THE MAIN SULPHIDE ORE BELT OF FINLAND BETWEEN LAKE LADOGA AND THE BOTHNIAN BAY

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The formation of the Main Sulphide Ore Belt of Finland (containing 80—90 % of its known sulphide ore resources) can be divided into four main stages: the (1) formation of the Outokumpu- (Cu, Co, Zn) and Vihanti-type (Zn, Pb, Cu) stratabound mineralizations close to the Archean continental shelf at the evolutionary stage of the Svecofenno-Karelidic orogeny; the (2) partial remobilization, redeposition and recrystallization of the Outokumpu- and Vihanti-type of ores during the revolutionary stage of the Svecofenno-Karelidic orogeny about 1800—1900 Ma ago; the (3) formation of the Kotalahti Ni, Cu Ore Zone together with the basic and ultrabasic intrusions in connection with deep movements about 1900 Ma ago; the (4) stepwise sinking (in both space and time) of the Main Sulphide Ore Belt to form steps or grabens, in which the ores were preserved from the erosion during the Proterozoic and Phanerozoic eons. These block movements took place after the Svecofenno-Karelidic orogeny, they are believed to have been caused by the isostatic forces resulting from the denudation of the ancient Svecofenno-Karelidic mountain ranges, situated mainly on the SW side of the Archaean continental shelf. Five points are presented to support the final hypothesis.

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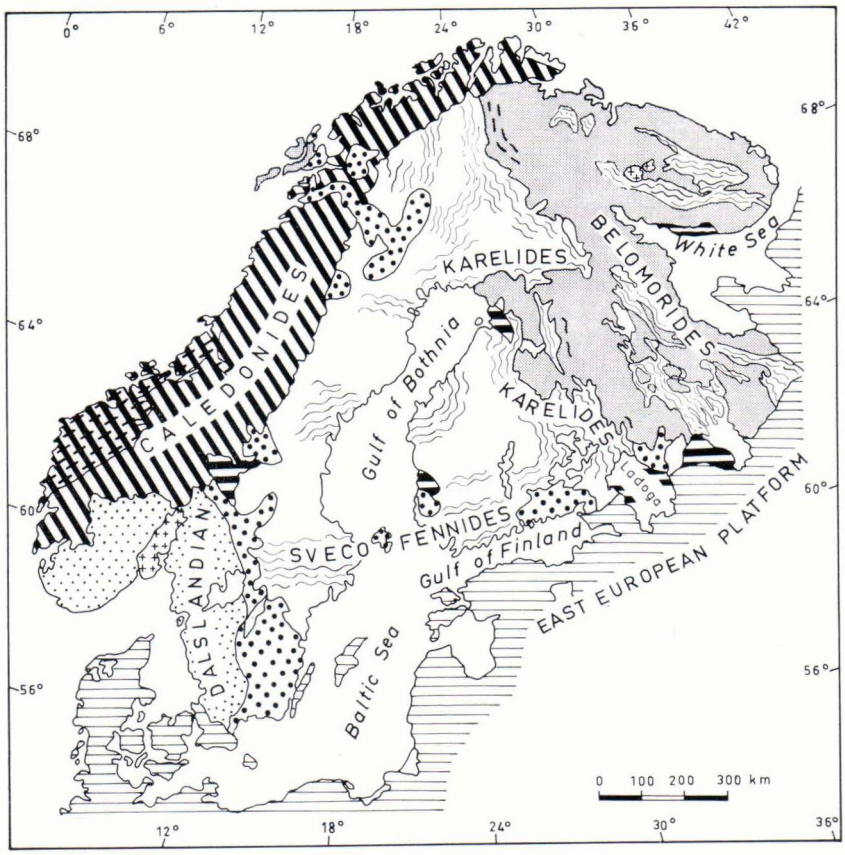
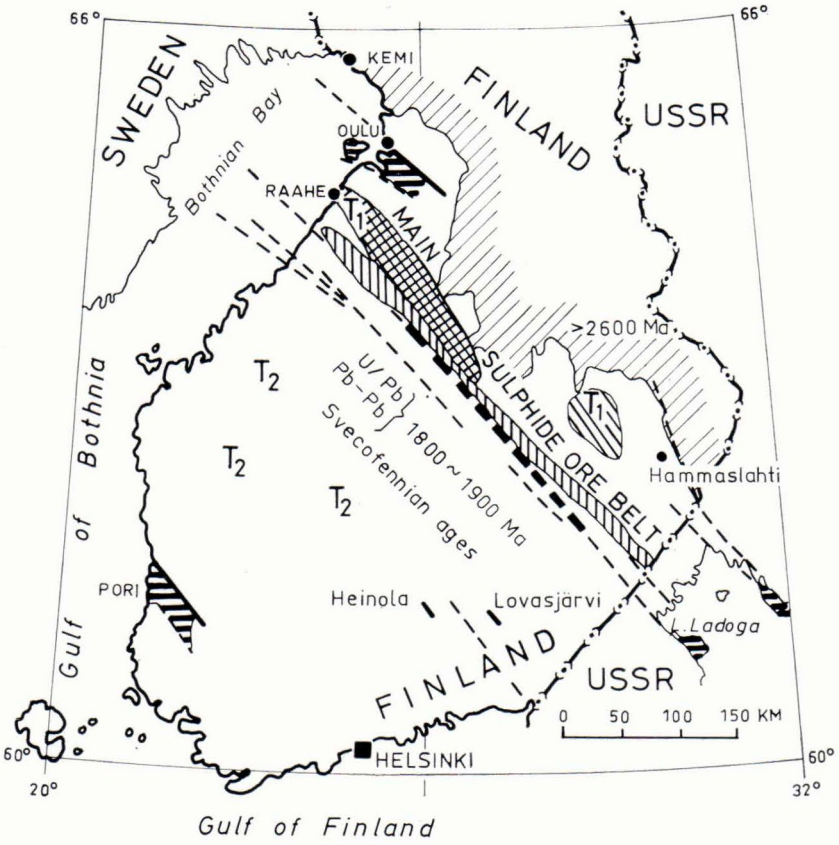
The main Sulphide Ore Belt of Finland is situated between Lake Ladoga and the Bothnian Bay (Figs. 1 and 2) close to the Archaean continental shelf. It contains about 80—90 % of the known sulphide ore resources of Finland and is divided (Kahma 1973) into three main metallogenic units, viz., the Kotalahti Ni, Cu Ore Zone, the Vihanti Zn, Pb, Cu Ore Zone and the Outokumpu Cu, Co, Zn Ore District, in addition to which there is the separate Hammaslahti Cu ore deposit in the SE part of the Belt. The formation of these ore deposits and their preservation from erosion during the Proterozoic and Phanerozoic eons are considered to have occurred in four stages:

(1) The formation of the Outokumpu- and Vihanti-type stratabound mineralizations close to the Archaean continental shelf at the evolutionary stage of the Svecofenno-Karelidic orogeny.



	Oslo graben and Khibiny intrusions	250 - 350 Ma
	Phanerozoic platform	< 570 Ma
	Riphean platform	570 - 1600 Ma
	Jotnian platform	~ 1300 Ma
	Caledonides	400 - 600 Ma
	Caledonized Precambrian rock	
	Dalslandian folded region	800 - 1200 Ma
	Gothian complex (mainly granites)	1200 - 1750 Ma
	Svecofenno-Karelidic folded region	1750 - 2600 Ma
	Archaean folded region	>2600 Ma

Fig. 1. The main Geologic Units of Fennoscandia.



Jotnian (Riphean) about 1300 ~ 1600 Ma

Faults

Deep negative gravimetric anomaly

Svecofenno-Karelides 1750-(2300) Ma

Kotalahti zone (Ni, Cu)
U/Pb ≈ 1900 Ma

Vihanti zone (Zn, Cu, Pb, Ba)
Pb-Pb ≈ 1950 Ma, U/Pb ≈ 1870 ~ 1900 Ma

Outokumpu district (Cu, Co, Zn, Ni)
Pb-Pb ≈ 2100 Ma, U/Pb ≈ 1860 Ma

Main Sulphide Ore Belt

T_1, T_2 The relative average temperatures of the Svecofenno-Karelidic metamorphism, $T_1 < T_2$

Archaean > 2600 Ma

Fig. 2. The main Sulphide Ore Belt and its surroundings.

