Occurrences of energy critical elements; Lithium – Cobalt and Graphite in Europe, a preliminary overview.

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FRAME
FORECASTING AND ASSESSING EUROPE'S STRATEGIC RAW MATERIALS NEEDS
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Project website

Occurrences of energy- critical elements; Lithium Cobalt and Graphite in Europe, an overview.

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GeoERA

EuroGeoSurveys
The Geological Surveys of Europe

Abstract:
There are, based on extracts from the national mineral resource databases of the EuroGeoSurvey members, 1195 occurrences of Li, Co and graphite in Europe, 17of these are active mines This compilation is part of work package 5 of the FRAME project (Forecasting and Assessing Europe's Strategic Raw Materials needs) a section within the framework of the GeoERA project. The data collected classify the occurrences according to their genetic type, their occurrence type and production status. We regard in this compilation all Co locations with a mean Co >100ppm as occurrences for Co. For the other commodities, Li bearing minerals or graphite must be positively identified or explored for to be included.

Methodology

We collected from European Geological Surveys basic geographical information, status (active/closed/not exploited), occurrence type (occurrence/prospect/deposit) and genetic type for each occurrence. We show the distribution of Li, Co and graphite occurrences in different EU countries (Fig. 1) and their locations and classification according to their genetic types, in Fig 2, 3 and 4..

Results: Lithium

Spatial distribution

The distribution of lithium in Europe shows a **strong clustering** (Fig. 2) highlighting the Li potential of the Variscan belt of south and central Europe.

Deposit types

High-grade Li deposits (Gourcerol et al., 2019; Gloaguen et al., 2018) are represented by:

- Li-rich **LCT pegmatites**
- **Rare metal granites** (Melleton et al., 2015)
- **Atypical stratiform deposits** such as Jadar, encountered in intramontane lacustrine evaporate basins

Medium-grade Li deposits (Gourcerol et al., 2019) are represented by:

- hydrothermal deposits such as **greisens**
- **Li-bearing quartz veins** associated with some peraluminous rare metal granites.

Other types (Gloaguen et al., 2018)
Li-rich (tosudite) **hydrothermal alteration aureole** around gold quartz veins; **Cookeite/lithiophorite in black shales** (Dauphiné: ave. 441 ppm Li_2O, up to 1 847 ppm) or in **bauxite deposits and Mn-(Fe) deposits**. Li-rich clays (hectorite) are presently unknown in the EU.

Lithium carrier

Lithium is hosted by various minerals such as phosphates (amblygonite, montebrasite, triphylite), inosilicate (spodumene), phyllosilicates (lepidolite series, zinnwaldite, petalite) and scarce borosilicate (jadarite). Co-products are generally Ta, Nb, Sn, Be.

Examples, grades & tonnages

Jadar-type Li deposits occur in Serbia and Bosnia. In 2017, the total mineral resources report 135.7 Mt of ore at a grade of 1.86 % Li_2O and 15.4 % B_2O_3 (Rio Tinto, 2017) that represents a giant deposit of 2.524 Mt of Li_2O. / Wolfsberg pegmatites, Austria (236 366.46t Li_2O – grade 1.0%) / Sepeda pegmatites, Portugal (221 728.1t Li_2O – grade 1.0%). / Beauvoir rare-metal granite, France (375 000t Li2O – grade 0.78%) / Cinovec greisen (Czech Republic, 5 652 990.2t Li_2O - grade 0.4 Li_2O). / Argemela quartz-amblygonite veins mine (Portugal, 80 400t Li_2O – grade 0.4%).

Results: Cobalt

Spatial distribution

Most of the known Co-bearing deposits and showings in Europe are clustered in the Nordic countries (Finland, Sweden and Norway). Deposits are more scattered throughout southern-central Europe (Fig. 3). The deposits in the Nordic countries mostly represent magmatic Ni-Cu and Fe-Ti-V deposits and VMS deposits, whereas elsewhere in Europe genetic types are more varied from sediment-hosted, to lateritic and 5-element vein types, among others a common minor constituent in a number of different ore types.

