

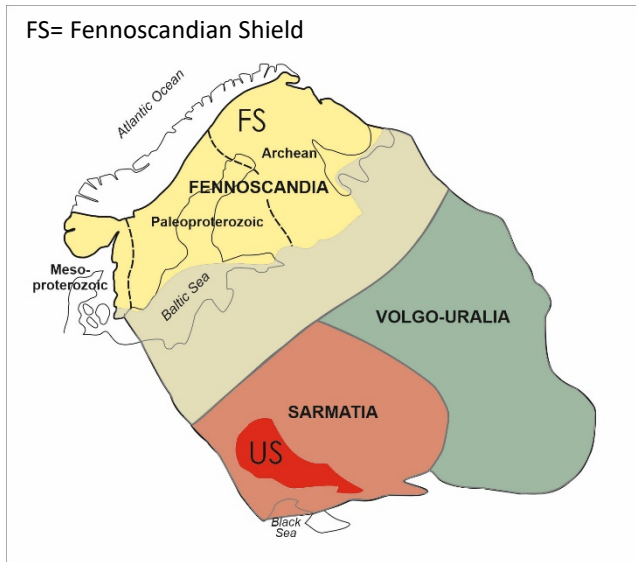
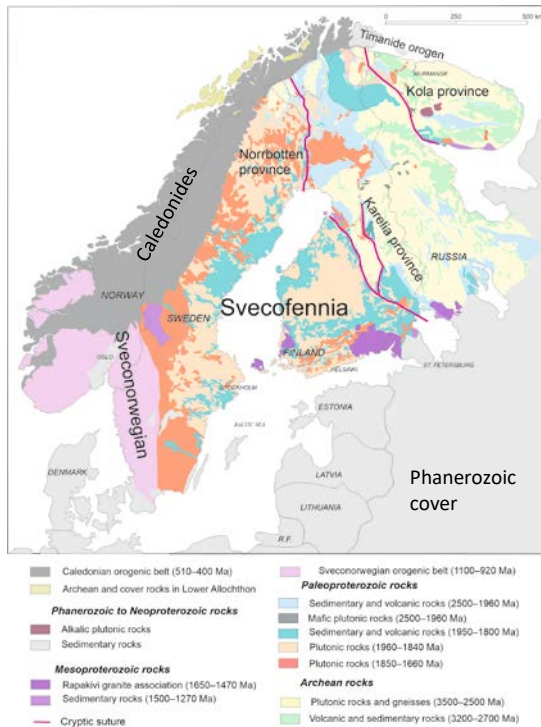


GTK

METALLOGENY AND GEOLOGY OF FINLAND

Raimo Lahtinen and Pasi Eilu

Geology of Fennoscandia



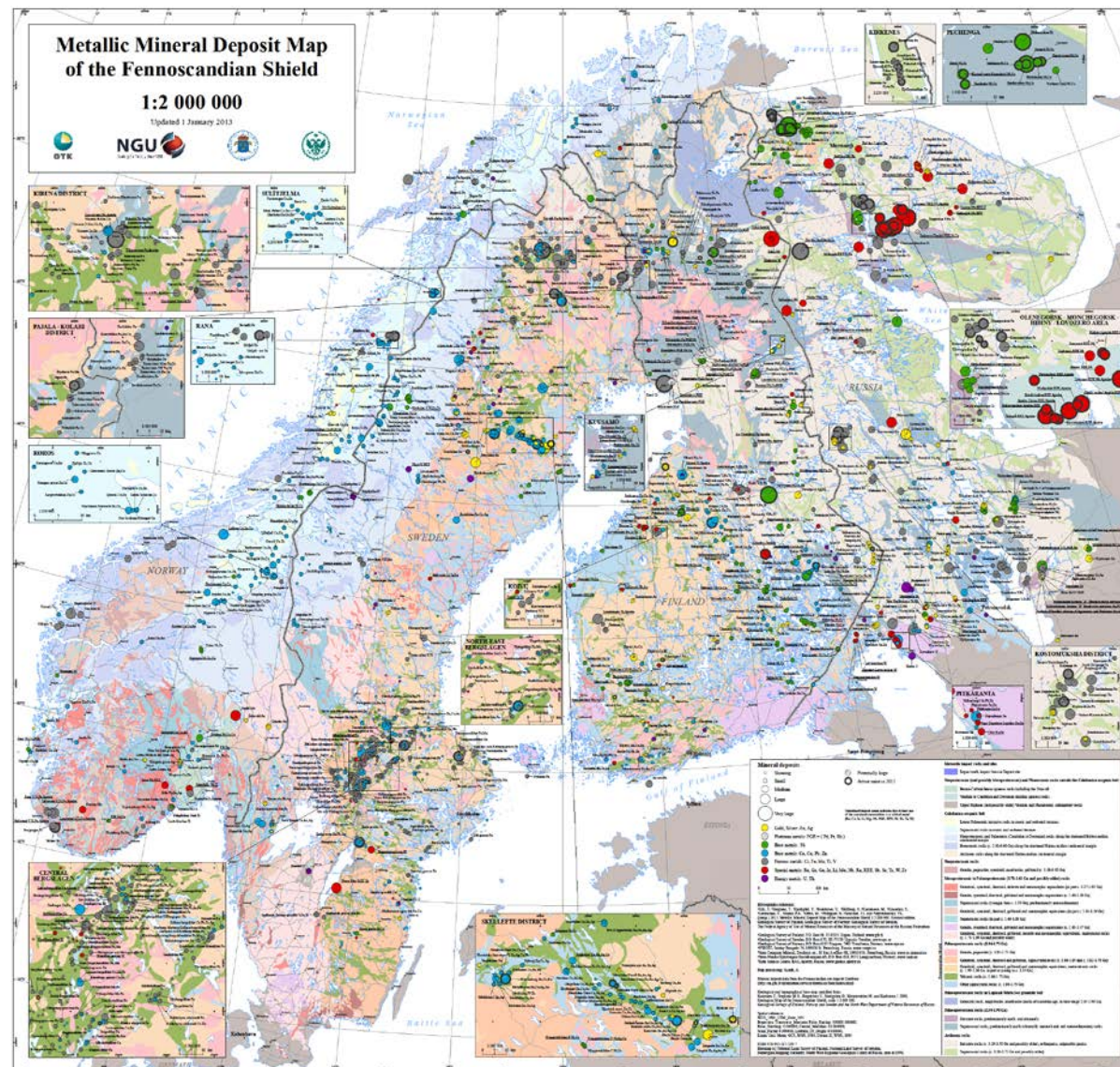
Geological map of the Fennoscandian Shield, scale 1:2,000,000. Koistinen et al., 2001

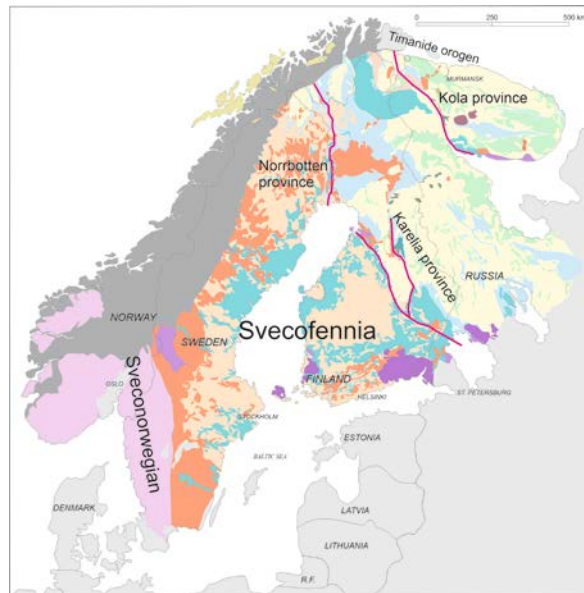
Crustal segments of East European Craton modified after Gorbatshev and Bogdanova, 1993

