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Application of the United Nations Framework Classification for Resources and the United Nations Resource Management System in different geographical contexts

United Nations Framework Classification for Resources Case Study: Rare Earth Elements, Exploration Prospects and Secondary Resources in Sweden

Prepared by the Geological Survey of Sweden**

Summary

The United Nations Framework Classification for Resources (UNFC) can be applied to projects producing minerals, oil and gas, renewable energy, underground storage, and anthropogenic resources.

Within the Mineral Intelligence for Europe (Mintell4EU) project, under the umbrella of the European Union-financed project GeoERA, the Geological Survey of Sweden undertook a case study on Rare Earth Elements (REE) projects. In this report, the application of UNFC to three potentially economic REE deposits in Sweden demonstrates how the results reflect the processes that are applied and build the projects over time. The three separate projects differ in stage, maturity and type. Two of the projects are typical exploration projects (Olserum and Norra Kärr), and the third can be considered a secondary resources project (LKAB). This case study shows that classifying a mining or exploration project according to UNFC using public information is both possible and straightforward. UNFC complements the Committee for Mineral Reserves International Reporting Standards (CRIRSCO) family of codes with its additional focus on environmental and socio-economic viability. Classifying projects according to UNFC using public information such as the CRIRSCO codes is essential for effective, easier and accurate comparison of different projects.

The three classified projects are a clear challenge and may be one of the most significant risks to the success of a Swedish mining or exploration project in the permitting process. Several projects in Sweden have been delayed due to complicated permitting processes. The delay in the process is costly and can itself lead to projects failing.

* The rescheduled session dates will be confirmed at a later stage.

** In cooperation with Lena Lundqvist and Erika Ingvald of the Geological Survey of Sweden. The case study was reviewed by the Minerals Working Group of the United Nations Economic Commission for Europe (UNECE) Expert Group on Resource Management (EGRM) and Ghadi Sabra (student and expert supporting the UNECE secretariat) and reviewed and edited by the UNECE secretariat (Charlotte Griffiths and Slavko Solar). Early drafts were reviewed by the Geological Survey of Finland (GTK) and involved companies.

Contents

I. Introduction/Background

1. The United Nations Framework Classification for Resources (UNFC)[1] has been developed for projects producing minerals, oil and gas, renewable energy, underground storage, and anthropogenic resources. Water is currently being added to the suite of resources to which UNFC applies. UNFC is established as a tool for policy formulation, government resource management, industry business process management and capital allocation. UNFC comprises the technical (F axis) and geological (G axis), as well as environmental, social and economic viability (E axis) of a project, which makes UNFC very useful as a communications tool between companies and governments as well as broader society.

2. Within the Mineral Intelligence for Europe (Mintell4EU) project,[2] under the umbrella of the European Union (EU)-financed project GeoERA, the Geological Survey of Sweden (SGU) has taken responsibility for doing a case study on Rare Earth Elements (REE) projects. In this report, the application of UNFC to three potentially economical deposits of REEs in Sweden (Figure I) demonstrates how UNFC classification results reflect the processes that are applied and build the projects over time. The report documents the principles in the cases presented. It does not necessarily reflect accurate estimates of the project quantities. The Geological Survey wanted to test classifying projects according to UNFC using only public data, and to the extent possible, this report is based on the best data publicly available.

3. Many organizations wishing to apply UNFC may be concerned that changing their reporting standards will create an undesirable break in records. This can easily be avoided. The Horizon 2020 ORAMA (Optimizing quality of information in RAw MAterial data collection across Europe) project[3] presents tables that show a straightforward way to translate the Committee for Mineral Reserves International Reporting Standards (CRIRSCO) classified mineral deposits to UNFC.[4] Another practical example has been presented in a previous case study: the Nordkalk limestone and Forsand sand and gravel mines resources demonstrate how CRIRSCO inventories may bridge over to UNFC (Figure II, Table 1), provided their inventories have been generated with the same professional diligence.[5]

4. UNFC has been applied to three separate projects that differ in stage, maturity and type. Two of the projects are typical exploration projects (Olserum and Norra Kärr), and the third can be considered a secondary resources project (LKAB project: Rare Earth Elements and MonoAmmonium Phosphate (ReeMAP)). For the ReeMAP project, a Pan European Reserves and Resources Reporting Committee (PERC) classification is underway but not yet published. Therefore, information published on the project website was used for the UNFC classification[6], as well as published research papers. For the exploration projects, a bridging approach was adopted between UNFC and NI43-101, which is the CRIRSCO Code applied by companies to Olserum and Norra Kärr. The experience of the Geological Survey of Sweden is that this process is straightforward, thanks to guidelines from the ORAMA project.

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[1] United Nations Framework Classification for Resources Update 2019. https://unece.org/fileadmin/DAM/energy/se/pdfs/UNFC/publ/UNFC_ES61_Update_2019.pdf

[2] https://geoera.eu/projects/mintell4eu7/mintell4eu-wp4-unfc-pilot/

[3] https://orama-h2020.eu/

[4] Optimizing quality of information in RAw MAterial data collection across Europe -ORAMA 2019. Kresse C. (ed) Technical Guidance note: Bridging document between CRIRSCO and United Nations Framework Classification for Resources (UNFC).

[5] UNFC Case Studies from Finland/Estland, Sweden and Norway – Nordkalk limestone and Forsand sand and gravel mines. https://unece.org/DAM/energy/se/pdfs/egrm/egrm11_apr2020/ECE_ENERGY_GE.3_2020_10_UNFC_Nordic_Case_Studies.pdf

[6] https://ree-map.com/

5. Mining on land often requires consideration of competing interests for land, water and other environmental resources handled through legal and regulatory framework conditions. The three REE projects in this report (the Norra Kärr and Olserum deposits and the ReeMAP project) demonstrate how environmental, social and economic conditions have been considered for reaching decisions and how UNFC reflects them. The guidance document on applying UNFC in the Nordic countries[7] has helped this case study.

6. Norra Kärr and Olserum reflect exploration projects of different maturity and of different REE compositions, whereas the ReeMAP project shows how UNFC reflects a planned mining waste operation.

7. One important issue is the type of mineralisation involved and, thus, what elements constitute the mineralisation and what processes are needed to extract these elements.

8. The Olserum object is characteristically a heavy REE object. It has an even higher concentration of the Heavy Rare Earths (HREE) than the Norra Kärr object. The REEs are mainly found within the minerals monazite and xenotime instead of eudialyte, the main REE-mineral at Norra Kärr.

Figure I
Overview of the three different examples in this report Norra Kärr, Olserum and the LKAB's ReeMAP project of secondary resources

Note: LKAB's ReeMAP project is concentrated on several of LKAB mines such as Malmberget and Svappavaara.

9. Norra Kärr is a more mature project than Olserum. A mining concession has been applied for and at one stage granted. However, due to several appeals in different courts, the company still awaits its final permits to take the next step towards environmental

[7] A_guidance_for_the_application_of_the_UNFC.pdf (unece.org) 2018 by the Geological Surveys of Finland (GTK), Norway (NGU) and Sweden (SGU), the Swedish Association of Mines, Minerals and Metal Producers (SveMin), Norwegian Mineral Industry and Petronavit a.s..

permitting. During this procedure, the project moves up and down along the E axis of the UNFC coding. The Norra Kärr object is one of the three objects that highlights the challenges that accompany the chain of permits and appeals in Sweden and thus the difficulties with different interests of land use. In the fall of 2020, the Mining Inspectorate bounced the application back to the company, which was waiting for a Natura 2000 assessment.

10. The Norra Kärr Prospect is rich in HREEs, which is very attractive to the global market. Almost all of the REEs in the Norra Kärr Prospect are concentrated in the silicate eudialyte, making this mineralisation almost unique in the world. The process of extracting REEs from eudialyte has been tested successfully at a laboratory scale, and in 2021 the company presented a processing scheme for the deposit.

