghelescu, D. Flores, D. French, P. Gonçalves, A. Guedes, L.G. Popescu, G. Predeanu, J. Ribeiro, V. Slăvescu, C.R. Ward
Extraction of heavy and rare earth metals from bottom ash: a kinetic study of the acid attack	ICCP Program & Abstract Book. 69th Annual Meeting of the International Committee for Coal and Organic Petrology, September 3-9.

	2017, Bucharest, Romania. Schriftenreihe der Deutschen Gesellschaft für Geowissenschaften Heft 92, 114-116. ISBN 978-3-510-49239-8. C. Onose, M. Mihaly, E.A. Rogozea, G. Predeanu, B. Valentim, A. Guedes, D. Cadar, N.L. Olteanu, A. Meghea
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An overview of the RAREASH project (Assessment of possible recycling directions of heavy & rare metals recovered from combustion waste products)	JORNADAS DO ICT, 26-27 June 2017, Universidade do Minho, Braga, Portugal, 25. A. Gonçalves, G. Predeanu, B. Bialecka, L.G. Popescu, B. Valentim, A.T. Abagiu, L. Anghelescu, D. Flores, J. Ribeiro, V. Slavescu, A. Guedes, J. Moszko.
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New possibilities for conservation of natural resources by high capitalization of energy industry wastes.	International Journal of Environmental Science, 2017, 2, 1-6. Popescu, L.G., Abagiu, A.T., Anghelescu, L., Marica, M.M., Predeanu, G., Valentim, B
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Eco-friendly extraction of heavy and rare earth metals from combustion waste products - the kinetic study of the acid attack.	ICCP Program & Abstract Book. 67th Annual Meeting of the International Committee for Coal and Organic Petrology. Schriftenreihe der Deutschen Gesellschaft für Geowissenschaften Heft 87, 129-130. ISBN 978-3-510-49236-7. Onose C., Tane A., Mihaly M., Stamate D., Stamate, Popa D., A., Rogozea A.
Coal ashes a potential secondary raw material for the recovery of heavy & rare metals.	ICCP Program & Abstract Book. 67th Annual Meeting of the International Committee for Coal and Organic Petrology. Schriftenreihe der Deutschen Gesellschaft für Geowissenschaften Heft 87, 135-136. ISBN 978-3-510-49236-7. Predeanu G., Popescu L.G., Abagiu T.A., Valentim B., Guedes A., Bialecka B., Moszko J.
Project's Brochure	www.upb-cpmte.ro/rareash-proiect/

❖ StartGeoDelineation

Title	Link (doi or similar)
Anisotropy of magnetic susceptibility (AMS) in the Siilinjärvi carbonatite complex, eastern Finland	EGU2017, Vienna-Austria. Almqvist, B., Karell, F., Högdahl, K., Malehmir, A., Heino, P., and Salo, A., 2017
Magnetic characterization of magnetite and hematite from the Blötberget apatite-iron-oxide deposits (Bergslagen), central Sweden.	Canadian Journal of Earth Sciences, in press. https://doi.org/10.1139/cjes-2018-0183 Almqvist, B., Bjork, A., Mattsson, H., Hedlund, D., Gunnarsson, K., Malehmir, A., Högdahl, K., Bäckström, E., and Marsden, P., 2018.
Magnetic properties for characterization and quantification of magnetite and hematite in apatite iron-oxide deposits at Blötberget, central Sweden.	Nordic Geological Winter Meeting, Helsinki, Finland. Björk, A., Almqvist, B.S.G., Setter, M., Högdahl, K., Malehmir, A., 2016.
Mineralogy and petrology of mafic dikes from the Siilinjärvi carbonatite complex, Finland.	https://2dgf.dk/foreningen/33rd-nordic-geological-winter-meeting/ngwm-2018-abstracts/1-igneous-rocks-and-processes/ Carlsson, M., et al., (2018).
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Landstreamer seismics and physical property measurements in the Siilinjärvi open-pit apatite (phosphate) mine, central Finland.	Geophysics, 82, B29–B48. https://doi.org/10.1190/geo2016-0443.1 Malehmir, A., Heinonen, S., Dehgahnnejad, M., Heino, P., Maries, G., Karell, F., Suikkanen, M., and Salo, A., 2017.
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	Schön, M., and Marsden, P., 2017.
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ANNEX II:

Funded project	Title	Reference
AMDREY Patent	Procedimiento para la depuración de aguas contaminadas por metales, e instalación correspondiente	ES2534806, Universidad de Huelva-CSIC, 2016.
AMDREY Patent	Procedimiento de obtención de un recurso renovable de metales a partir de aguas ácidas de mina, e instalación correspondiente	ES2550526, Universidad de Huelva-CSIC, 2016.
EXTRAVAN Start-up	Ferrovan	www.ferrovan.com
RAREASH Patent	Odzysk metali ziem rzadkich z popiołów (Recovery of rare earth elements from ashes)	L.G. Popescu, G. Predeanu, J. Ribeiro, V. Slăvescu, C.R. Ward. Patent P.423021, 2017
StartGeoDelineation MSc thesis	Petrografisk och mineralogisk karakterisering av metadiabaser i Siilinjärvi.	Matias Carlsson (2017). Thesis 37001, Åbo Akademi.
StartGeoDelineation MSc thesis	Characterizing magnetic susceptibility and remanent magnetization of magnetite and hematite rich drill-core samples at Blötberget.	Andreas Bjork (2017). MSc thesis published in Diva, Uppsala University.
StartGeoDelineation MSc thesis	Gravity and Magnetic Survey, Modelling and Interpretation in the Blötberget Iron-Oxide Mining Area, Bergslagen, Sweden.	Ezra Yehuwalashet (2016). MSc thesis published in Diva, Uppsala University