Eilu, P (ed), 2012. Mineral deposits and metallogeny of Fennoscandia
GTK Special Paper 53

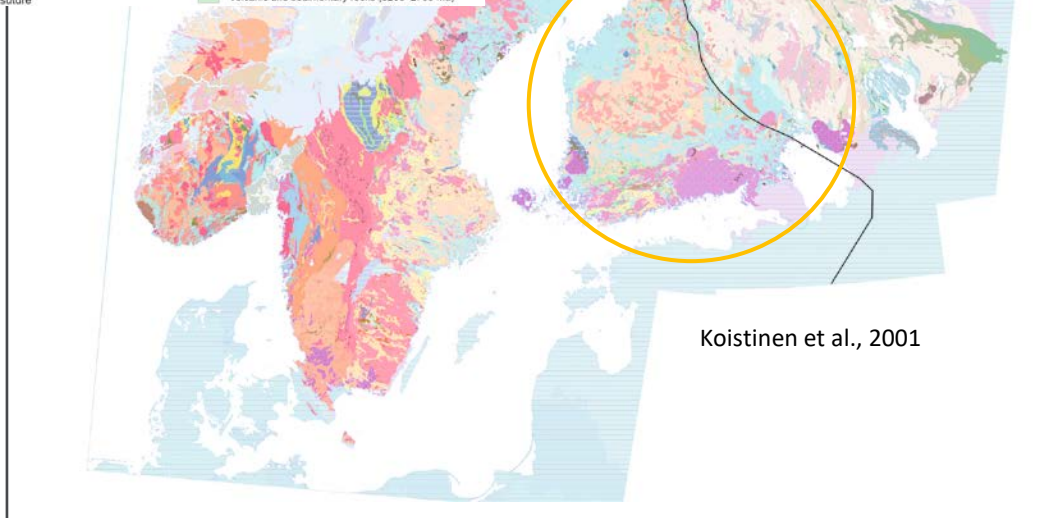
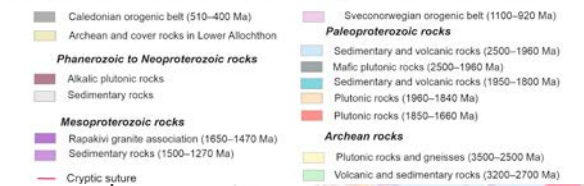
Maier, Lahtinen, O'Brien (eds.), 2015
Mineral Deposits of Finland
- Includes descriptions of most deposits referred to in this talk

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<https://www.gtk.fi/en/services/data-sets-and-online-services-geo-fi/map-services/>





Paleoproterozoic sutures
Kohonen et al., 2021



Koistinen et al., 2001

Main geological units in Finland

Crustal stabilization (1.76-1.65 Ga)
Up to present ≤ 1km sedimentary cover (Hall et al., 2020)

Paleoproterozoic crust

Svecofennian (2.0-1.77 Ga)
Lapland-Kola (2.0-1.87 Ga)
Cryptic sutures ca. 1.92-1.91 Ga

Archean crust

Paleoproterozoic magmatism and sedimentary cover (2.50-1.92 Ga)
- Rifting stages at 2.5, 2.45, 2.3, 2.2, 2.1-2.05, 2.0-1.95 Ga

Archean (3.6-2.6 Ga)

Archean

- 3.6 Ga + 3.2 Ga TTG (oldest)
- 2.83-2.72 Ga TTG (common)
- 2.74-2.68 Ga sanukitoids

- Oijärvi, Tipasjärvi, Kuhmo and Suomussalmi greenstone belts; 2.84-2.79 Ga, oceanic plateau type komatiites and basalts

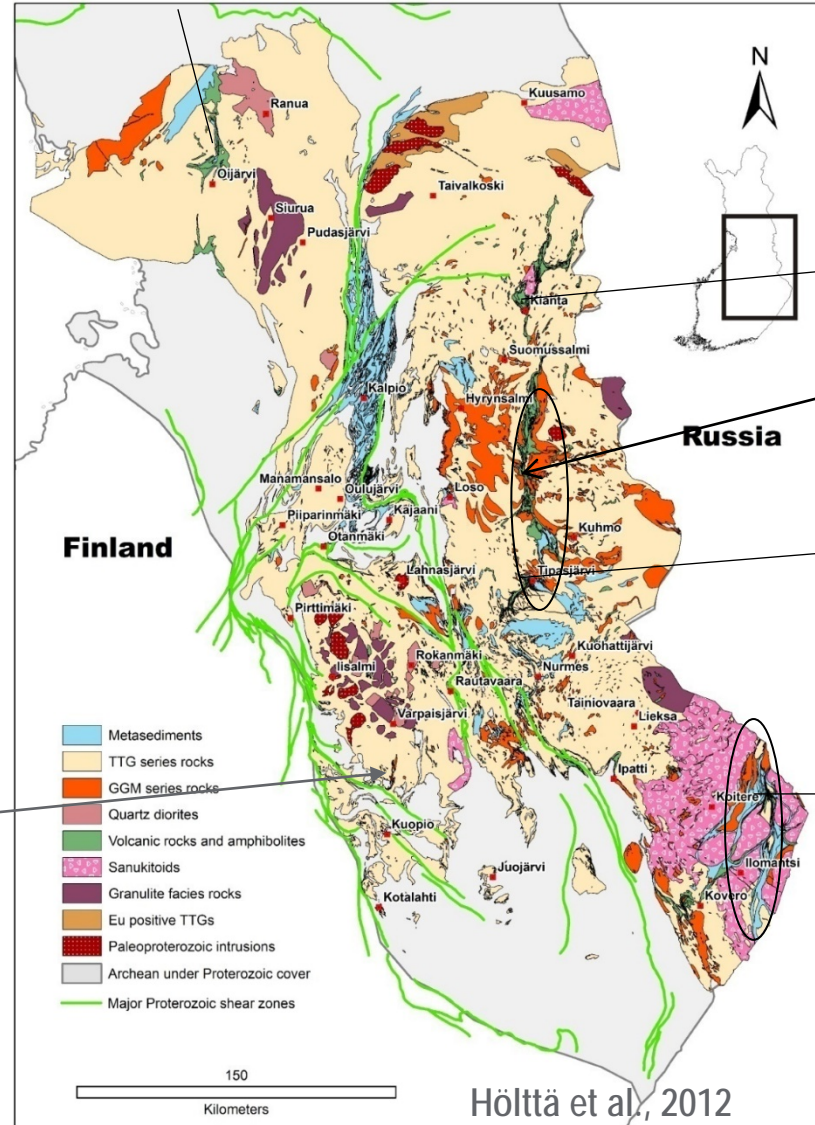
- Ilomantsi greenstone belts; 2.75-2.73 Ga island arc rocks

- Metamorphism 2.71-2.62 Ga

- Siilinjärvi carbonatite 2.61 Ga (apatite mine)