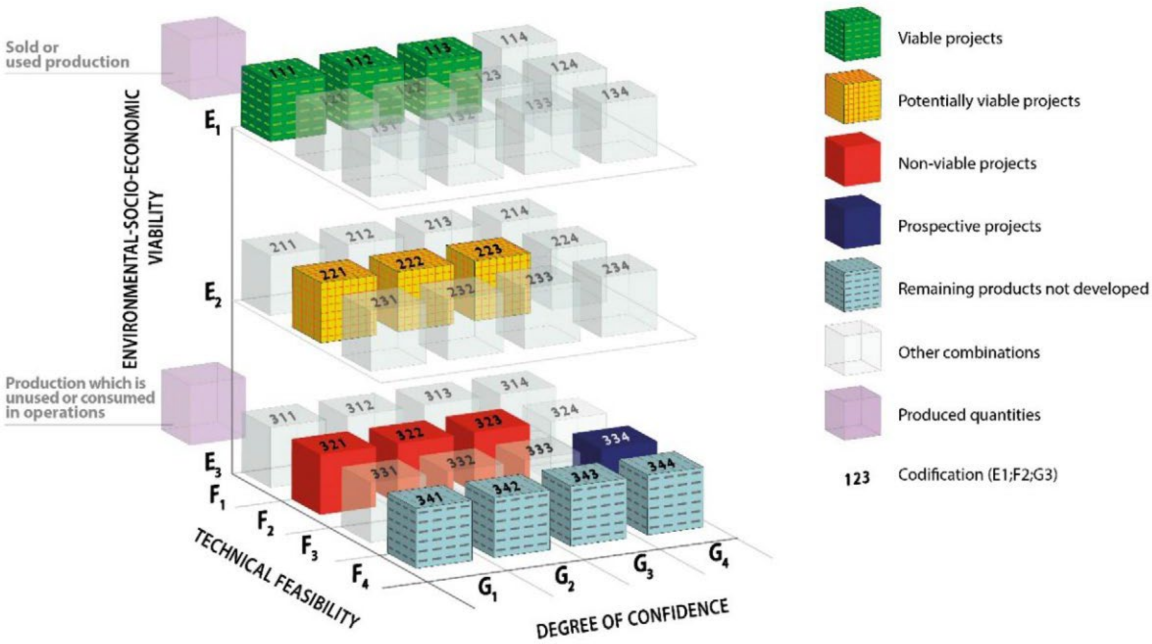
11. The ReeMAP project of LKAB differs from the others by highlighting the possibility of extracting REE and phosphorus from mining waste and involves processes never used in a full-scale integrated project in Sweden.

II. The United Nations Framework Classification for Resources

12. The ORAMA project shows how to perform UNFC classification. In this report, a short introduction is given.

13. The classification is based upon three criteria: Environmental-Socio-Economic Viability (E), Technical Feasibility (F) and Degree of Confidence (G; previously denominated the geological axis but renamed it to accommodate for other resources such as renewable energy and anthropogenic resources). These three parameters are visualised in a diagram with three axes (Figure II). These parameters are classified individually. Each parameter is divided into three to four sub-classes based on maturity of the project.

Figure II
The UNFC Classification System



14. To classify a mineral deposit properly according to UNFC, a chain of processes needs to be followed. This procedure is described in the final report 1.5 of the ORAMA project.[8]

15. First of all, there has to be a source of material that is considered for future production. Before a project is conceived, the mineralisation is categorised as E3[9] and F4[10]. The confidence in the estimates is reflected in the range of quantities where G1 reflects estimates with a high level of confidence, G2 with a moderate level of confidence and G3 with a low level of confidence. G4[11] is used for prospects with a probability of less than 1 that a source exists at all.

16. Once a project is conceived, it will be given an E Category reflecting its environmental and socio-economic maturity. The project can move up and down along this axis depending on different permits granted, and eventual appeals decided. It will also be given an F Category reflecting how far the project is matured technically, from early studies to production and abandonment. Two sets of produced quantities are reflected:

- Quantities delivered outside the project for sale or use. These quantities are produced from the class defined by Categories E1[12], F1[13]
- Quantities not delivered from the project and either not used, as is the case with mine tailings and flared gas, or used in operations, as is the case with quantities used for site remediation and fuel gas. These quantities are delivered from Class E3.1[14]F1.

17. Material balance is preserved, so unless there is a re-evaluation of the initial product quantities not developed by identified projects (initial quantities in place), the sum of the quantities produced, remaining to be produced by projects and remaining products not developed from identified projects will be constant.

III. Bridging from another Classification System

18. There are different ways to classify a mineral deposit according to maturity. One important way is given by the CRIRSCO Template[15] (founded in 1994), which aims to provide transparency to investors and stock markets. CRIRSCO provides international standard definitions for reporting mineral resources and mineral reserves, including provisions for country-specific requirements, i.e., of a legal and investment regulatory nature, and agreed to be incorporated into UNFC in 1999. Both Olserum and Norra Kärr have been classified according to the CRIRSCO Code NI43-101, which is used in Canada. Thus, this report gives attention to bridging from NI 43-101 to UNFC.

19. Bridging from a CRIRSCO Code can be done by using the classification scheme of the technical guidance note proposed by the ORAMA Project (Figure III).

[8] Optimizing quality of information in RAw MAterial data collection across Europe (ORAMA 2019 - Deliverable 1.5 Good practice guidelines for harmonisation of resource and reserve data).

[9] E3: Development and operation are not expected to become environmentally-socially-economically viable in the foreseeable future or evaluation is at too early a stage to determine environmental-socio-economic viability.

[10] F4: Technical feasibility of a development project cannot be evaluated due to limited data.

[11] G4: Product quantity associated with a Prospective Project, estimated primarily on indirect evidence.

[12] E1: Development and operation are confirmed to be environmentally-socially-economically viable.

[13] F1: Technical feasibility of a development project has been confirmed.

[14] E3.1: Estimate of product that is forecast to be developed, but which will be unused or consumed in operations.

[15] http://www.crirsco.com/templates/CRIRSCO_International_Reporting_Template_October_2019.pdf

Figure III

Mapping of CRIRSCO Template to UNFC-2009 "minimum" Categories and Classes*

Geological knowledge and confidence

CRIRSCO Template		UNFC-2009 "minimum" Categories			UNFC-2009 Class
Mineral Reserve	Proven	E1	F1	G1	Commercial Projects
	Probable			G2	
Mineral Resource	Measured	E2	F2	G1	Potentially Commercial Projects
	Indicated			G2	
	Inferred			G3	
Exploration Target		E3	F3	G4	Exploration Projects

Note: In UNFC (2019), the Class terminologies are different to those in UNFC-2009: "Commercial Projects", "Potentially Commercial Projects", and "Exploration Projects" are now "Viable Projects", "Potentially Viable Projects", and "Prospective Projects" respectively.

* From: Optimizing quality of information in RAw MAterial data collection across Europe-ORAMA 2019. Kresse C. (ed) Technical Guidance note: Bridging document between the CRIRSCO Template and the United Nations Framework Classification for Resources (UNFC).

20. Geological studies, including estimates of tonnes, grade, quality, etc., enable the classification of the resources on the G axis based on the detail of the study and the degree of confidence in the geological model. Mineral reserves are classified as G2 (probable) or G1 (proven).

21. Mineral resources are classified as G3 (inferred), G2 (indicated) or G1 (measured), reflecting an increasing level of geological knowledge and confidence.

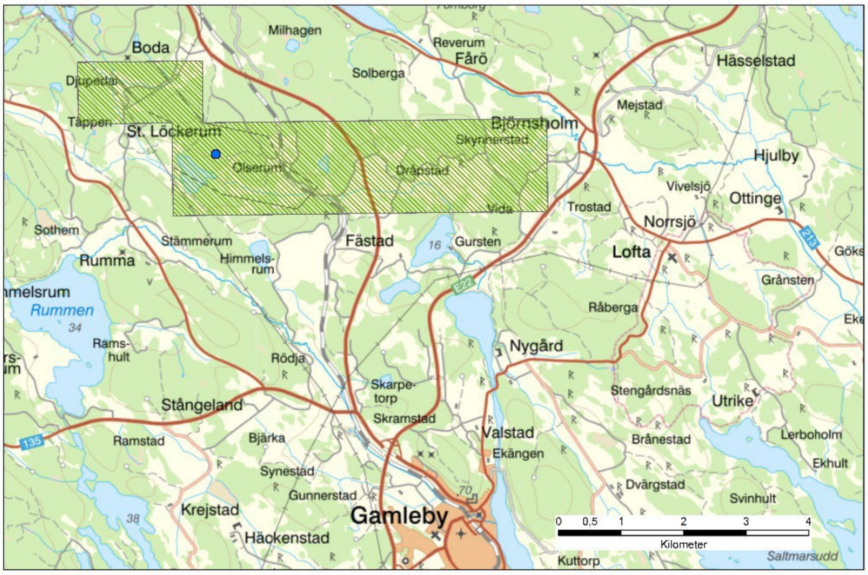
Table 1
An abbreviated version of UNFC showing the primary classes

Total Commodity Initially in Place	Extracted		Sales Production		
			Non-Sales Production		
		Class	Categories		
			E	F	G
	Future recovery by commercial development projects or mining operations	Commercial Projects	1	1	1, 2, 3
	Potential future recovery by contingent development projects or mining operations	Potentially Commercial Projects	2	2	1, 2, 3
		Non-Commercial Projects	3	2	1, 2, 3
	Additional quantities in place associated with known deposits		3	4	1, 2, 3
	Potential future recovery by successful exploration activities	Exploration Projects	3	3	4
	Additional quantities in place associated with potential deposits		3	4	4

Source: D1.5.1. Technical guidance notes UNFC.