Main deposit types:

- **stratiform sediment-hosted** deposits (60%)
- **magmatic Ni-Cu-Co-PGE** deposits (23%)
- **lateritic Ni-Co** deposits (15%), cobalt is recovered as a by-product (10-90 % recovery, Mudd et al., 2013).

Other types of deposits containing Co

IOCG, VMS (Besshi-type), 5-element vein deposits, black-shale hosted Ni-Cu-Zn deposits, and Fe-Cu-skarn deposits (Slack et al., 2017). Co-grades are between 0.01-0.1%.

Examples, grades & tonnages

The only active mines producing cobalt are located in Finland. Kevitsa mine in northern Finland is a large low-grade Ni-Cu-PGE deposit, which produced 591 t of Co in 2018. Kylylahti mine is a small-sized Outokumpu-type Cu-Zn-Ni-Co deposit, which produced 278 t of Co in 2018 (New Boliden, 2019). Terrafame is a large, low-grade black-shale hosted Zn-Ni-Cu-Co mine which produces Co as by-product to Ni and Zn, but production figures for Co are not published (2013: 286 t). The highest grades occur in sediment-hosted deposits of the Central African Copper Belt (0.1-1.1% Co), lateritic Ni deposits (0.1-0.22% Co), some VMS deposit-types (Windy Craggy 0.66% Co, Outokumpu-type deposits 0.1-0.25% Co), and 5-element vein deposits and ultramafic-hosted hydrothermal deposits (up to %-level, e.g. Dobsina, Bou Azzer; Hitzman et al. 2017, Slack et al. 2017).