Oijärvi GB

- Au deposits



Suomussalmi GB

- Ni-, Au-, Mo-deposits

Kuhmo GB

- Ni-, Au-deposits

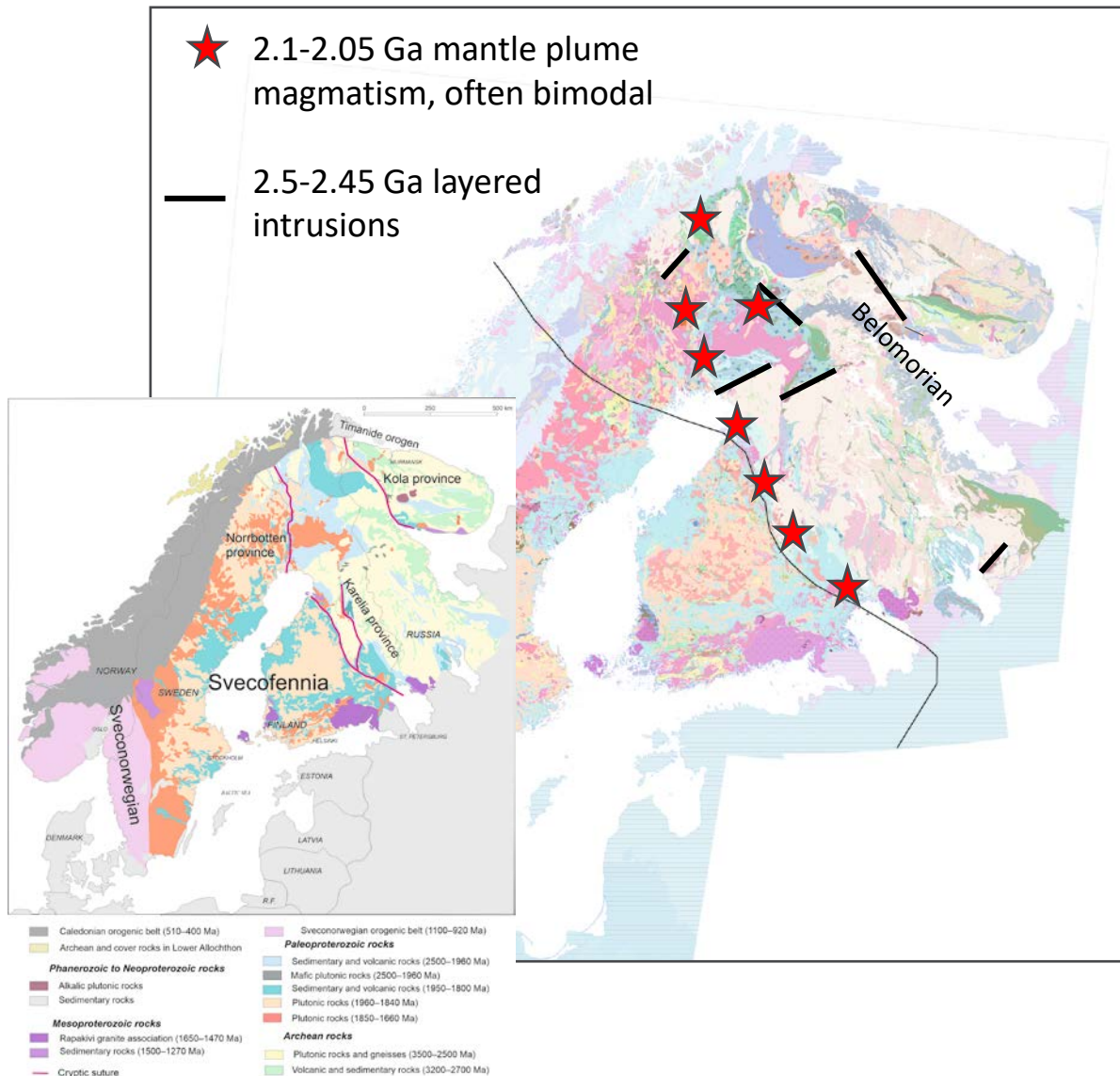
Tipasjärvi GB

- Sotkamo Ag-mine
- Ni-deposits

Ilomantsi GB

- Pampalo Au-mine (suspended)

Archean provinces: Norrbotten-Karelia-Kola



Archean crust exposed or under Paleoproterozoic rocks

Paleoproterozoic magmatism and sedimentary cover (2.50-1.92 Ga) at the western margin of the Karelia province

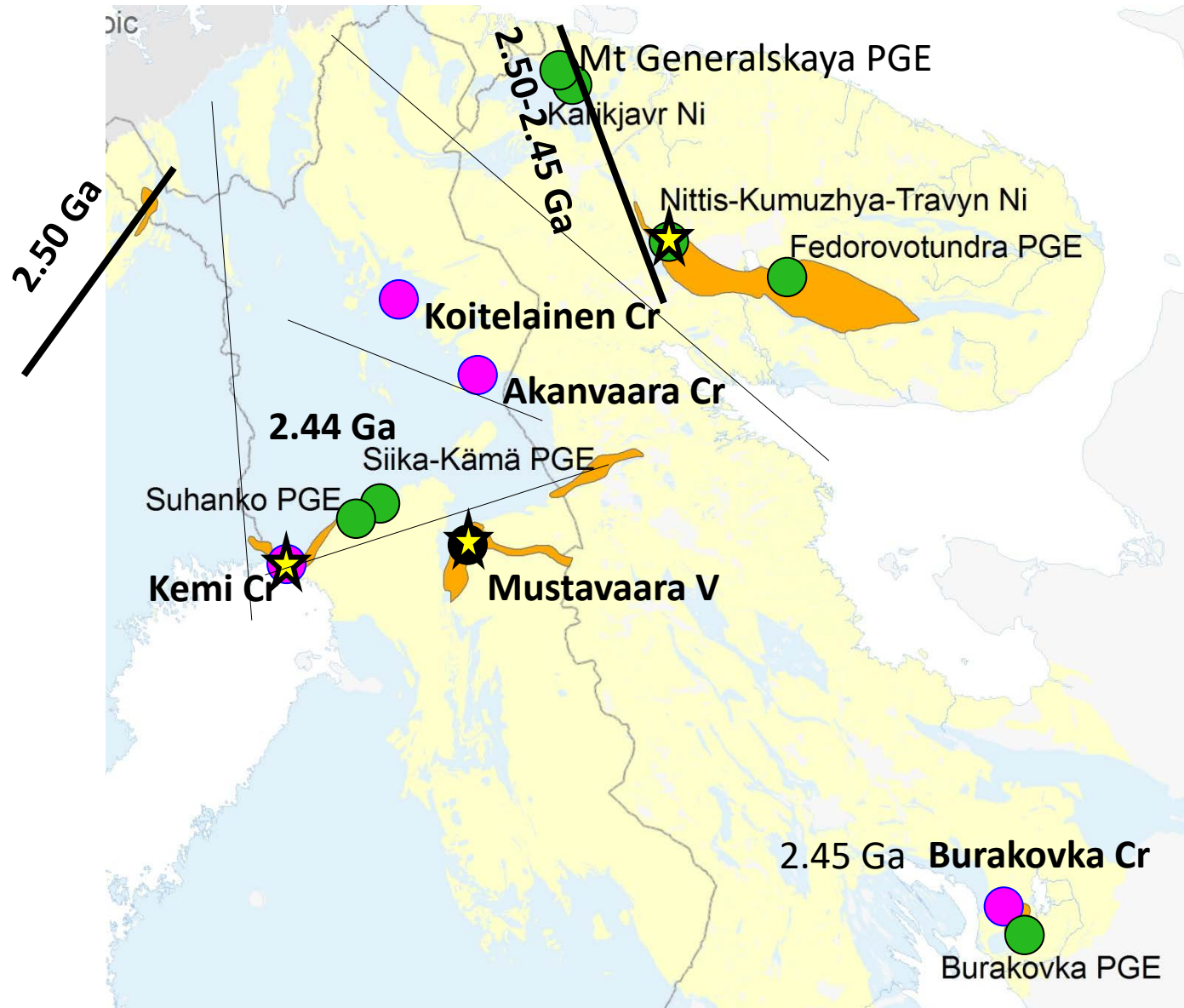
- Rifting stages at 2.5, 2.45, 2.3, 2.2, 2.1-2.05, 2.0-1.95 Ga
- 2.52-2.45 Ga incipient rifting, including layered intrusions
 - Was there a breakup?
- 2.4-2.1 Ga Epeiric sea setting in central Lapland
- 2.1-2.05 Ga breakup; aulacogen
- Passive margin stage to 1.94-1.92 Ga
- 1.98-1.95 Ga marginal basin (Jormua-Outokumpu system)
- Foreland basin system from 1.92 Ga to 1.86 Ga in Lapland
- See Köykkä et al., 2019.

