

ORORGENIC GOLD MINERAL SYSTEMS IN FINLAND

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Geological Survey of Finland

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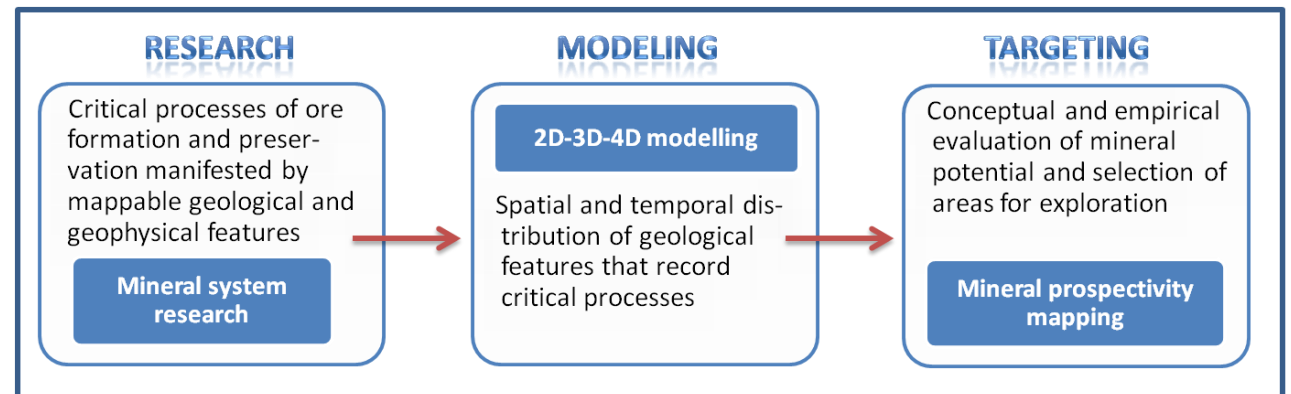
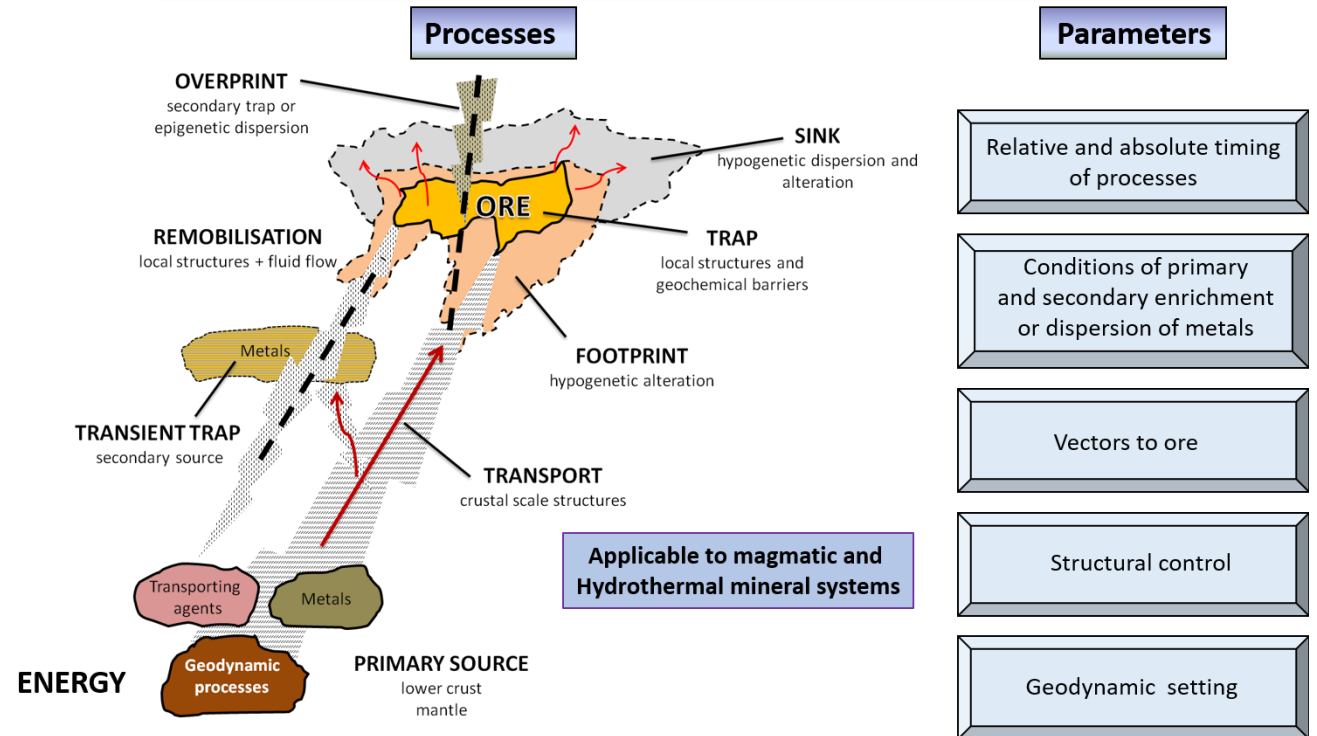
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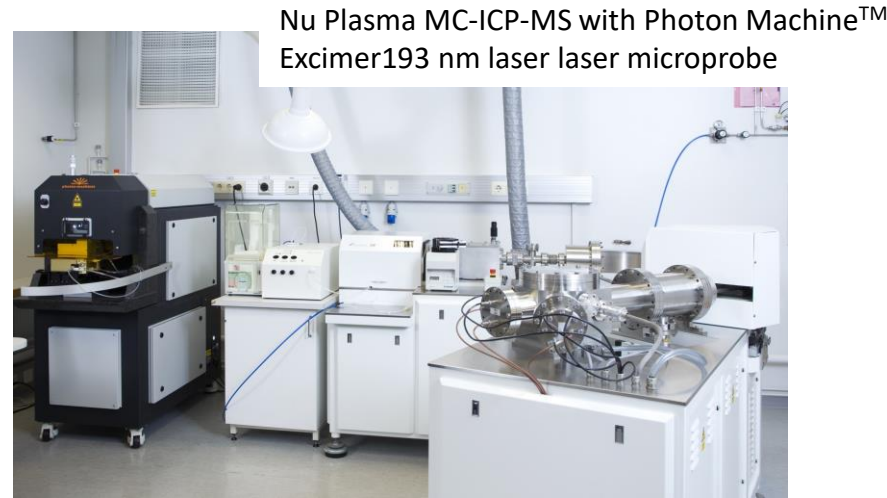
Mineral Systems: Critical Processes and Parameters



Laboratories for mineral systems research at GTK



Mineralogy, mineral chemistry

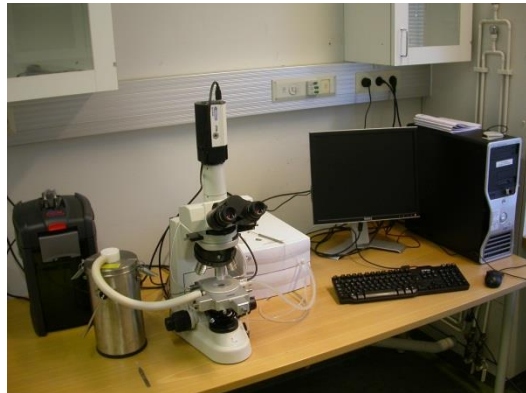


Geochronology, stable and radiogenic isotopes, trace elements

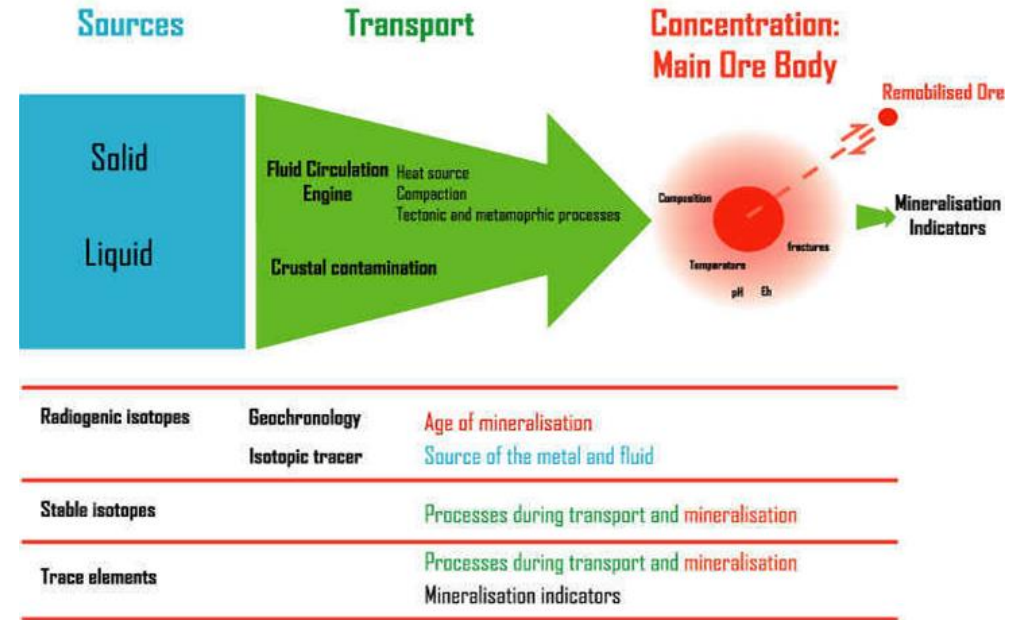
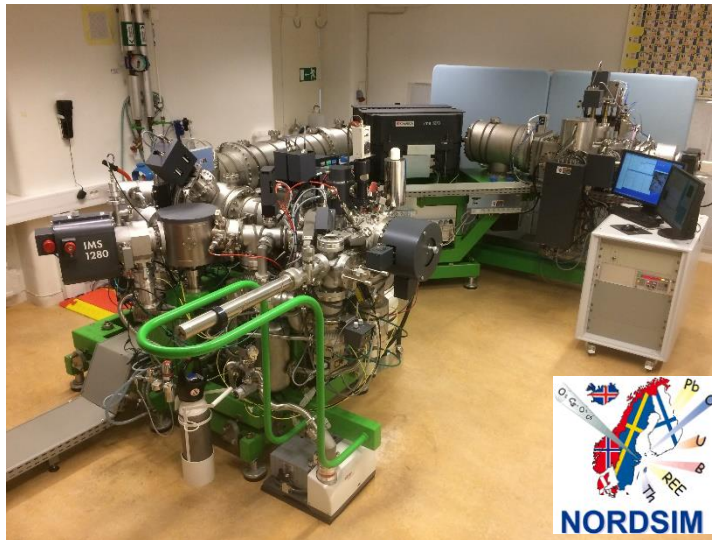


Linkam MDSG 600 microT

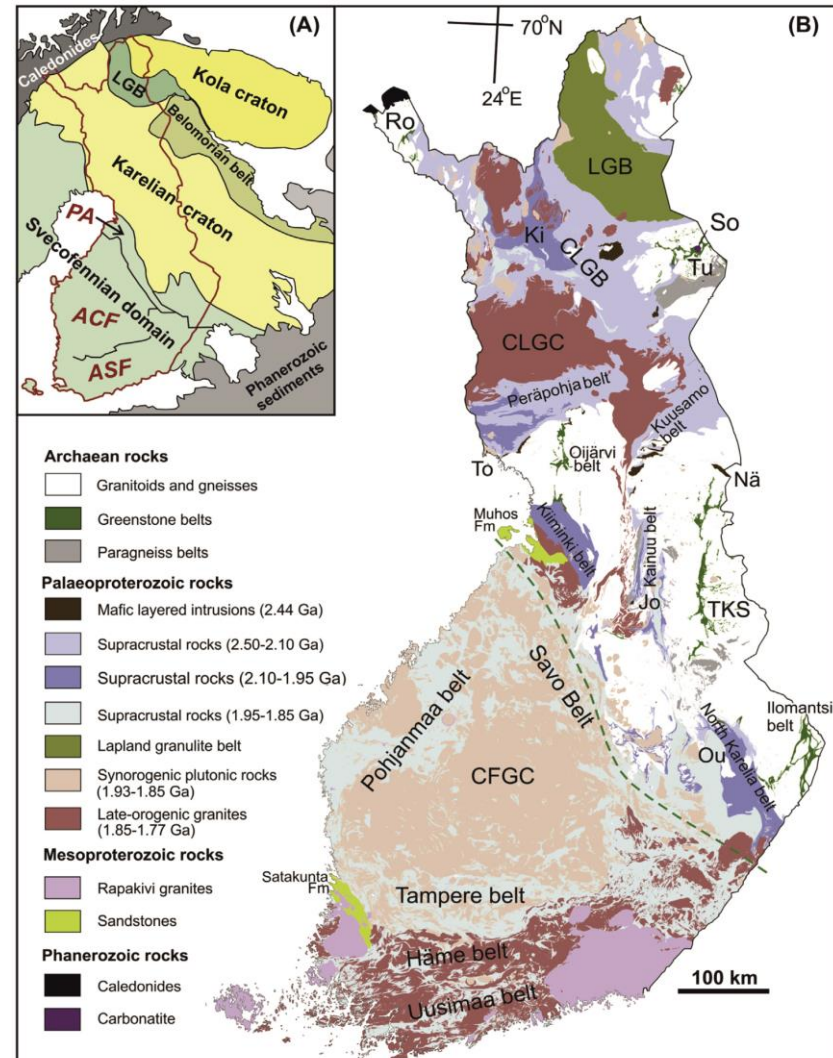
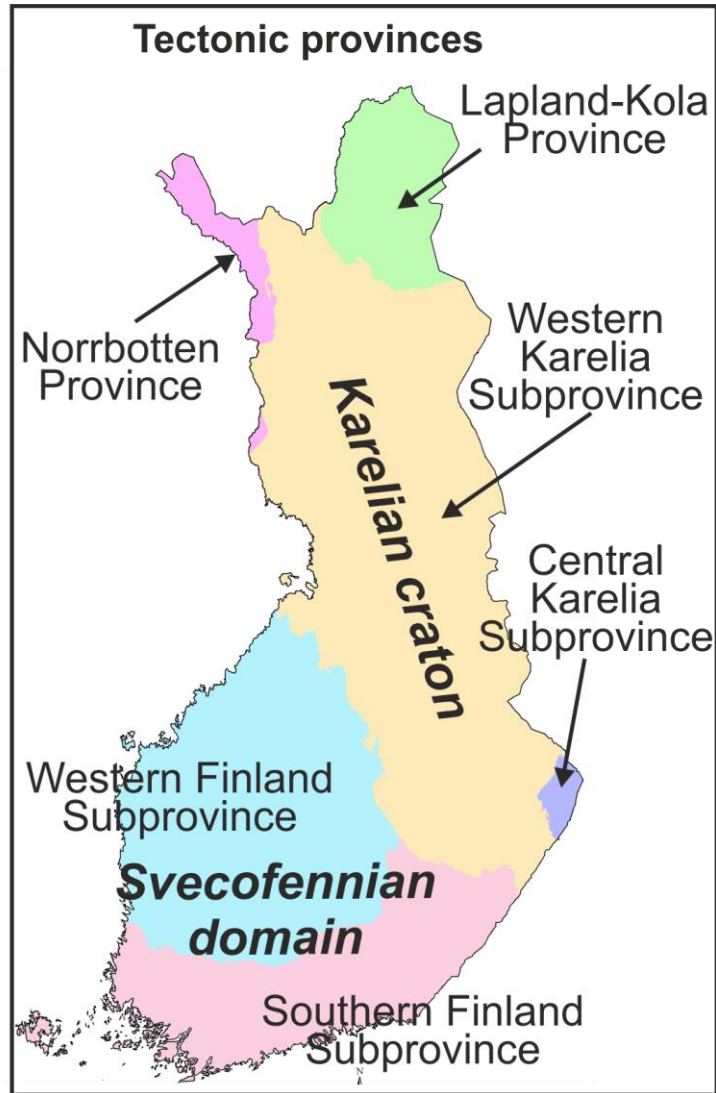
Access to CAMECA ims1280 ion microprobe
NORDSIM, Stockholm