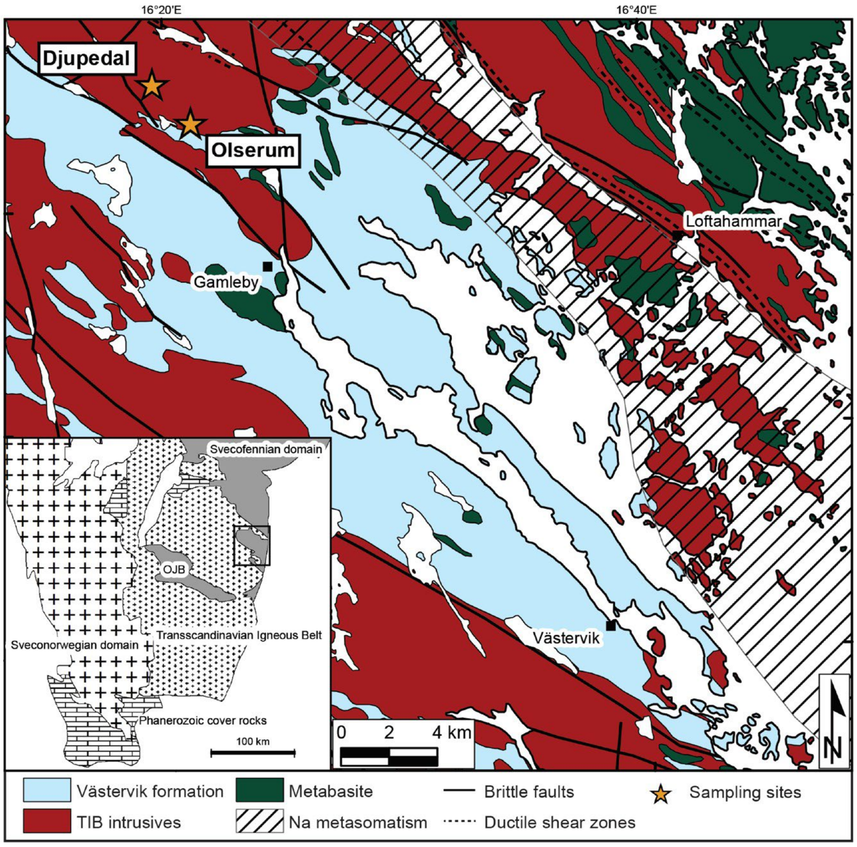
IV. The Olserum Rare Earth Element Prospect

Figure IV
Locations for the exploration permit of the REE Deposit Olserum



Note: See Figure I for a geographical overview.

Figure V
Geological map of the Olserum Prospect*



* From: Andersson S.S., Wagner T., Jonsson E., Fusswinkel T., Leijd, M. and Berg J.T. 2018b: Origin of the high-temperature Olserum-Djupedal REE-phosphate mineralisation, SE Sweden: A unique contact-metamorphic-hydrothermal system. *Ore Geology Reviews* v.101, 740-764.

22. The Olserum REE mineralisation is situated in south-east Sweden (Figures I and IV), approximately 30 km northwest of the port town of Västervik, Kalmar County, 7 km northwest of the village Gamleby. The mineralisation is situated at the border between metasedimentary rocks and granite (Figure V).

A. History

23. The Olserum REE mineralisation is well known and has seen exploration ever since the 1950s, although at that time the target was iron. In the 1970s, the Swedish Geological Survey (SGU) continued to explore the metasedimentary package around Västervik for uranium. The investigations included boulder hunting, radiometric and magnetic ground surveys, mapping and sampling for geochemical and petrographical analyses. Apatite and monazite were identified together with anomalous values of yttrium. However, the anomalies were not examined for rare earth elements due to the lack of demand at that time.

24. In the 1990s, SGU followed up earlier uranium exploration to identify and classify rare earth occurrences in Sweden. The rare earth mineralisation in Olserum was then noticed in close association with the uranium and magnetite bearing heavy mineral beds in sedimentary rock.

25. In 2003, IGE Nordic AB claimed Olserum and commenced a drilling programme. By 2005, a total of 5130 metres in 31 drill holes had been completed at Olserum and adjacent areas.

26. In 2013, Tasman Metals Ltd continued with an exploration drilling project. Classification according to NI 43-101 was also done in 2013 by Reed Leyton Consulting,

requested by Tasman Metals Ltd (now part of Leading Edge Materials (LEM)). In total, 36 diamond drill holes and c. 6127 m drilled metres have been drilled in the area.

27. The resource estimate is based on 18 of these drill holes. The project was drilled within an area of approximately 400 m x 100-150 m. The mineralisation was intersected in all the drill sections and is known to extend at least a depth of 250 m below the surface. The mineralisation strikes approximately NW-SE, and the dips vary between 70 and 85 degrees to the NE.

28. In 2016, Tasman Metals Ltd focused on Norra Kärr (see below) and did not renew the exploration permits for Olserum. The project was at that stage put on hold, and no work was done at Olserum for four years.

29. All the co-land information was subsequently examined by a small private company, Explora Mineral AB.[16] In 2020, the company applied for an exploration permit and continued its exploration efforts. Explora Mineral AB is owned by former employees from Tasman Metals Ltd, and they have a focus on early-stage exploration.

30. As the owners of the company, previous Tasman Metals AB employees and additionally with assignments of Leading Edge Minerals (LEM) had access to all earlier information allowing them to continue exploring without any delay or data loss. The permit is valid until 2023. On exactly the same day, another company, European Mining Exploration AB, applied for the same mineralisation and minerals. Both companies were granted permits to explore the object for scandium, yttrium and lanthanum. Whether that will have a positive or a negative impact on exploration and results is not yet known.

B. Geology

31. Andersson et al.[17] [18] [19] describe the geology of the Olserum REE mineralisation. A geological map is presented in Figure V. The mineralisation is mainly located in sediments of the Västervik sedimentary formation, specifically in layers containing heavy minerals close to granite contact.

32. The Västervik formation is a metasedimentary succession deposited in a delta at c. 1.88-1.85Ga. At c. 1.8 Ga, the Västervik formation suffered high temperature–low-pressure metamorphism due to intrusion of a red, medium-grained, massive or weakly foliated granite that is part of the Tran-Scandinavian Igneous Belt (TIB). The Västervik formation forms a u-shaped synform with a horizontal fold axis trending to the northwest. The Olserum deposit lies on the northwestern edge of this synform, completely surrounded by granite. The synform coincides roughly with the northwest-southeast trending regional deformation zone on a regional scale.

33. Primary structures are quite common within the Västervik formation. However, no primary structures are preserved at Olserum. They are all wiped out by amphibolite-grade metamorphism. The metasedimentary sequence at Olserum has an E-W trend and is approximately 600 m by length and up to 100 m wide. The contacts to the surrounding granite are steep, dipping towards the north. The principal lithologies comprising the Olserum metasedimentary sequence are biotite and amphibole bearing quartzite, quarzitic gneiss, psammitic gneiss, biotite and magnetite bearing quartzite, the latter being interpreted as heavy mineral beds and now as paleo placer deposits.

[16] http://www.exloraminerals.com

[17] Andersson S.S., Wagner T., Jonsson E. and Michallik R.M. 2018a: Mineralogy, paragenesis and mineral chemistry of REEs in the Olserum-Djupedal REE-phosphate mineralization, SW Sweden. *American Mineralogist* v.103, pp 125-142.

[18] Andersson S.S., Wagner T., Jonsson E., Fusswinkel T., Leijd, M. and Berg J.T. 2018b: Origin of the high-temperature Olserum-Djupedal REE-phosphate mineralization, SE Sweden: A unique contact-metamorphic- hydrothermal system. *Ore Geology Reviews* v. 101 pp740-764.

[19] Andersson S.S., Wagner R., Jonsson E., Fusswinkel T. and Whitehouse M., 2019: Apatite as a tracer of the source, chemistry and evolution of ore-forming fluids: The case of the Olserum-Djupedal REE-phosphate mineralization, SE Sweden. *Geochimica and Cosmochimica Acta* v. 255. Pp 167-187.

34. Extensive metasomatism accompanied the metamorphic event, leading to hydrothermal overprintand redistribution of the REE-bearing phases.

