

# Finnish historical and current Ni-Cu-PGE deposits highlight country-wide exploration potential

## Introduction

In 2017, Finland celebrates its 100 years of independence, but the mining industry has played an even longer important role in its history. Presently, the most significant magmatic Ni-Cu-Co-PGE (Fig. 1) and Cr-Ti-Fe-V resources of the European Union are located in Finland, within the Fennoscandian Shield.

Historical deposits like the Pechenga and Outokumpu deposits were previously the most important sources of nickel, copper and cobalt in Finland. Several Paleoproterozoic orogenic intrusion-hosted Ni-(Cu) deposits in the central and southern parts of Finland were important metal sources for the Finnish smelters. The intrusion-related Kevitsa Ni-Cu-PGE, black shale-hosted Talvivaara Ni-Zn-Cu-Co, and layered intrusion-related Kemi Cr deposits include significant metal resources.

Finland's EEA (European Economic Area) agreement in 1994 and entry into the European Union in 1995 opened exploration and mining opportunities for international companies. They have launched several exploration and mining projects in Finland. However, only a limited amount of exploration has been carried out in Finland compared to Canada and Australia. The recently discovered Sakatti Cu-Ni-PGE deposit has highlighted the good exploration potential of Finland. In addition, the geodata of good quality, available at Geological Survey of Finland, plays important role in exploration success. Active Ni-Cu-PGE exploration, research and mining, as well as Ni-Cu production and the stainless steel industry, form a comprehensive value chain in Finland.

## Finnish Ni-Cu-PGE deposit types

The main Ni-Cu-PGE deposit types in Finland are related to Archean and Paleoproterozoic mafic-ultramafic rocks, Paleoproterozoic metamorphosed black shales of the Talvivaara type, and the ultramafic and metasomatic calc-silicate rocks of the ophiolitic Outokumpu association. Several komatiite-hosted Ni-Cu-PGE deposits have been discovered in the Archean and Paleoproterozoic

greenstone belts in northern and eastern Finland. Many 2.45 Ga mafic-ultramafic layered intrusions in Finland host contact-type PGE-Ni-Cu deposits and significant reef-type PGE deposits; their Ni resources typically are of low grade but large tonnage. Mafic-ultramafic magmatism at ca. 2.06 Ga produced significant Ni-Cu-PGE resources in the Central Lapland greenstone belt, including the Kevitsa and Sakatti deposits. The Svecofennian domain in central and southern Finland contains hundreds of small, ca. 1.88 Ga, mafic-ultramafic orogenic intrusions; many of these host nickel mineralisation (Fig. 1).

## Ni-Cu-PGE exploration potential

Significant exploration potential exists in the Fennoscandian Shield, which shares a similar geology and metallogeny with the ancient shields in globally (e.g., Canada and Australia).

The Archean provinces in eastern and northern Finland include komatiites (ca. 2.8–2.9 Ga) and other types of mafic-ultramafic rocks potential for nickel deposits. In the northern Fennoscandian Shield, rifting with mafic-ultramafic magmatism took place in multiple stages during 2.45–2.0 Ga (e.g., Lahtinen et al. 2008). The rifted Archean-Proterozoic boundary hosts several 2.45 Ga layered intrusions hosting mainly PGE-dominant sulphide deposits in the eastern and northern parts of Finland. Rift-related greenstone belts of central Lapland host extensive mafic-ultramafic formations with potential for nickel (e.g., Kevitsa intrusion).

From the exploration point of view, formations with potential for nickel deposits are still poorly understood, as the exploration focus has historically been on the outcropping part of the bedrock. Exploration potential has also been highlighted by the GTK in permissive tracts (i.e., Ni-Cu-PGE potential areas and belts) and in the assessments of undiscovered Ni-(Cu-PGE) resources in Finland (Fig. 2; Rasilainen et al. 2010a, 2010b, 2012).