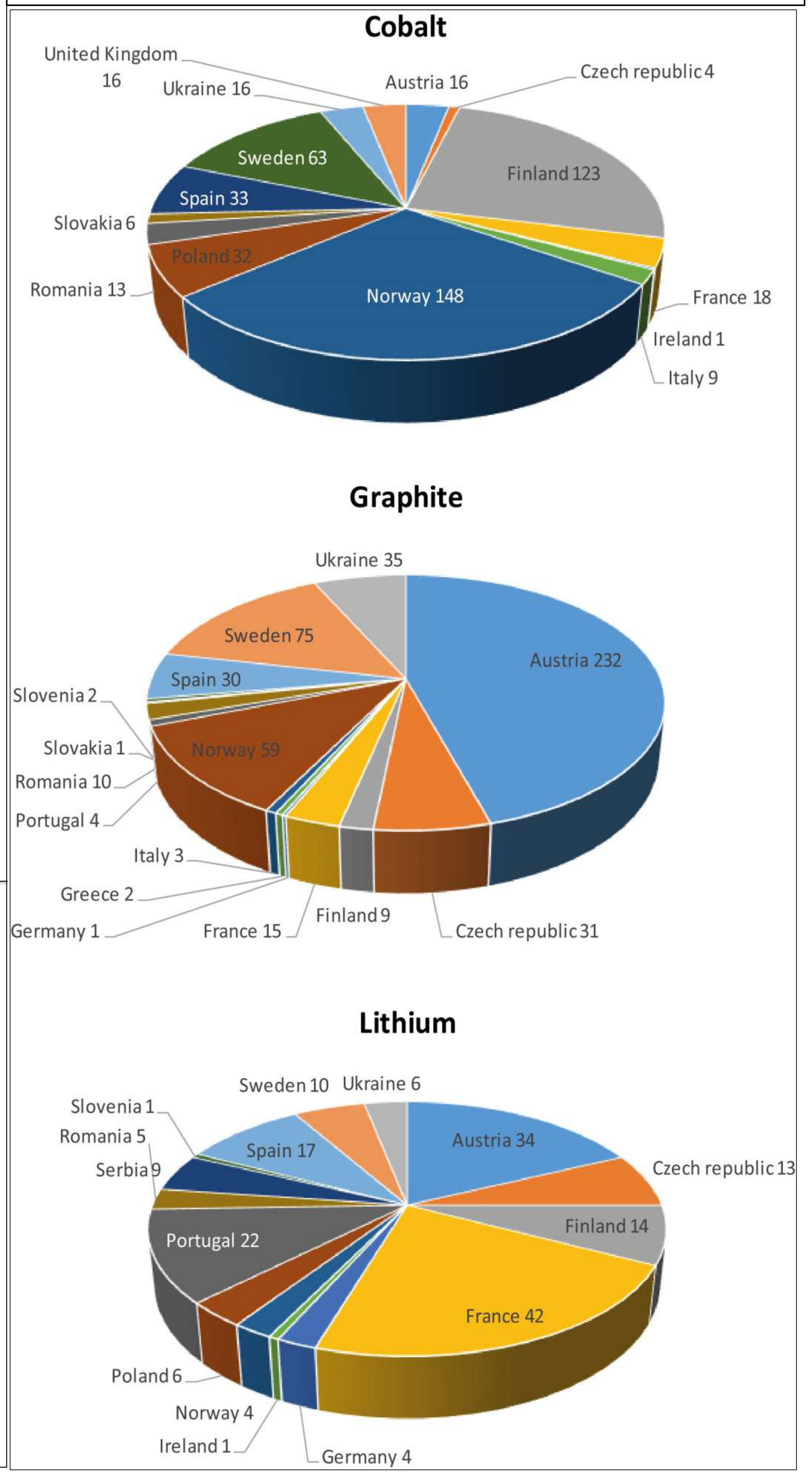

Fig. 1 The distribution of occurrences within the different European nations.

This project has received funding from the European Union's Horizon 2020 research and Innovation programme under grant agreement No 731166

Results: Graphite

Spatial distribution

Graphite is a common mineral in metamorphic rocks throughout Europe, however it is rare to find economically interesting deposits. The bulk of the graphite occurrences occur in Archaean and Proterozoic rocks of Northern Europe and Ukraine. In addition, a number of amorphous graphite occurrences are found in Phanerozoic rocks in Austria.

Deposit types

The graphite bearing rocks are typically organic rich paragneiss often associated with carbonates and iron formations.
In well-investigated areas (for instance in Norway) the graphite deposits show polyphasal deformation and are most commonly associated with upper amphibolite or granulite facies metamorphism (Gautneb et al., 2017). Graphite deposits are very good electrical conductors and are relatively easy to locate using geophysical methods.
We have in this study, divided graphite occurrences into **flake and amorphous types** which make up the bulk of the deposits. There are also a large number of showings where the genetic type is unknown. Vein deposits are known in Europe, but are mostly geological curiosities (Luque et al 2014).

Examples, grades & tonnages

Active mines are situated in Ukraine, Austria and Norway. The graphite contents vary from 2-3% up to over 40% (Gautneb & Tveten 2000). The Trælen deposit in Norway is the world's richest graphite deposit in current production with an average ore grade of 31%, and 1.8 Mt proven reserves.

