AEX PROJECT

Macro Perspective

http://ing.aexmetal.com

Alanya Massif YT Area
&
SIC Sudbury Igneous Complex
Noril’sk Tunguska Basin

Ni-Co-Cu-PM Magmatic Sulfide Deposits

Same Primary Ore Mineral formation

Same Other Ore Mineral formation

Similar Petrographic formation

Similar Geologic formation

AEX

✓ AEX ORE MİNERALS (EDS-SEM Analyses)

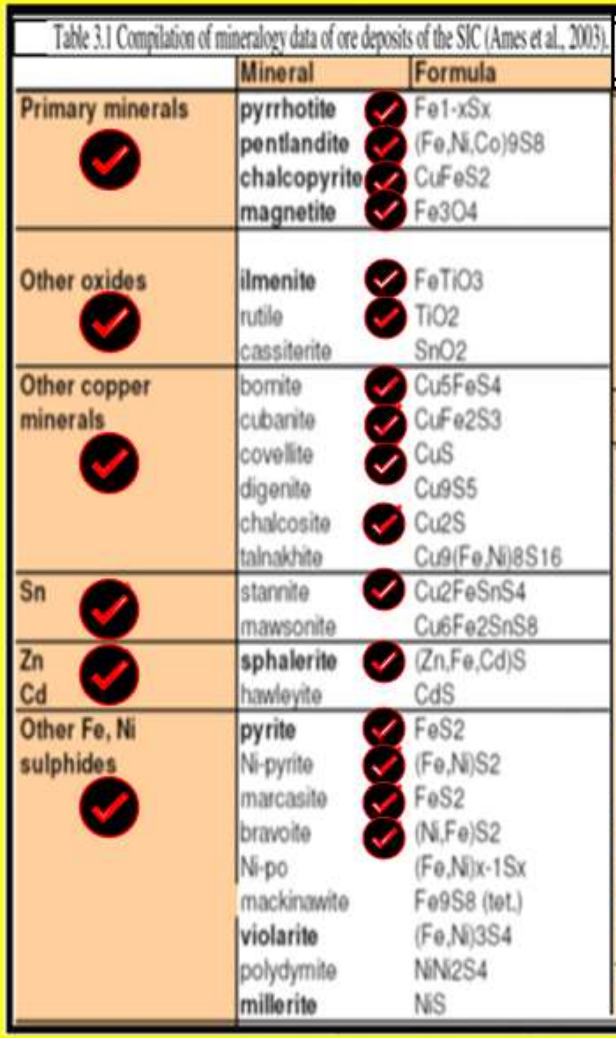
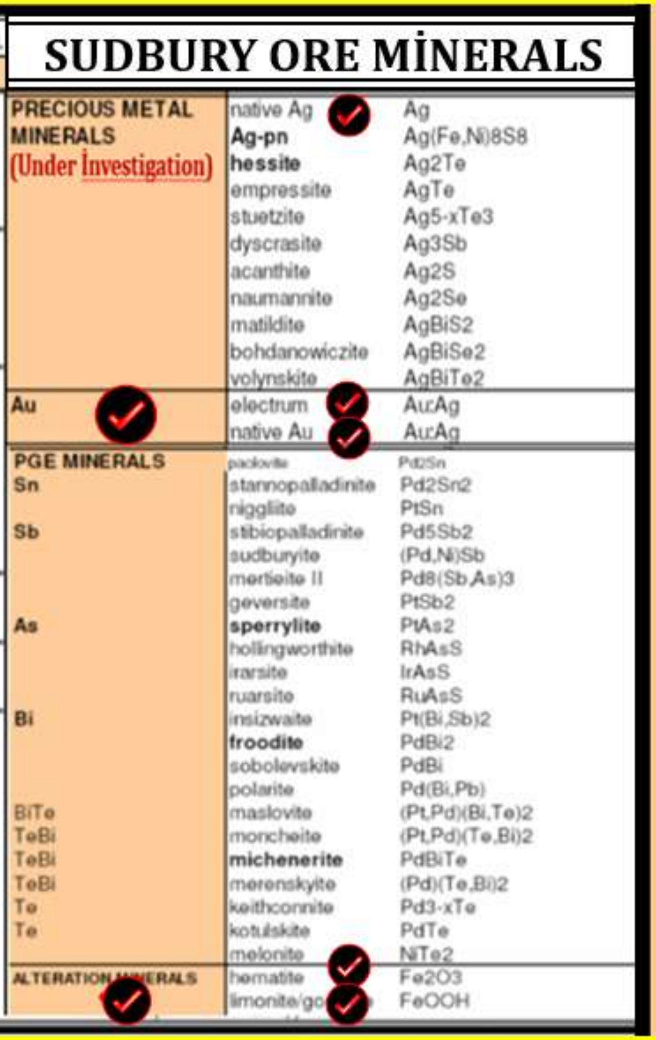


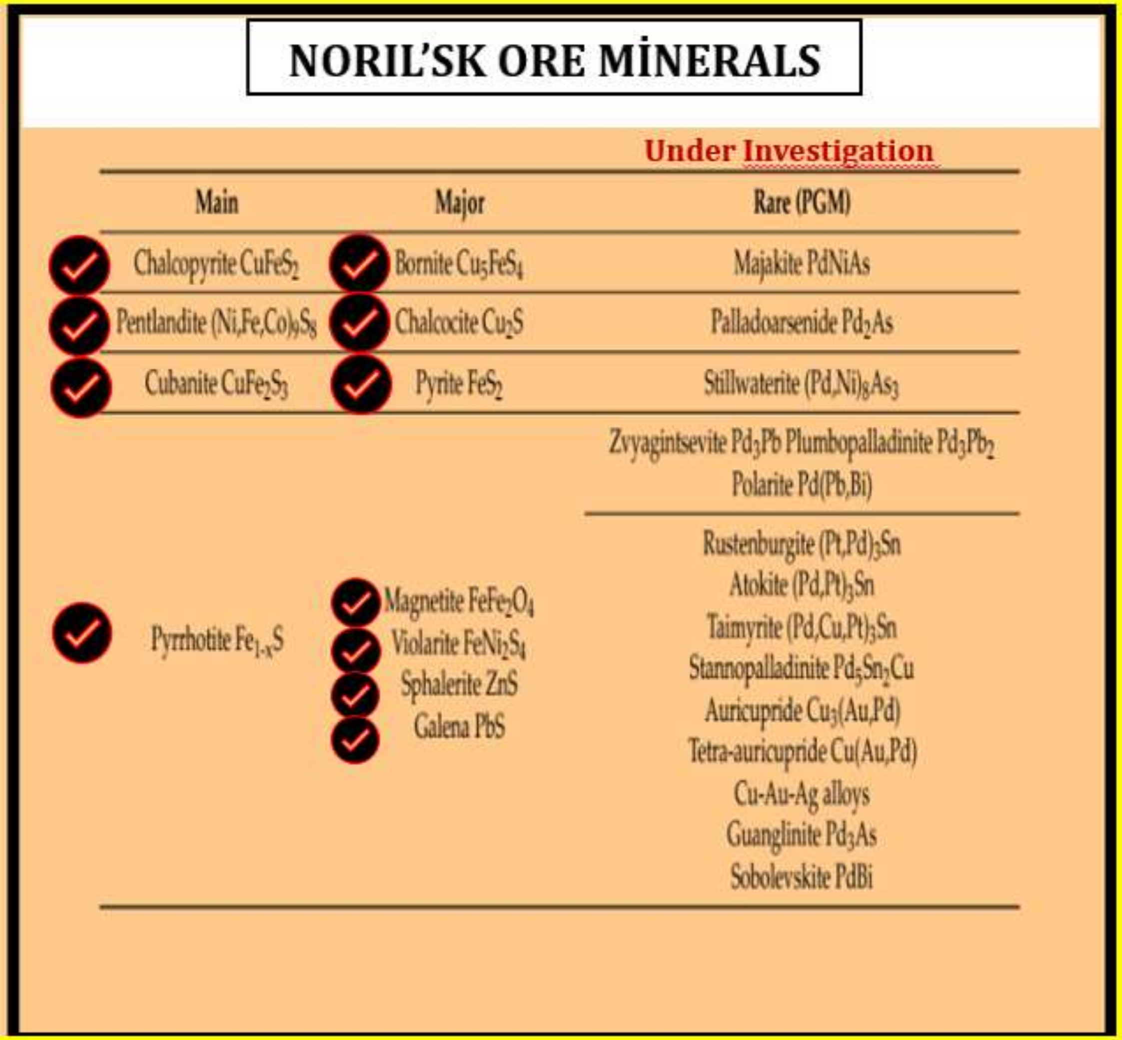
Table 3.1 Compilation of mineralogy data of ore deposits of the SIC (Ames et al., 2003).