Fluid inclusions



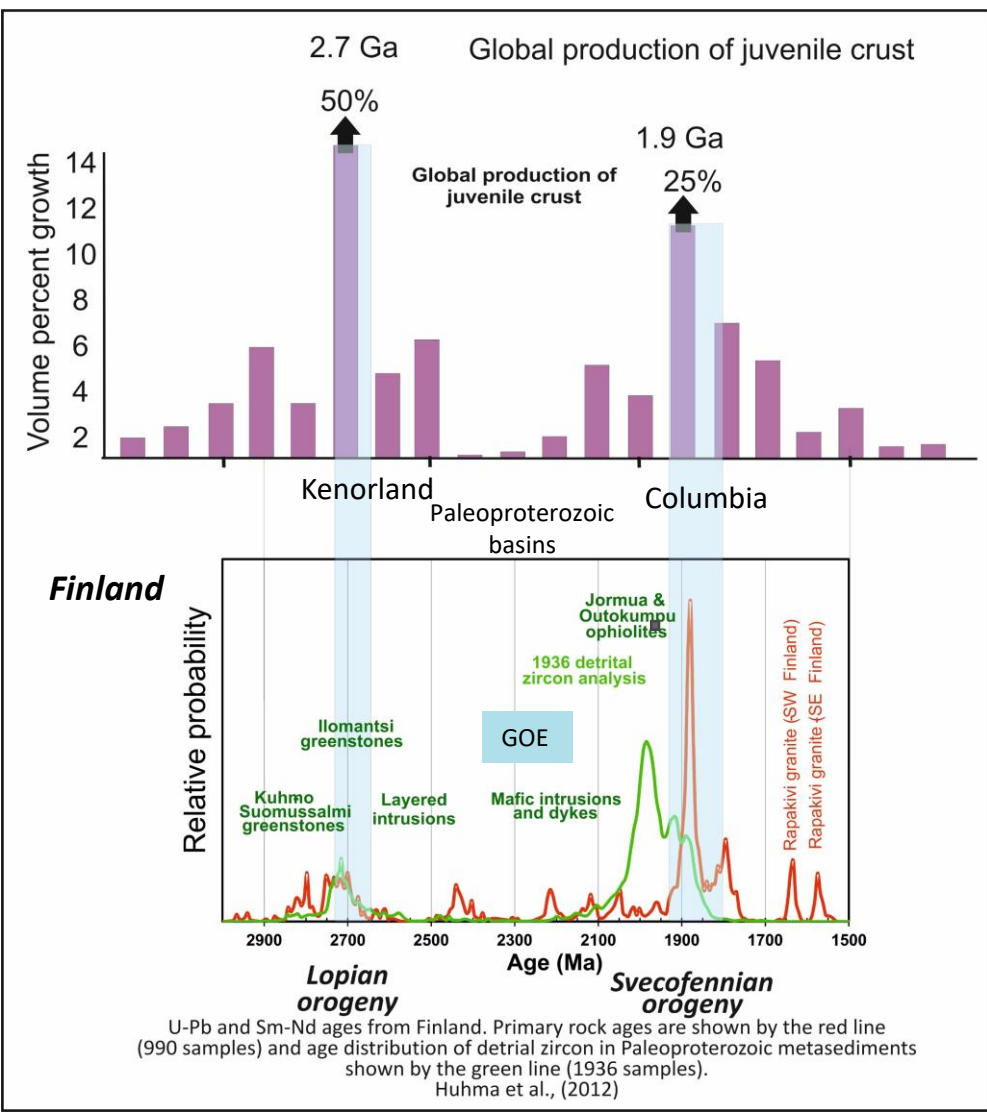
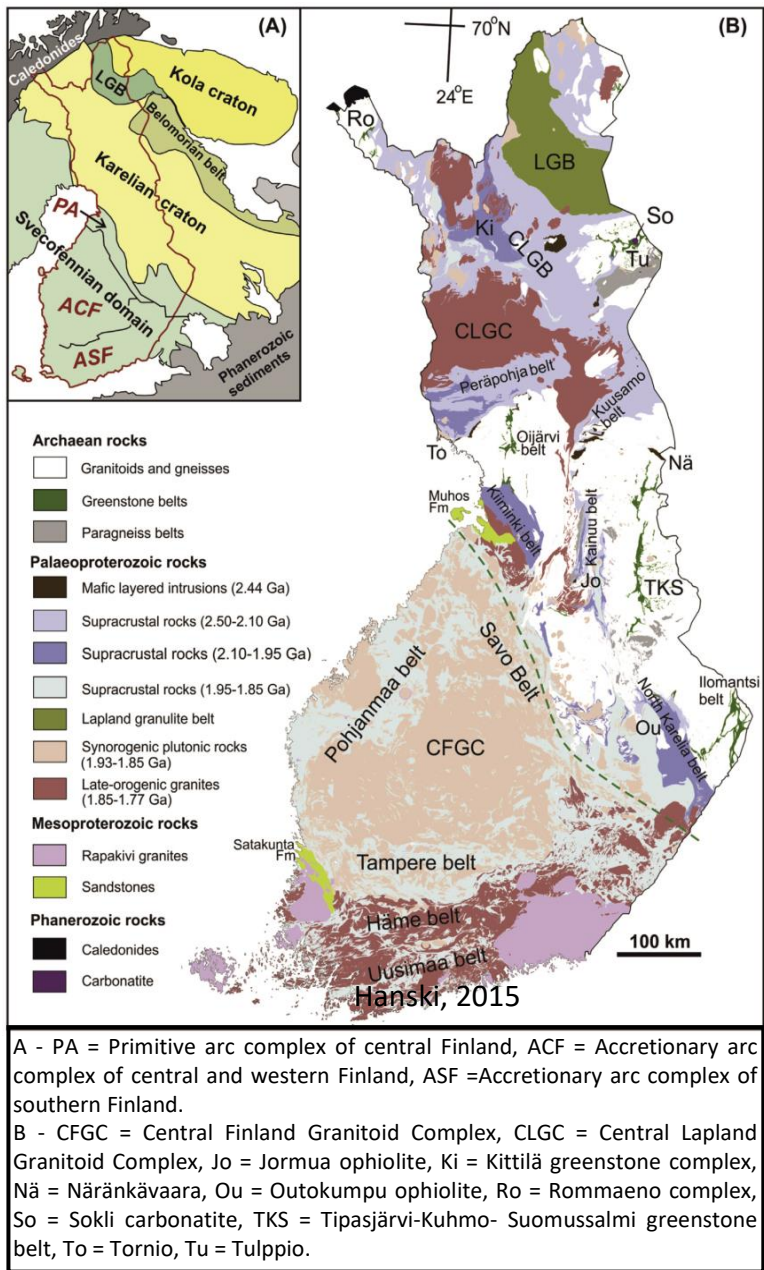
Lithosphere architecture in Finland



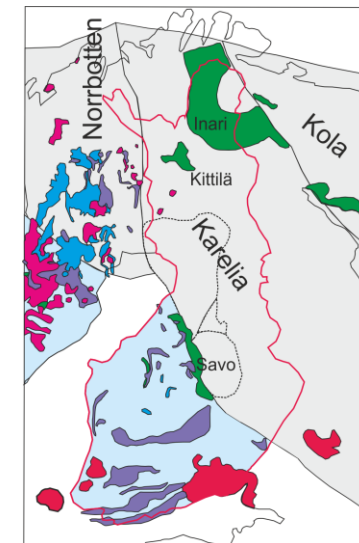
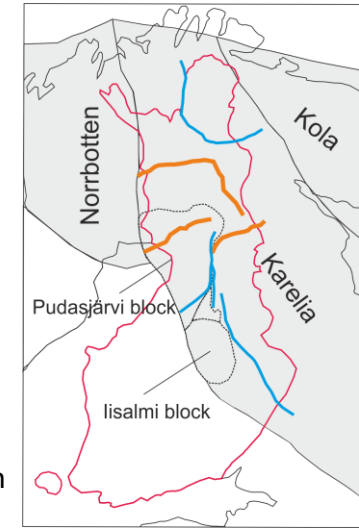
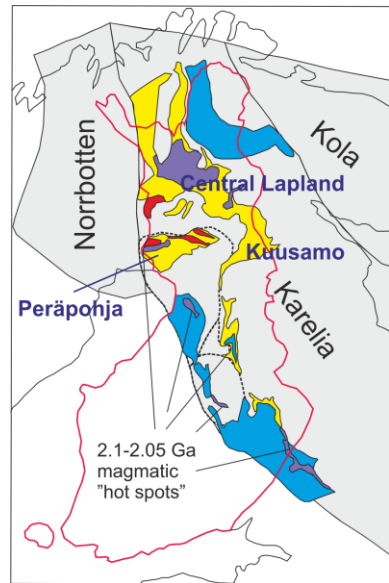
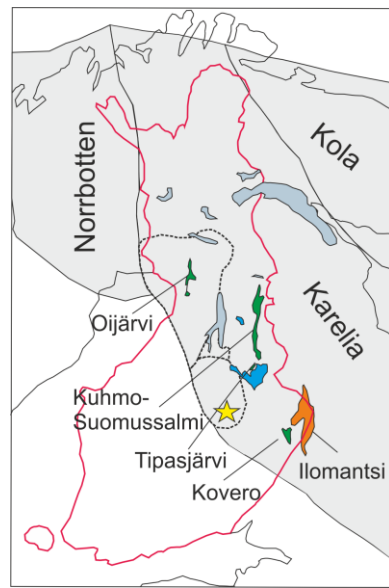
A - PA = Primitive arc complex of central Finland, ACF = Accretionary arc complex of central and western Finland, ASF = Accretionary arc complex of southern Finland.

B - CFGC = Central Finland Granitoid Complex, CLGC = Central Lapland Granitoid Complex, Jo = Jormua ophiolite, Ki = Kittilä greenstone complex, Nä = Näränkäväära, Ou = Outokumpu ophiolite, Ro = Rommaeno complex, So = Sokli carbonatite, TKS = Tipasjärvi-Kuhmo- Suomussalmi greenstone belt, To = Tornio, Tu = Tulppio.