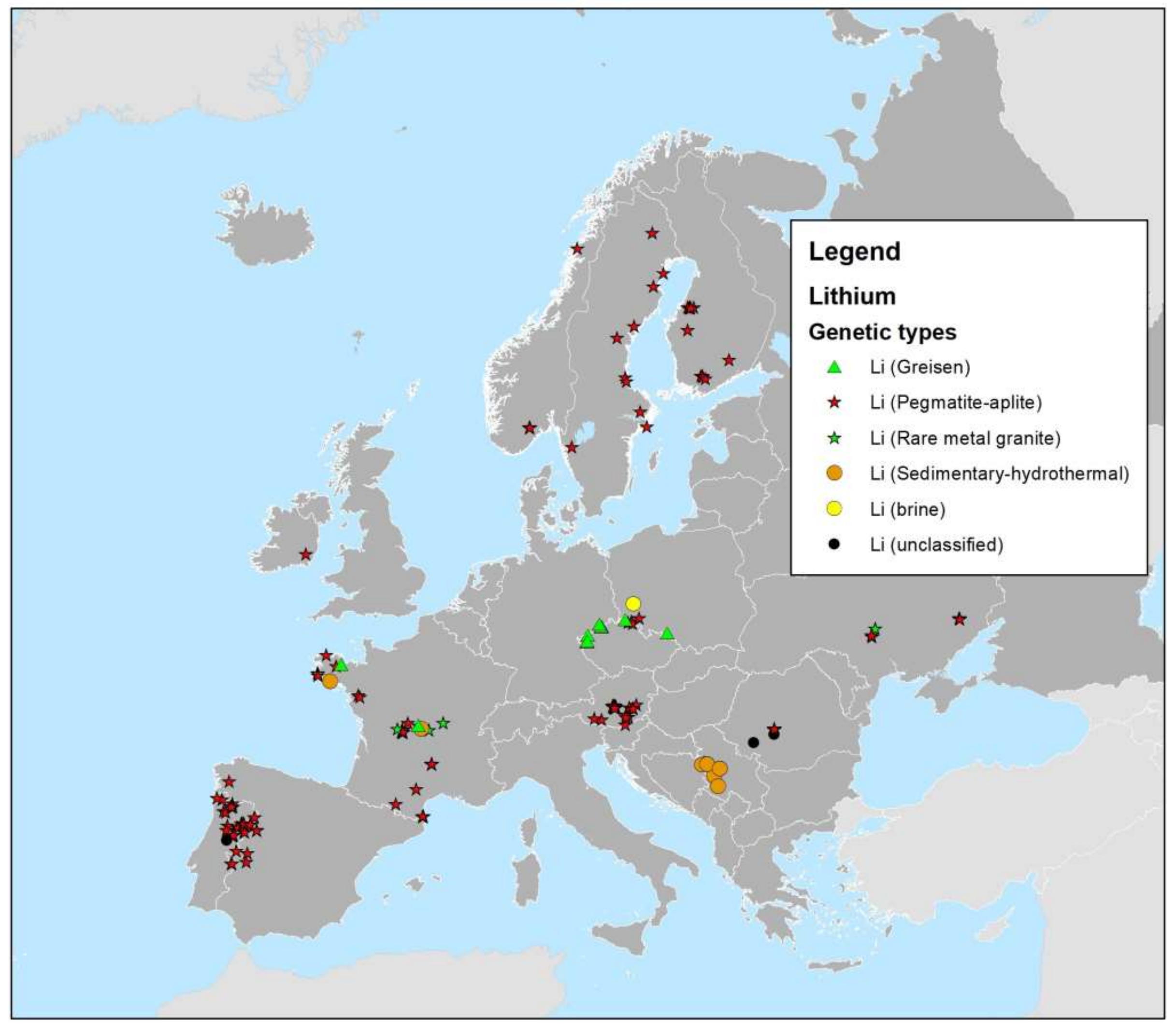

Fig. 2 The genetic types of Li- occurrences in Europe.