	Mineral		Formula
Primary minerals ✓	**pyrrhotite**	✓	Fe1-xSx
	pentlandite	✓	(Fe,Ni,Co)9S8
	chalcopyrite	✓	CuFeS2
	magnetite	✓	Fe3O4
Other oxides ✓	**ilmenite**	✓	FeTiO3
	rutile	✓	TiO2
	cassiterite		SnO2
Other copper minerals ✓	bornite	✓	Cu5FeS4
	cubanite	✓	CuFe2S3
	covellite	✓	CuS
	digenite		Cu9S5
	chalcosite	✓	Cu2S
	talnakhite		Cu9(Fe,Ni)8S16
Sn ✓	stannite	✓	Cu2FeSnS4
	mawsonite		Cu6Fe2SnS8
Zn Cd ✓	**sphalerite**	✓	(Zn,Fe,Cd)S
	hawleyite		CdS
Other Fe, Ni sulphides ✓	**pyrite**	✓	FeS2
	Ni-pyrite	✓	(Fe,Ni)S2
	marcasite	✓	FeS2
	bravoite	✓	(Ni,Fe)S2
	Ni-po		(Fe,Ni)x-1Sx
	mackinawite		Fe9S8 (tet.)
	violarite		(Fe,Ni)3S4
	polydymite		NiNi2S4
	millerite		NiS



SUDBURY ORE MİNERALS

PRECIOUS METAL MINERALS (Under İnvestigation)	native Ag	✓	Ag
	Ag-pn		Ag(Fe,Ni)8S8
	hessite		Ag2Te
	empressite		AgTe
	stuetzite		Ag5-xTe3
	dyscrasite		Ag3Sb
	acanthite		Ag2S
	naumannite		Ag2Se
	matildite		AgBiS2
	bohdanowiczite		AgBiSe2
	volynskite		AgBiTe2
Au ✓	electrum	✓	Au:Ag
	native Au	✓	Au:Ag
PGE MINERALS	paolovite		Pd2Sn
Sn	stannopalladinite		Pd2Sn2
	niggliite		PtSn
Sb	stibiopalladinite		Pd5Sb2
	sudburyite		(Pd,Ni)Sb
	mertieite II		Pd8(Sb,As)3
	geversite		PtSb2
As	**sperrylite**		PtAs2
	hollingworthite		RhAsS
	irarsite		IrAsS
	ruarsite		RuAsS
Bi	insizwaite		Pt(Bi,Sb)2
	froodite		PdBi2
	sobolevskite		PdBi
	polarite		Pd(Bi,Pb)
BiTe	maslovite		(Pt,Pd)(Bi,Te)2
TeBi	moncheite		(Pt,Pd)(Te,Bi)2
TeBi	**michenerite**		PdBiTe
TeBi	merenskyite		(Pd)(Te,Bi)2
Te	keithconnite		Pd3-xTe
Te	kotulskite		PdTe
	melonite		NiTe2
ALTERATION MINERALS ✓	hematite	✓	Fe2O3
	limonite/go	✓	FeOOH