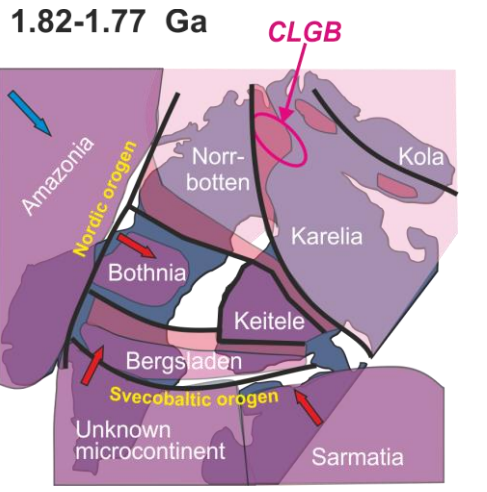
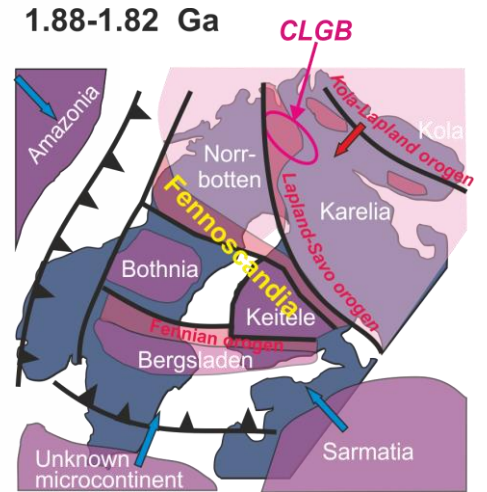
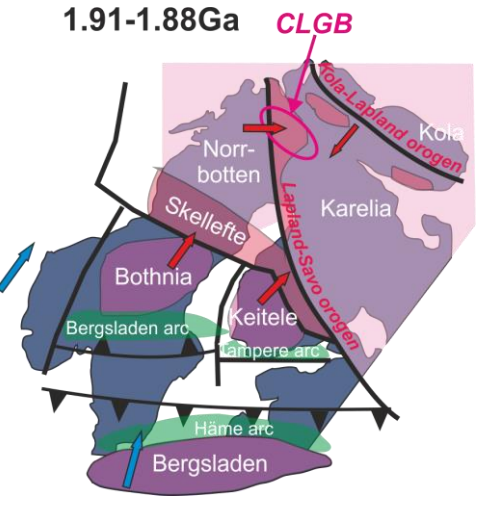
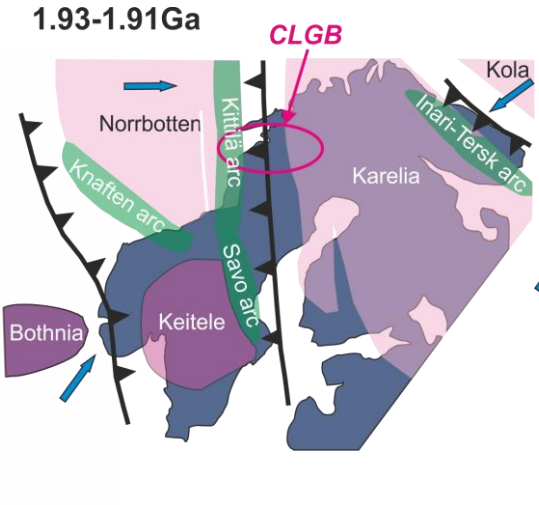
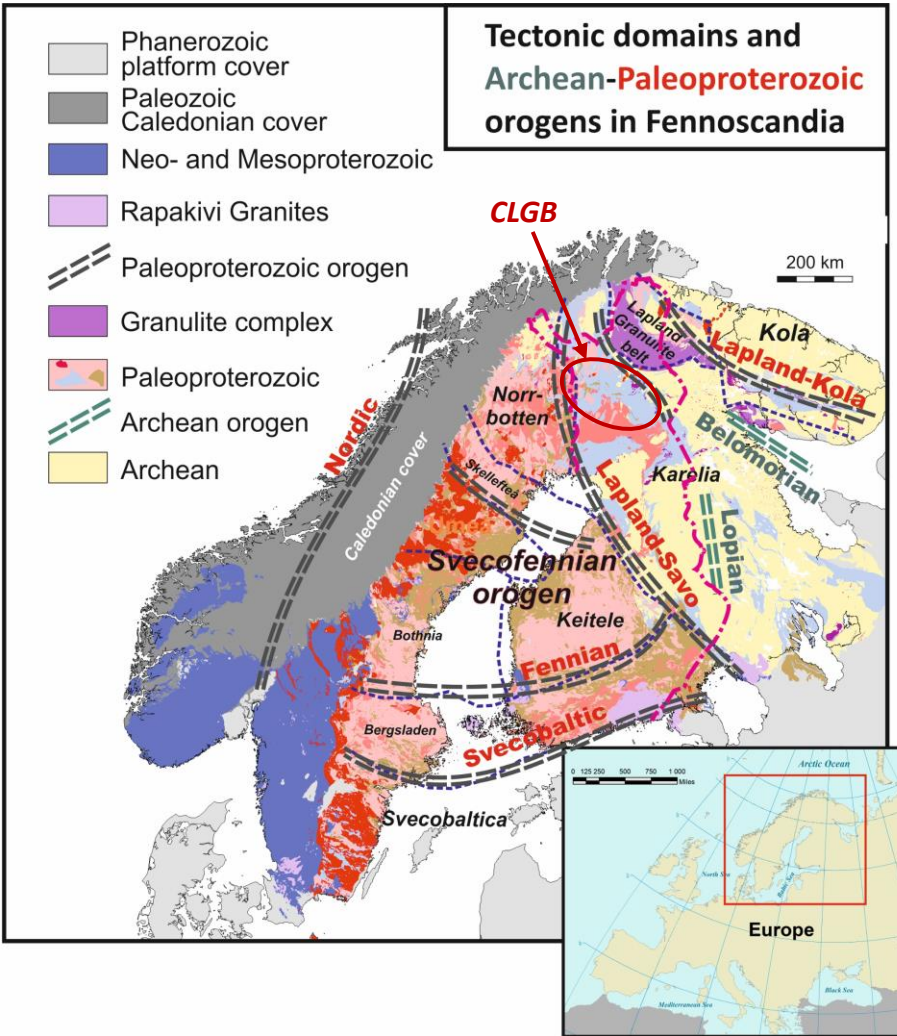
Development of the Fennoscandian lithosphere architecture: Archean and Paleoproterozoic orogenies in Finland



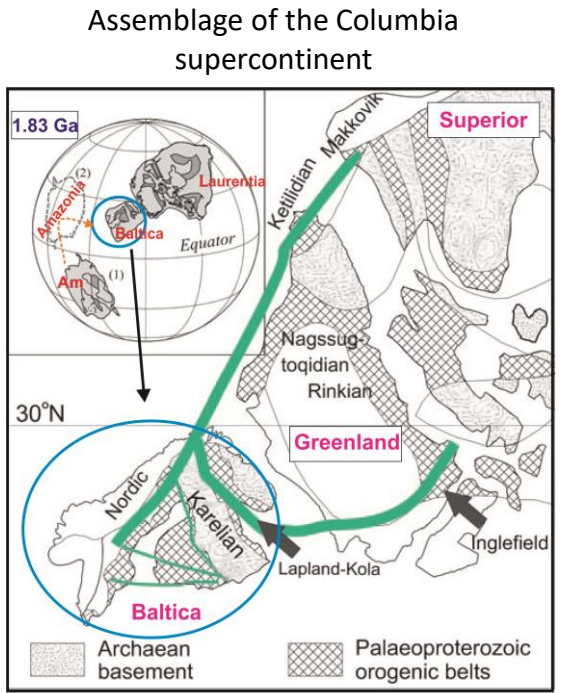
Lithosphere architecture and orogens in Finland



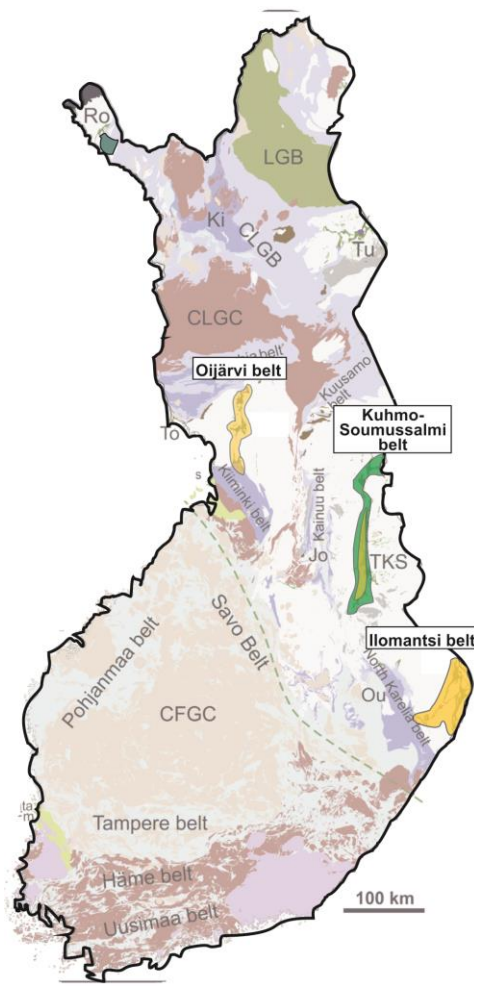
Svecofennian orogeny: Paleoproterozoic amalgamation of Fennoscandia



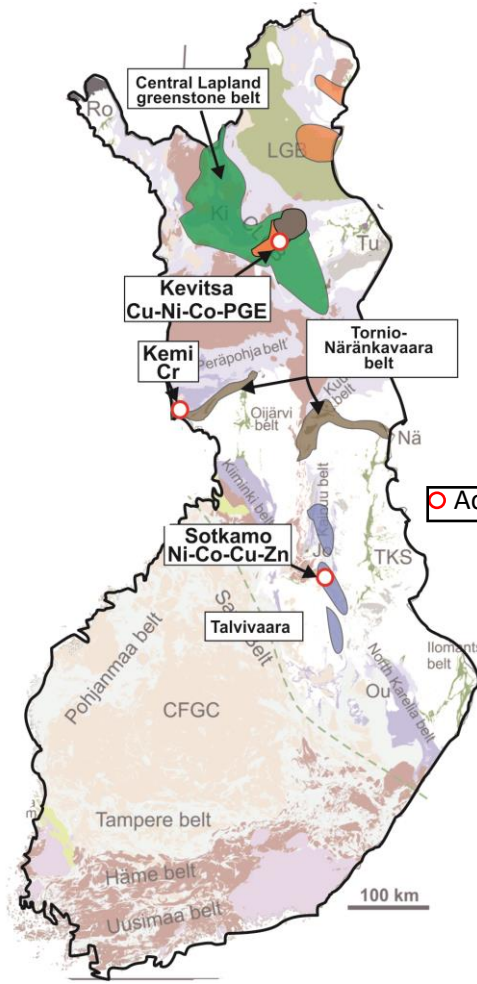
Lahtinen et al., 2005



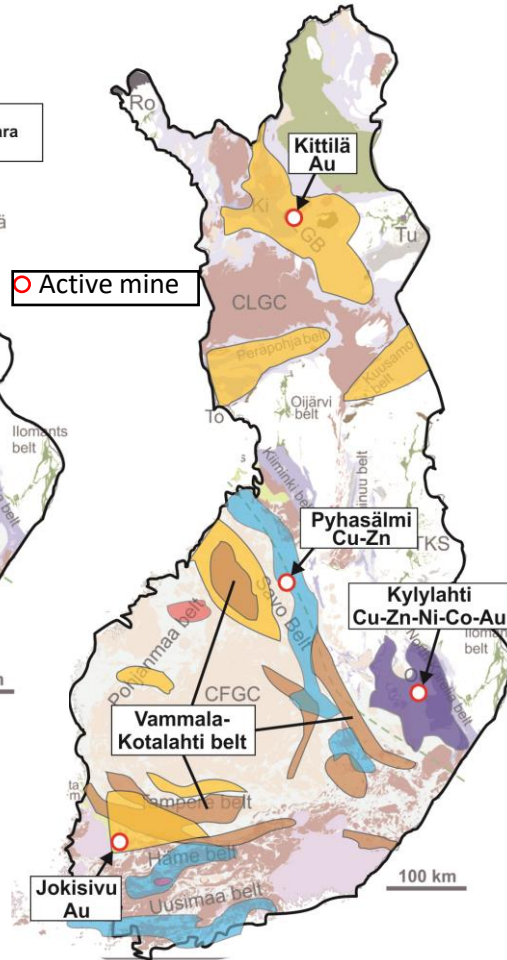
Lahtinen et al. (2008)



Archean



Paleoproterozoic basins

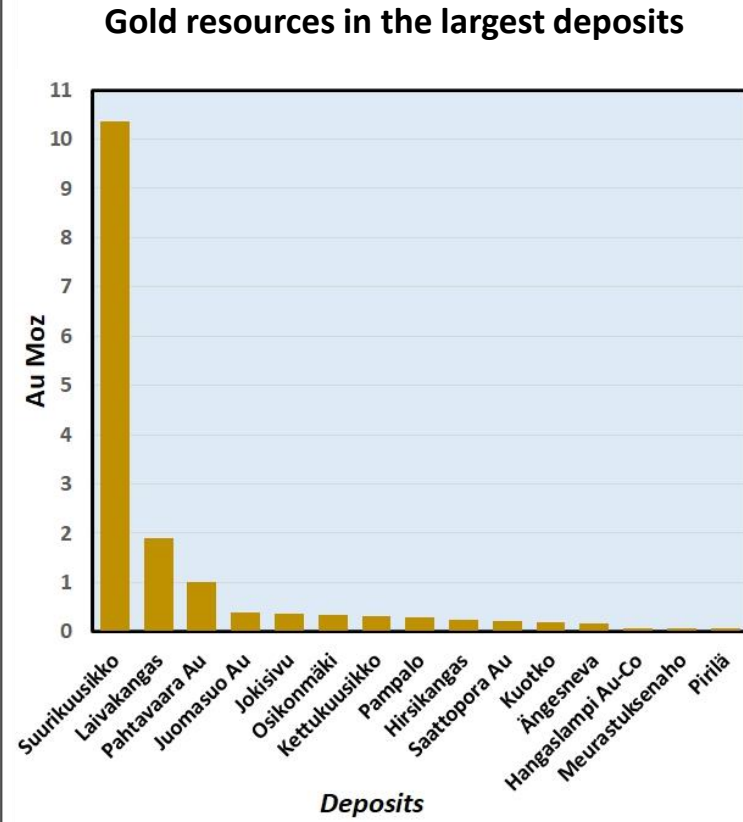
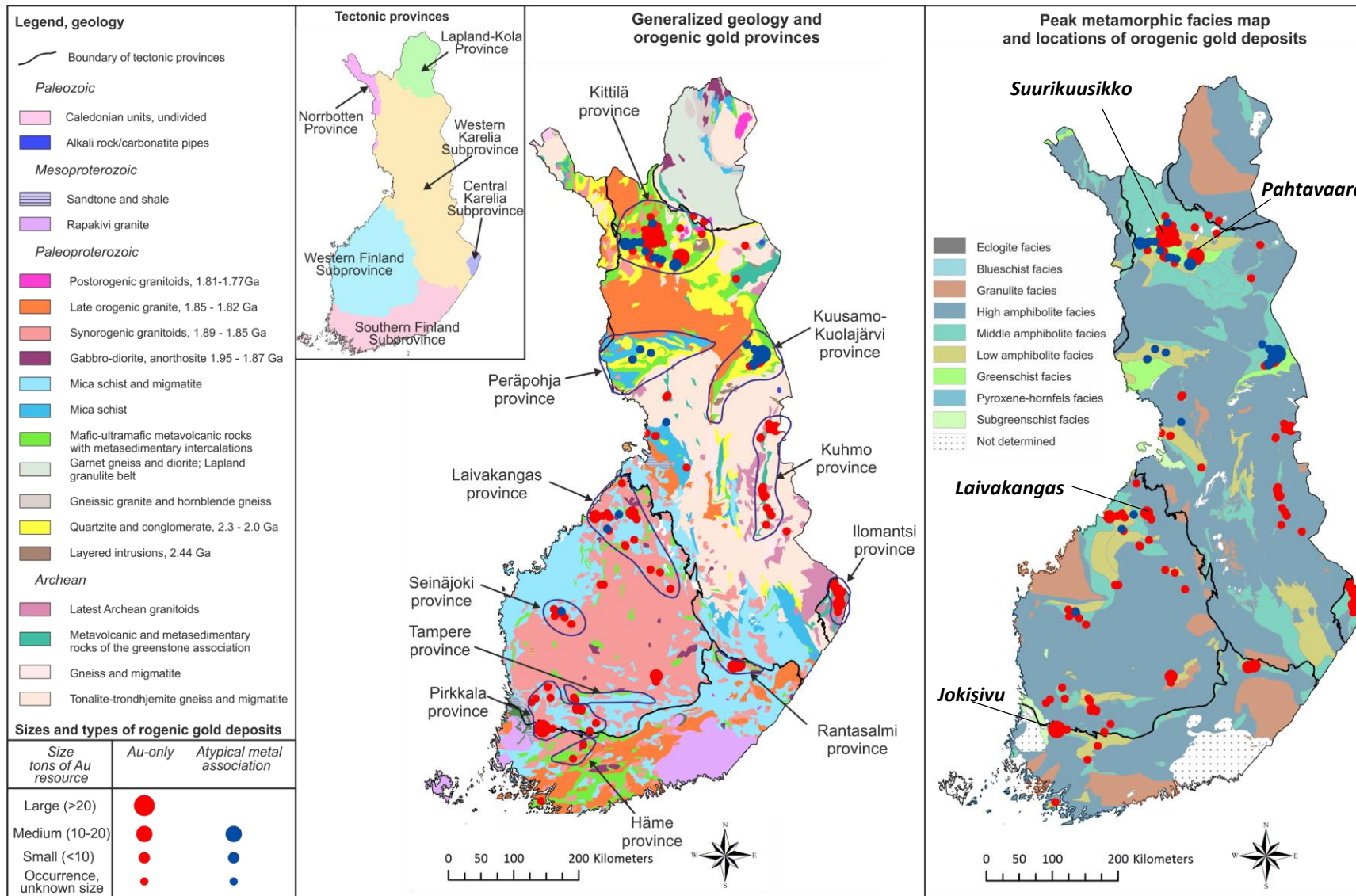


