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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 – A Case Study on Graphite

Prepared by the Geological Survey of Norway*

Summary

As part of exploration for graphite in Northern Norway, 24 deposits and occurrences have been classified according to the United Nations Framework Classification for Resources (UNFC). This case study focuses on flake graphite deposits and examines the Trælen and the Bukkemoen Deposit. In addition, UNFC was applied to 24 graphite deposits. The aggregated tonnage is 268 Mt with an average of 11.6 Mt. One deposit is in production and has a UNFC code of E1F1G1, one prospect under exploration has a UNFC code of E2F3G2. The rest of the projects are mostly classified as E3F3G4. The geological setting of the graphite deposits is similar, they date from Archean to Proterozoic and consist of metasedimentary origin. The graphite mineralization was formed during subsequent granulite phases of metamorphism.

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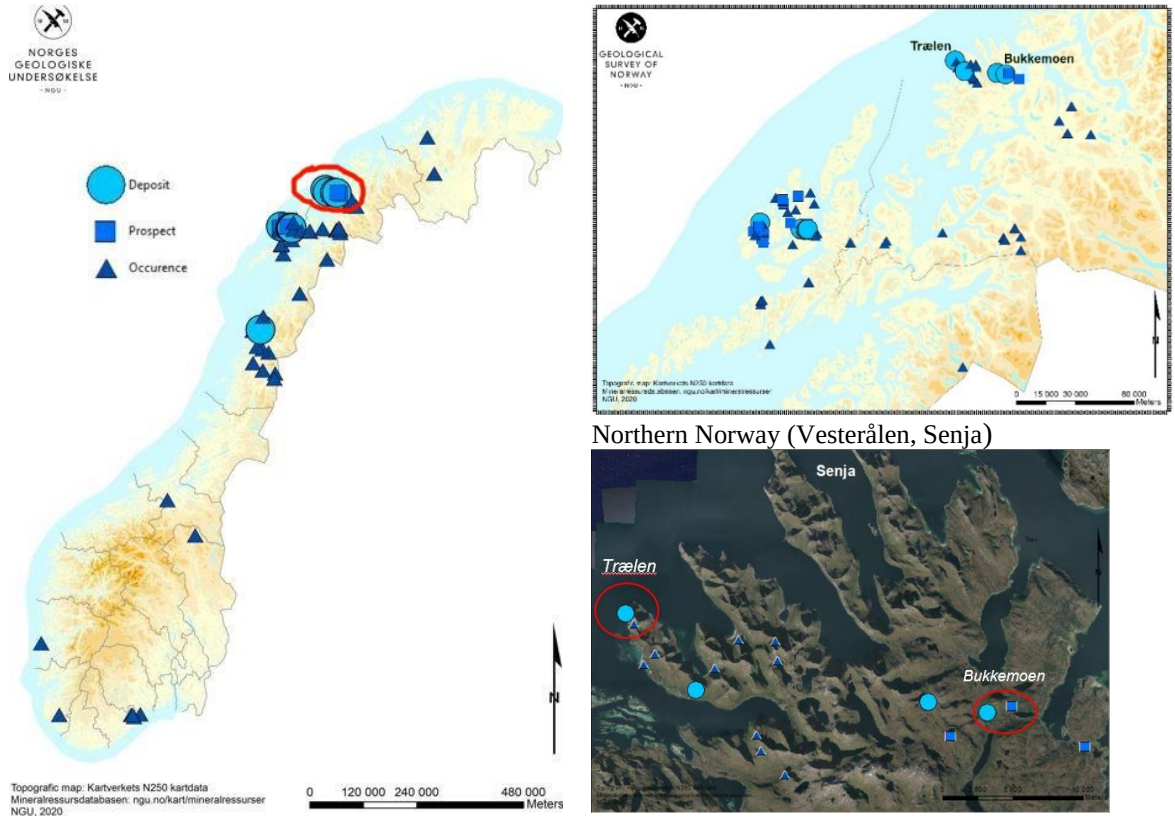
I. Introduction/Background

A. Definition of the Resource

1. This case study tests how flake graphite deposits can be classified using the United Nations Framework Classification for Resources (UNFC). The study focuses on the flake graphite deposits, and examines the Trælen deposit (active mine, Skaland Graphite AS) and the Bukkemoen deposit on the Senja peninsula in Troms County in Northern Norway (Figure I). In addition, UNFC was applied to 24 graphite deposits (Table 3). All the graphite occurrences are found in supracrustal granulite facies rocks of Archaean to Proterozoic age, comprising quartzites, migmatitic gneisses, iron formations, calcsilicates and graphite schist.

Figure I
Graphite occurrences in Northern Norway (Vesterålen and Senja)



2. The Skaland mine has been in operation since 1922, producing about 10,000 tonnes per year with an average grade of about 30% Total Carbon (TC). The Skaland mine was exhausted and closed in 2006.