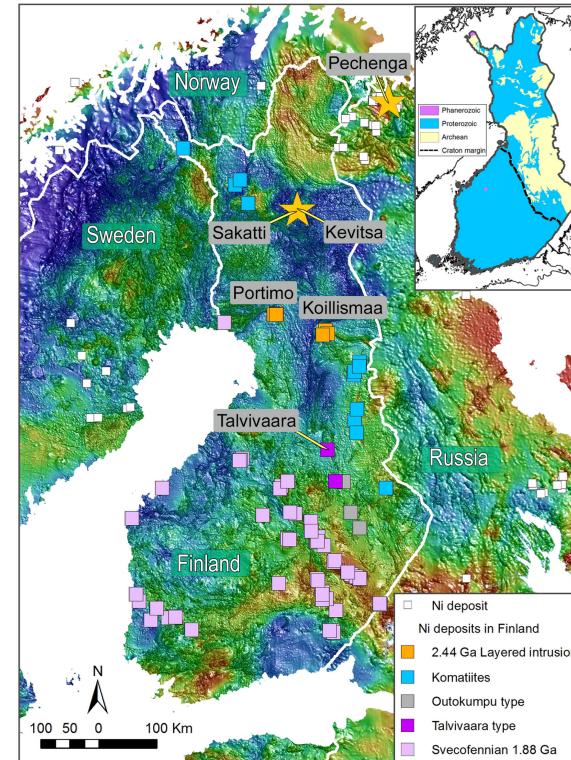


Figure 1. Distribution of Ni-Cu-PGE deposits in Finland, and Ni and PGE deposits in other parts of the Fennoscandian Shield. Yellow stars show location of the Sakatti, Kevitsa and Pechenga deposits. Base map: combined gravimetric + magnetic (red = high gravity, blue = low gravity). Source: Fennoscandian Ore Deposit Database (FODD 2016).

## Ni-Cu-PGE research

Magmatic sulphide ore research in Finland has developed along with the exploration and mining industry.

Exploration and research for the Svecofennian (1.88 Ga) nickel deposits began during the 1930 and continued actively several decades (Papunen and Vormaa 1985; Makkonen 2015).

In 1960, the Outokumpu Company commenced the Nickel Programme in order to collect extensive petrological database on Finnish mafic-ultramafic rocks, to be used to enhance nickel exploration. One of the most important tools developed within the programme was the use of nickel content in mafic silicates to discriminate between barren and nickel-potential formations (Häkli 1971). A follow-up project produced litho-geochemical tools for nickel exploration (Lamberg 2005).

Extensive magmatic sulphide ore research has also been carried out in numerous projects by the Turku and Oulu universities since the late 1960s and by the GTK (Makkonen 2015 and references therein).

Comprehensive compilations of Finnish nickel deposits include the work by Papunen and Gorbunov (1985), where the nickel-copper deposits of the Fennoscandian Shield and Scandinavian Caledonides were described, the work by Puustinen et al. (1995), the public FINNICKEL data base (Makkonen et al. 2009), the nickel chapters in Eilu et al. (2012), the assessment of undiscovered Ni-Cu-PGE resources in Finland (Rasilainen et al. 2010a, 2010b, 2012, 2014) and chapters in Mineral deposits of Finland (Maier et al. 2015).

## GTK's role in Ni-Cu-PGE exploration

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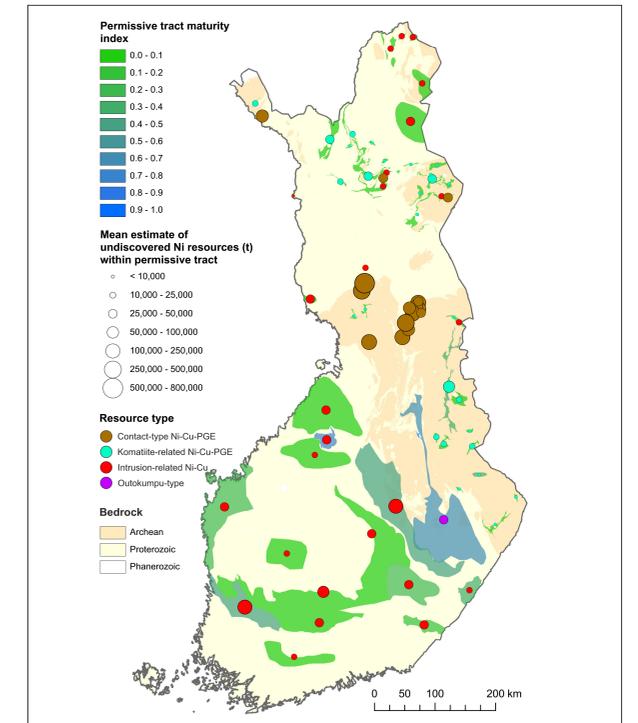