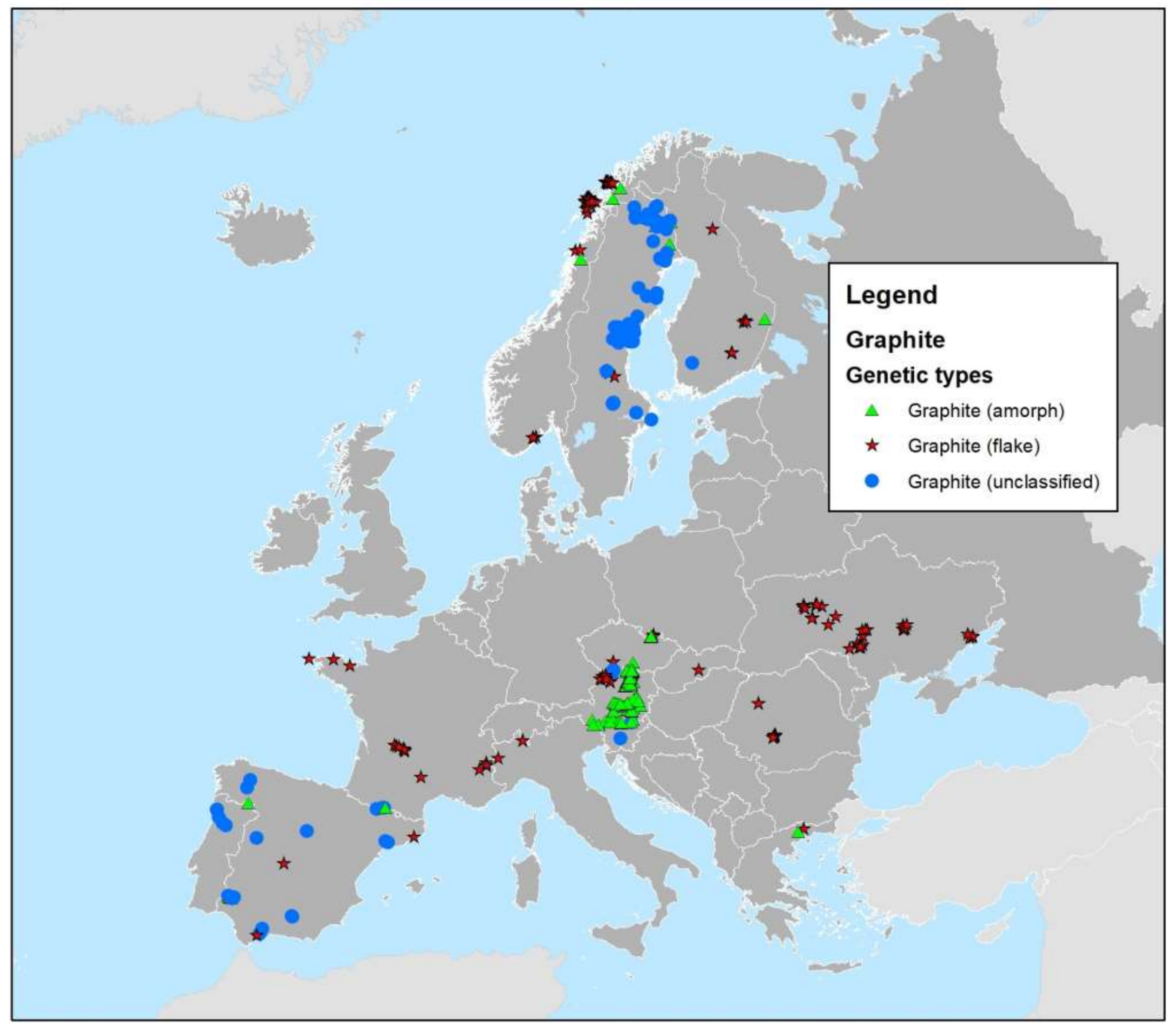

Fig. 4 The genetic types of graphite occurrences in Europe.