Svecofennian orogeny

Major mineral systems

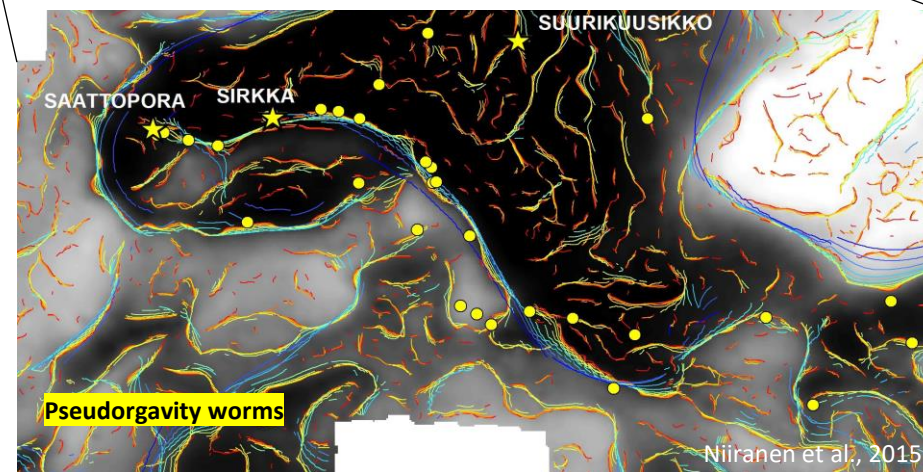
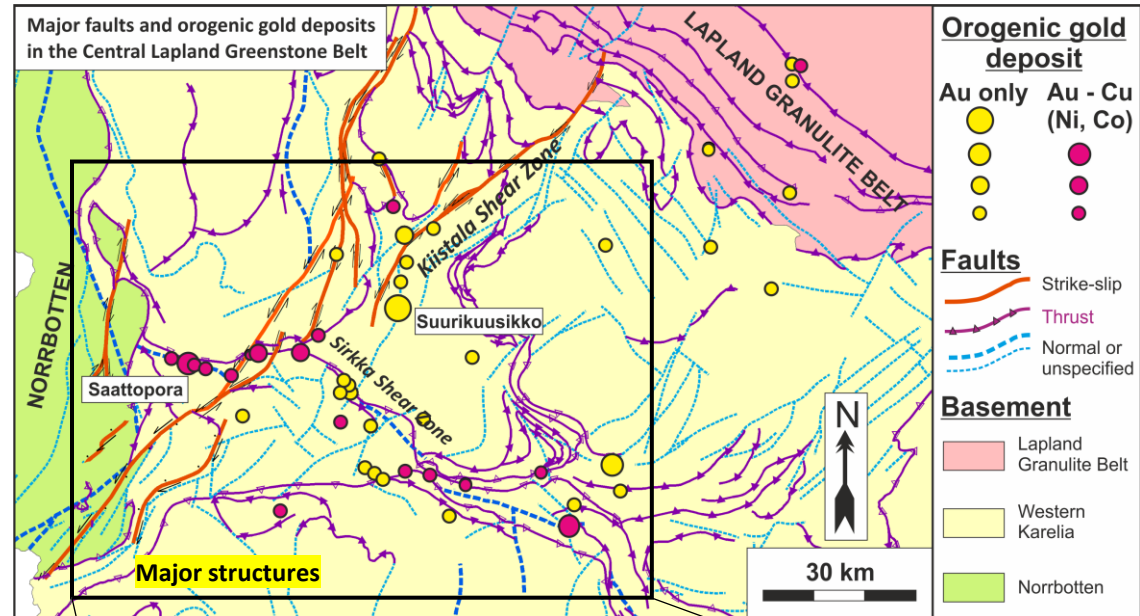
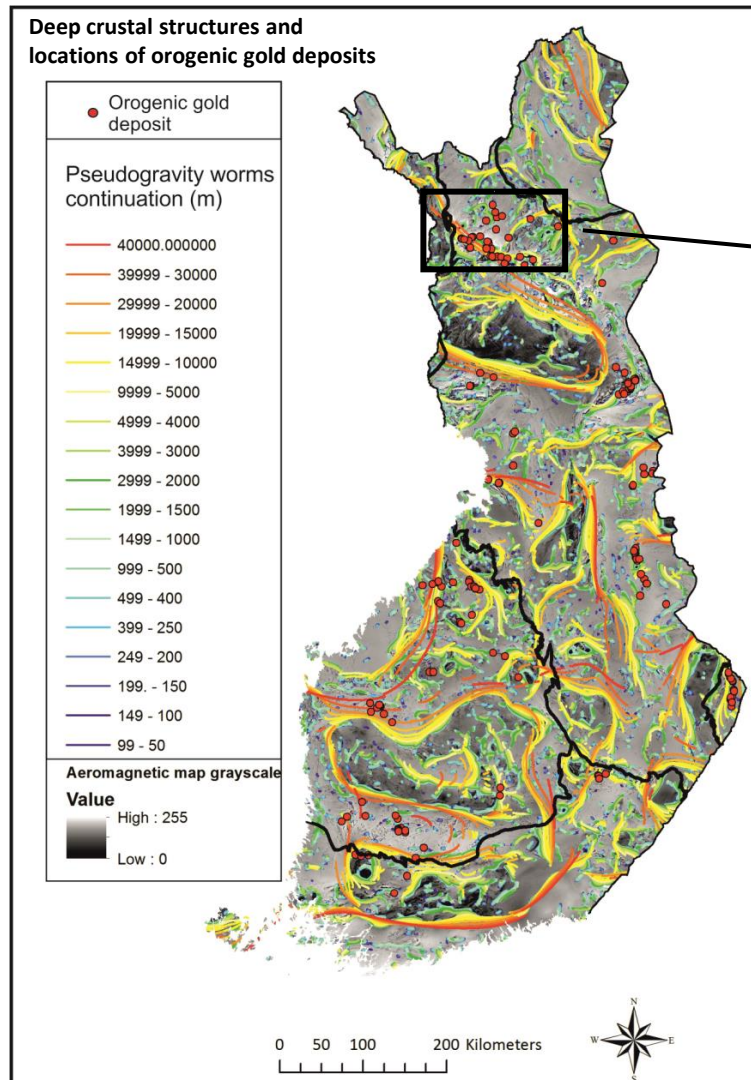
Type	Subtype	Metals	Age, Ga	Tectonic setting
Archean				
Orthomagmatic	Komatiites	Ni(-Cu)	2.95-2.75	Archean greenstone belt
Epigenetic-hydrothermal	Orogenic gold	Au	~2.7	Accretion-collision
Paleoproterozoic basins				
Orthomagmatic	Layered igneous complexes	Ni-Cu(-PGE)	2.44	Intracontinental rift
		PGE-reefs	2.44	
		Cr(-PGE)	2.44	
		Fe-Ti-V oxide	2.44	
	Komatiites	Ni(-Cu-PGE)	2.06	Continental margin rift
	Layered igneous complexes	Cu-Ni-PGE	2.06	
Sedimentary - polygenic	Talvivaara-type black schist	Ni-Zn-Cu-Co	2.0-1.90	Continental margin rift basin
Svecofennian orogeny				
Outokumpu-type	Outokumpu-type	Cu-Co	1.95-1.91	Oceanic ridge
Volcanic-hydrothermal	Volcanogenic massive sulphide	Cu-Zn	1.93-1.92	Island arc
Orthomagmatic	Synorogenic mafic-ultramafic intrusions	Ni-Cu(-PGE)	1.88	Arc-continent collision
Magmatic-hydrothermal	LCT pegmatites	Li, Nb-Ta	1.80-1.79	Continent-continent collision
Epigenetic-hydrothermal	Orogenic gold	Au-only	1.92 and 1.81-	Accretion-collision, late- to post-orogenic fault re-activation
		Au-Cu-Co-Ni	1.76	

Orogenic gold provinces in Finland: Orogenic gold deposits with Au-only and atypical Au-Cu-Co-Ni metal associations



Orogenic gold mineral systems in Finland: structures and fluid flow

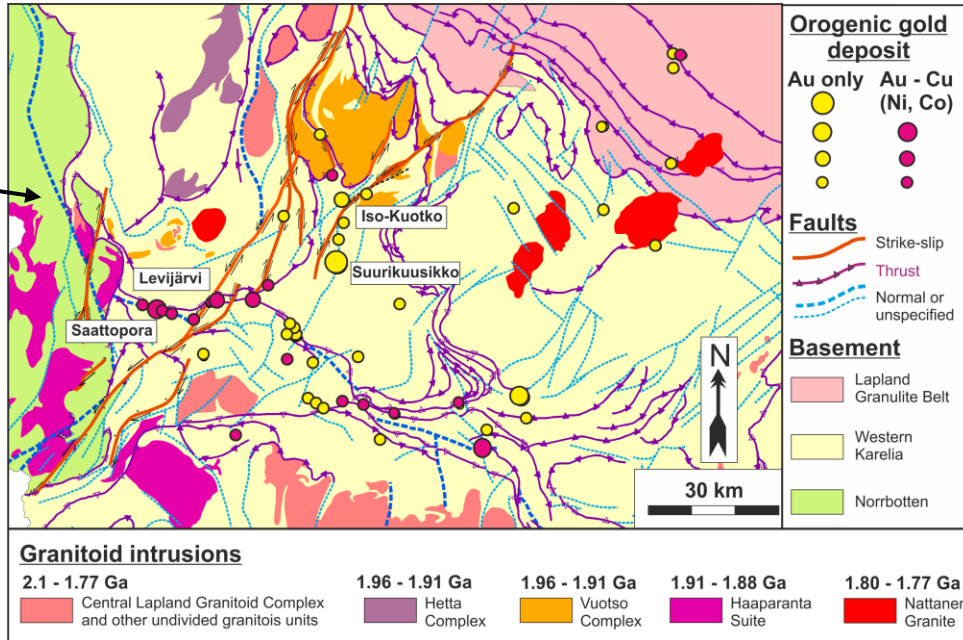
Central Lapland Greenstone Belt (Kittilä orogenic gold province)