35. The minerals and the abundance of the REEs are described in detail by Andersson et al.[20, 21, 22] The REE at Olserum are mainly hosted by the minerals monazite and xenotime. The commonly REE-bearing fluor apatite occurs in abundance but only carries REE to a minor extent. Allthese three REE-bearing phosphates are of metamorphic origin, formed by hydrothermal processes, although a primary detrital of apatite is probable. Monazite and xenotime occur as inclusions in apatite, biotite, and amphiboles, but also as medium and coarse, subhedral to euhedral grains in patches, veins and breccias. Monazite and xenotime crystals up to about 10 cm in size can be found. It is suggested that apatite was a major carrier of REE but was leached during metamorphism.

36. Monazite and xenotime were precipitated as inclusions in apatite during hydrothermal processes. These inclusions occur mainly in the core of the apatite, which suggests that the inclusions in the rims have been leached out and precipitated within the rock.

37. Due to the metamorphic and hydrothermal overprint, the rare earth bearing phosphates have beenwidely distributed throughout the metasedimentary package, resulting in low grade but large tonnage mineralisation with a high percentage of HREE, which are mainly hosted by xenotime. The highest REE grade is associated with magnetite bands and veins hosted by biotite and/or amphibole rich quartzites. The host rock is mineralised through monazite and xenotime inclusions in biotite and thin irregular magnetite veins.

C. Classification according to NI43-101

38. The sedimentary sequence of interest is approximately 600 m in length and up to 100 m wide. In total, 36 diamond drill holes and 6127 metres have been drilled in the area. 15 of those holes were drilled before 2012. In 2012, five more holes were added, and the rest after 2012. The resource estimate is based on 18 out of these 36 drill holes. In addition, 78 samples were taken from the drillcore for geochemical examination.

39. The object is classified according to NI 43-101 by Tasman Metals Ltd. The results are shown in Tables 2 and 3 (Tasman Metals Ltd press release 2013). At 0.4% Total Rare Earth Oxides (TREO) cut off, Indicated Resource of 4.5 Mt at 0.60% TREO and an Inferred Resource of 3.3 Mt at 0.63% TREO.

[20] Andersson S.S., Wagner T., Jonsson E. and Michallik R.M. 2018a: Mineralogy, paragenesis and mineral chemistry of REEs in the Olserum-Djupedal REE-phosphate mineralization, SW Sweden. *American Mineralogist* v.103, pp 125-142.

[21] Andersson S.S., Wagner T., Jonsson E., Fusswinkel T., Leijd, M. and Berg J.T. 2018b: Origin of the high-temperature Olserum-Djupedal REE-phosphate mineralization, SE Sweden: A unique contact-metamorphic- hydrothermal system. *Ore Geology Reviews* v. 101 pp740-764.

[22] Andersson S.S., Wagner R., Jonsson E., Fusswinkel T. and Whitehouse M., 2019: Apatite as a tracer of the source, chemistry and evolution of ore-forming fluids: The case of the Olserum-Djupedal REE-phosphate mineralization, SE Sweden. *Geochimica and Cosmochimica Acta* v. 255. Pp 167-187.

Table 2
Indicated Resource Estimate for the Olserum Prospect

TREO % Cut-off	*Million Tonnes*	*TREO %*	*% of HREO in TREO*	*Dy_2O_3 ppm*	*Y_2O_3 ppm*	*Nd_2O_3 ppm*	*Tonnes of Contained TREO*	
0.7	1.0	0.89	32.3	292	1800	1314	8,620	
0.6	1.7	0.78	32.9	262	1610	1146	13,360	
0.5	3.0	0.68	33.3	232	1420	996	20,650	
0.4	4.5	0.60	33.9	209	1283	878	27,260	BASE CASE
0.3	6.3	0.53	34.4	187	1146	769	33,530	
0.2	7.7	0.48	34.5	0.017	1042	700	37,030	

Table 3
Inferred Resource Estimate for the Olserum Prospect

TREO % Cut-off	*Million Tonnes*	*TREO %*	*% of HREO in TREO*	*Dy_2O_3 ppm*	*Y_2O_3 ppm*	*Nd_2O_3 ppm*	*Tonnes of Contained TREO*	
0.7	0.9	0.85	31.8	288	1667	1294	7,947	
0.6	1.6	0.77	32.5	264	1547	1151	12,088	
0.5	2.5	0.69	33.6	242	1445	1018	16,960	
0.4	3.3	0.63	33.7	222	1320	925	20,770	BASE CASE
0.3	4.2	0.57	33.9	202	1205	841	23,820	
0.2	4.7	0.54	33.9	191	1134	790	25,050	

D. UNFC Classification of the Olserum Prospect

40. The classification of the Olserum mineralisation according to UNFC has been bridged from the CRIRSCO Code NI43-101. Today, the Olserum Prospect is classified as an E2F1+F2G1+G2 project. The following paragraphs provide a detailed description of how this conclusion was reached.

1. E2 on the Environmental-Socio-Economic Viability Axis

41. The Olserum object is classified as E2. One of the owners of the exploration permits, Explora Minerals AB, has access to and refers to previous work and classification of Tasman Metals Ltd. This company has access to all significant data and a close relationship with the company that carried out the classification. Therefore, the company could continue the exploration without time or data loss. The project can still be classified as E2. Without this connection, the project would slide down to an E3. When more investigations are done, and the project applies for a mining concession or a prolonged exploration permit, it can move up along the E axis. The same movement along the E axis will happen if and when the project is fully communicated to and accepted by the public.

42. The estimation of the REEs done in 2013 indicates the project's economic potential, especially since the global demand for REEs has increased. The REEs of interest are mainly HREE which are considered the most critical. The Olserum object has a large potential because of contingent development projects.

43. However, as mentioned above, two separate companies have valid exploration permits for the same object. The reason for this is that both companies applied for an exploration permit simultaneously. Since both were considered qualified applicants, the Mining Inspector was obliged to grant them a permit according to the Swedish administrative decree. This is a unique situation that can result in a difficult situation further along the chain of development of the project if the time comes to apply for a mining concession. There are also potential challenges concerning land usein this area of Sweden.

2. F1+F2 on the Technical Feasibility Axis

44. The object is classified as a strong F2 moving towards F1. The REEs are concentrated mainly in monazite and xenotime, to some extent also in fluorapatite. There is a well-established, fairly simple method of extracting REEs from these phosphates. Successful tests have been performed to make a high-value mineral concentrate from the Olserum mineralisation. No hydrometallurgical tests have been doneso far. When accurate full-scale testing is done, the object may move into an F1.

3. G1+G2 on the Degree of Confidence Axis

45. The geology of REE mineralisation is considered to be known. Regional mapping has been done by SGU, and the area has been subjected to several rounds of exploration. The previous owner performed a substantial amount of drilling and mapping and the current owner has access to this information. The deposit has been classified according to NI43-101. The Olserum object has also been the target of recent research projects.

V. The Norra Kärr REE Deposit

46. The Norra Kärr Project is an intermediate-stage exploration project. It is located in southern Sweden, approximately 300 km SW of Stockholm, just outside the little town of Gränna, and just a few kilometres east of highway E4 (Figures I and VI). The Norra Kärr alkaline intrusion was first discovered and described in 1906 by SGU during a regional mapping programme. During the 1940s, several scientific studies were carried out, including detailed petrographical work, to describe it.

47. The Swedish mining company Boliden started exploration for zirconium at Norra Kärr during the 1940s. The exploration stopped when the price of zirconium fell. Today, permits are held by Leading Edge Materials Ltd (previously Tasman Metals Ltd).