3. Since 2006, the mine at Trælen, 8 km north from the Skaland mine, has been active. This is currently the world's richest flake graphite mine in operation.

4. In 2019, the Skaland graphite mine AS was bought by Mineral Commodities Ltd., an Australian company.

5. The Bukkemoen graphite flake deposit is located approximately 20 km southeast of the Skaland graphite operations. Together, these deposits comprise part of the largest continuous geophysical helicopter-borne anomaly known to be associated with graphite in Scandinavia. The geophysical anomaly is divided into three parts: Bukkemoen to the south, Bukken to the north and Litjkollen to the east.

B. Methodology

6. To classify the resource using UNFC, a bridging from the Committee for Mineral Reserves International Reporting Standards (CRIRCSO) Template compliant data was used for the Trælen deposit, as it had Joint Ore Reserves Committee (JORC) compliant resource estimates. Other graphite deposits in Norway have not been classified using a CRIRCSO-based system.

7. Different sources were used to gather the available data to define the parameters needed for the E and F axes, such as information from the Norwegian Water Resources and Energy Directorate https://www.nve.no/, the Directorate of Mining https://dirmin.no/, and maps from https://www.nordatlas.no/ and https://kommunekart.com/. For the Trælen deposit, data from the company website *www.mineralcommodities.com/* was used.

8. Since 2015 and 2018, the Geological Survey of Norway (NGU) has conducted detailed investigations employing different geological and geophysical methods to define mineral deposits in Northern Norway (Vesterålen and Senja). A variety of the following methods and data were used to identify the mineralized areas: Geophysical methods/Helicopter-borne electromagnetic (HEM), Charged Potential (CP), Self Potential (SP), 2D Resistivity (also called ERT), Induced Polarization (IP), Ground conductivity meter Geonics EM31 (Geonics 1984), Geological methods/Geological mapping, Structural analysis, Sampling, Chemical analyses TC, Total Sulphur (TS), Geological drilling. The results of the investigations have been outlined in reports and manuscripts which can be found on NGU's website. Geophysical data can be downloaded here http://geo.ngu.no/mapserver/GeofysikkWMS2. Reports can be downloaded from: Litteratursøk | Norges geologiske undersøkelse (ngu.no).

C. The United Nations Framework Classification for Resources

9. The Trælen deposit is located 8 km from the existing Skaland processing plant infrastructure. The mine has been in production since 1932. For the Trælen deposit, the company Mineral Commodities Ltd had access to 133 drill holes, 15.5 km drill core in total and 1245 analysed drill samples. As Trælen is the world's richest flake graphite mine in operation, one could suggest that it should be classified as G1 by default, but the data on mineral reserves are not available. Resources have been classified using JORC standard with 106 000 t of indicated graphite and 291 000 t of inferred graphite resources. Based on that data and by using the bridging approach from CRIRCSO-compliant data, the G axis status is classified as G2+G3. Additionally, Mineral Commodities Ltd commented in the maiden JORC resource estimation for the Skaland graphite project as follows:

(a) *Mineral tenement and land tenure status – the Skaland Graphite AS operating license for the Trælen Mine was renewed on 28 May 2019 for ten years. To the knowledge of Wardell Armstrong International Limited (WAI), all licenses and permits are in good standing with no known impediments;*