Structural evolution and timing of ore deposition

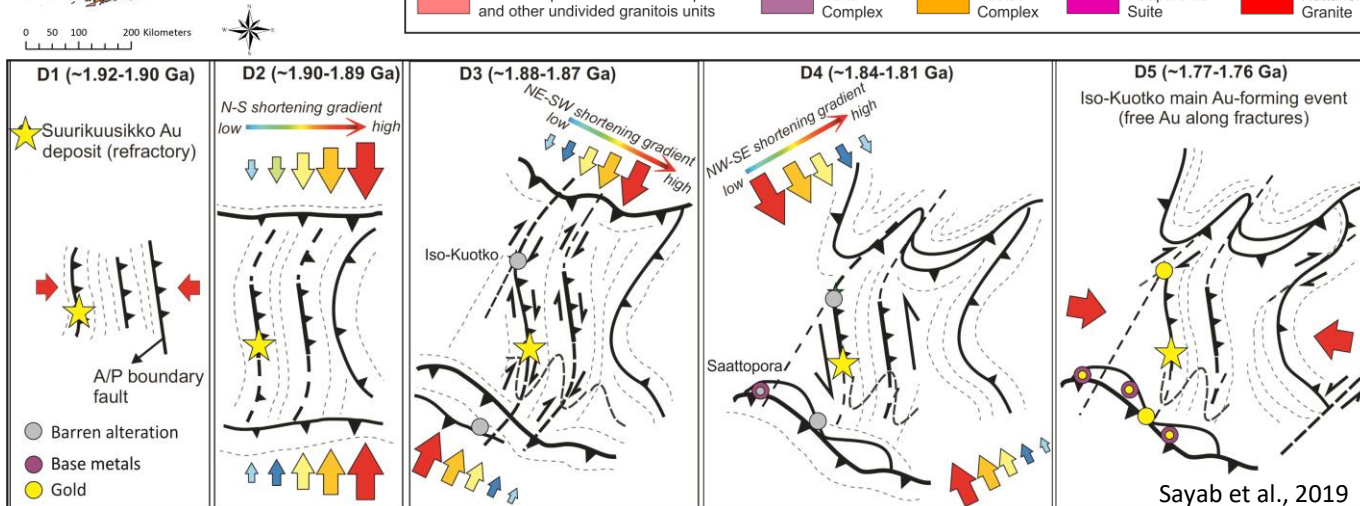
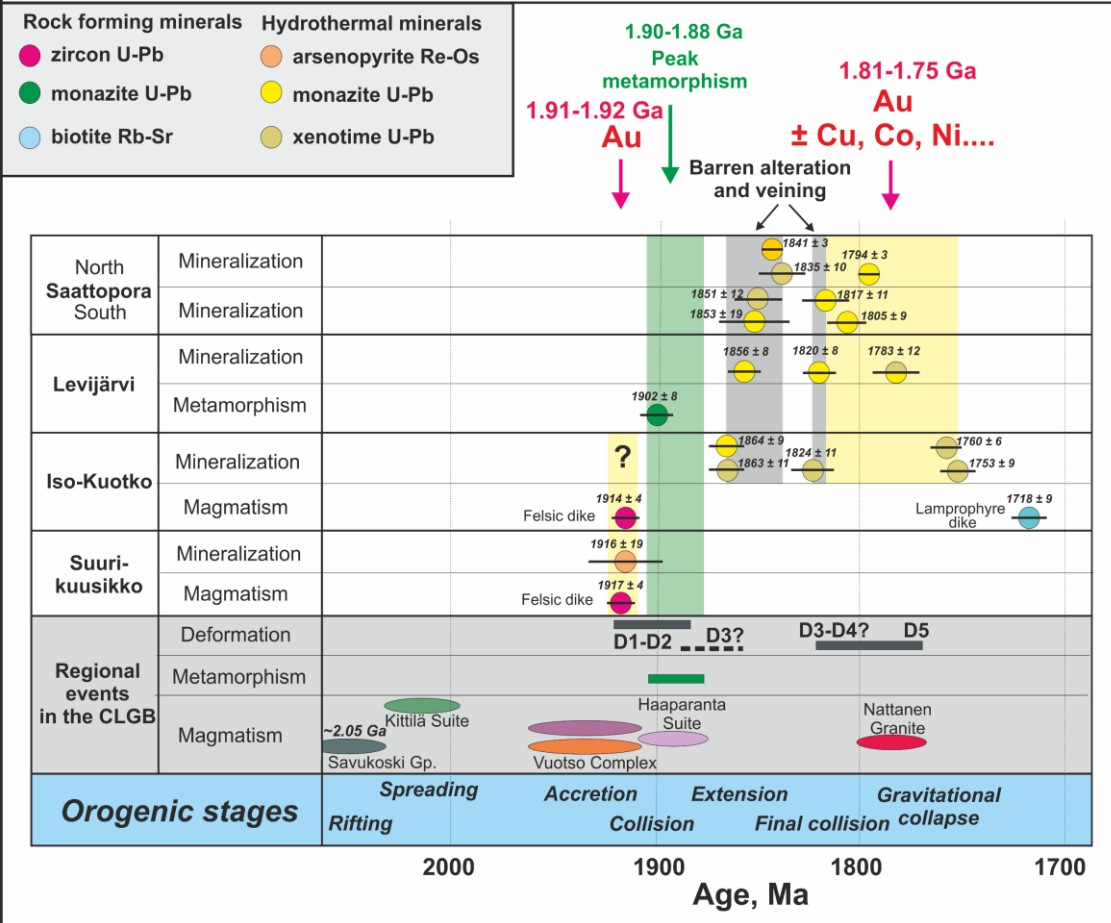
Central Lapland Greenstone Belt (Kittilä orogenic gold province)

Basement, structures and granitoid intrusions

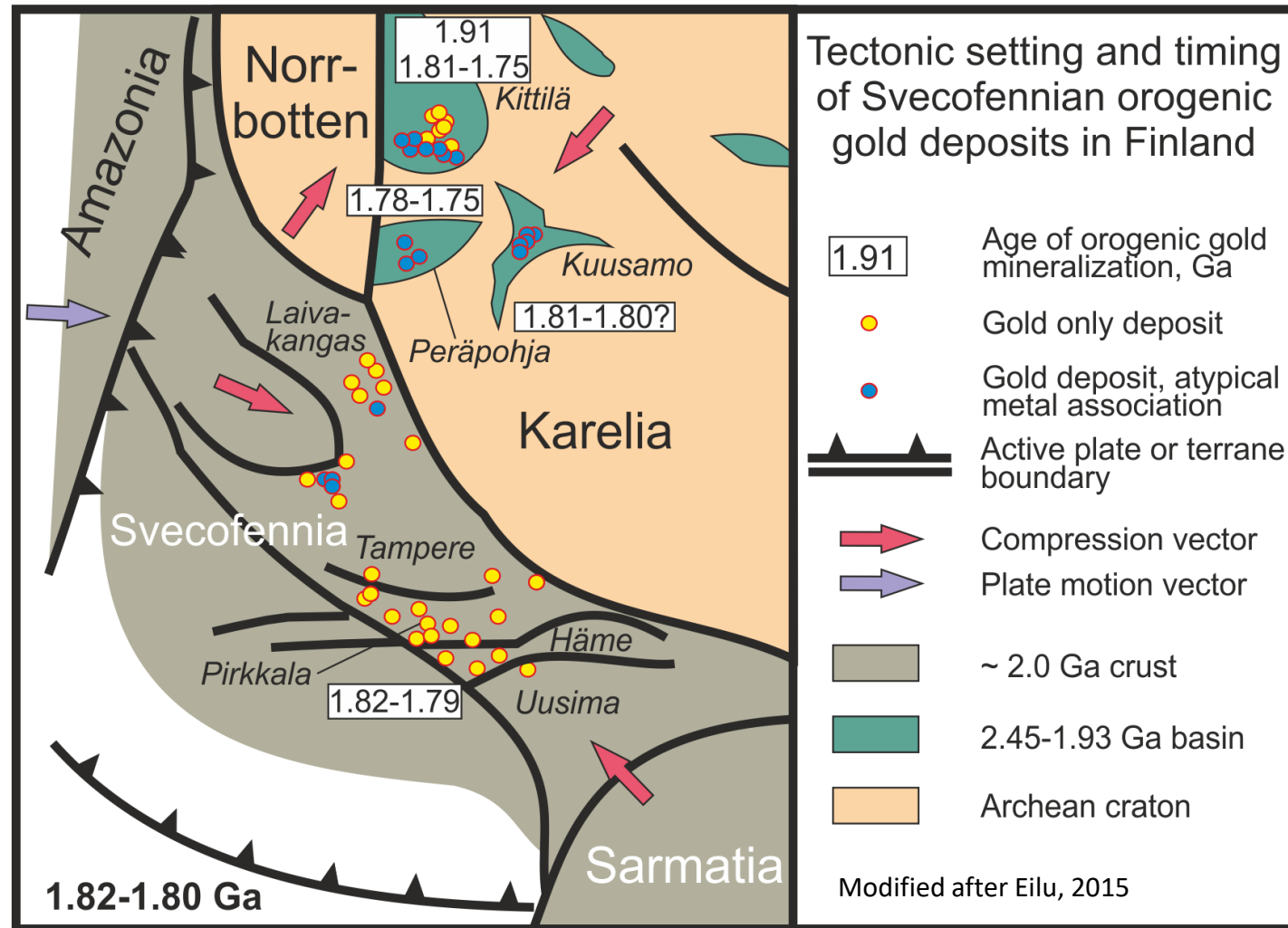
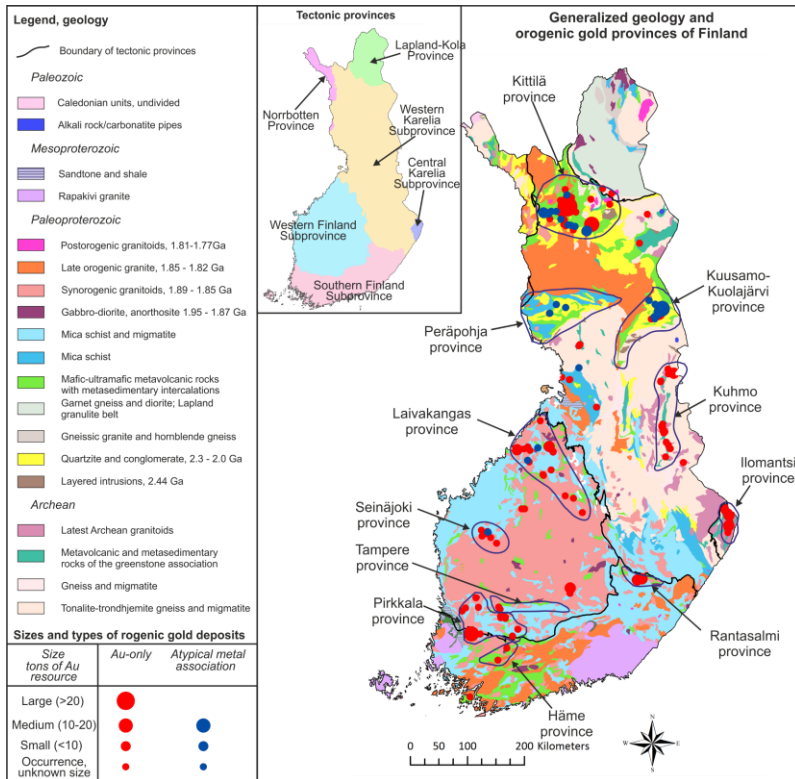


U-Pb and Re-Os geochronology of hydrothermal minerals with known structural-textural settings: barren and fertile hydrothermal events

Ages of hydrothermal, magmatic, metamorphic and deformational events in the Central Lapland Greenstone Belt (Kittilä orogenic gold province)



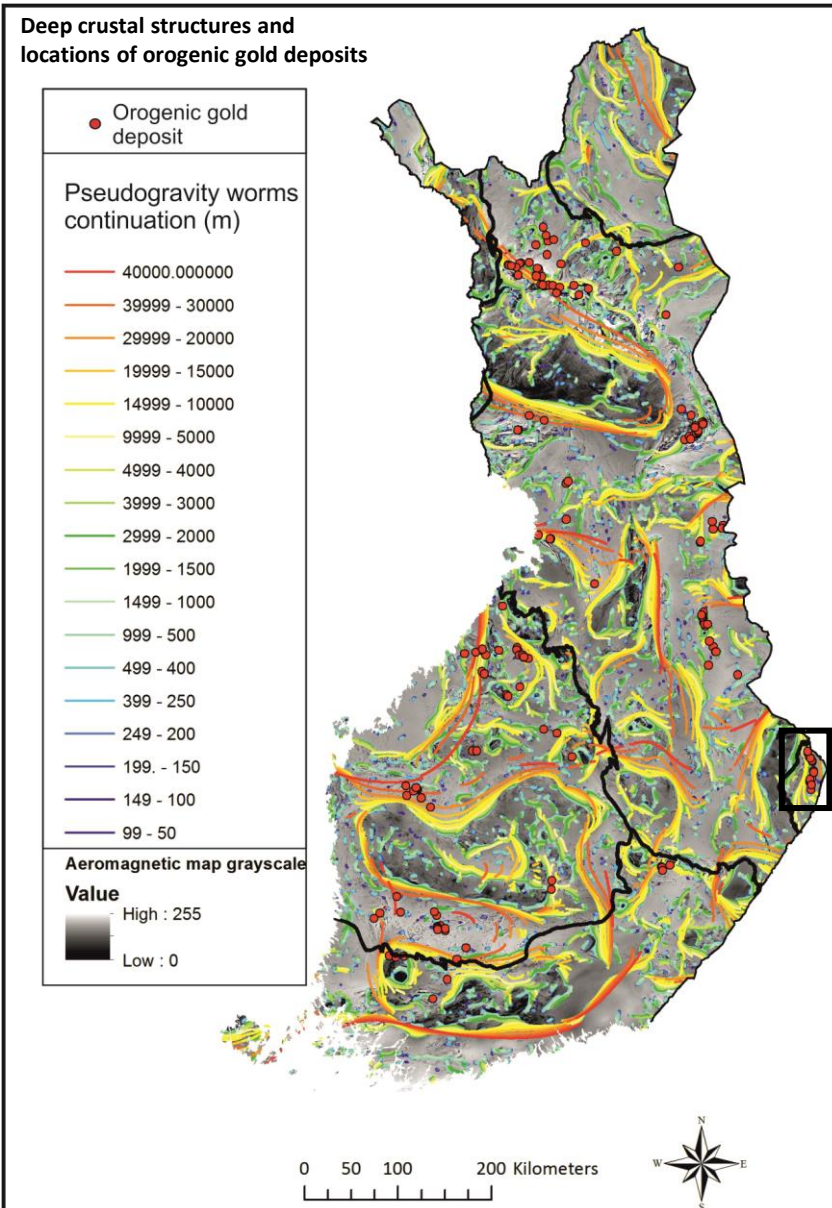
Timing of orogenic gold deposition: Svecofennian orogeny, Finland



