Gone are the days of the AA, AAA and 9-volt battery; today a new language of abbreviations based on chemical composition is needed to understand batteries: NiMH, LFP, VRB, LMO….the list is endless. Heavy investment in research and development, mainly driven by the electric vehicle and renewable energy industries, is leading to an explosion in innovation. New battery compositions are judged based on a balance between cost, weight, stability/safety, lifespan and energy/power output. When new innovation is successful it has implications - particularly on raw material sourcing; this article dives into the battery raw materials space specific to Europe.

Europe is experiencing huge growth in the battery production space, with over major 30 battery factories (so-called gigafactories) either in construction or planned. A major driver behind this growth is European Green Deal announced in 2020 along with the post-Brexit UK setting out an ambitious 'Ten Point Plan for a Green Industrial Revolution'. The aim of the Green Deal is to facilitate the energy transition, fight climate change and reduce environmental degradation with promises including ensuring the EU provides '*globally competitive and resilient industry*'. The introduction of the Green Deal and the desire to shorten supply chains has led to a surge in exploration of battery metals and materials in Europe. This has also triggered numerous projects to help the EU achieve its goal, including the EU-funded European Battery Alliance (EBA) which has been set-up for research and development into the battery supply chain. Regional organisations have also been instigated to improve communication and sharing of information relating to battery supply chains, such as the Finnish Mining Group and Critical Minerals Association (UK).

Metal has been mined in Europe for millennia and continues to be of major importance to many European countries. However, European mining has been eclipsed thanks to competitive advantages elsewhere, including cheaper labour and energy prices, less stringent environmental legislation and a higher tolerance for heavy industry. So does Europe have the potential to be 'globally competitive' in the battery metals space? It certainly has the right geology - with a long and complex geological history leading to the development of numerous metallogenic provinces endowed with a wide variety of mineral deposits (*Figure 1*). This includes the ancient (2-billion-year-old) bedrock found in Fennoscanndia, with major iron ore, base metal and precious metal deposits found throughout Sweden, Finland, Norway and the Kola Peninsula of Russia. In the west, Spain and Portugal have a number of operating mines and exploration properties from the Iberian Pyrite belt to the Northern Portugal tungsten-gold district. The UK and Ireland have a long-established connection with mining, particularly copper-tin in Cornwall and lead-zinc in the Republic of Ireland. Eastern Europe contains significant reserves of iron ore and manganese concentrated in Ukraine and base and precious metals found throughout the Balkan countries. Central Europe is endowed with copper in the Kupferschiefer area of Germany and Poland in addition to the Erzgebirge District straddling the border between Czech Republic and Germany famed for silver, tin, tungsten and uranium.

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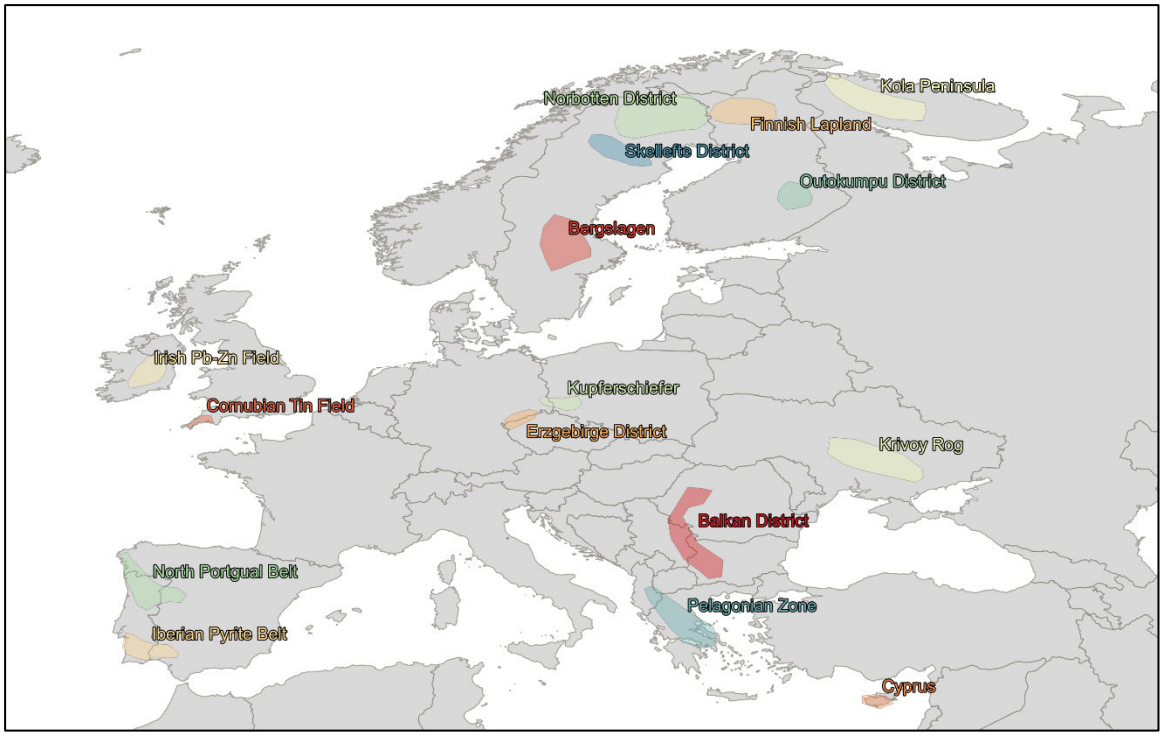