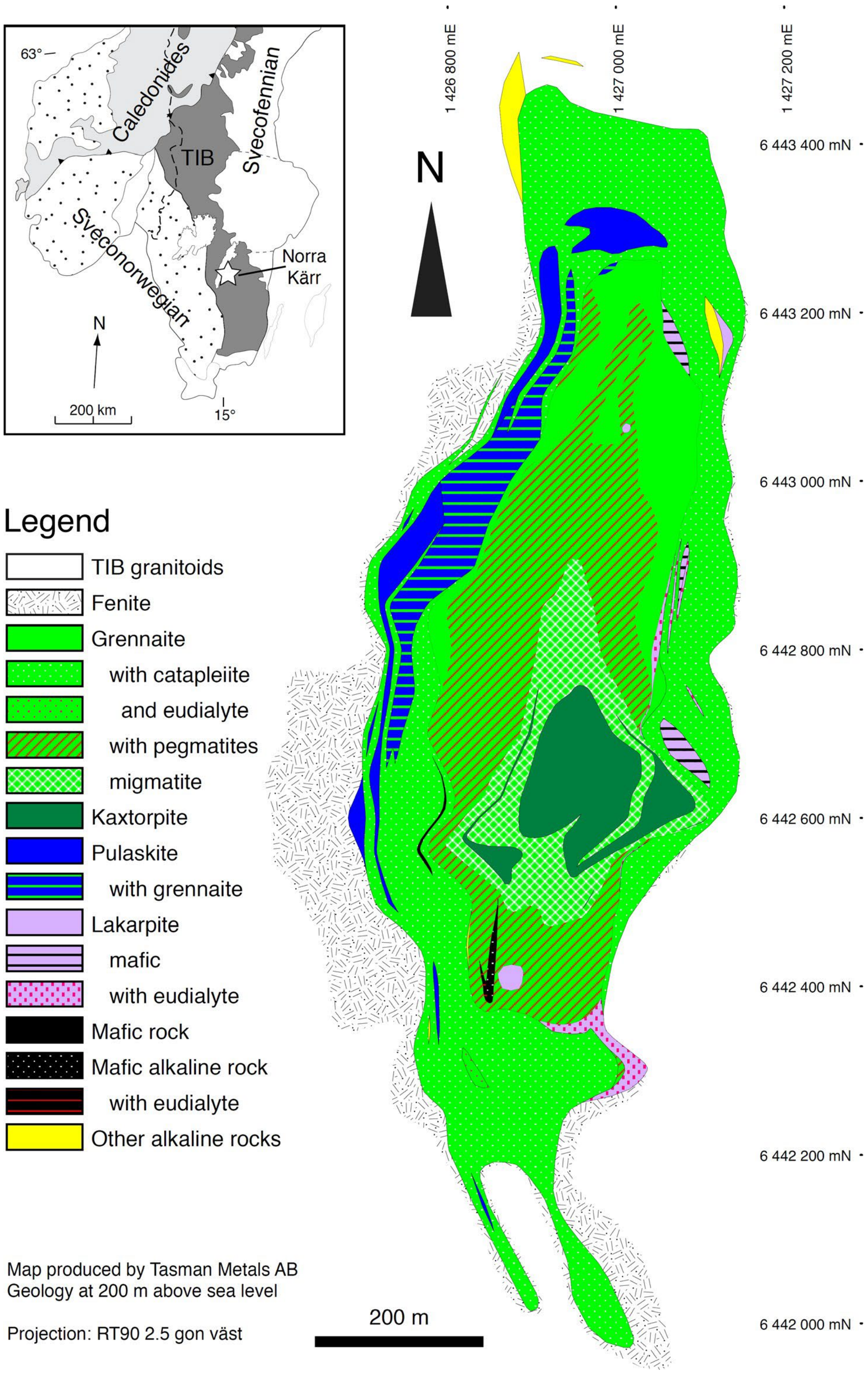
48. Based on a pre-feasibility study by Tasman Metals Ltd and given the location of Norra Kärr and the chemical composition of the deposit, REE production[23] is possible with a low environmental impact. The high grade of HREE at Norra Kärr can provide economic material with a positive impact on the security of supply of REEs within Europe for a long time.

[23] GBM Mineral Engineering, Wardell Armstrong International Limited (WAI) and Golder Associates Limited 2015: Norra Kärr Project PFS, Gränna, Sweden. Amended & Restated Pre-feasibility Study - NI 43-101 - Technical report for the Norra Kärr Rare Earth Element Deposit.

Figure VI
The location of the Norra Kärr exploration permit

Note: Refer to Figure I for an overview of the geographical location.

Figure VII
Geological map of the Norra Kärr Alkaline Complex*



* From: Sjöqvist A. 2015: Agpaitic rocks of the Norra Kärr Alkaline complex: Chemistry, Origin and age of Eudialyte hosted-zirconium and Rare-Earth element ore. Thesis for Licentiate degree. Gothenburg University, Institute of earth sciences.

49. The geology of Norra Kärr is shown in Figure VII. The surface has been disturbed only by exploration drilling, trenching and sampling. The Norra Kärr deposit is one of the world's largest known heavy REE resources, with an unusual enrichment in the most critical REEs that are essential for high strength permanent magnets (dysprosium (Dy),

terbium (Tb), neodymium (Nd) and praseodymium (Pr)). It has an HREE/Total Rare Earth Elements (TREE) ratio of 53%, which makes Norra Kärr a deposit with one of the highest HREE ratios of all large REE deposits in the world. The deposit has the capacity to supply all of the forecasted HREE requirements of Europe for more than 20 years and to considerably reduce reliance on imported REEs, mainly from China.

50. Information about the production, tonnage, etc., stated here, refers to the Pre-Feasibility Study (PFS) published in January 2015 by GBM Minerals Engineering Consultants Limited (GBM), Wardell Armstrong International Limited (WAI) and Golder Associates (Golder) on behalf of Tasman Ltd. The PFS has been made public.

51. The PFS is a complete study addressing, in addition to mining and processing, all required on-site and off-site infrastructure, land access, reagent and fuel transport and storage, power access, water recycling and purification, waste rock and tailings storage, and final closure. The conclusions are supported by drilling, sampling, and process testing. The PFS also includes the classification of the object according to NI 43-101.

Table 4
Timeline showing the prolonged procedure of receiving valid permits for the Norra Kärr Project

2009	Exploration permit Norra Kärr No.1
2012	Prolonged exploration permits until 2015
2015	Prolonged exploration permits until 2017
2016	The Administrative Court repeals the decision of the Mining Inspectorate of Sweden
2017	The Court of Appeals repealed the judgement of the Administrative Court
2017	Prolonged exploration permits until 2019
2019	Prolonged exploration permits until 2024
2021	Prolonged exploration permits until 2025
2013	Mining concession
2014	The Government dismissed the appeal and decided not to repeal the Mining Lease
2016	The Supreme Administrative Court repealed the decision of the Government
2016	The Government returned the application for a Mining Lease to the Mining Inspectorate for a retrial
2021	The project was bounced back to the company by the Swedish Mining Inspectorate, awaiting Natura 2000 assessment

Source: Leading Edge Materials.

52. In addition to REEs, Norra Kärr can be a major supplier of hafnium (Hf) for superalloys, zirconium (Zr) for chemically resistive materials, and industrial mineral nepheline and feldspar for aggregates which would make the deposit well-utilized and minimize the waste.

53. According to the study, the ore is planned to be processed via a simple flowsheet, comprising crushing, grinding, magnetic separation, sulphuric acid leaching and precipitation of a purified mixed REE-oxalate, which is calcined to form a mixed rare earth oxide product. An average annual Rare Earth Oxides (REO) output of 5,120 tonnes is predicted, reflecting the recommendations of a market study for the most critical REEs. The PFS model provides for REE separation to individual saleable oxides by an external partner on a commercial basis. Such REE separation facilities operate within Europe today (2020).

54. Norra Kärr is currently in the middle of a prolonged process of achieving all necessary permits to start mining. The process to date is shown in Table 4. The permits have been appealed at several levels. Due to this process, the classification of the project has travelled up and down along the E axis. Concurrent with the permitting process, exploration is continuing.

A. Geology

55. Norra Kärr is a zoned, peralkaline, agpaitic, nepheline-syenite intrusive complex with a concentric layering (Figure VII) emplaced in a rift setting. The intrusion covers an area approximately 450 m x 1,500 m in size and is more than 350 m deep - these dimensions have been confirmed by drilling. The intrusion has been dated at 1489 ± 8 Ma.[24] It intrudes older gneisses and granites of the Trans-Scandinavian Igneous Belt (dated to c. 1810–1740 Ma) in an extensional regime. It is located along a long-lived north-trending regional fault.

56. The Norra Kärr alkaline intrusion is enriched in zirconium (Zr), heavy REEs, yttrium (Y), niobium (Nb) and hafnium (Hf). These elements occur in minerals that are uncommon on a global scale.

57. It has been debated whether the Norra Kärr intrusion has been deformed and metamorphosedor not. Ar-Ar ages on sodic amphibole from Norra Kärr and muscovite and biotite from the country rocks give plateau ages at 1.1 Ga and 0.94 Ga, which correspond to ages derived for Sveconorwegian shear zones in the area.[25] Together with textural and crystal-chemical evidence, these ages prove a Sveconorwegian overprint of the Norra Kärr alkaline complex.

58. Structural observations from Norra Kärr state that magmatic layering and orientation of early deformation fabrics suggest the body was emplaced as a sill. Three deformational phases can be observed:

- N-S to NE-SW compression giving a shallow-dipping foliation
- E-W compression that developed a regional N-S trending synform, dipping to the west. A flattening foliation is overprinting the earlier fabric. In places, the foliation is associated withreverse thrust mylonites
- N-S compression developing a minor conjugate NE-trending kink folds.