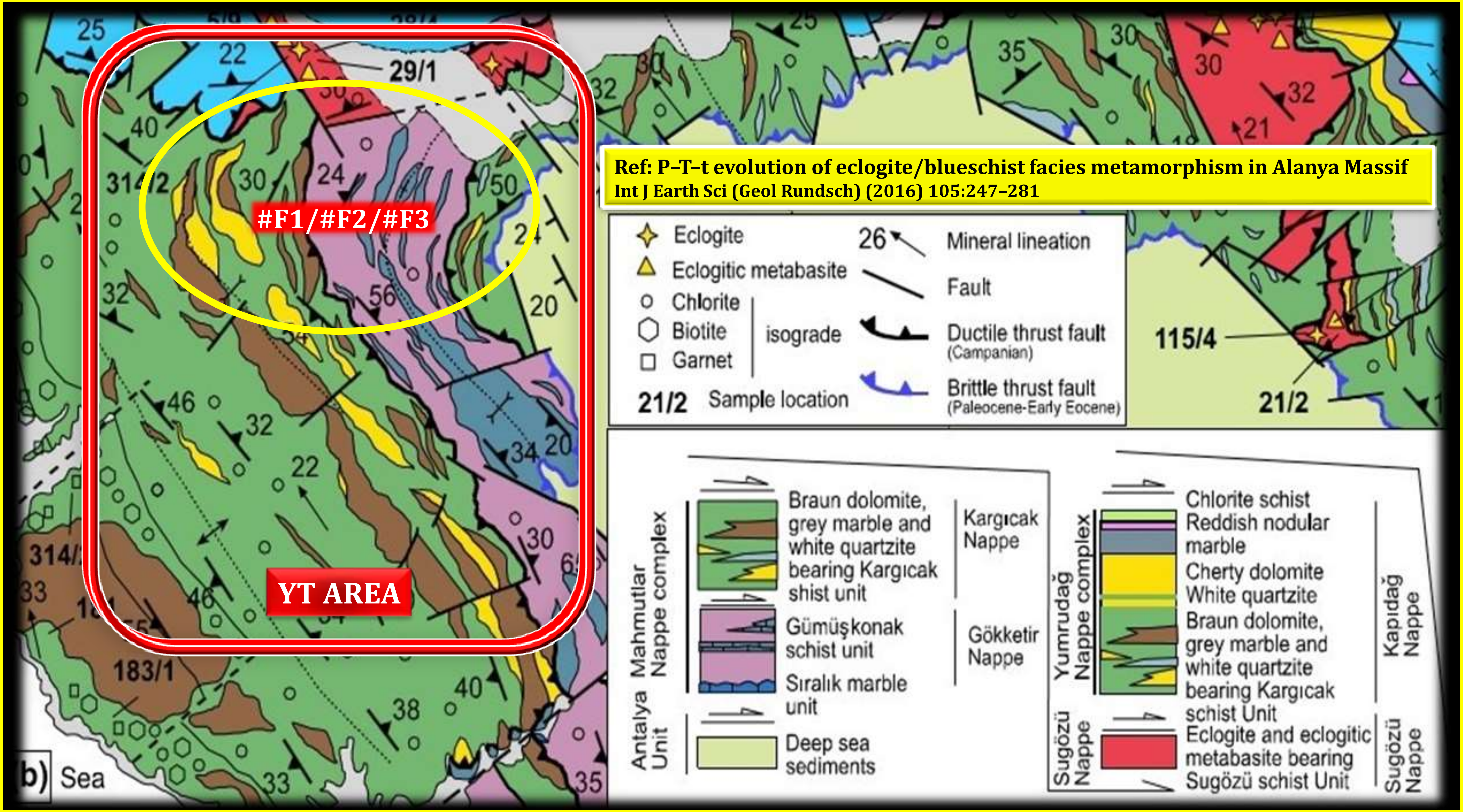
NORIL'SK ORE MİNERALS

Under Investigation

	Main		Major	Rare (PGM)
✓	Chalcopyrite $CuFeS_2$	✓	Bornite Cu_5FeS_4	Majakite PdNiAs
✓	Pentlandite $(Ni,Fe,Co)_9S_8$	✓	Chalcocite Cu_2S	Palladoarsenide Pd_2As
✓	Cubanite $CuFe_2S_3$	✓	Pyrite FeS_2	Stillwaterite $(Pd,Ni)_8As_3$
				Zvyagintsevite Pd_3Pb Plumbopalladinite Pd_3Pb_2 Polarite Pd(Pb,Bi)
✓	Pyrrhotite $Fe_{1-x}S$	✓ ✓ ✓ ✓	Magnetite $FeFe_2O_4$ Violarite $FeNi_2S_4$ Sphalerite ZnS Galena PbS	Rustenburgite $(Pt,Pd)_3Sn$ Atokite $(Pd,Pt)_3Sn$ Taimyrite $(Pd,Cu,Pt)_3Sn$ Stannopalladinite Pd_5Sn_2Cu Auricupride $Cu_3(Au,Pd)$ Tetra-auricupride Cu(Au,Pd) Cu-Au-Ag alloys Guanglinite Pd_3As Sobolevskite PdBi

Two outstanding Ni-Co-Cu deposits in the World
Sudbury – Ontario,Canada & Noril'sk – Talnakh, Russia

Ref: P–T–t evolution of eclogite/blueschist facies metamorphism in Alanya Massif
Int J Earth Sci (Geol Rundsch) (2016) 105:247–281



AEX YT AREA
N-SE FAULTS

Ref: MTA GeoScience Map

Alanya Massif Seismic Data

The North-Eastern Mediterranean Sea, in the light of marine seismic reflection data
Güven Özhan MTA Genel Müdürlüğü Jeofizik Etüdleri Dairesi, Ankara.

ABSTRACT

- The seismic data elucidated especially the Upper Miocene and Plio-Quatemary units in detail. However, the deep seismic information is not so clear because of acoustic masking of the evaporitic high velocity layers.

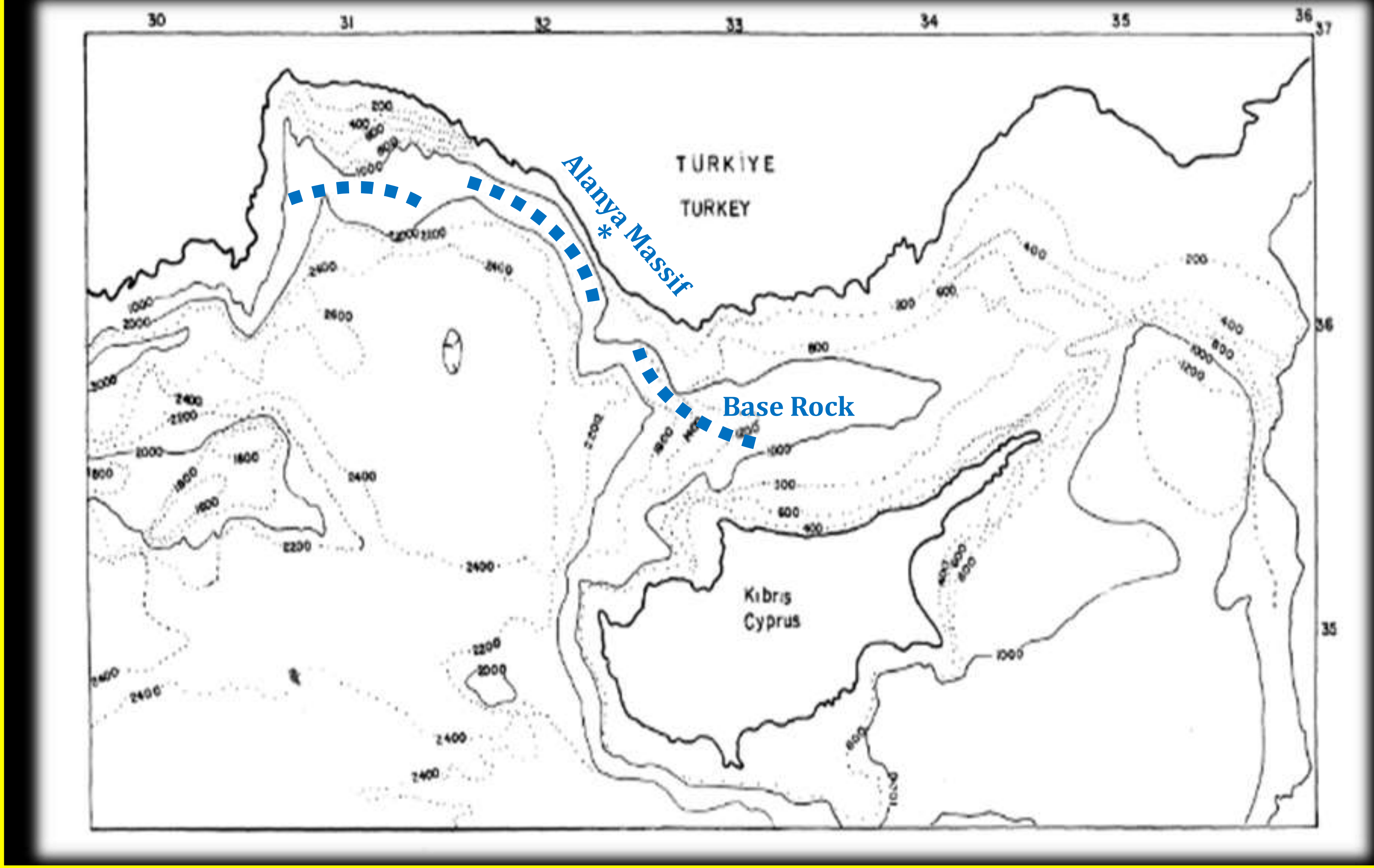
- In the both Antalya and Mersin Basins the evaporitic units, which are seen locally in the shape of diapiric features, are marked by the boundary of the non-evaporitic units where laterally change occurs.
The seismic data suggest that the Antalya and Mersin Basins are controled technically by the vertical movements.

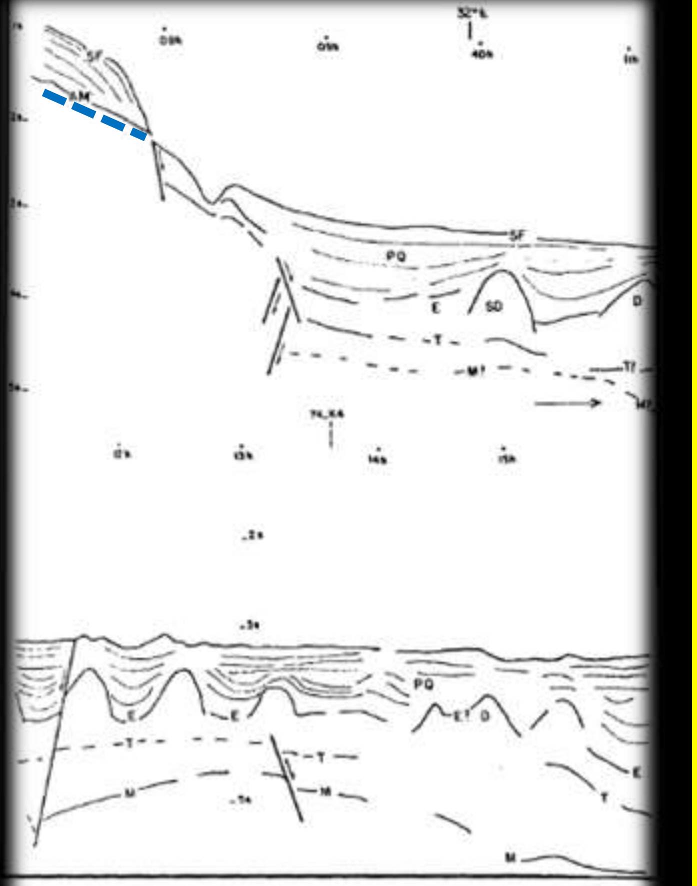
- Especially, the subsidence has played a main role and, novadays, that is still active.
Several opinions have been proposed by the authors, concerning the evolution of those basins.
In general, the region doesn't fit in with an ideal plate tectonic's model, so the opinions remain controversial.