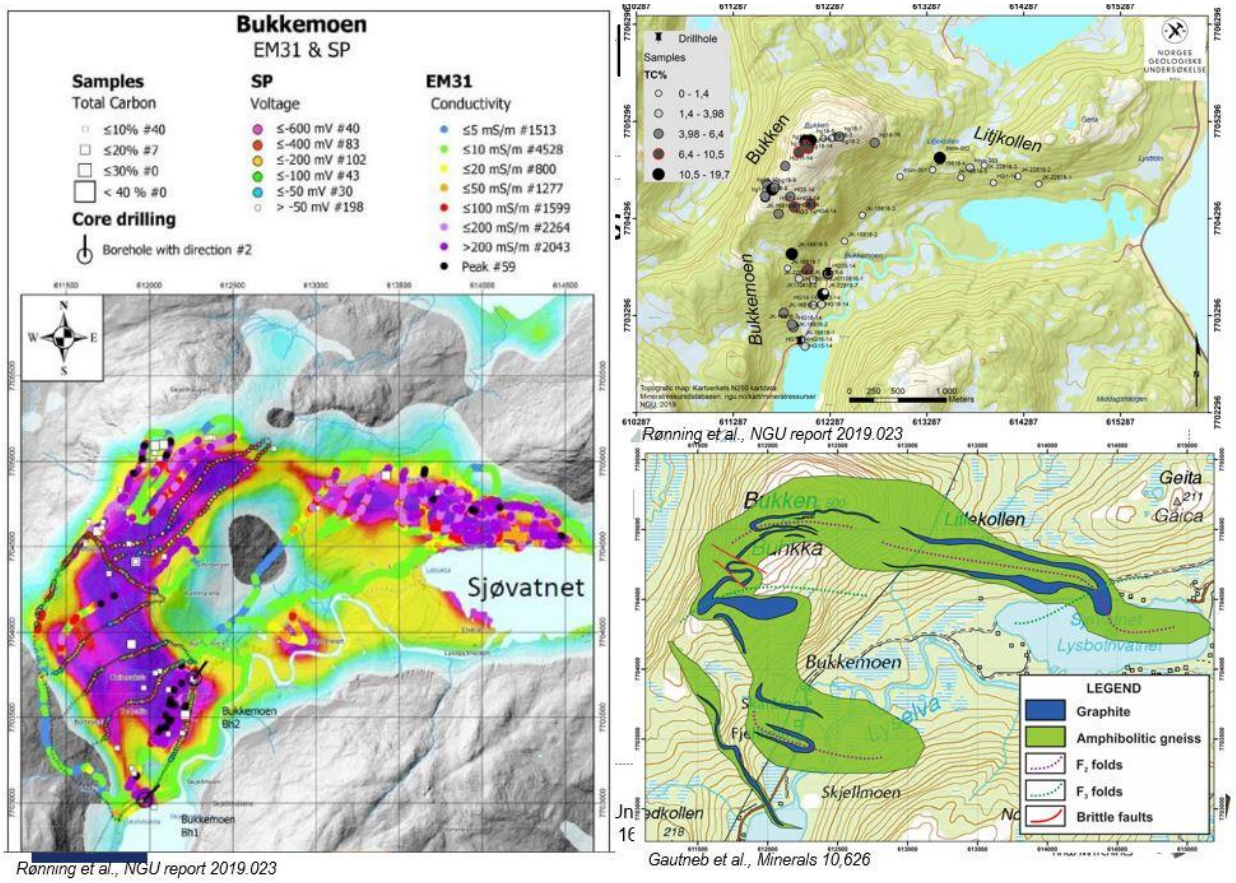
(b) *Environmental factors or assumptions - WAI understands that all necessary environmental permits required to operate the mine and process plant are in place (www.mineralcommodities.com/).*

1. Recommended UNFC Classification of the Trælen Deposit: E1F1G1,2,3

10. In the case of the Bukkemoen deposit, NGU employed numerous geological and geophysical methods between 2015 and 2018. The main survey goals were to ground true resistivity anomalies discovered by a helicopter-borne geophysical survey during the project "Minerals in Northern Norway" between 2012 and 2014, funded by the Norwegian Government (Figure II). 51 samples have been collected and analysed, with an average of 5% TC. The maximum content of TC is 19,7%. Two drill holes with cores have been completed, to a depth of about 40m, and 20 drill samples have been analysed with a TC content of 3 to 5%.

Figure II

1. Self-potential, EM31 conductivity apparent resistivity*, 2. Analysed samples, drill cores, 3. Structural mapping*****



* 7kHz, from Rodionov et al. 2014; Rønning et al., NGU report 2019.023.

** From Rønning et al., NGU report 2019.023.

*** From Gautneb et al., Minerals 10.626.

11. Based on the geophysical and geological mapping, Bukkemoen was divided into three graphite anomalies and sub-localities within the deposit. The total extent of the deposit is 5.3 km x 0.6 km (included marine area in Sjøvatnet), with Bukkemoen covering 0.5 km x 0.5 km, Bukken covering 1.5 km x 0.4 km, and Litjkollen covering 1.6 km x 0.35 km. Variations in TC% and contained graphite are summarized in Table 1 and Table 2.

Table 1

Variation in total carbon at Bukkemoen, Senja

Variation in TC *Area/Sub-area*	*No. of samples*	*Average (%)*	*Max (%)*	*Min (%)*	*StdDev (%)*	*Median (%)*
Bukkemoen						
Bukkemoen	20	5.2	14.1	2.2	3.3	4.0
Bukken	27	6.5	19.7	0.6	4.5	5.0
Litjkollen	4	5.3	16.3	0.6	7.4	2.1

Table 2
Tonnage and Contained Graphite, Bukkemoen, Senja

Occurrence Name	*% TC*	*Tonnage (Mt)*	*Contained Graphite (Mt)*
Bukken	6,5	51,03	3,34
Litjkollen	5,3	34,54	1,83

12. The extent of the deposit has been extrapolated to a depth of 100 m. A volume estimation for Bukken includes 3,34 Mt of contained graphite and an estimate for Litkjollen 1,83 Mt**. The position on the G axis is classified as G3**. This area should be explored further, and detailed ground geophysics and deeper core drilling are recommended in all three areas (Rønning et al.,2019b).