Figure 1: Main mining districts of Europe

So Europe has minerals and knows how to mine, but what about battery metals? The commonly discussed batteries metals/minerals are lithium, cobalt, graphite, nickel and manganese. They are all essential depending on the chemistry of the battery, but other metals are often required in significantly higher quantities, including copper, aluminium, tin and iron. In addition, depending on the battery chemistry, significantly quantities of zinc, vanadium, manganese, titanium and phosphorous may be required with future battery chemistry changes likely to add sodium and magnesium to the list. The good news for Europe is the majority of these metals and materials exist within the reaches of the continent and are often found in existing mining districts. The bad news is a number of key deposits are either not yet proven to be commercially viable, are at an early stage of exploration (requiring a significant investment in time and money) or may encounter significant barriers to permitting due to potential environmental and social impacts. The below provides a snapshot of the current situation in Europe relating to some of the key battery constituents.

Lithium is currently experiencing a revolution globally and Europe is playing catchup with established producers such as Australia and in South America. There has been some mine production historically on a small-scale but the deposits currently being explored are not due to come online for a number of years. Some of the more notable projects include the Jadar project in Serbia, Cinovec-Zinnwald in Czech Republic/Germany, Keliber in Finland, Wolfsberg in Austria, Mina do Barroso in Portugal, Vulcan in Germany and a cluster of projects in Cornwall, southwest England including the British Lithium and Cornish Lithium projects. Lithium is found in a variety of forms, but with the exception of the conventional spodumene deposits mined elsewhere, the other deposits do not have current analogous operations. This includes Jadarite (lithium-boron silicate mineral) in the Jadar deposit, lithium-bearing micas in the Cinovec-Zinnwald and British Lithium deposits and lithium in solution in geothermal brines in the Vulcan and Cornish Lithium projects. All are exciting prospects with ongoing technical studies and major potential sources in the future.

Cobalt is best friends with nickel and copper; where you find one, you often find the other. Many European copper and nickel deposits contain significant quantities of cobalt (albeit at very low grades generally) and are produced as by-products; however, the growing demand is fuelling exploration focussing on cobalt, with Finland leading the way as a potential source.

Nickel is already a key player in the European mining industry in two main forms: nickel sulphide deposits (such as Terrafame and Kevitsa, Finland) and nickel laterite deposits (such as in Albania, Kosovo and Greece). The town of Nikel in Russia is close to the borders with Finland and Norway and contains one of the world's largest nickel deposits in Pechenga and there is significant ongoing exploration in the surrounding area.

Provenance of graphite is not often discussed but the Traelen mine in northern Norway and Zavalievsky mine in Ukraine are both operational and well-positioned to feed this critical material to European battery producers. Sweden and Finland also have a number of deposits currently being explored with the Vittangi deposit (Sweden) particularly well-advanced.

Manganese is also available in economically significant quantities in Europe: in particular the Nikpol area of Ukraine is a world-class mining district. Manganese is also found associated with iron ore deposits and one such example of this is the Chvaletice historic iron ore mine in Czech Republic. There are plans to re-process the tailings waste material that contains elevated levels of manganese. This form of mining – of re-processing old waste material – could become more important particularly in areas such as Europe where historic mining operations are commonplace. Mineral processing techniques have enabled improved recovery of previously discarded by-products to the point where previously sub-economic material – such as manganese, vanadium or rare earth elements (such as from apatite-monazite rich deposits such as the Kiruna iron ore) – become viable to process (particularly when coupled with increased commodity prices).

As for the other metals critical to battery production – Europe does have its fair share. This includes bauxite deposits of Greece and Hungary, iron ore deposits mainly concentrated in Sweden and Ukraine, copper and tin deposits throughout the continent along with titanium, vanadium and phosphorous.

So Europe has the potential mineral endowment to provide at least some of the required feedstock to the exploding battery production industry, but before we all go rushing off into the back and beyond with our sulphide-sniffer dogs (yes, that's a thing!), significant research is required to understand if they are viable considering all economic and sustainability criteria. The proposed new EU batteries regulation off to back of the Green Deal is thick with sustainability requirements and some of these extend to miners. Attention will need to be paid in particular to each mine's carbon footprint, environmental and human rights impacts, which will be checked through supply chain due diligence processes.

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