- Reflectors of the Alanya massif define the lower limit of young sediments. It can be observed that the reflectors of the Alanya Massif suddenly submerged under the reflectors of Tertiary and older formations.
Bathymetric data when examined, the extension of Alanya Massif in the seait is believed that the extension merges with Cyprus in the south.

Alanya Massif & Seismic Data

The North-Eastern Mediterranean Sea, in the light of marine seismic reflection data
Güven Özhan MTA Genel Müdürlüğü Jeofizik Etüdleri Dairesi, Ankara.





Şekil 11. Profil L
AM: Alanya Masifi PQ: Pliyo-Kuvaterner,
E: Evaporit T: Tersiyer SF: Deniz tabam SD:
Tuz domu M: Mesozoyik D: Dom

Figure 11. Line L
AM: Alanya Massive PQ: Plio-Quaternary E:
Evaporite T: Tertiary SF: Sea floor SD: Salt
dome M: Mesozoic D: Dome

Nickel Sulphide Deposits - The principal ore mineral is pentlandite $(Fe,Ni)_9S_8$ are formed from the precipitation of nickel minerals by hydrothermal fluids. These sulfide deposits are also called magmatic sulfide deposits. *The main benefit to sulphide ores is that they can be concentrated using a simple physical separation technique called flotation.* Most nickel sulfide deposits have been processed by concentration through a froth flotation process followed by pyrometallurgical extraction.

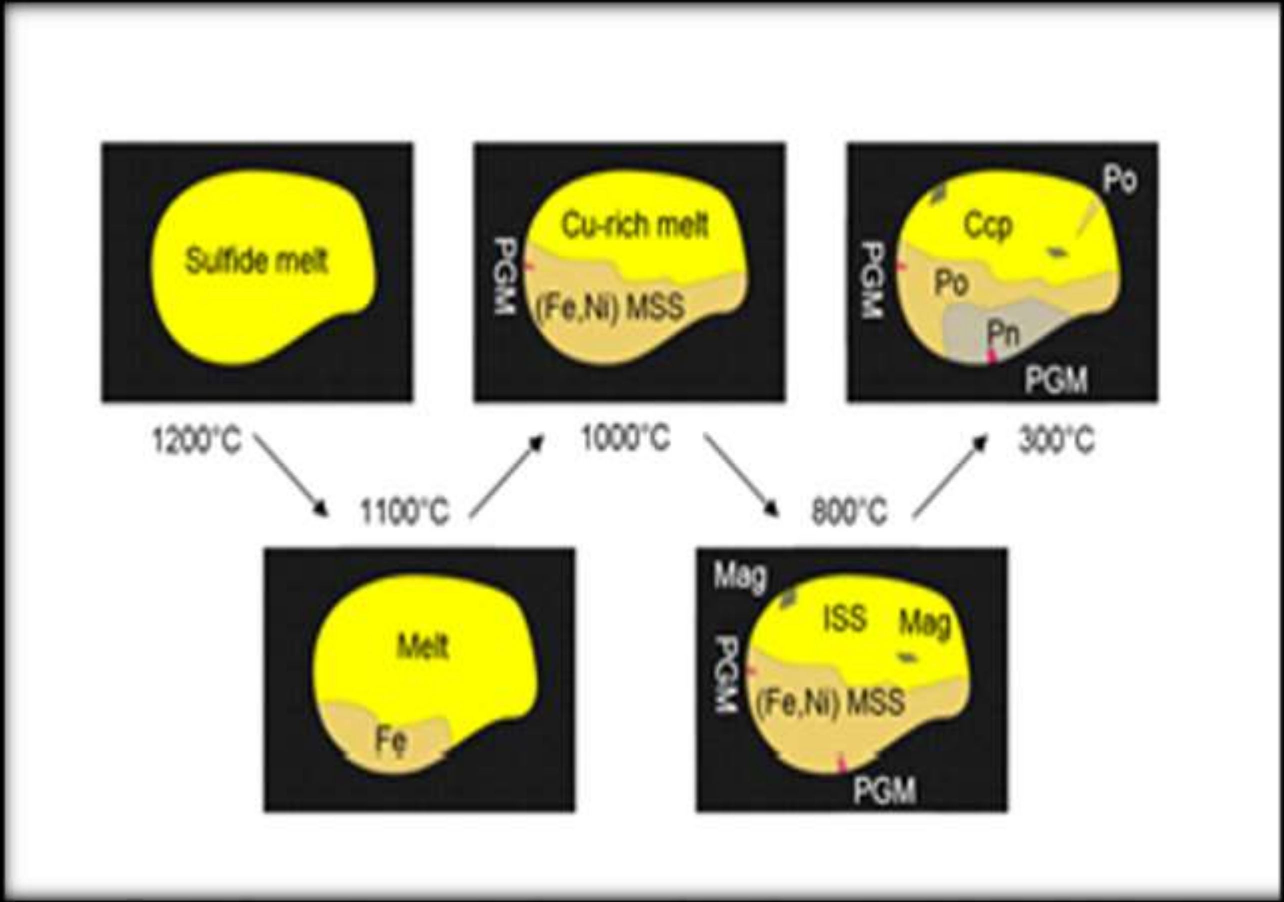
Magmas (magma is a mixture of molten rock, volatiles and solids that is found beneath the surface of the Earth - Lava is the extrusive equivalent of magma) originate in the upper mantle and contain small amounts of nickel, copper and PGE.
As the magmas ascend through the crust they cool as they encounter the colder crustal rocks.