Incipient break up: 2.50–2.44 Ga

Largest
PGE±Ni-Cu,
V-Ti,
Cr
deposits

★ Mine

Orange polygons:
Defined metallogenic belts with
2.50-2.44 Ga layered intrusions





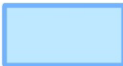







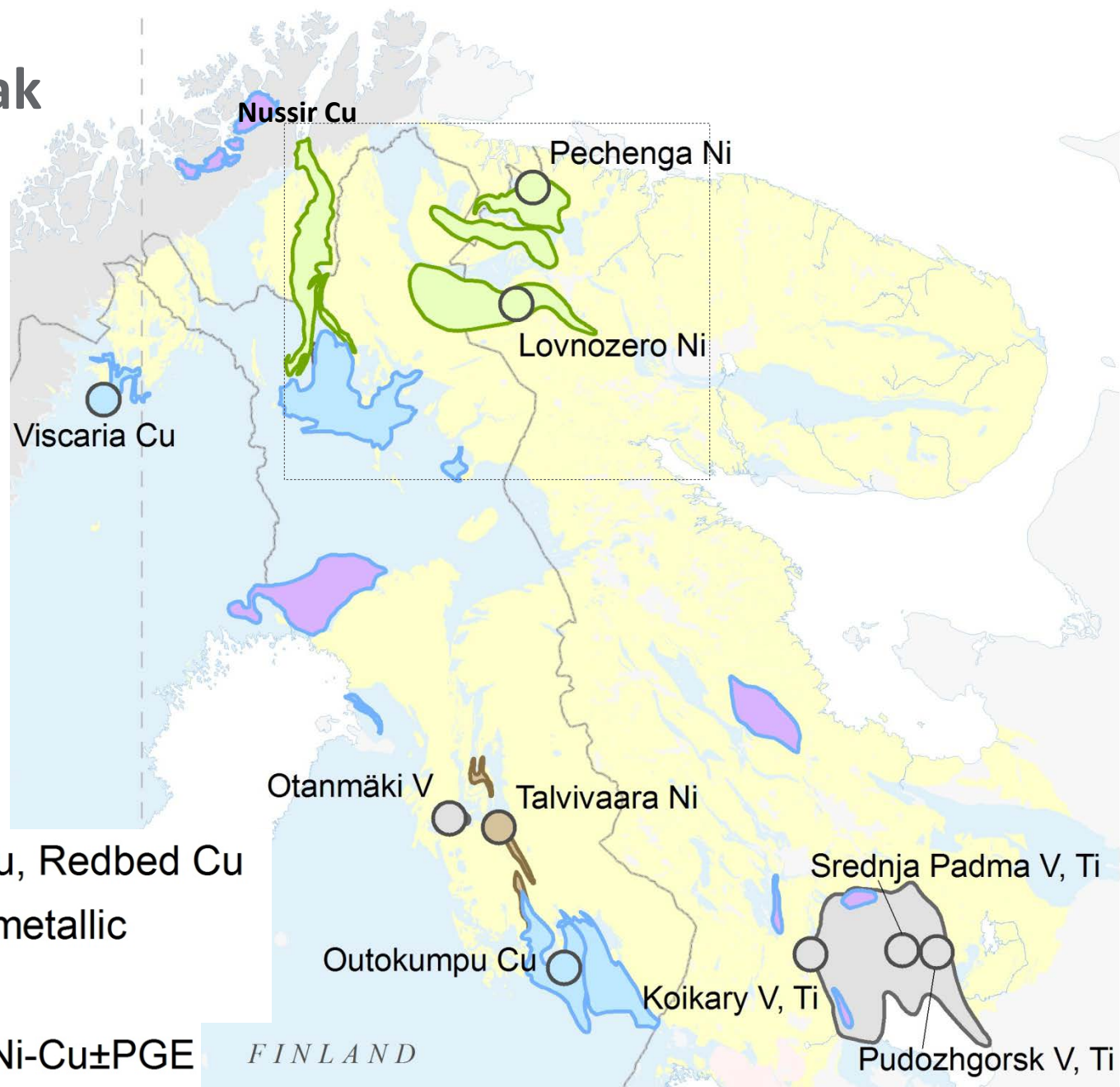
Kenorland final break up, intracontinental basins: 2.2–1.95 Ga

Talvivaara -sediment-hosted
low-grade Ni-Co-Cu-Zn

Outokumpu-type Cu-Co
Cu-rich proto-ore within
peridotitic sea floor at ~1950 Ma
Peltonen et al., 2008