13. The Bukkemoen deposit is located approximately 20 km southeast off the existing Skaland graphite operations. Mineral Commodities Ltd has signed a landowner agreement to explore the Bukkemoen graphite prospect, with exploration rights for 10 years. The suggested interpretation for the F axis is therefore F3.1- *Site-specific studies have identified a potential development with sufficient confidence to warrant further testing*. The Bukkemoen area is also in deer grazing area and is about 5 km from a nature reservation area. However, the nature reservation area and reindeer grazing areas are not in conflict with the mineral deposit. Instead, in the Bukkemoen area, according to the Norwegian Water Resources and Energy Directorate (NVE) landslides might occur.

14. The proposal for the E axis is E3.2-*Environmental-socio-economic viability cannot yet be determined due to insufficient information.*

2. Final UNFC Classification of the Bukkemoen Deposit: E3.2F3.1G3

15. UNFC was applied to all graphite deposits in Norway (Table 1). NGU used a combination of airborne and ground geophysics to estimate the dimensions of the mineralized areas, combined with sampling and analysis of the graphite content. To estimate the volume calculation, the following approach was used: L = length of mineralized zones in metres (from airborne and ground geophysics), W = average apparent width (m) of graphite zones (from EM31, drilling and observations), α = average dip in degrees from field observations (used to calculate real width).

16. NGU does not have access to drilling data for almost all the graphite deposits, thus with extrapolation, the mineralization continues 100 m down the dip, the volume (V) of each occurrence would be: $V = L\ W\ (\sin(\alpha))\ 100$.

17. The amount of contained graphite (Cg) was calculated as: $Cg = V\ \rho\ (\%TC)$; (ρ)= 2437 kg/m^3- as the average density from petrophysical measurements, % TC as the average total carbon for each deposit.

18. The depth of the deposit is not a measured value but an extrapolation, the volume estimation has a low confidence level. See Rønning et al., 2019a; Rønning et al., 2019b; Gautneb et al., 2020 for details.

Table 3
UNFC applied to graphite deposits*

Deposit/company name	*Average TC*	*Tonnage (Mt)*	*Contained graphite (Mt)*	*E*	*F*	*G*
Trælen*	22	1,785	0,4	1	1	1+2+3
Jennestad	9,6	3,44	0,33	2	3	2
Rendalsvik	11,1	1,9	0,21	3	3	2
Bukken area	6,5	51,03	3,34	3.2	3	3
Litljkollen	5,3	34,54	1,83	3.2	3.1	3
Vardfjellet	9,2	12,84	1,18	3	3.3	3
Grunnvåg	5,2	22,77	1,19	3	4	3
Smines	7,1	18,89	1,34	3	4	3
Nord-Værnes	4,1	0,6	0,02	3	4	3
Sommarland	12,5	0,85	0,11	3	4.1	3
Brenna	10,1	7,94	0,8	3	4.1	3
Skogsøya	20	1,42	0,28	3	4.1	3
Evassåsen	7,6	2,12	0,16	3	4.1	3
Vikeid Central	13,8	8,89	1,23	3	4.1	3
Vikeid West	11,3	29,63	3,35	3	4.1	3
Ånstad	36,8	0,21	0,08	3	4.1	3
Alsvåg	8,9	0,25	0,02	3	4.1	3
Instøya	9,3	14,82	1,38	3	4.1	3
Rødhamran	14,8	1,38	0,2	3	4.1	3
Romset	14,7	9,63	1,42	3	4.1	3
Hesten	5,8	2,07	0,12	3	4.2	3
Haugsnes	16,2	8,4	1,36	3	4.2	3
Møkland	13,2	3,4	0,45	3	4.2	3
Svinøya	11,7	0,17	0,02	3	4	3

* Based on company information (Minerals Commodity Ltd 2020). From Gautneb et al., 2020**.**

II. Challenges

19. It was challenging to find data for the E and F axes and to find data on land use. This is because E and F data were collected only in the early stages when mining was planned. In most places geological information is also limited for most early-stage exploration projects. Another challenge was to find good examples of how to apply UNFC and how to get more accurate depth and volume estimations for those occurrences with less geological data.

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Acronyms

UNFC:	United Nations Framework Classification for Resources
CRIRSCO:	Committee for Mineral Reserves International Reporting Standards
JORC:	Joint Ore Reserves Committee
NGU:	Geological Survey of Norway
HEM:	Helicopter-borne Electromagnetic
CP:	Charged Potential
SP:	Self Potential
ERT:	2D Resistivity
IP:	Induced Polarization
WAI:	Wardell Armstrong International Limited
TC:	Total Carbon
TS:	Total Sulphur
NVE:	Norwegian Water Resources and Energy Directorate
Cg:	Contained graphite