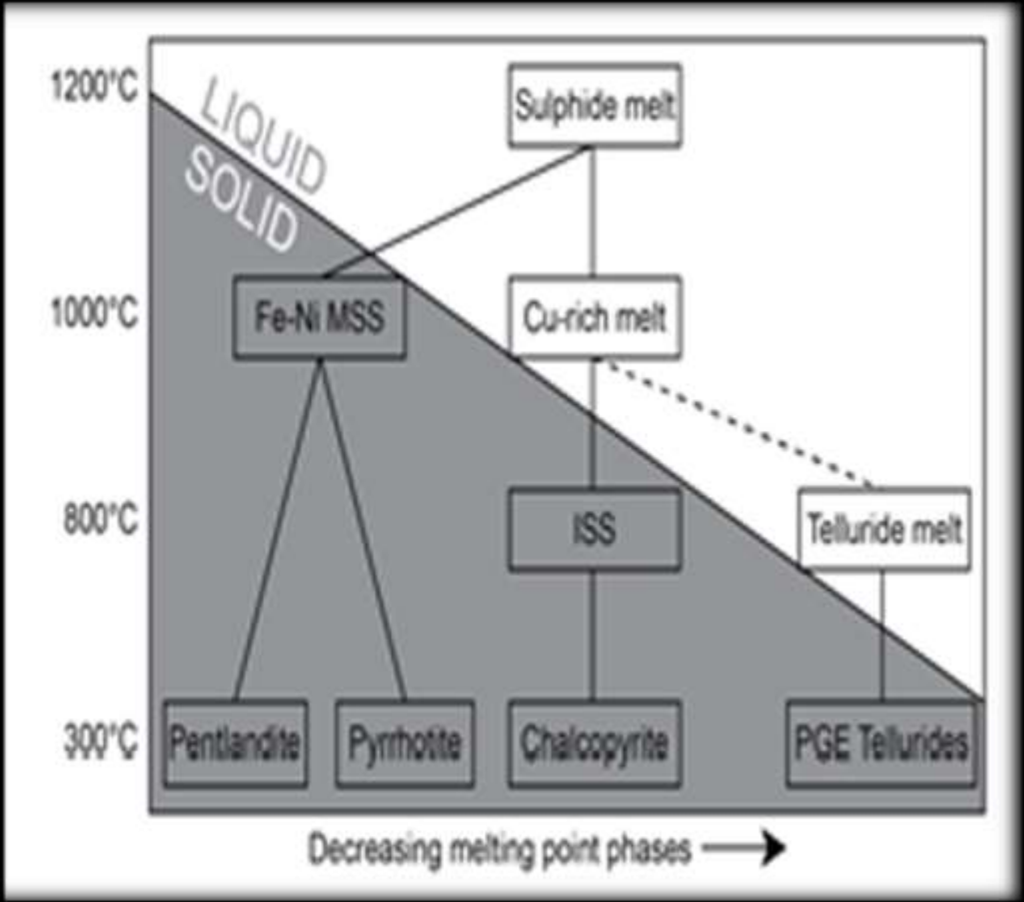
If the original sulfur (S) content of the magma is sufficient, or if S is added from crustal wall rocks, a sulphide liquid forms as droplets dispersed throughout the magma. Because the partition coefficients of Nickel, Copper, Iron and Platinum Group Elements (PGE) favor sulphide liquid these elements transfer into the sulphide droplets in the magma.
The sulphide droplets sink toward the base of the magma because of their greater density and form sulphide concentrations.
On further cooling, the sulphide liquid crystallizes to form the ore deposits that contain these metals.

There are two main types of nickel sulphide deposits. In the first, Ni-Cu sulphide deposits, Nickel (Ni) and Copper (Cu) are the main economic commodities - Copper may be either a co-product or by-product, and Cobalt (Co), Platinum Group Elements (PGE) and Gold (Au),Silver (Ag) are the usual by-products.
The second type of deposit is mined exclusively for PGE’s with the other associated metals being by-products.

Nickel sulphide deposits can occur as individual sulphide bodies but groups of deposits may occur in areas or belts ten’s, even hundreds of kilometers long. Such groups of deposits are known as districts.

Two giant Ni-Cu districts stand out above all the rest in the world:
Sudbury – Ontario,Canada and Noril’sk – Talnakh, Russia.





Sulfides are accessory phases in all types of mantle xenoliths.
The major sulfide phases present in mantle rocks are pyrrhotite ,pentlandite and chalcopyrite.
Also present are the ‘monosulfide solid solution’ (mss) and ‘intermediate solid solution’ (iss) phases.
The observed mineralogy of mantle sulfides, however, likely represents low temperature (<300 °C) re-equilibration of high-temperature mss or, possibly, sulfide melt.

Global distribution of sediment-hosted metals controlled by craton edge stability

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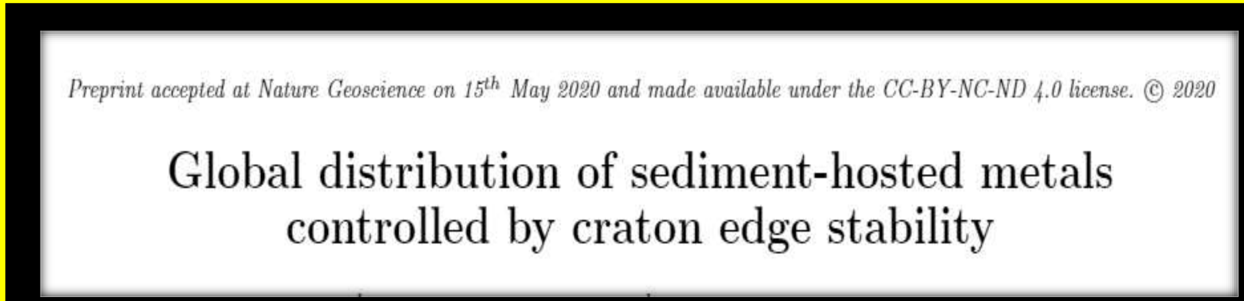
Abstract

Sustainable development and the transition to a clean-energy economy drives ever-increasing demand for base metals, substantially outstripping the discovery rate of new deposits and necessitating dramatic improvements in exploration success. Rifting of the continents has formed widespread sedimentary basins, some of which contain large quantities of copper, lead and zinc. Despite over a century of research, the geological structure responsible for the spatial distribution of such fertile regions remains enigmatic. Here, we use statistical tests to compare deposit locations with new maps of lithospheric thickness, which outline the base of tectonic plates. We find that 85% of sediment-hosted base metals, including all giant deposits (>10 megatonnes of metal), occur within 200 kilometres of the transition between thick and thin lithosphere. Rifting in this setting produces greater subsidence and lower basal heat flow, enlarging the depth extent of hydrothermal circulation available for forming giant deposits. Given that mineralization ages span the past two billion years, this observation implies long-term lithospheric edge stability and a genetic link between deep Earth processes and near-surface hydrothermal mineral systems. This discovery provides an unprecedented global framework for identifying fertile regions for targeted mineral exploration, reducing the search space for new deposits by two-thirds on this lithospheric thickness criterion alone.

https://eartharxiv.org/2kjvc#



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Global distribution of sediment-hosted metals controlled by craton edge stability