B. Mineral Resource Classification according to NI 43-101

59. The mineral resources at Norra Kärr have been reported following the NI 43-101 standards. The estimation has been optimised to allow the production of 5,000 tonnes per year of separated REO over a mine life of 20 years. Conventional open-pit mining at an average annual rate of 1.18 million tonnes and a grade of 0.59% total REO is assumed.

60. The mineral reserves and resources of Norra Kärr are presented in Tables 5 and 6.

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[24] Sjöqvist A. 2015: Agpaitic rocks of the Norra Kärr Alkaline complex: Chemistry, Origin and age of Eudialyte hosted- zirconium and Rare-Earth element ore. *Thesis for Licentiate degree. Gothenburg University, Institute of earth sciences*.

[25] Sjöqvist A.S.L., Cornell D.H., Andersen T., Erambert M., Ek M. and Leijd M., 2013: Three compositional varieties of rare earth element ore: Eudialyte-group minerals from the Norra Kärr alkaline complex, southern Sweden. *Minerals*, 3(1) pp 94- 120.

Table 5
Norra Kärr mineral reserve estimate (WAI, November 2014)

Classification	Ore Tonnes (kt)	TREO (%)	HREO (%)	% HREO in TREO	Ce_2O_3 (%)	Dy_2O_3 (%)	Er_2O_3 (%)	Eu_2O_3 (%)	Gd_2O_3 (%)	Ho_2O_3 (%)	La_2O_3 (%)	Lu_2O_3 (%)
Proved	-	-	-	-	-	-	-	-	-	-	-	-
Probable	23 571	0.592	0.314	0.531	0.124	0.0269	0.0184	0.00218	0.0196	0.00593	0.0551	0.00234
TOTAL	23 571	0.592	0.314	0.531	0.124	0.0269	0.0184	0.00218	0.0196	0.00593	0.0551	0.00234

Classification	Ore Tonnes (kt)	Nd_2O_3 (%)	Pr_2O_3 (%)	Sm_2O_3 (%)	Tb_2O_3 (%)	Tm_2O_3 (%)	Y_2O_3 (%)	Yb_2O_3 (%)	Zr (%)	U (%)	Th (%)	Hf (%)
Proved	-	-	-	-	-	-	-	-	-	-	-	-
Probable	23 571	0.0648	0.0161	0.0178	0.00396	0.00280	0.215	0.0172	1.36	0.00131	0.000663	0.0286
TOTAL	23 571	0.0648	0.0161	0.0178	0.00396	0.00280	0.215	0.0172	1.36	0.00131	0.000663	0.0286

Notes:

1) *Mineral Reserves are reported based on material contained within the Design Final Pit Shell.*
2) *Mineral Reserves are constrained a designed 20yr mine life.*
3) *Mineral Reserves are reported for combined GTM and PGT mineralisation only.*
4) *Mineral Reserves reported have been adjusted for Mining factors, at 3.5 % Dilution and 5.0 % Loss.*
5) *Mineral Reserves are reported to 3 S.F.*
6) *Total Rare Earth Oxides (TREO) includes: La_2O_3, Ce_2O_3, Pr_2O_3, Nd_2O_3, Sm_2O_3, Eu_2O_3, Gd_2O_3, Tb_2O_3, Dy_2O_3, Ho_2O_3, Er_2O_3, Tm_2O_3, Yb_2O_3, Lu_2O_3, Y_2O_3.*
7) *Heavy Rare Earth Oxides (HREO) includes: Eu_2O_3, Gd_2O_3, Tb_2O_3, Dy_2O_3, Ho_2O_3, Er_2O_3, Tm_2O_3, Yb_2O_3, Lu_2O_3, Y_2O_3.*

Table 6
Norra Kärr mineral resource estimate (WAI, 2014)

Classification	TREO % Cut-Off Grade	Tonnes (kt)	Density (t/m3)	TREO (%)	% HREO in TREO	Dy2O3 (%)	Y2O3 (%)	Eu2O3 (%)	La2O3 (%)	Nd2O3 (%)	Ce2O3 (%)	Gd2O3 (%)	Tb2O3 (%)	Pr2O3 (%)	Sm2O3 (%)	Lu2O3 (%)
Indicated	0.2	36 821.60	2.71	0.55	53.18	0.02532	0.20053	0.00203	0.05190	0.06025	0.11560	0.01825	0.00371	0.01504	0.01647	0.00227
	0.4	31 109.16	2.70	0.61	52.60	0.02729	0.21775	0.00222	0.05729	0.06680	0.12823	0.01997	0.00403	0.01668	0.01815	0.00238
	0.6	17 124.71	2.72	0.68	52.23	0.02994	0.24290	0.00253	0.06214	0.07686	0.14413	0.02260	0.00447	0.01896	0.02083	0.00251

Notes:

1. Mineral Resources that are not Mineral Reserves do not have demonstrated economic viability
2. Mineral Resources are reported inclusive of any Mineral Reserves
3. The Mineral Resources reported have been constrained on the basis of a 20 yr. pit.
4. Mineral Resources are reported for the combined GTM, PGT, GTC and ELAK mineralisation only.
5. The Mineral Resources reported represent estimated contained metal in the ground and has not been adjusted for metallurgical recovery.
6. Total Rare Earth Oxides (TREO) includes: La_2O_3, Ce_2O_3, Pr_2O_3, Nd_2O_3, Sm_2O_3, Eu_2O_3, Gd_2O_3, Tb_2O_3, Dy_2O_3, Ho_2O_3, Er_2O_3, Tm_2O_3, Yb_2O_3, Lu_2O_3, Y_2O_3.
7. Heavy Rare Earth Oxides (HREO) includes: Eu_2O_3, Gd_2O_3, Tb_2O_3, Dy_2O_3, Ho_2O_3, Er_2O_3, Tm_2O_3, Yb_2O_3, Lu_2O_3, Y_2O_3.
8. Preferred Base Case Mineral Resources are reported at a TREO % cut-off grade of 0.4 % TREO.

VI. UNFC Classification of the Norra Kärr Deposit

61. The classification of the Norra Kärr project according to NI 43-101 is bridged over to the UNFC classification in this report. The Mineral Reserve and Resource estimates were completed by WAI. According to WAI, Norra Kärr has a probable mineral reserve of about 23 kt and an indicated mineral resource of TREO with a 0.4% cut-off of approximately 31 kt. “WAI believes that the Mineral Resource is robust and based on sound geological and sample data with the grade estimates representative of the sample data.”

62. Using the UNFC classification, Norra Kärr can be rated as an E2F2.1G2 project per Table 1. In the following sections, a detailed description of how this conclusion was reached is presented.

A. E2 of the Environmental-Socio-Economic Viability Axis

63. The exploration license of the Norra Kärr project is claimed by LEM, previously Tasman Metals Ltd. The project was initially claimed via exploration permit “Norra Kärr No.1” valid for three years, first granted on 31 August 2009. Today, the project consists of four claims, Norra KärrNo 1, No 2, No 3 and No 4, in total approximately 5000 ha. These exploration licenses have been renewed on two prior occasions, and a request for a three-year extension was submitted to the Swedish Mining Inspectorate (“Bergsstaten”) in August 2019. This permit is valid until 2023.

64. Today, LEM has received a prolonged exploration permit until 2025 due to the COVID-19 pandemic. However, this permit has been appealed, and LEM awaits the result.

65. A 25-year Mining Lease (exploitation concession) was granted to Tasman Metals AB covering Norra Kärr in 2013 following submission of substantial application documents. Both relevant permitting authorities ("Bergsstaten" and "Länsstyrelsen") approved the granting of the Norra Kärr Mining Lease. The project is classified with a probable reserve which means that at this stage, the object moved upwards on the E axis to an E1.

66. In March 2015, Tasman published a comprehensive PFS for the Norra Kärr project. The project stands out as one of few advanced HREE projects globally, and the only one that can produce more than 200 tonnes per year of dysprosium oxide for more than 20 years with a capital investmentof less than US$400 million.

67. In 2016, following an appeal to the Supreme Administrative Court of Sweden regarding the decision-making process of the Mining Inspectorate of Sweden (Bergsstaten) and the subsequent decisions taken by the Government, Bergsstaten has requested further information from the Company, including a Natura 2000 assessment regarding the potential future impact of a mine neighbouring Natura 2000 sites in the region. Natura 2000 areas do not exist in the Mining Lease application area. As a result of the appeal, the Norra Kärr deposit was reversed on the environmental and socio-economic scale from E1 to E2. After the Mining Inspectorate bounced the project back to the company, it is awaiting the Natura 2000 assessment, so the project remained as E2. The project will move back to E1 if all the permits are granted and final plans for the REE open pit mine are done. A simplified timeline is presented in Table 4.