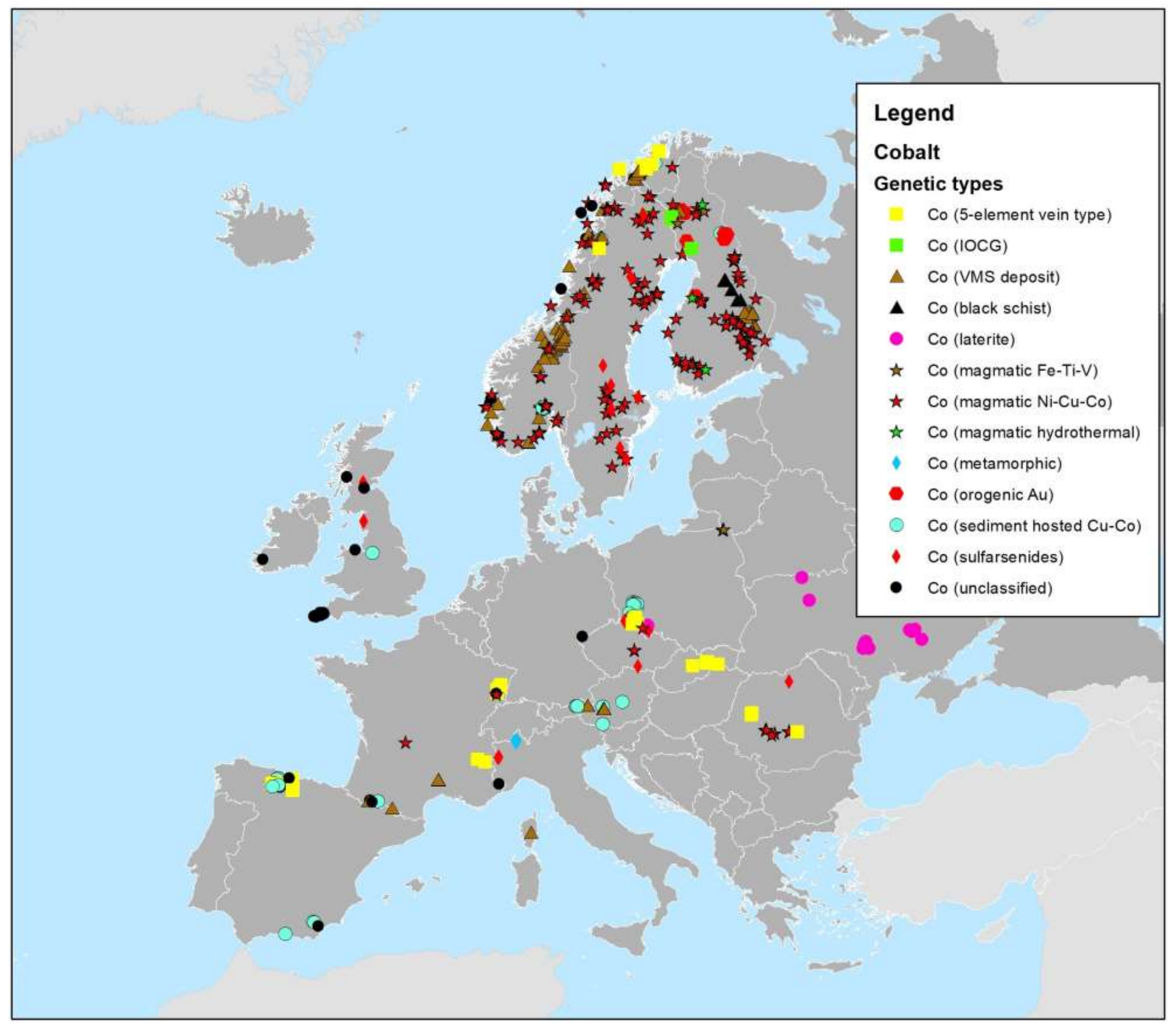

Fig. 3 The genetic types of Co- occurrences in Europe.

Based on contributions from authors and from: Anders Hallberg (SGU), Daniel de Oliveira (LNEG), Boris Malyuk (GIU), Klemen Teran (GeoZs), Stanislav Soltes (SGIDS) Stanislav Mikulski (PGI), Roberto Martinez Orio (IGME Spain), Sebastian Pfleiderer (GBA), Antje Wittenberg (BGR), Petr Rambousek (CGS), Mauro Lucarini (ISPRA), Eoin McGrath (GSI) Zoltan Horvath (MBFSZ), Kostas Laskarides (IGME Greece), George Tudor (IGR).

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