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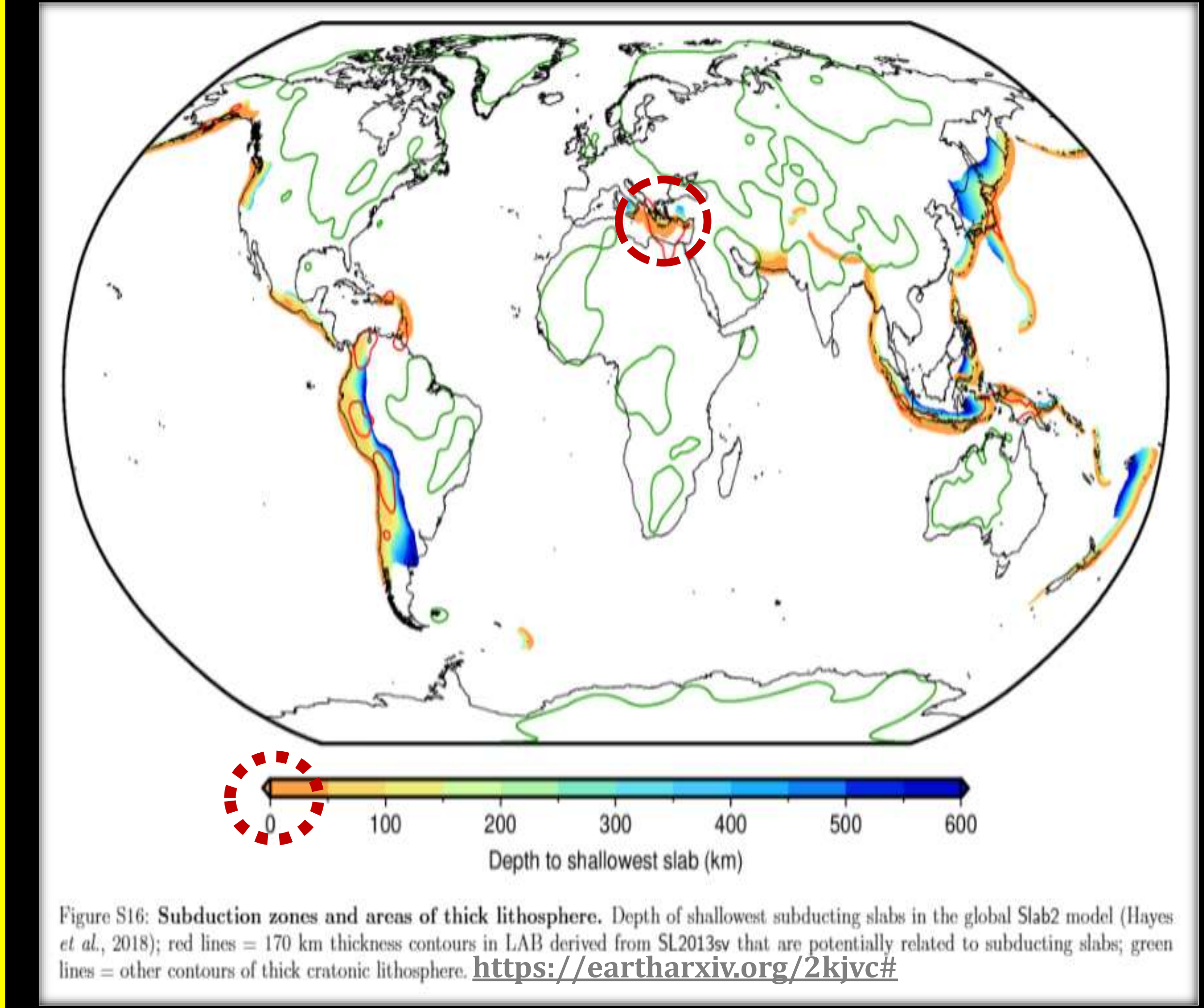

Figure S16: **Subduction zones and areas of thick lithosphere.** Depth of shallowest subducting slabs in the global Slab2 model (Hayes *et al.*, 2018); red lines = 170 km thickness contours in LAB derived from SL2013sv that are potentially related to subducting slabs; green lines = other contours of thick cratonic lithosphere. https://eartharxiv.org/2kjvc#

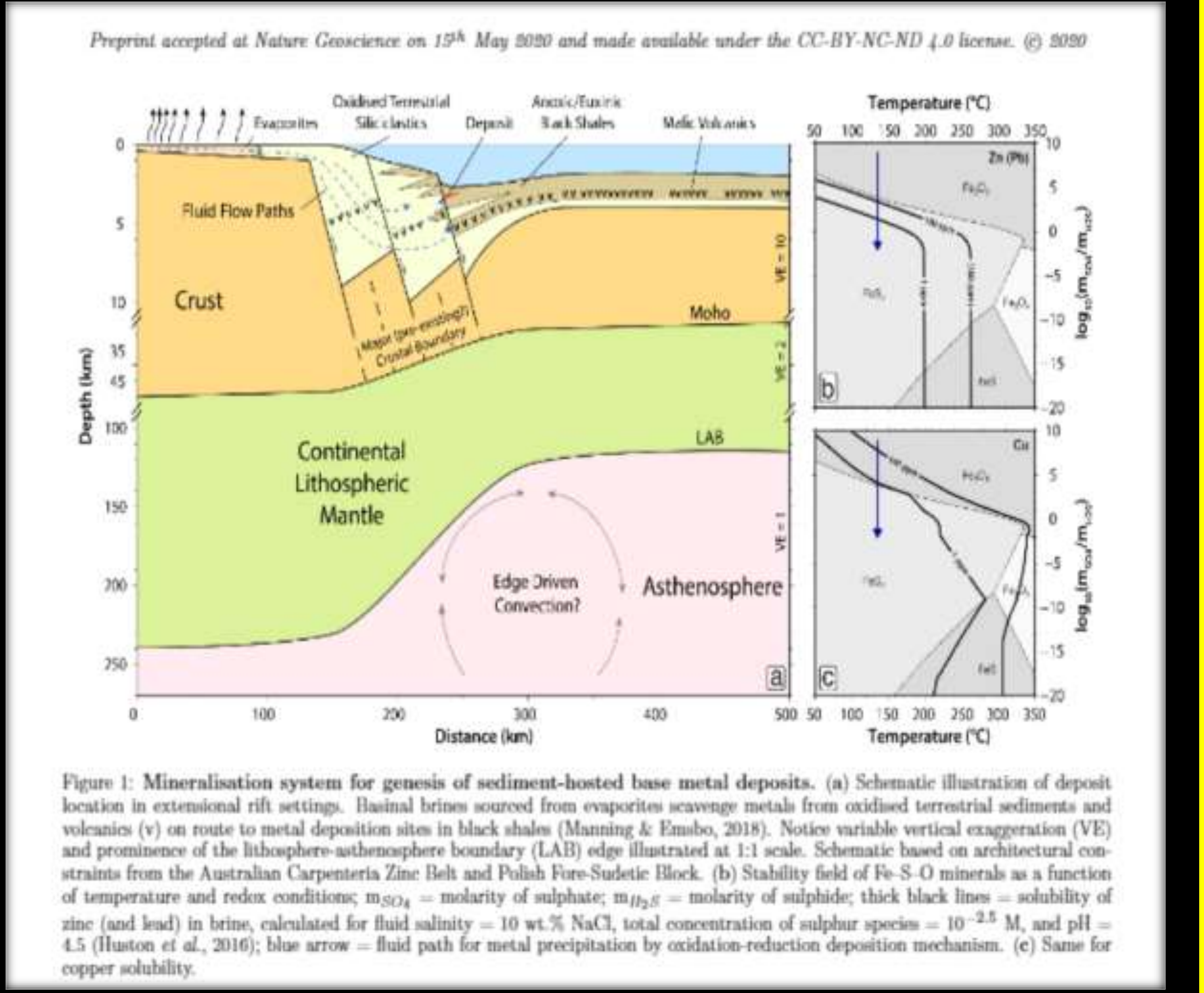

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Figure 1: **Mineralisation system for genesis of sediment-hosted base metal deposits.** (**a**) Schematic illustration of deposit location in extensional rift settings. Basinal brines sourced from evaporites scavenge metals from oxidised terrestrial sediments and volcanics (v) on route to metal deposition sites in black shales (Manning & Emsbo, 2018). Notice variable vertical exaggeration (VE) and prominence of the lithosphere-asthenosphere boundary (LAB) edge illustrated at 1:1 scale. Schematic based on architectural constraints from the Australian Carpenteria Zinc Belt and Polish Fore-Sudetic Block. (**b**) Stability field of Fe-S-O minerals as a function of temperature and redox conditions; m_{SO_4} = molarity of sulphate; m_{H_2S} = molarity of sulphide; thick black lines = solubility of zinc (and lead) in brine, calculated for fluid salinity = 10 wt.% NaCl, total concentration of sulphur species = $10^{-2.5}$ M, and pH = 4.5 (Huston *et al.*, 2016); blue arrow = fluid path for metal precipitation by oxidation-reduction deposition mechanism. (**c**) Same for copper solubility.