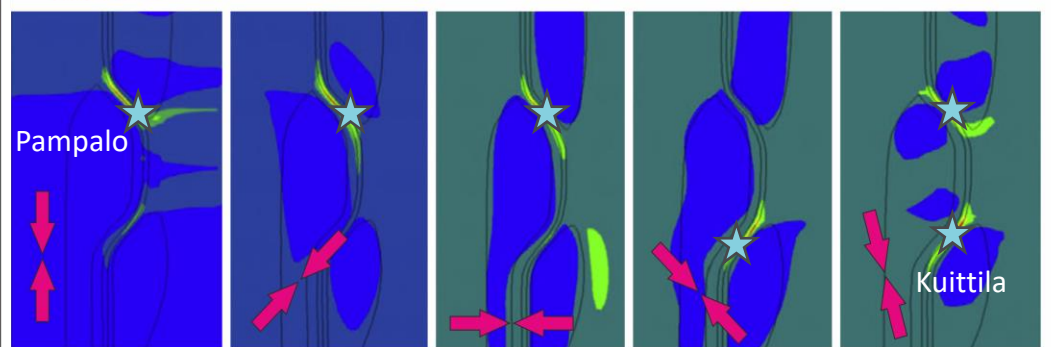
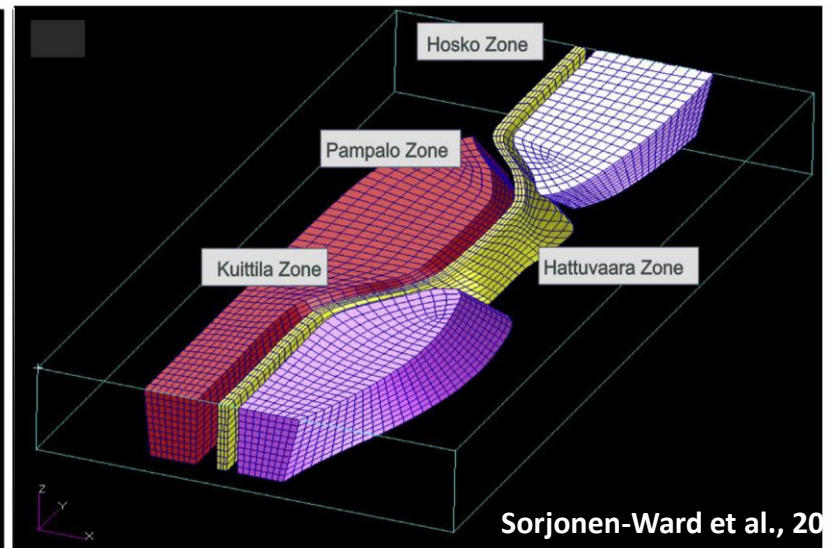
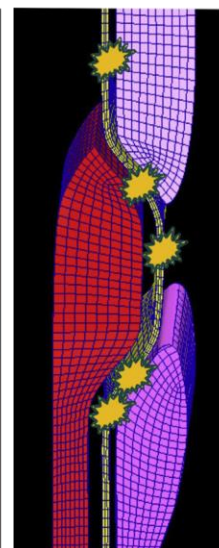
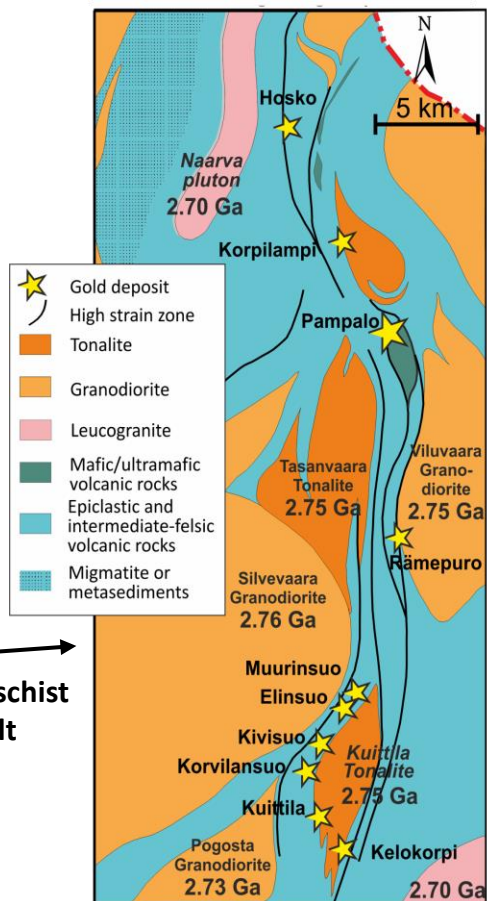
- Multiple hydrothermal events with fertile and barren stages
- The first fertile stage occurred at the early stage of accretion-collision, at 1.91-1.92 Ga in the Kittilä Province
- Most of gold deposited between 1.82 and 1.75 Ga at the late- to post-orogenic stages in all Svecofennian provinces

Crustal structures and fluid flow

Archean Hattu schist belt (Ilomantsi orogenic gold province)

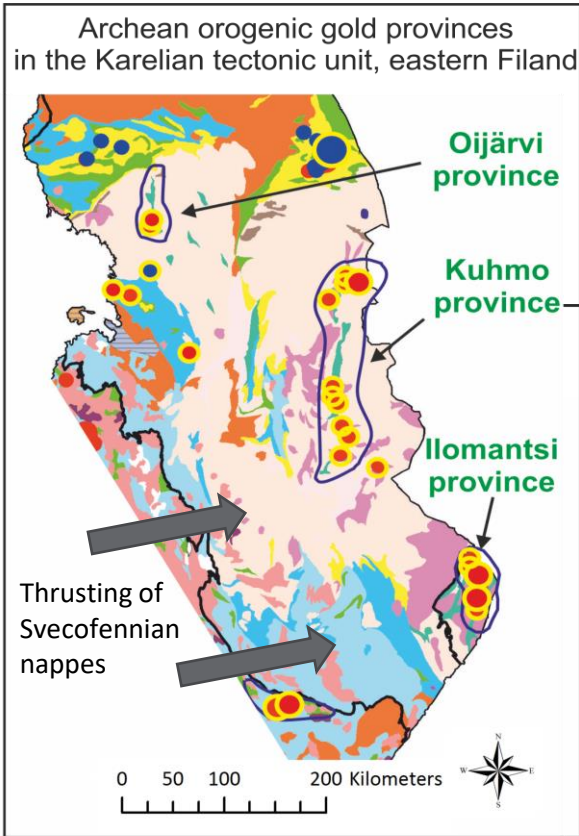


Hattu schist belt



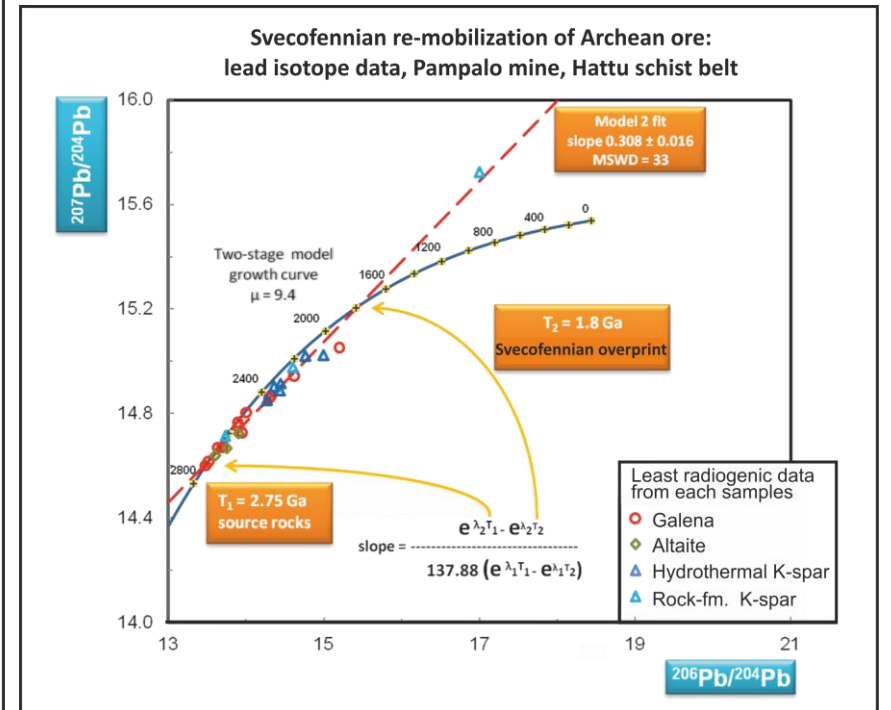
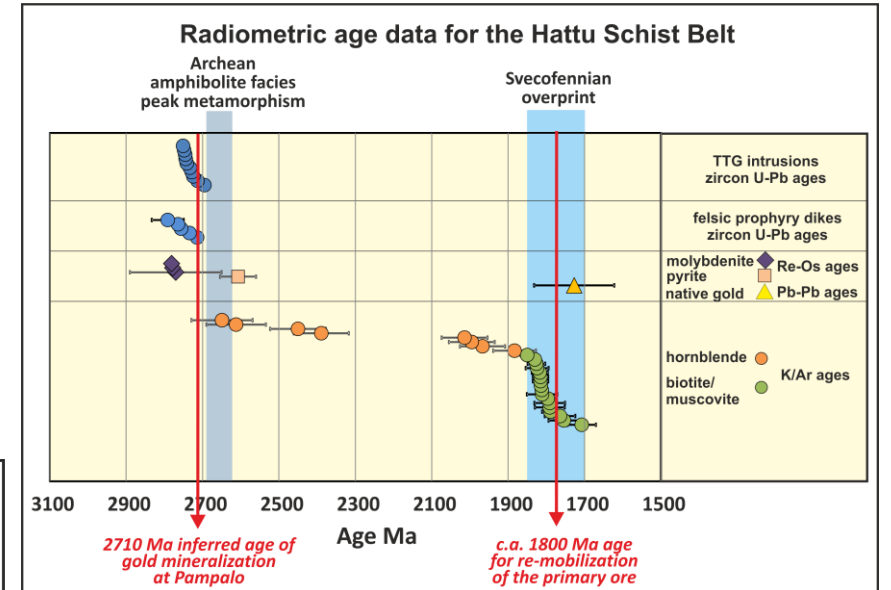
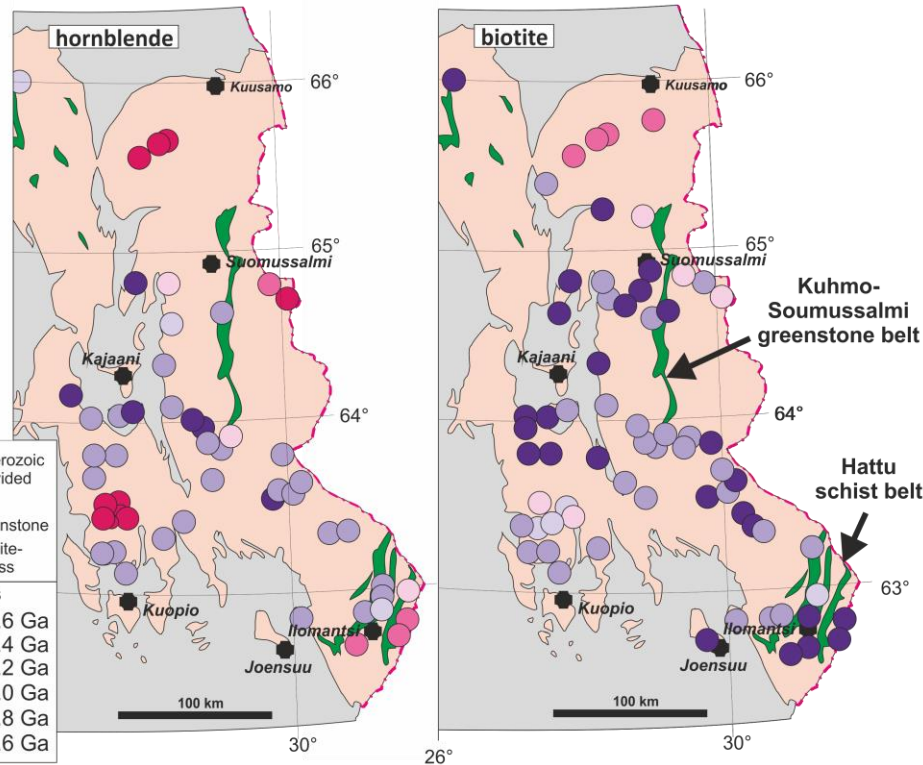
Sevcofennian overprint on Archean orogenic gold systems

Hattu schist belt (Ilomantsi orogenic gold province)



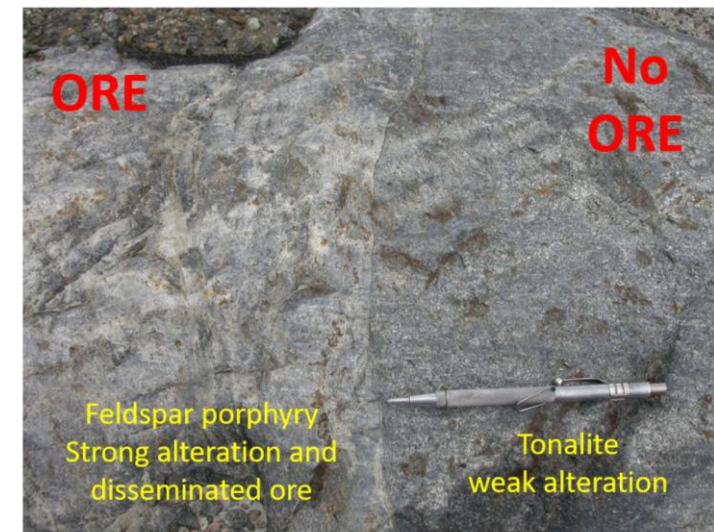
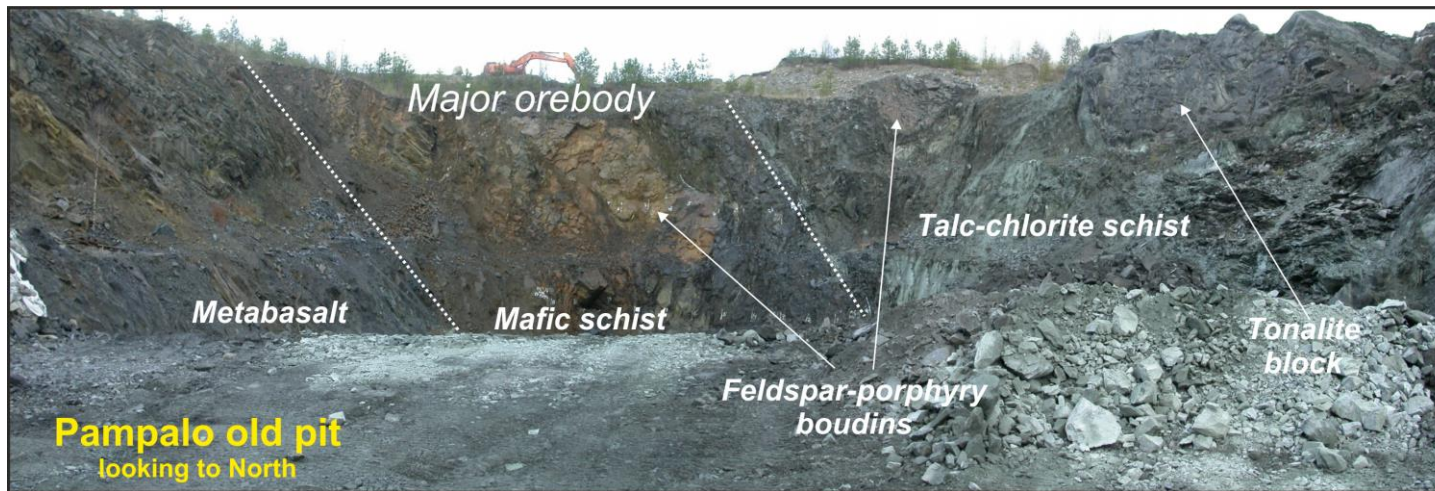
Potential modification of ~ 2.7 Ga primary mineralization: upgrading or re-mobilization during the 1.92-1.80 Ga Svecofennian orogeny