Figure 2. The mean estimate of undiscovered Ni-(Cu-PGE) resources plotted on each permissive tract. The permissive tracts and estimated resources are based on Rasilainen et al. (2010a, 2010b, 2012, 2014). The bedrock map is based on GTK geological map database (Bedrock of Finland-DigikP).

## Geological Survey of Finland

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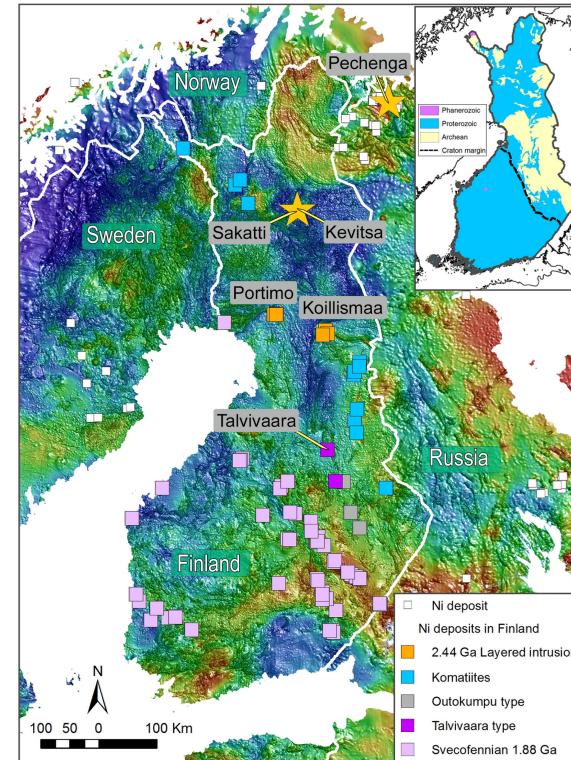


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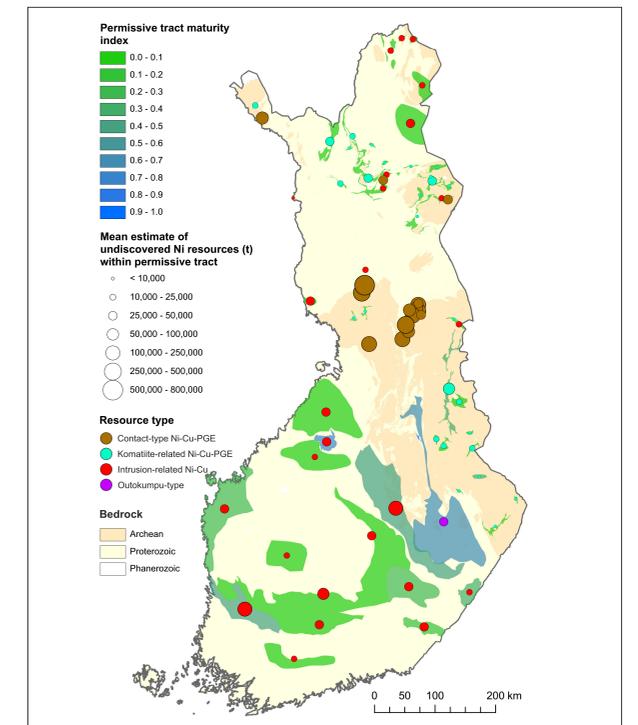


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