Noril’sk–Talnakh Cu–Ni–PGE deposits: a revised tectonic model

Alexander Yakubchuk - Anatoly Nikishin

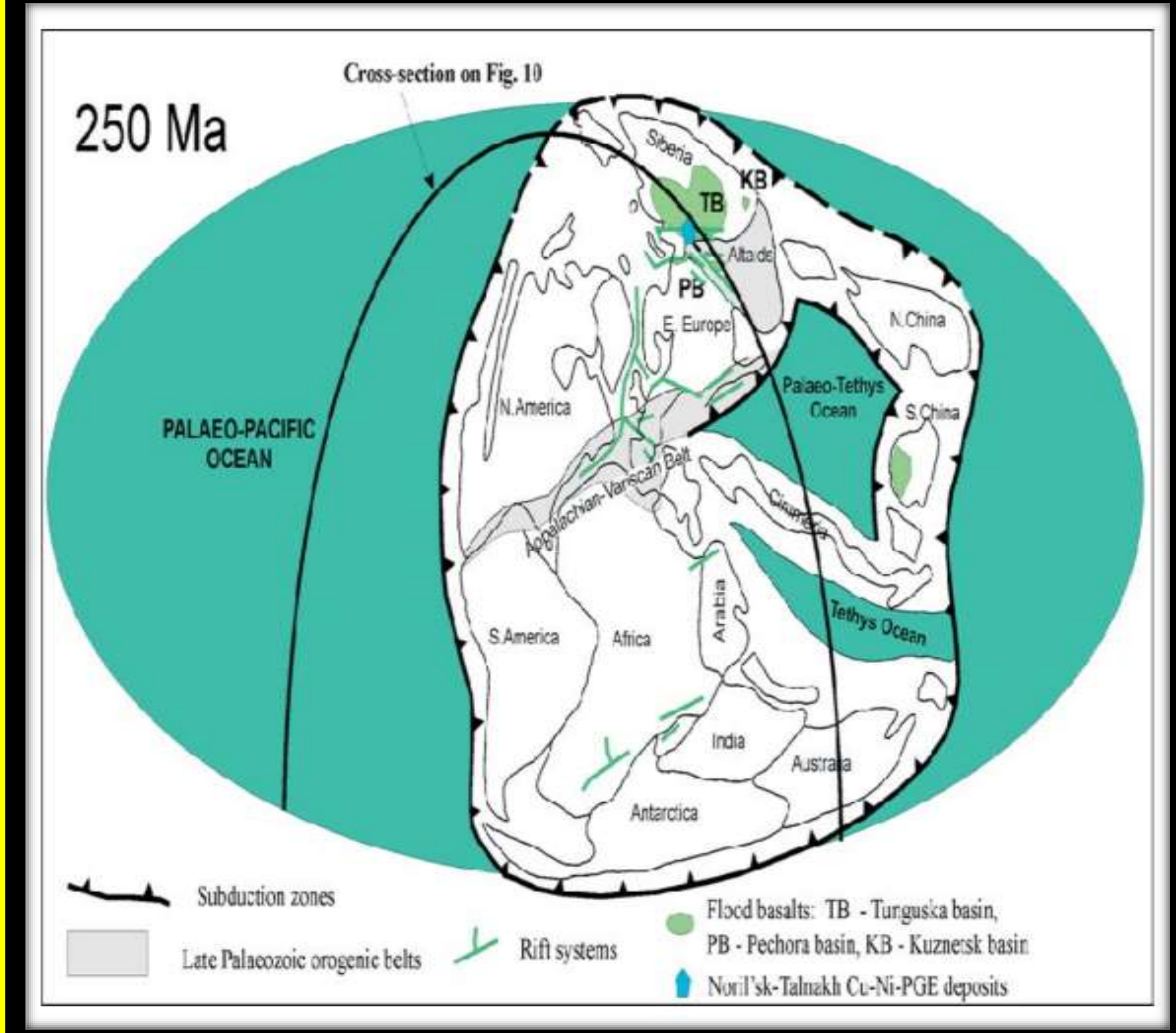


Fig. 9 Permo-Triassic (250 Ma) reconstruction (simplified after Scotese and McKerrow) showing location of major continental rifts, flood basalt provinces and related Cu–Ni–PGE mineralization

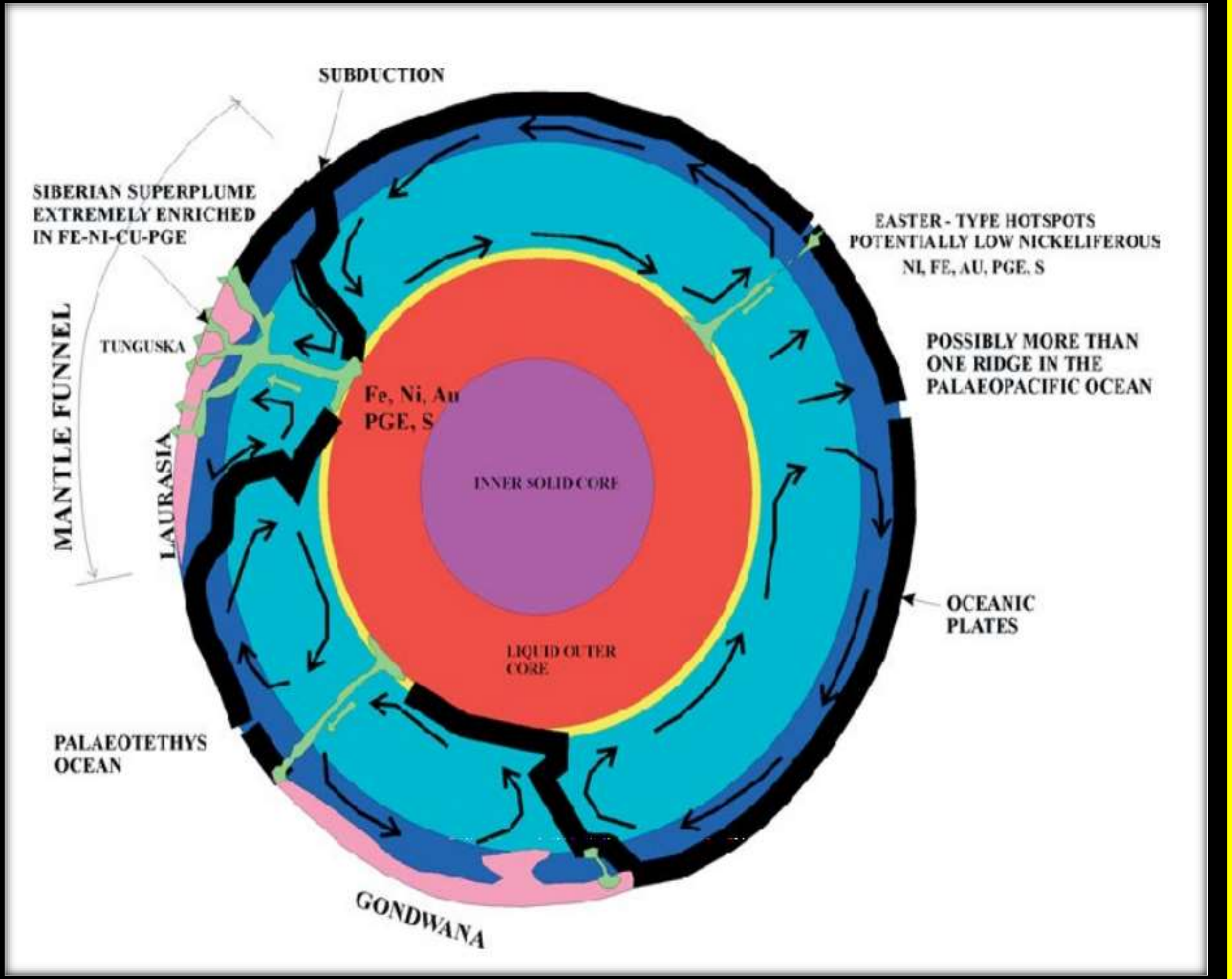


Fig. 10 Possible structure of the Earth at the Permian– Triassic transition. We suggest the presence of a whole-mantle subduction funnel under Laurasia, which might stimulate focused ascent of the Cu–Ni–PGE-rich mantle plume (green) in the geometric centre of the continent. Black arrows show possible convection in the mantle

- The origin of Ni,Cu,PGE sulfide deposits of Norilsk and Talnakh located in the northwest flank of the Triassic basalt trap formation of Siberia is considered. It is shown that ore elements of these deposits (probably, except Fe) are derived from the crust rather than from the mantle. They entered the basalts owing to a remobilization (recycling) of ore elements from the Paleoproterozoic sediments and from the rocks of the Siberian platform’s basement.