(2) The partial remobilization, redeposition and recrystallization of the Outokumpu- and Vihanti-type of ores during the revolutionary stage of the Svecofenno-Karelidic orogeny about 1800—1900 Ma ago.

(3) The formation of the Kotalahti Ore Zone together with the basic and ultrabasic intrusions in connection with deep movements about 1900 Ma ago.

(4) The stepwise sinking (in both space and time) of the Main Sulphide Ore Belt to form steps or grabens, in which the ores were preserved from the erosion during the Proterozoic and Phanerozoic eons. These block movements took place after the Svecofenno-Karelidic orogeny, they are believed to been caused by the isostatic forces resulting from the denudation of the ancient Svecofenno-Karelidic mountain ranges, situated mainly on the SW side of the Archaean continental shelf (Figs. 1 and 2).

The sulphide ore types and their genesis belonging into points (1)—(3) have been dealt with in many papers. They have been marked on a map, and a genetic model has been presented by the author (Kahma 1973). Since then they have also been discussed by, *e.g.*, Helovuori (1974), Gaál *et al.* (1975), Piirainen (1975), Peltola (1977), Gaál (1977), Hyvärinen *et al.* (1977), Isokangas (1977), Mikkola *et al.* (1977); see also the plate-tectonic model by Hietanen (1975).

The hypothesis propounded in point (4) is, as far as I know, new and can be supported by the following facts and points of view:

1. Riphean formations are found on the east and west shores of Lake Ladoga. Jotnian formations — a part of the Riphean — are found in the Oulu and Pori grabens. Seismic measurements and diamond drillings (Veltheim 1969) show that the thickness of the Jotnian sediments varies — probably stepwise — from 30 m up to 1 km.
2. SE—NW-striking diabase dikes are known to exist in the Lovasjärvi and Heinola areas (Laitakari 1969), (Fig. 2), the radiometric ages of which are 1670 Ma and 1550 Ma, respectively. Diabases and basic effusives have also been found in the area of Lake Ladoga. These facts show that some of the SE—NW-striking faults and fractures that appeared after the Svecofenno-Karelidic orogeny have extended into the mantle.
3. Between Lake Ladoga and the Bothnian Bay there is a deep negative gravimetric anomaly (50—250 $\mu m/s^2$) in connection with a fault zone (Fig. 1). On the basis of the bathymetric map (Tulkki 1977), these faults seem to have extensions even on the bottom of the Bothnian Bay.
4. On the southwest side of the deep negative gravimetric anomaly and its extensions in Finnish territory, no places are known where the basement of the Svecofenno-Karelidic supracrustal rocks of SW Finland can be seen. The surroundings of these supracrustal rocks, however, are acidic, as on the side of the old eastern Archaean basement ($>$ 2600 Ma). These facts, together with the dominance of migmatites (20—30 % migmatites + 10—20 % crystalline schists of volcanic or sedimentary origin, (Simonen 1962, Kahma 1973) on the SW side compared with the dominance of the crystalline schists on the NE side (over 50 % schists + 10 % migmatites) show that the old basement of SW Finland is strongly ultrametamorphosed. The metamorphic rocks of SW Finland thus represent a higher average metamorphic temperature and probably also a deeper section of the then existing earth's crust than the Main Sulphide Ore Belt.

5. The radiometric measurements of the samples from the southwest side of the Main Sulphide Ore Belt give consistent so-called Svecofennian ages independent of the radiometric methods used. The lead model ages (Fig. 1) of the sulphides of the Vihanti Ore Zone and the Outokumpu Ore District are somewhat older than these »Svecofennian» ages as well as the ages of their surrounding intrusives. These discordant ages together with the partial remobilization of the Outokumpu- and Vihanti-type sulphide ores as well as the Archaean basement (the formation of mantled domes, Eskola 1949) point to more moderate temperatures during the Svecofenno-Karelidic metamorphism. It does not seem to represent as deep a section of then existing earth crust as in SW Finland, where the daughter nuclides of the radioactive elements have completely separated from their original source minerals (Neuvonen 1961).

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