Distribution of K-Ar ages for hornblende and biotite from the Archean rocks of the Karelian domain in eastern Finland (redrawn after Kontinen et al., 1992)



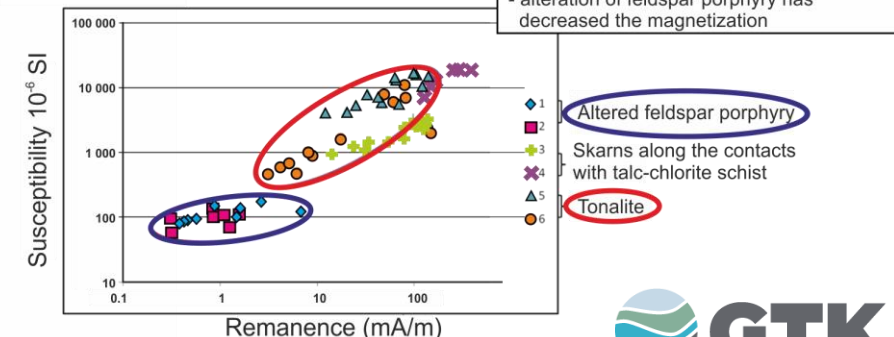
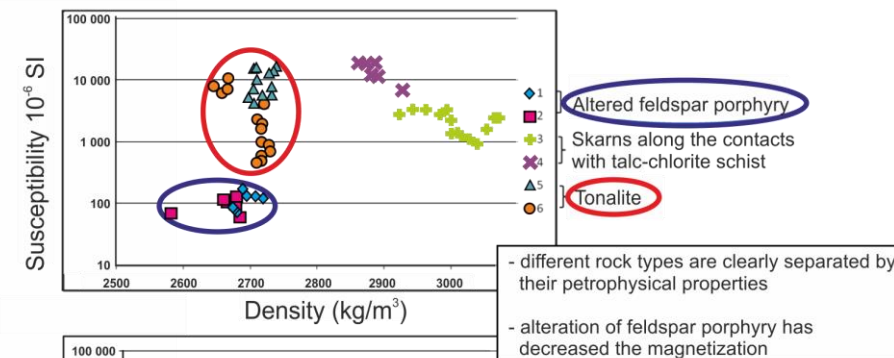
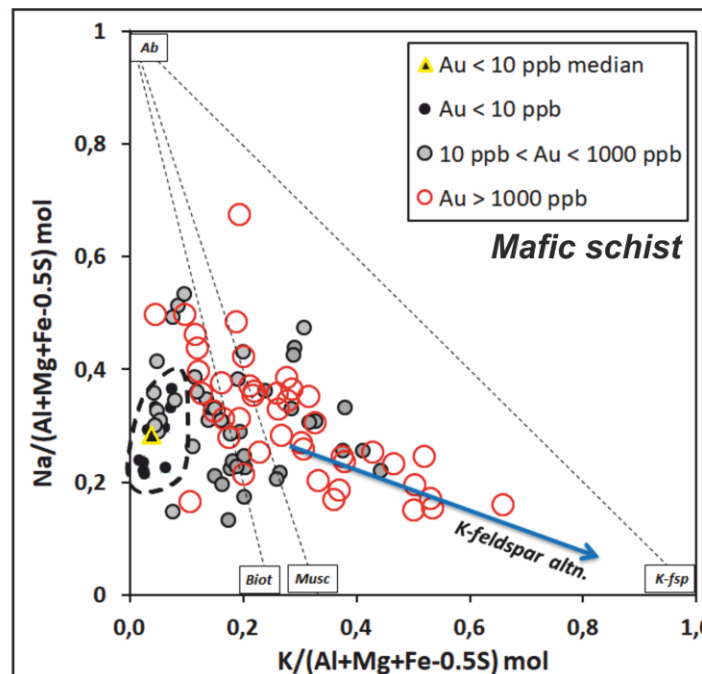
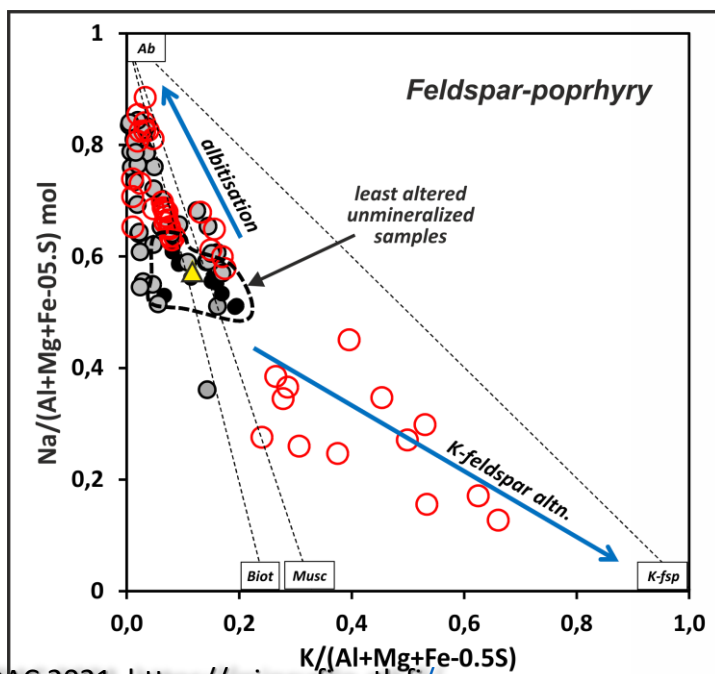
Footprints: vectors to ore – litho-geochemistry and petrophysics

Hattu schist belt, Pampalo mine (Ilomantsi orogenic gold province)



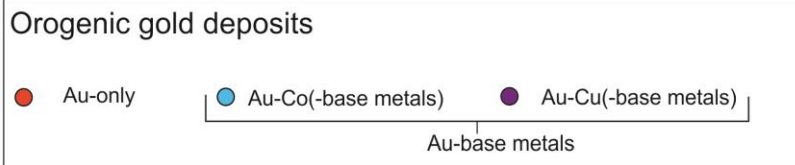
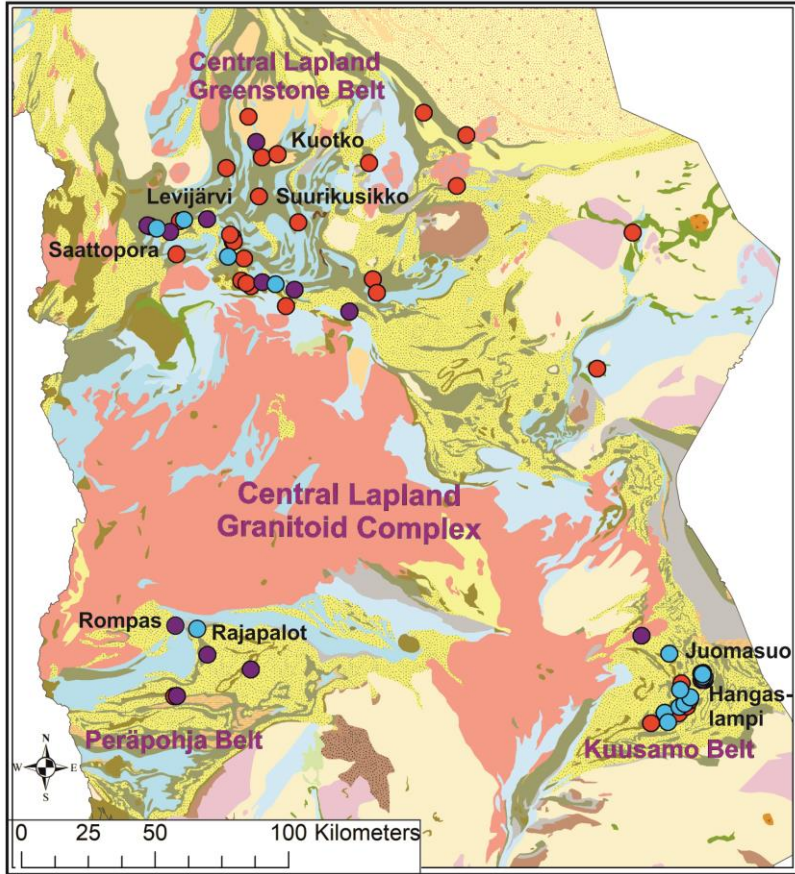
Zircon ²⁰⁷Pb-²⁰⁶Pb ages : Zircon ²⁰⁷Pb-²⁰⁶Pb age:

2712±4 –2717±8 Ma 2725 ± 12 Ma

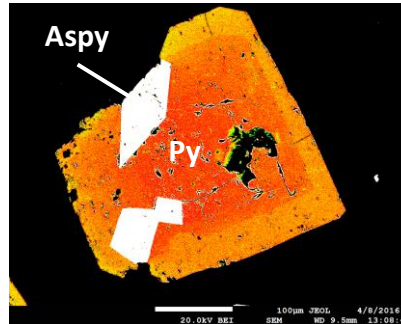
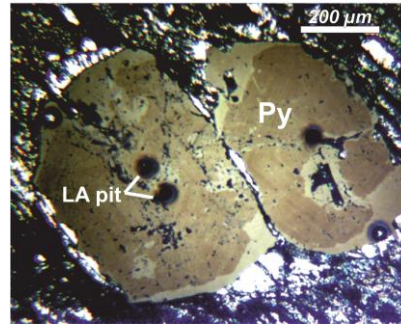


Footprints: development of vectoring tools based on mineral trace elements

Au-only and Au-base metal orogenic gold deposits northern Finland
(Central Lapland Greenstone Belt, Kuusamo Belt, Peräpohja Belt)

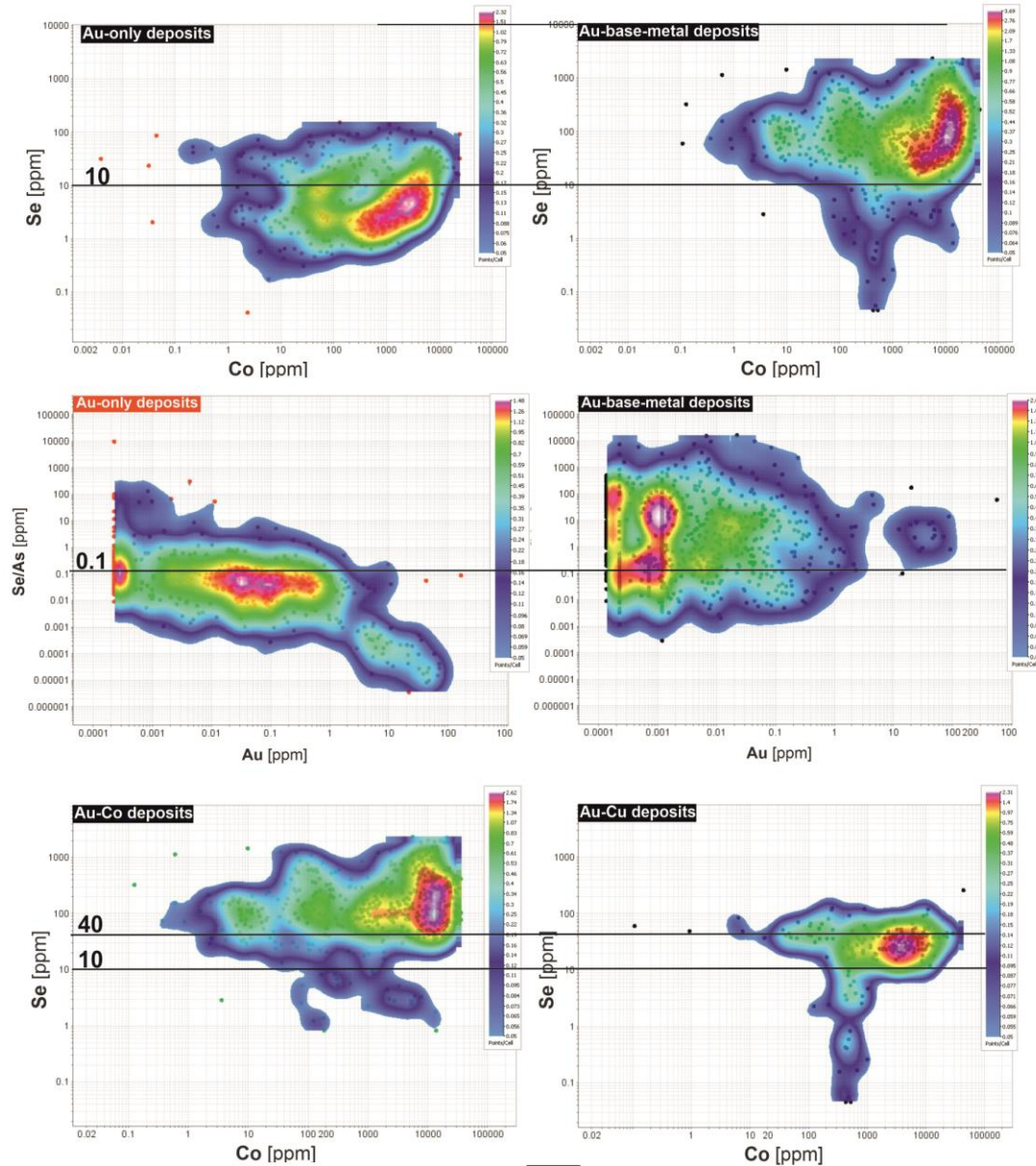


Trace element analyses by LA-ICPMS
In polished sections with known
structural, textural and paragenetical
settings of minerals.