B. F2.1 on the Technical Feasibility Axis

68. The project is a Development Pending project classified as F2.1.[26] Extensive metallurgical tests were done on representative samples from Norra Kärr.

69. According to LEM, the Norra Kärr deposit is well suited to open-pit mining, which leads to a relatively lower cost of mining.

70. Mineralogy has shown that the only REE-bearing mineral with significant abundance at Norra Kärr is the zircon silicate eudialyte. Eudialyte is weakly magnetic (paramagnetic) and dissolves rapidly in weak acid at low temperatures. As a result, an uncomplicated flow sheet has been developed that can be achieved with standard mining and processing equipment and widely available chemicals.

71. Furthermore, the non-magnetic fraction from the bedrock constitutes nepheline and feldspar. It is probable that these "waste products" find a market of their own. So far, no full-scale experiments in processing REE from eudialyte have been done. When these are done, the project will move up to F1.

C. G1+G2 on the Degree of Confidence Axis

72. The geology of the area is considered to be known. Mapping and drilling have been done by several exploration companies. Mapping on a regional and local scale has been done by SGU, and several detailed research projects, have been published by Norra Kärr. Tasman Metals Ltd (now LEM, Sweden) has carried out an exploration programme comprising geological mapping, geophysical surveys, and structural mapping. In total, 119 surface diamond holes of 20,420 m in length have been drilled. The PFS by companies GBM and WAI concludes that the sample data is both accurate and precise, and the risk of biased sampling affecting the Mineral Reserve and Resource estimates is low.

[26] United Nations Framework Classification of Resources (Update 2019).

VII. The Kiruna-Malmberget Secondary Resource Deposit

A. LKAB Minerals

73. LKAB Minerals is an international industrial minerals company in a leading position in Sweden with anumber of products. The company has two main business areas, iron ore and special products. LKAB Minerals is part of LKAB, an international high-tech mining and minerals corporate group, mining and refining Swedish iron ore for the global steel market. The Swedish Government is the sole owner of LKAB.

74. Sweden is the number one producer of iron ore in Europe, with more than 90% of European production, and LKAB is the main producer. Sustainability is at the core of the company and its ambition is to be one of the most innovative, resource-efficient and responsible companies in the industry. The turnover of the corporate group was about 31 billion Kronor in 2019. The Group, which has approximately 4,300 employees in 12 countries, includes industrial minerals, drill systems, train cargo, and real estate. In 2019-2020 the company invested approximately 700 million Kronor in exploration.

75. Mineral reserves and resources from all of LKAB's mines are reported on the LKAB website.[27] In 2020, the Kiruna mine reported a proven mineral reserve of 246 Mt and a probable mineral reserve of 491 Mt. Corresponding figures from Malmberget are 79 Mt and 186 Mt. From Leväniemi mine in Svappavaara, the corresponding figures are 81 Mt and 10Mt. LKAB is working on a PERC classification of the ReeMAP project. Currently, only phosphor is reported. In Kiruna, a measured resource of 188 Mt and an indicated resource of 893 Mt are reported. Corresponding figures from Malmberget are a measured resource of 99 Mt and an indicated resource of 429 Mt. In the future, the plan is to include REE in the classification. When this is done, it will be an excellent opportunity to see how well the UNFC classification corresponds to the PERC classification.

76. The magnetite deposits with or without hematite of Kiruna and Malmberget have mineralogical and textural features that are different from most other iron deposits in the world. Most characteristic is the presence of apatite as an important gangue mineral, which contributes to the high phosphorus content of the ores.[28] Apatite occurs mainly as disseminated grains in the ore or form band, schlieren or veinlets. Disseminated apatite occurs interstitially to magnetite as subhedral and equidimensional or prismatic grains up to 0.5 mm large.[29]

B. Rare Earth Elements from Mining Waste from Iron Ore Operations in Northern Sweden

77. In a press release dated 29 May 2020[30], LKAB presented a pilot study on producing apatite from mining waste. Furthermore, LKAB states that it expects to produce about 400,000 tonnes apatite/year using only falling waste from the ongoing iron ore mined in Kiruna and Malmberget, where falling waste is material that would normally not have been processed.

78. In late September 2020, LKAB Minerals announced its plans to invest in a new fossil-free industrial park (ReeMAP) to produce, e.g., REEs, gypsum, and phosphorus-based mineral fertiliser from its mining waste originating from its significant iron ore

[27] https://www.lkab.com/en/about-lkab/from-mine-to-port/exploration/mineral-reserves-and-mineral-resources/

[28] Frietsch R. & Perdahl J.-A. 1995: Rare earth elements in apatite and magnetite in Kiruna-type iron ores and some other iron ore types. *Ore geology reviews* v.9 p. 489-510.

[29] Pålsson B.I., Nartinsson O., Wanhainen C. & Fredriksson A. 2014: Unlocking rare earth elements from European apatite iron ores. ERE2014 First European rare eath resources conference. Milos.

[30] https://www.lkab.com/en/press-releases/lkab-produces-apatite-from-mine-waste-in-a-new-pilot-plant/

production.[31, 32] Within the ReeMAP-project, LKAB is now developing techniques for recycling its waste and has decided to increase its ambition to also switch to producing Direct-Reduced Iron (DRI) instead of today's pellets and to produce input goods, including hydrogen gas, and to electrify the processes to eliminate CO_2 emissions (Figure VIII) in the process.

79. The goal is for the industrial park to contribute up to 30% of Europe's present demand for REEs. The operations will ship one million tonnes of products a year in total, and therefore the existing infrastructure with trains and connecting harbours is of the essence. At the moment, LKAB is looking at the municipalities of Skellefteå, Luleå and Helsingborg with well-functioning harbours to establish the industrial park.

C. Waste Deposit

80. The iron ore of the LKAB mines is mainly magnetite, associated with apatite (a calcium phosphate). Apatite of the Kiruna ores shows a common pattern with 2000–7000 ppm REE, with a weak to moderate Light Rare Earth Elements (LREE)/HREE fractionation.[33] Total contents for REO in fluor-apatite, such as the apatite from Kiruna and Malmberget, including only lanthanum (La), cerium (Ce) and neodymium (Nd), range from 0.04 to 0.91 with an average of 0.25% by weight.[34]

81. REEs are mainly found in apatite, the main mineral of interest. To a lesser extent, other REE-bearing minerals are found. Due to the relatively low content of REE in the apatite, recovery of REE will be made in conjunction with phosphorus fertiliser production and gypsum, which increases the operation's resource efficiency and decreases its economic risk. According to Pierre Heeroma and Niklas Johansson, LKAB (personal communication), the economic calculations for industry development are insensitive to world market prices on REEs. Also, after intense investments in exploration over the last few years, the life of mine now reaches beyond 2060. LKAB plans to invest between one and two billion Euros yearly for the entire development project for the upcoming 15 to 20 years.

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31 https://www.lkab.com/en/about-lkab/technological-and-process-development/research-collaborations/reemap--dagens-avfall-blir-morgondagens-resurser/

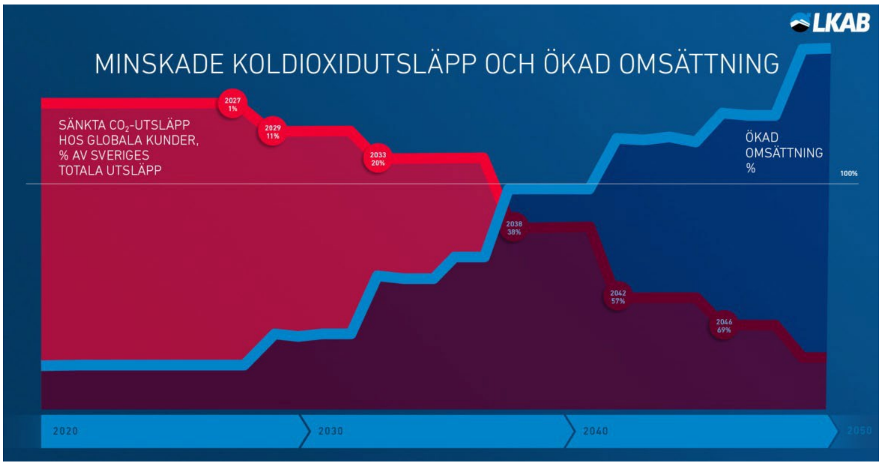
32 https://ree-map.com/

33 Frietsch R. & Perdahl J.-A. 1995: Rare earth elements in apatite and magnetite in Kiruna-type iron ores and some other iron ore types. *Ore geology reviews* v.9 p. 489-510.

34 Pålsson B.I., Nartinsson O., Wanhainen C. & Fredriksson A. 2014: Unlocking rare earth elements from European apatite iron ores. ERE2014 First EuropeanEuroean rare eartheath resources conference. Milos.