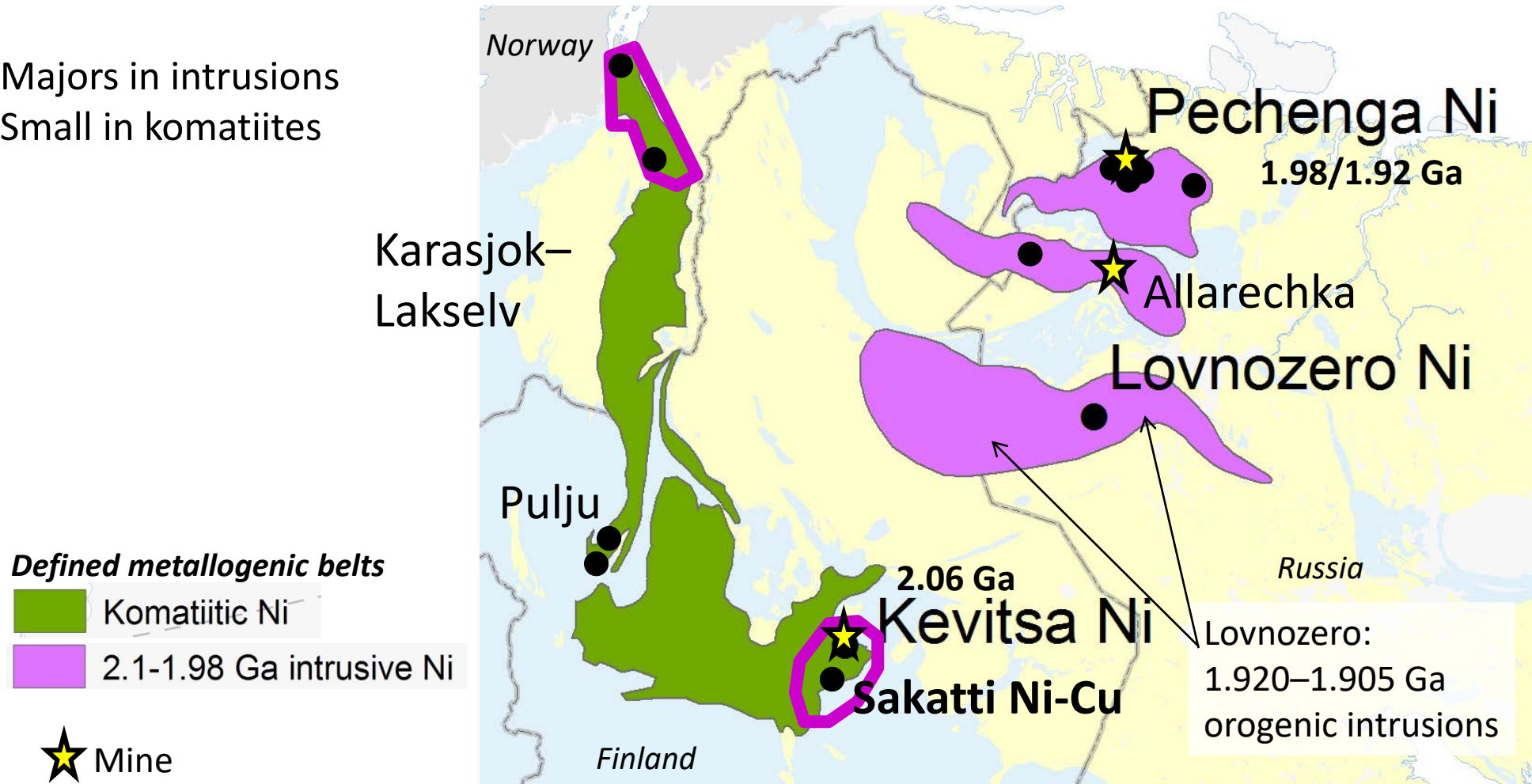
Defined metallogenic belts

-   Clastic-hosted Cu, Redbed Cu
-   Black shale polymetallic
-   Volcanic Cu-Zn
-   Mafic-ultramafic Ni-Cu±PGE
-   Intrusion-hosted V-Ti-Fe

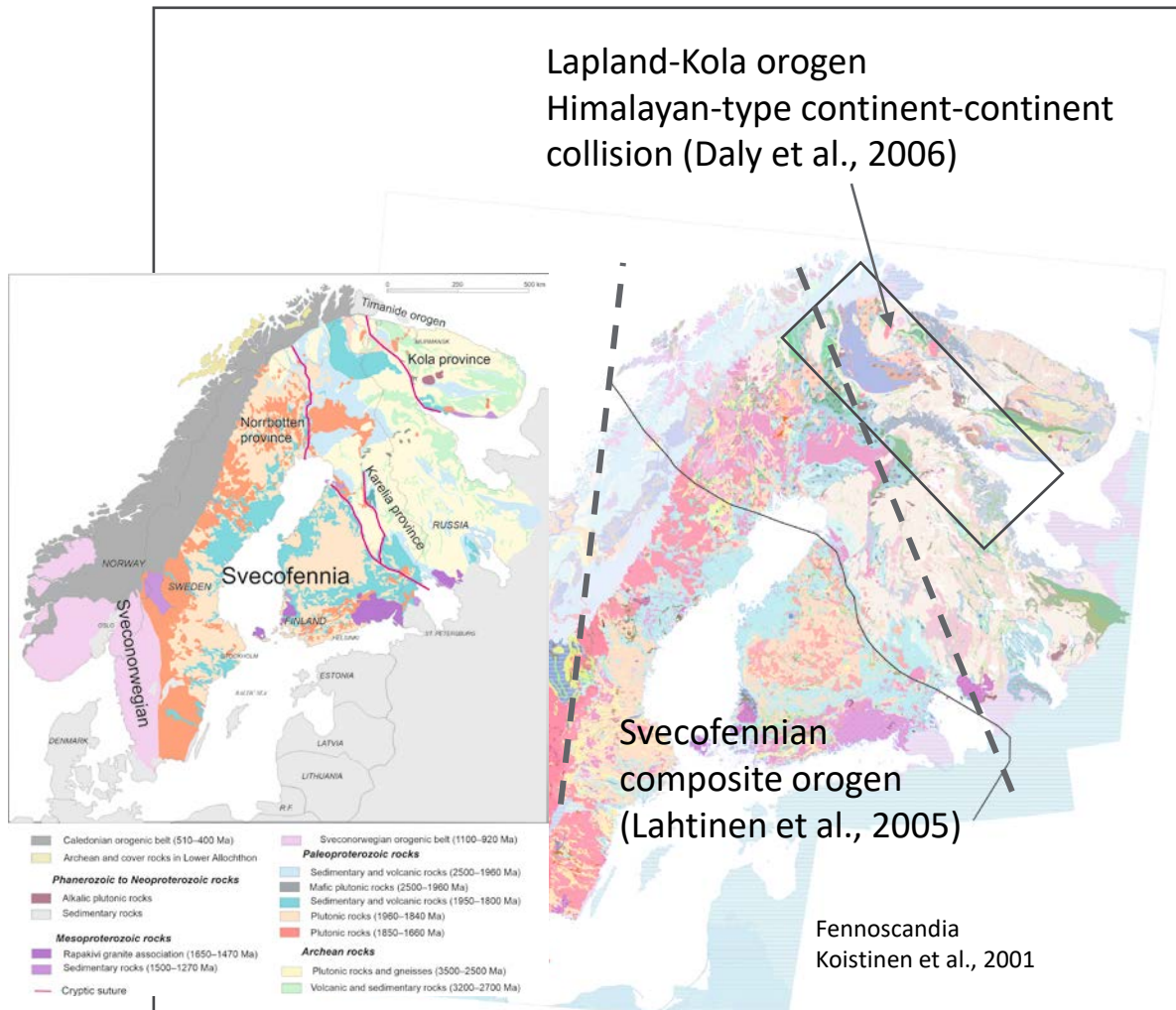


Kenorland final break up, mafic-ultramafic magmatism: 2.1–1.95 Ga

- Majors in intrusions
- Small in komatiites



Major Paleoproterozoic orogenic stages in Finland



Paleoproterozoic major orogenies

Svecofennian orogeny (1.92-1.77 Ga)

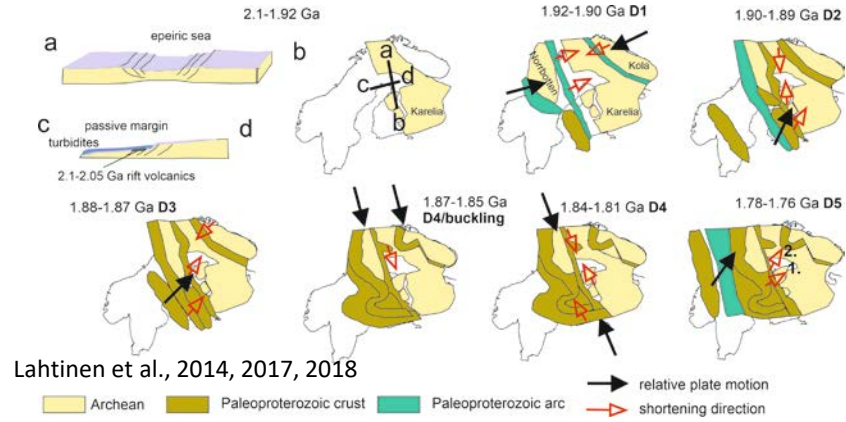
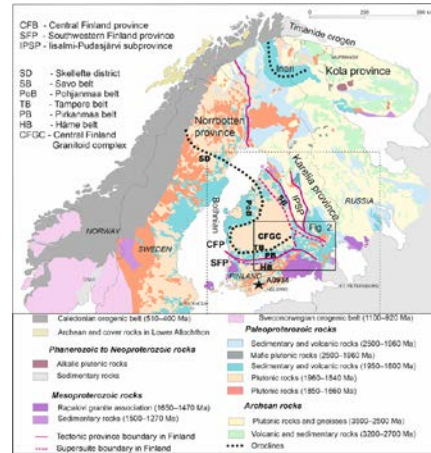
- Several collisional stages at 1.92 Ga, 1.88 Ga, 1.86 Ga, 1.83 Ga, 1.78 Ga
- Orocline forming event at 1.87 Ga