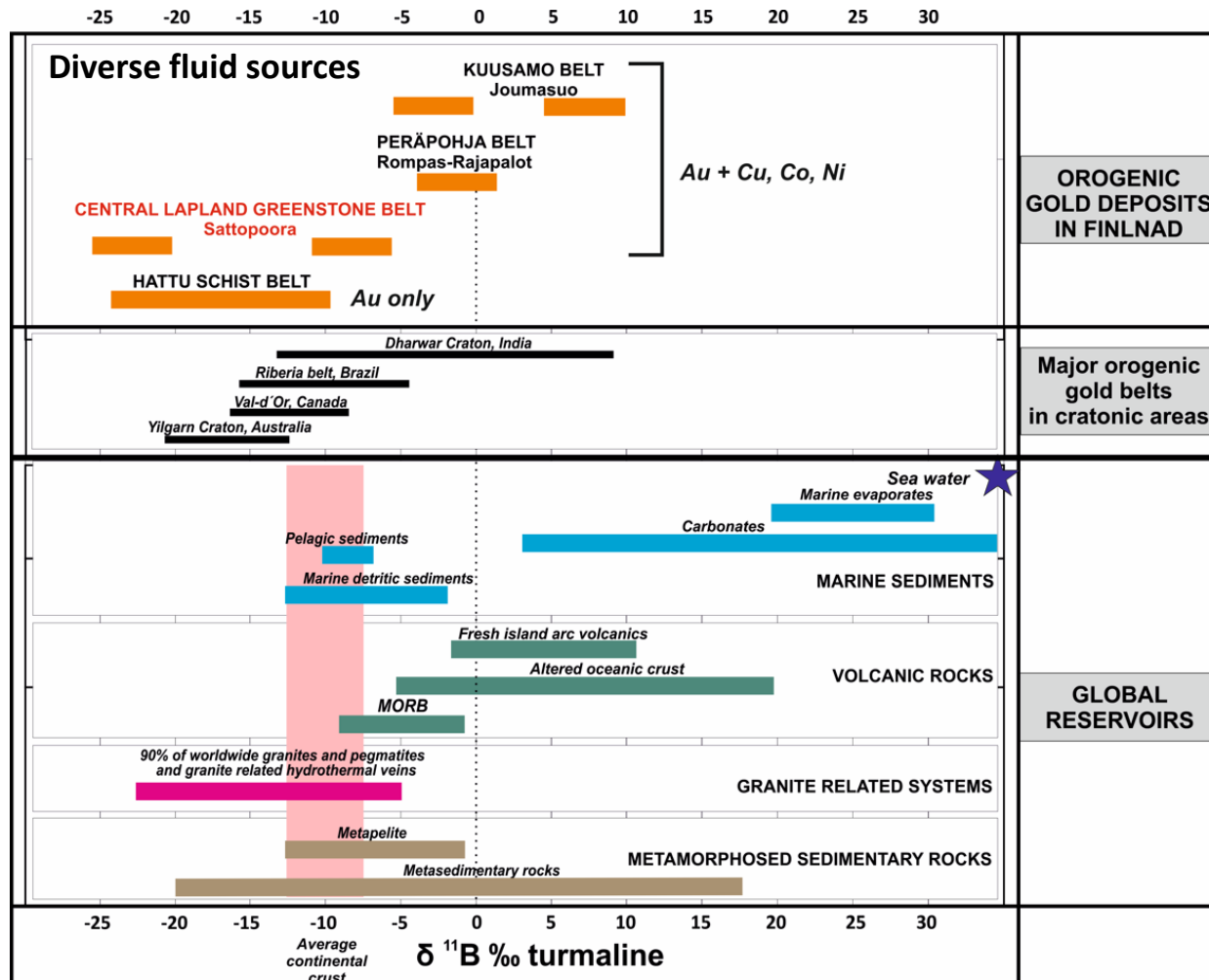
Primary footprint properties
of minerals is inherited
in secondary footprints (e.g. till,
stream sediments).

Trace elements in pyrite

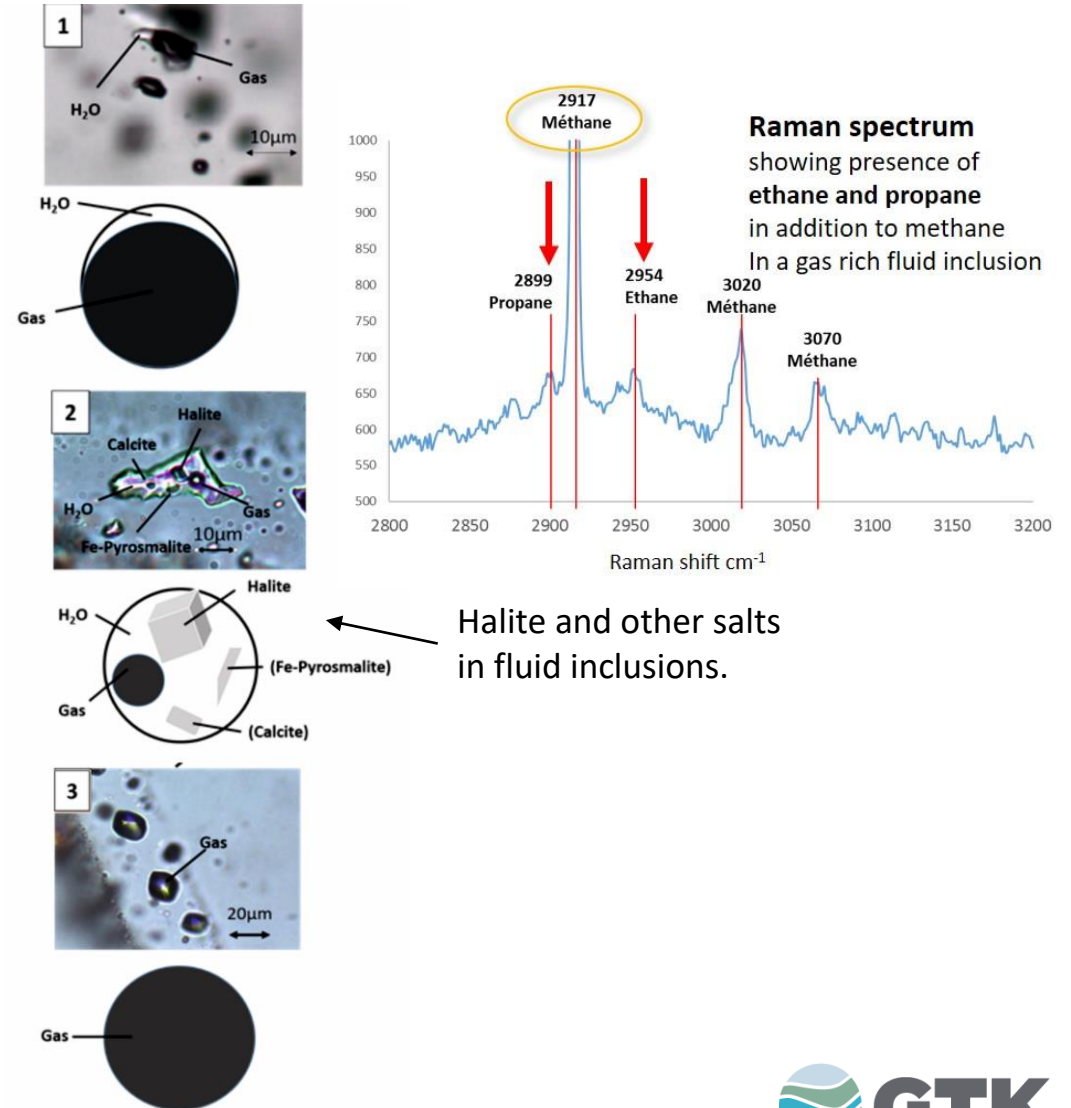


Sources of fluids

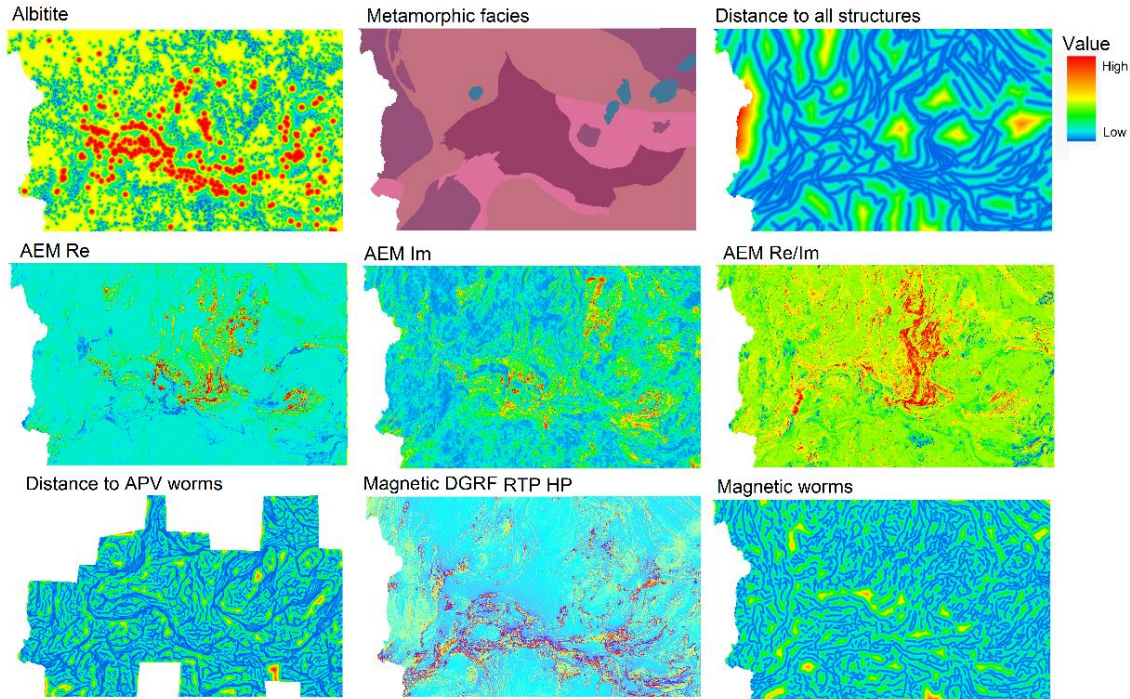
Boron isotope data from tourmaline



Compositions of fluids inferred from fluid inclusions



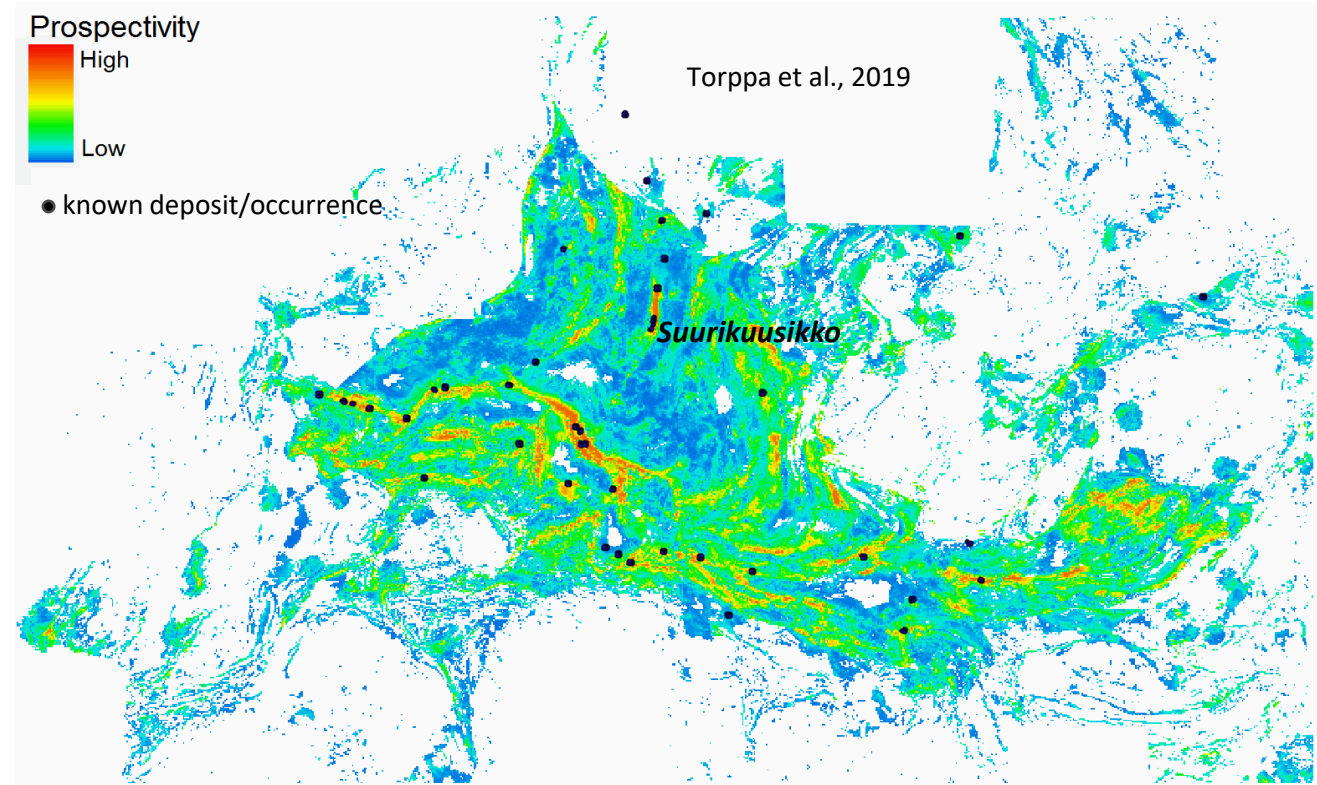
Implication of key parameters of orogenic gold mineral systems: province-scale mineral prospectivity evaluation



Key mineral system parameters

- structures: faults and rock contacts
- metamorphism
- alteration
- distribution of black schists

Central Lapland Greenstone Belt (Kittilä orogenic gold province)



Conclusions

Orogenic gold mineral systems are present in Archean and Paleoproterozoic (Svecofennian) tectonic domains of Finland.

Orogenic gold deposits with Au-Co-Cu-Ni (atypical) metal associations are common in northern Finland.

Orogenic gold systems with atypical metal associations are potential future sources of cobalt.

Building up robust geochronological, lithogeochemical, mineral trace element and isotope geochemistry databases for orogenic gold mineral systems of Finland form the basis of development of new models and exploration tools in various projects at GTK.

Incorporation of mineral systems`critical parameters into mineral prospectivity mapping supports better prediction of areas with enhanced potential of orogenic gold deposits.





GTK

THANK YOU!

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