Figure VIII

Relationship between CO_2 emissions and turnover



Note: Diagram showing decrease of CO_2 emissions with global customers with each step of development (in red), and simultaneously increased turnover (in blue).

82. Sandström and Fredriksson (2012)[35] described a procedure with the leaching of REE from apatite residue from LKAB mining waste, where an apatite concentrate is produced by flotation.

83. Different acids were used in experiments on leaching the REE from the apatite concentrate. Both hydrochloric and nitric acid resulted in good results. Nitric acid is preferred due to a less corrosive media than hydrochloric acid. Sulphuric acid resulted in a huge amount of gypsum. With proper pH control, REE can be effectively precipitated from the nitric acid leachate by ammonia addition, thus, providing possibilities to produce both REE and fertiliser.

84. Furthermore, Sandström and Fredriksson (2012) showed that the recoveries of the heavier elements were slightly higher than those for, the lighter ones. The work of optimising the extraction of REE from the apatite by hydrometallurgical means is still in progress.

D. UNFC Classification of the LKAB Waste Deposit

85. As of now, ReeMAP can be classified as an E2F2G1+G2 project. A description of how this conclusion was attained is available in the following paragraphs.

1. E2 on the Environmental-Socio-Economic Viability Axis

86. The ongoing feasibility study is expected to be completed soon. The plan is to reach full production capacity of REEs in 2027, if environmental permits are granted and construction can start.

87. A mine cannot be moved since its location must be where the ore is, and hence there are often issues related to the competition of land that needs to be solved for such an operation to be fully permitted. An industry like the one LKAB is planning to refine REE concentrate is less restricted regarding location. Close proximity to infrastructure is key, but apart from that, there are fewer restrictions related to location than for an ordinary mining operation. This will make it possible to locate it in an industrialised area, more or less prepared for new industries to move into. This means that the permitting process should be much more straightforward than for a mining operation.

[35] Sandström Å. and Fredriksson A .2012: Apatite for extraction-leaching of Kirunavaara apatite for simultaneous production of fertilizer and REE. International Mineral Process Congress (IMPC) 2012. India.

88. Once the location has been decided, the application for an environmental permit can be finalised, and the process can be moved forward. There are no obvious obstacles that can be identified at this time.

89. Also, since the mining waste at hand originates from ongoing operations with full permits, it will be more straightforward than would be the case with historical mine waste if concessions and environmental permits are absent. Currently, it is not clear from Swedish legislation how historical waste should be treated from a legal and permitting perspective if someone would like to use it as a resource.

90. However, there are challenges, especially regarding time constraints. Environmental permitting processes for the mining and minerals industry are now lengthy and fairly unpredictable in Sweden. In this case, LKAB has an ongoing application for comprehensive permits for the operations in Malmberget and Kiruna. This is also where LKAB will locate the apatite plant extracting the apatite from the waste before it can be processed to REE concentrate. The comprehensive permitting process for the mine sites can potentially affect the entire timeline of the REE project.

91. Government agencies and the company have the ambition to achieve a high degree of environmental performance. Aided by the authorities, LKAB hopes to satisfy all requirements and that the process will be efficient and help create environmental benefit through the realisation of the ReeMAP project.

92. Once all the permits are in place to become operational, ReeMAP will move to E1.

2. F2 on the Technical Feasibility Axis

93. With the announced investment plan, the financial part of the F axis is clearly F1. However, the development of the processes is still ongoing within ReeMAP, and the construction plans are not finalised; therefore, it is safe to say that the project is at the F2 stage and on its way to F1 later thisyear.

94. What will be key to the success of the ReeMAP project is the development of the hydro process, where most of the new technology will be developed. According to LKAB, there is currently no comparable upgrading process that creates high-grade products while utilizing by-products.

95. Several of the sub-stages make use of known and proven process technology. Still, the challenge is matching them to an effective and economically sustainable process that meets high expectations for product quality.

96. Today, development occurs in a lab setting and in bench-scale tests. The results due in 2021 will be a decisive factor in the attainment of the project.

97. The idea is to reach full production capacity in 2027, if environmental permits are granted and construction can start on plan.

3. G1+G2+G3 on the Degree of Confidence Axis

98. The waste going into this process is considered well known. There have been several research studiesdone throughout the years.[36, 37, 38] The mineral character, as well as the REE content, is known and described in those studies. In the light of these studies and the research undertaken by LKAB, the company can announce that it will be able to provide 30% of the EU's current REE demand.

[36] Frietsch R. & Perdahl J.-A. 1995: Rare earth elements in apatite and magnetite in Kiruna-type iron ores and some other iron ore types. *Ore geology reviews* v.9 p. 489-510.

[37] Sandström Å. and Fredriksson A .2012: Apatite for extraction-leaching of Kirunavaara apatite for simultaneous production of fertilizer and REE. International Mineral Process Congress (IMPC) 2012. India.

[38] Pålsson B.I., Nartinsson O., Wanhainen C. & Fredriksson A. 2014: Unlocking rare earth elements from European apatite iron ores. ERE2014 First European rare earth resources conference. Milos.

99. In addition to that, and according to LKAB, the facility will produce five times the present need of cadmium-low phosphorous fertiliser for Sweden, with the opportunity to save up to 700,000 tonnes of CO_2 emissions (corresponding to 1% of Sweden's total emissions in 2019) compared to the alternative of increasing the production of mineral fertilisers with the technique that is traditionally used today.

VIII. Conclusions, Challenges and Experiences

100. This report demonstrates that classifying a mining or exploration project using public information is possible and fairly straightforward. Furthermore, bridging over from a project classified according to the CRIRSCO family of codes is also quite easy. The ORAMA guidelines have proven to be very helpful for this case study. UNFC and the CRIRSCO family of codes are complementary, with UNFC having an additional focus on environmental and socio-economic viability. In carrying out the UNFC classification based on public information, the mapping that is available between the CRIRSCO Template and UNFC is needed and makes classification according to UNFC easier and more accurate.

101. Looking at the three projects classified in this case study, it is clear that a challenge and maybe one of the largest risks to the success of a Swedish mining or exploration project is the permitting process. Several projects in Sweden have been delayed due to complicated permitting processes with far-reaching possibilities to appeal decisions legally. The delay in the process is costly and can itself cause the projects to fail.

102. In March 2021, the Swedish Government announced a governmental study to improve permitting processes in terms of transparency and predictability to ensure access to innovation critical raw materials. The outcome of this work will be reported in October 2022.

Acronyms

CRIRSCO:	Committee for Mineral Reserves International Reporting Standards
DRI:	Direct-Reduced Iron
EU:	European Union
GBM:	GBM Minerals Engineering Consultants Limited
HREE:	Heavy Rare Earths
HREO:	Heavy Rare Earth Oxides
LEM:	Leading Edge Materials
LREE:	Light Rare Earth Elements
Mintell4EU:	Mineral Intelligence for Europe Project
ORAMA:	Optimizing quality of information in RAw MAterial data collection across Europe
PERC:	Pan European Reserves and Resources Reporting Committee
PFS:	Pre-Feasibility Studies
REE:	Rare Earth Elements
ReeMAP:	LKAB Project: Rare Earth Elements and MonoAmmonium Phosphate
SGU:	Geologic Survey of Sweden
TIB:	Trans-Scandinavian Igneous Belt
TREE:	Total Rare Earth Elements
TREO:	Total Rare Earth Oxides
UNFC:	United Nations Framework Classification for Resources
WAI:	Wardell Armstrong International Limited

Chemical Elements/Compounds

Ce:	Cerium
Dy:	Dysprosium
Hf:	Hafnium
La:	Lanthanum
Nb:	Niobium
Nd:	Neodymium
Pr:	Praseodymium
Tb:	Terbium
Th:	Thorium
U:	Uranium
Y:	Yttrium
Zr:	Zirconium

Chemical Formula/Name of the Chemical Compound

Dy_2O_3:	Dysprosium(III) oxide
Y_2O_3:	Yttrium(III) oxide
Nd_2O_3:	Neodymium(III) oxide
Gd_2O_3:	Gadolinium(III) oxide
HO_2O_3:	Holmium(III) oxide
La_2O_3:	Lanthanum oxide
Lu_2O_3:	Lutetium(III) oxide
Pr_2O_3:	Praseodymium(III) oxide
Sm_2O_3:	Samarium(III) oxide
Tb_2O_3:	Terbium(III) oxide
Tm_2O_3:	Thulium(III) oxide
Yb_2O_3:	Ytterbium(III) oxide
Ce_2O_3:	Cerium(III) oxide
Er_2O_3:	Erbium(III) oxide
Eu_2O_3:	Europium(III) oxide