Lapland-Kola orogeny (1.92-1.87 Ga)

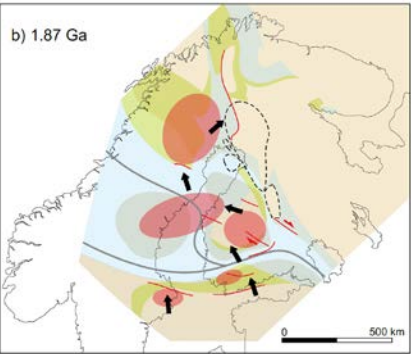
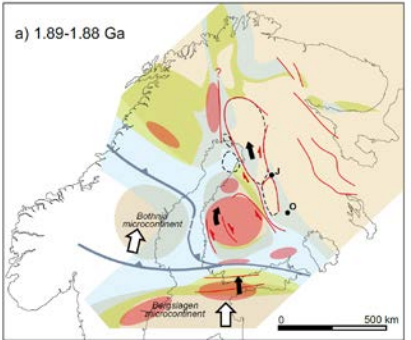
Cryptic sutures ca. 1.92-1.91 Ga

- Jormua-Outokumpu suture is non-subduction and due to closure of a marginal basin (note Archean lithospheric mantle and abundant Cu-Co deposits;)

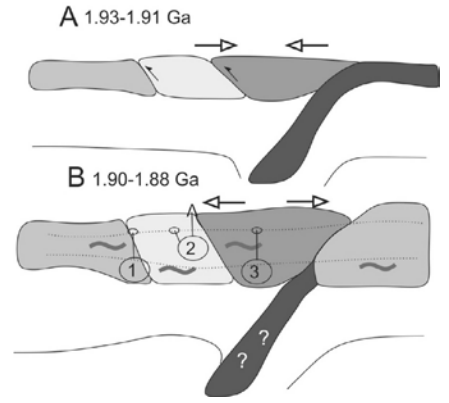
Svecofennian tectonic evolution – many models



Lahtinen et al., 2014, 2017, 2018



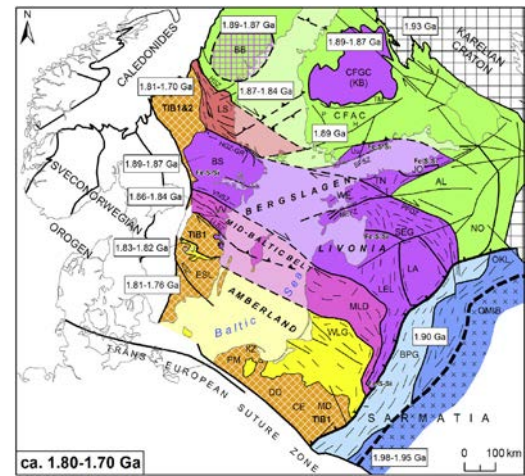
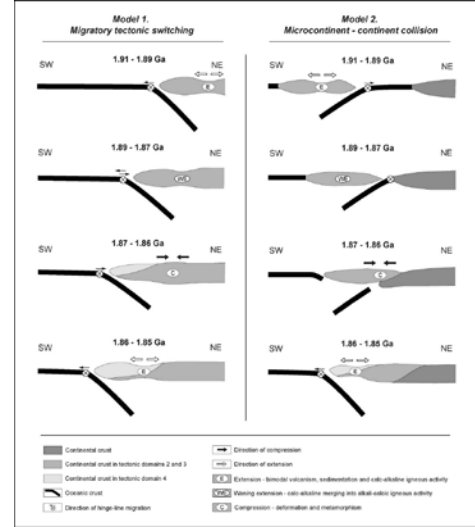
Nironen, 2017



Korja et al., 2009
Nikkilä et al., 2016

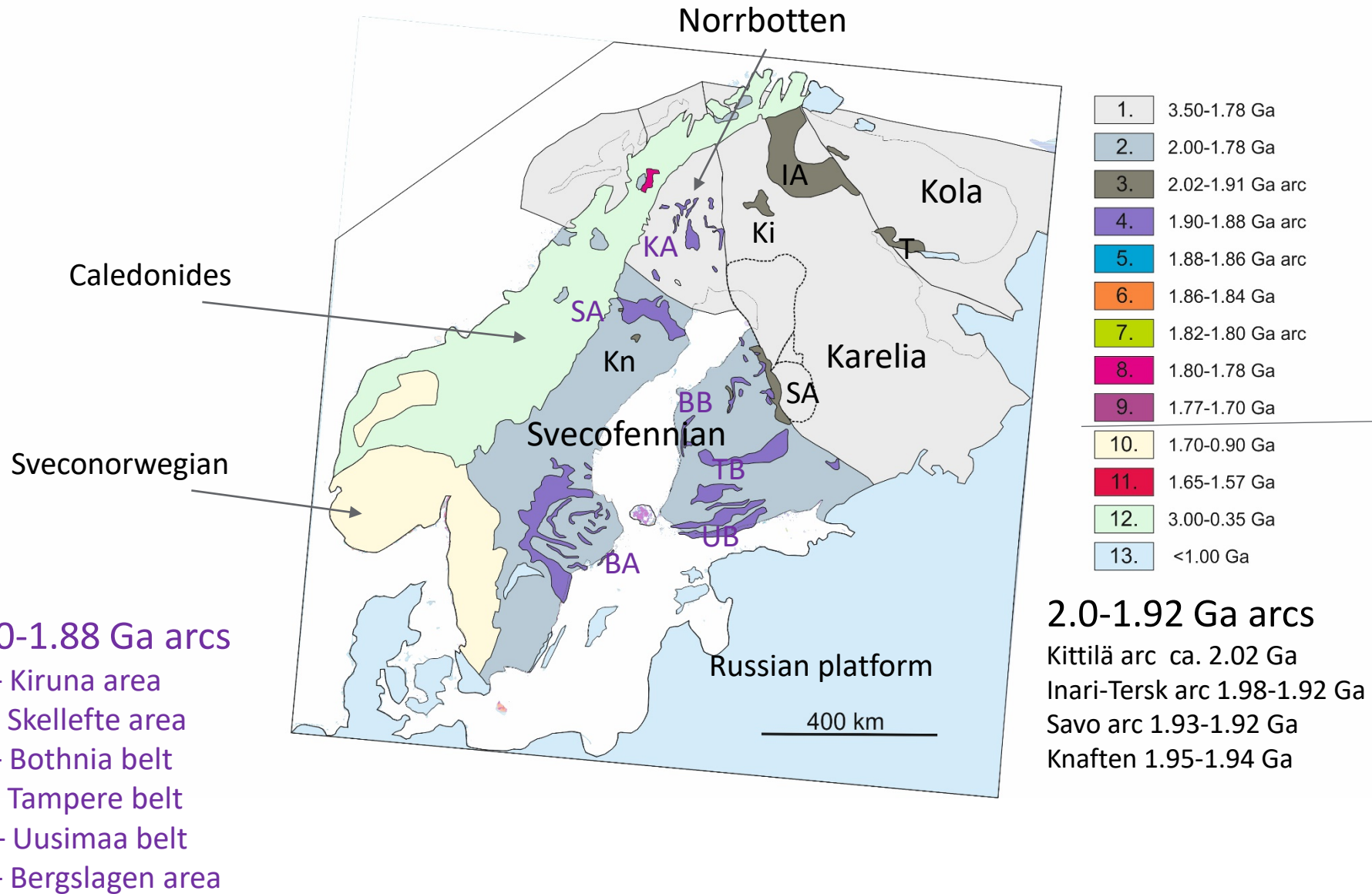
- Tectonic switching – SW accretion (e.g., Hermansson et al., 2008; Bogdanova et al., 2015; W accretion (Mints et al., 2020)
- Microcontinent accretion (Lahtinen et al., 2005; Korja et al., 2006; Nironen, 2017)
- Collisions, accretion and oroclines (Lahtinen et al., 2014, 2017, 2018)
- Crustal spreading in central Finland (Korja et al., 2009; Nikkilä et al., 2016)

Hermansson et al., 2008

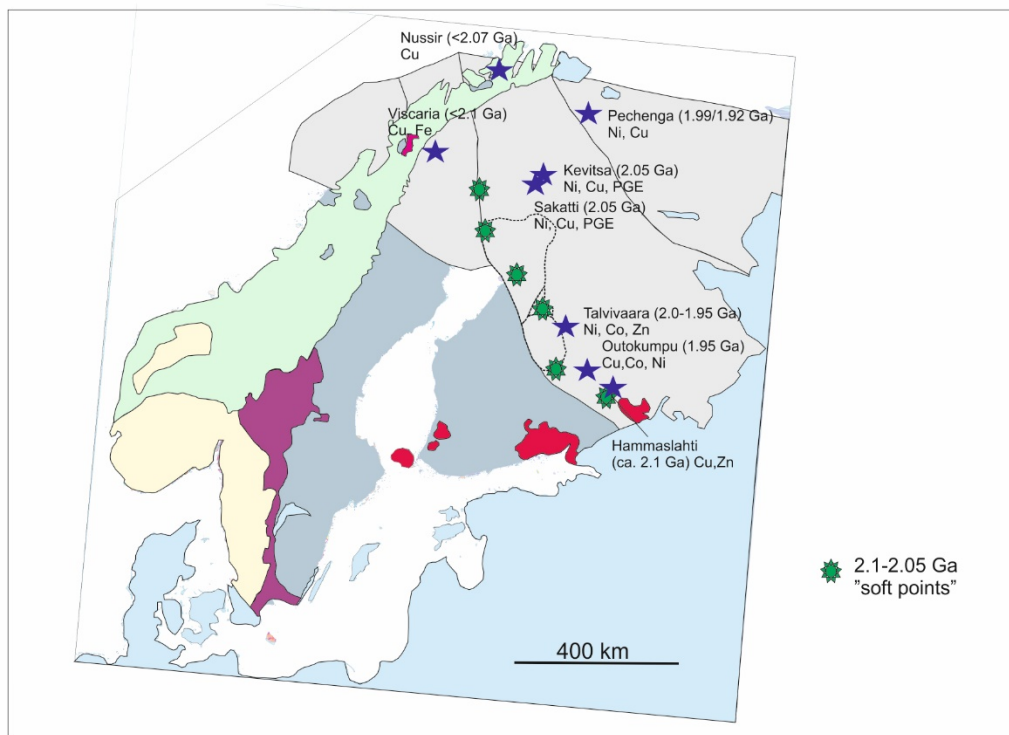


Bogdanova et al., 2015

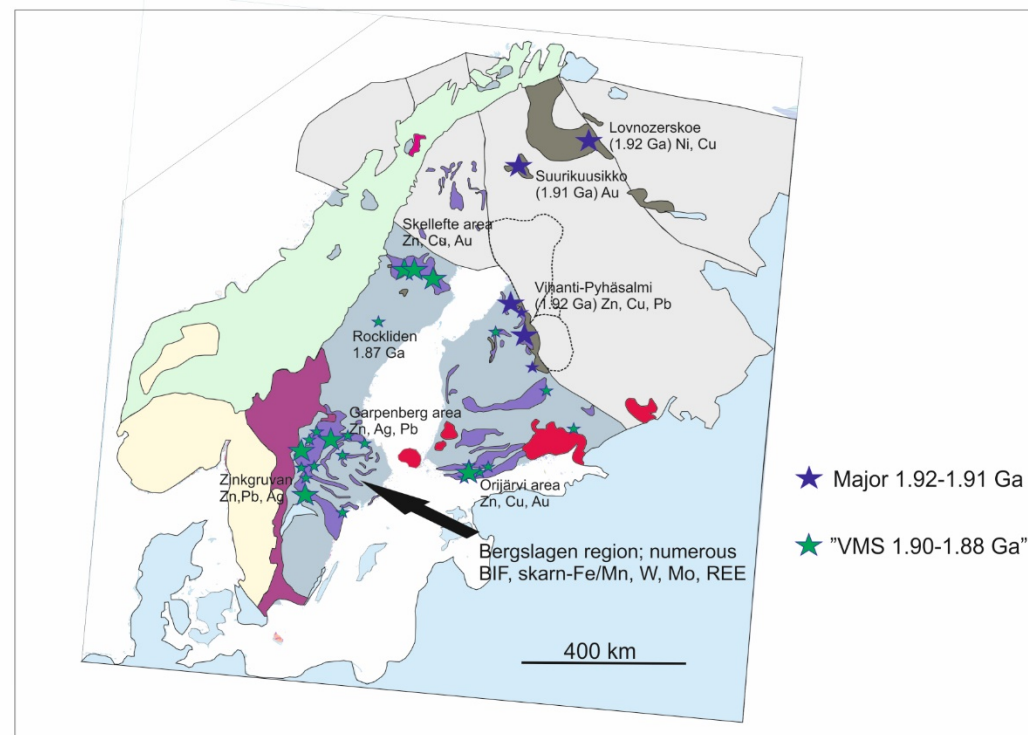
Major Paleoproterozoic arcs



Major metallogenic features at 2.1-1.89 Ga

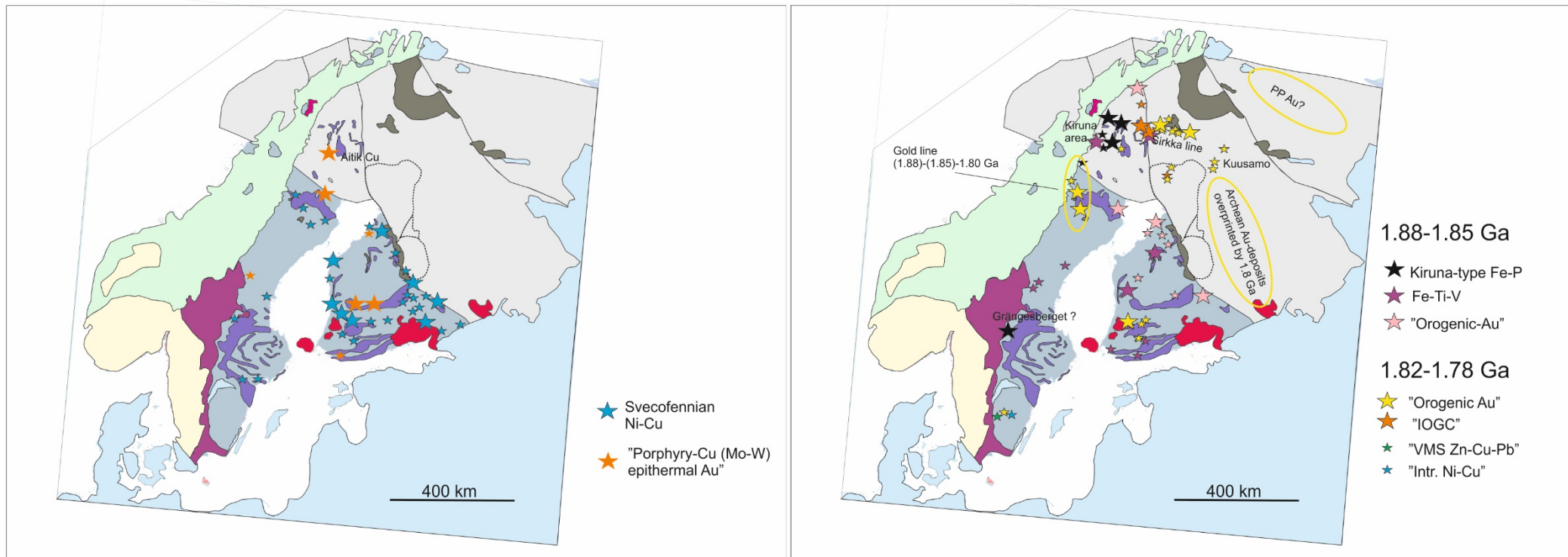


Rift-related deposits +
sedimentary deposits (Nussir and Talvivaara)



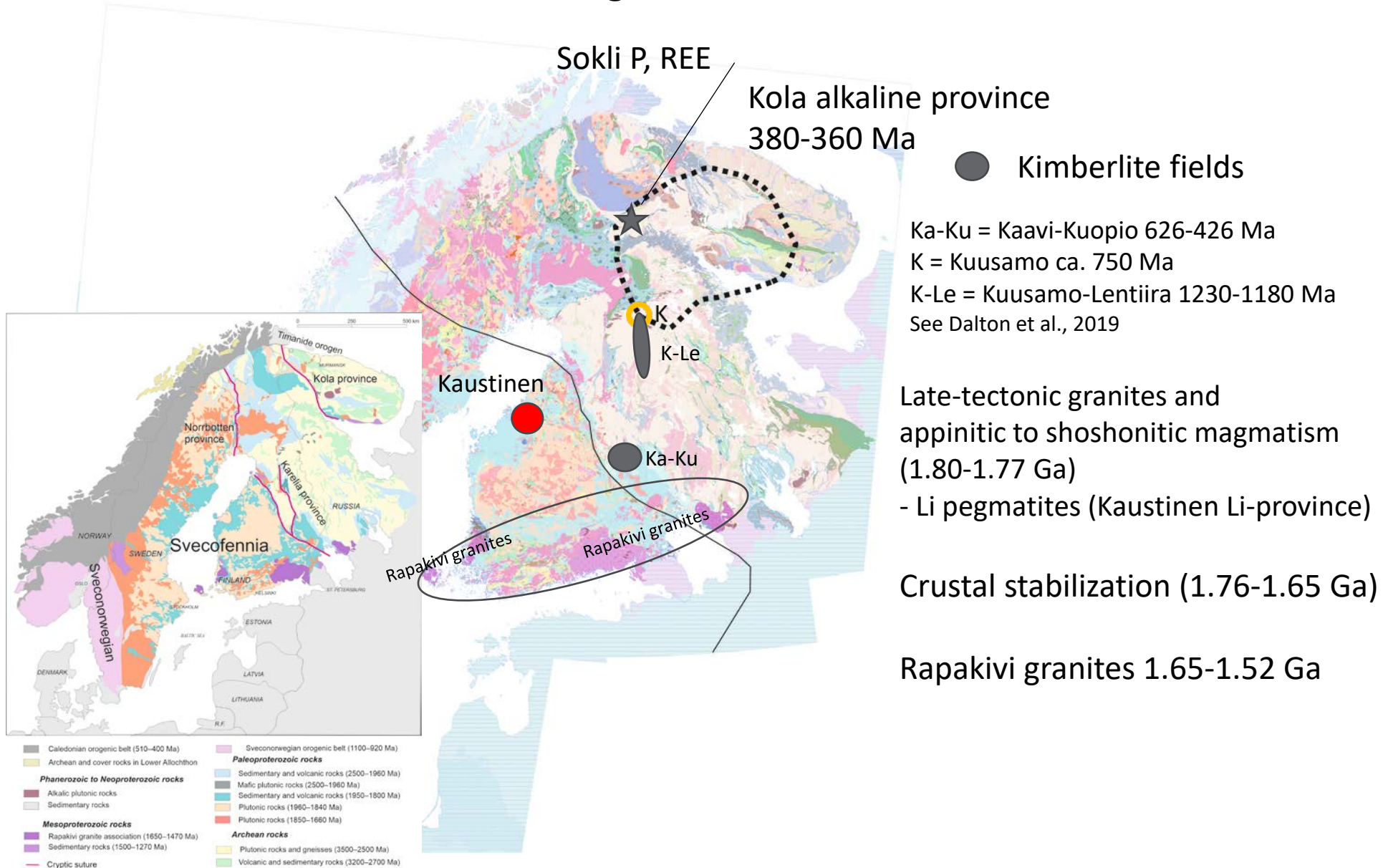
Lovrozenskoe plutonic Ni-Cu
Suurikuusikko orogenic Au
Vihanti-Pyhäsalmi VHMS
Skellefte VHMS
Orijärvi (Bergslagen-type VHMS)

Selected metallogeny at 1.89-1.78 Ga



Epithermal 1.90-1.88 Ga
 Porphyry Cu ca. 1885-1880 Ma
 Plutonic Ni-Cu 1882±2 Ma

Late-tectonic to cratonic stage



- **Concluding remarks for metallogeny of Finland**
- Archean crust in Finland is characterized by mid-crustal exhumation level with few shallow (2-5 km) greenstone belts (Au, Ag, Ni)
- Incipient rifting at 2.52-2.44 Ga includes voluminous layered intrusions - PGE-Cr-Ni-Cu
- Continental breakup at 2.1-2.05 Ga by mantle plume is very potential stage for Ni-Cu-PGE, especially in the aulacogen (Kevitsa, Sakatti); voluminous komatiites
- Renewed rifting and formation of a marginal basin/s: Outokumpu-type Cu-Co, Talvivaara Ni-Cu-Co-Zn
- 1.93-1.92 Ga arc, and VHMS deposits in extended backarc (Pyhäsalmi-Vihanti)
- Foreland fold and thrust belt related orogenic Au (Suurikuusikko)
- 1.90-1.88 Ga arc (Orijärvi-type VHMS+Au) and 1.88 Ga syntectonic Ni (Vammala-Kotalahti)
- Orogenic Au, especially at ca. 1.80 Ga

Thanks