- Prospecting criteria for similar deposits are as follows:

(1) a presence of a large Paleoproterozoic aulacogen and a related magmatic sulfide Cu,Ni mineralization;
(2) a confinement of perspective areas to troughs associated with long-lived deep fault zones;
(3) association with mobile orogenic belts, island-arc systems and tectonomagmatic activation zones;
(4) temporal association with boundaries of global periods characterized by active processes of continental breakup and large-scale trap magmatism.

A combination of several factors (the first one is obligatory) is favorable for the discovery of a large ore body

- The deposits of the Noril'sk region have developed within flat, elongate bodies (15 X 2 X 0.2 km) that intrude argillites, evaporites and coal measures, adjacent to a major, transcrustal fault and immediately below the centre of a 3.5 km-thick volcanic basin. An anticlinal axis that transects the axis of the basin at a high angle has brought these intrusions to surface to give rise to the two major ore junctions, Noril'sk and Talnakh.

- When most major Ni-Cu sulfide deposits, the light of studies at Norilsk, Sudbury, three factors become apparent:

(i) the concentration of sulfides in channels or conduits through which much magma has flowed (feeder conduits for intrusions are much more prospective targets for exploration than the base of the intrusions themselves);
(ii) the interaction of the source magma with country rocks, either leading to the incorporation of sulfur, or the felsification of the magma in question; and
(iii) fractional crystallisation of sulfide liquid giving rise to Cu-rich ores which may be far removed from the ‘source’ ore.

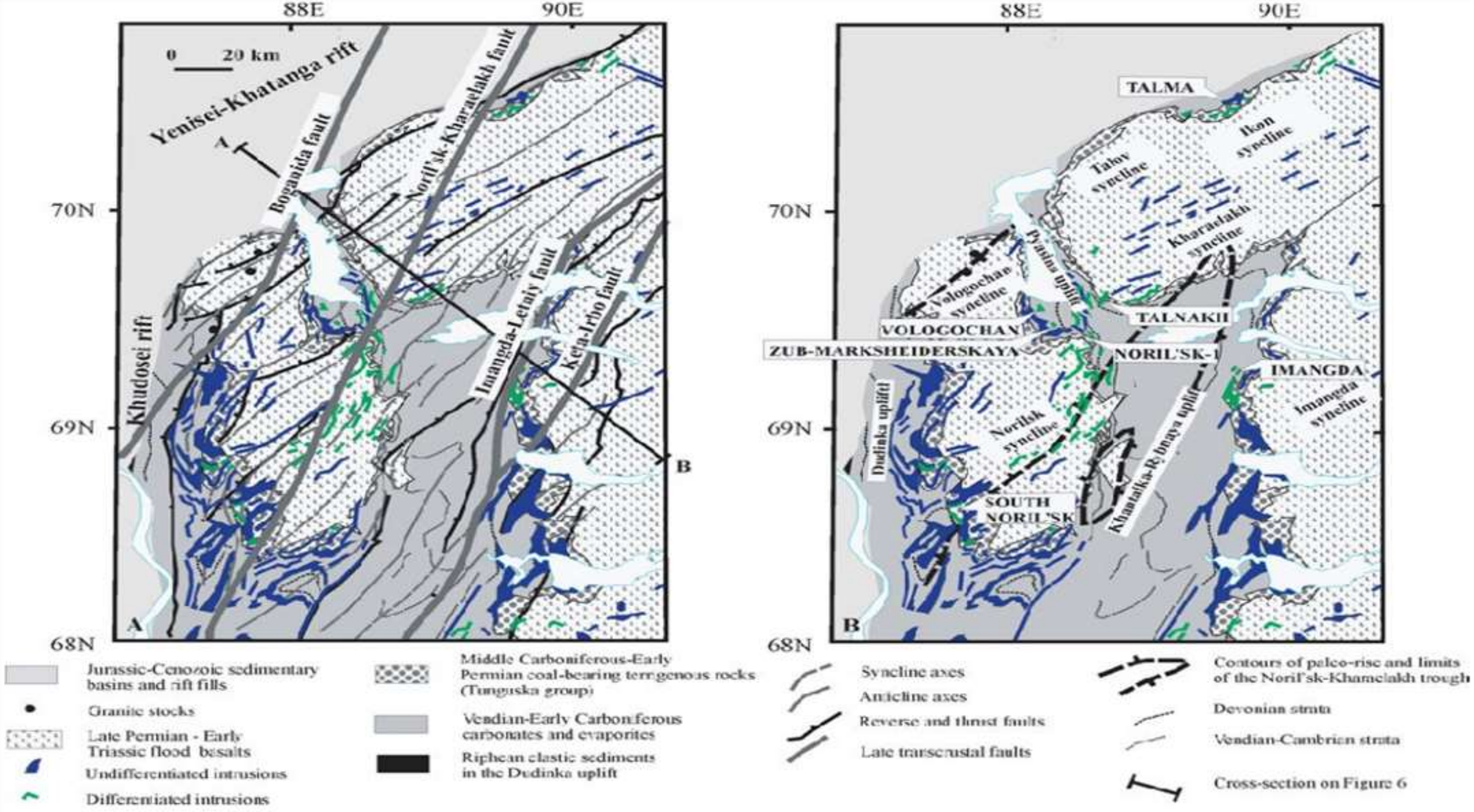


Fig. 3 Geologic map of the Noril'sk–Kharaelakh trough (compiled using Sherman 1991). **A** Post-mineralization compressional structures, **B** syn-mineralization pre-compressional structures

The Siberian superplume province

SIC Sudbury Igneous Complex

Birthplace of a World Famous Mining District

●Sudbury area a world class mining district hosts of the world's largest Ni-Cu-PGE magmatic sulphide deposits.

●The Greater Sudbury area is an astonishingly rich mining district. By every measure it is huge.
The district has produced more than 8 million tonnes each of nickel and copper, and over 3200 tonnes of silver, 300 tonnes of platinum and 100 tonnes of gold.
Based on today's metal prices, more than 77 mines have produced an estimated CDN$ 500 billion worth of metal in the past century.

●From the late 1920s until around 2000, all significant magmatic sulphide deposits of the Sudbury Structure were the property of either INCO Ltd (now VALE INCO) or Falconbridge Ltd. (now XSTRATA-GLENCORE).

●The first mineralization in the area was discovered by a surveyor (1856) and described by Murray (1857) of the Geological Survey of Canada. Several decades later the site was found to lie only 200 m west of the open pit of the Creighton Mine (Giblin 1984). The first discovery of mineralization, which led to the development of a mine, was made in 1883 during construction of the Canadian Pacific Railway. A rail-cut exposed high grade mineralization, which was later (1884) developed as the Murray Mine. By 1999, after 112 years of exploration, approximately 116 deposits have been found.

- **Genetic Models of Ore Deposits of the Sudbury Igneous Complex The Ni-Cu-PGE sulphide deposits of the SIC are generally classified into three main groups:**

(1) Contact Deposits
(2) Offset Deposits and
(3) Footwall Deposits (mostly Cu-Ni-PGE deposits).

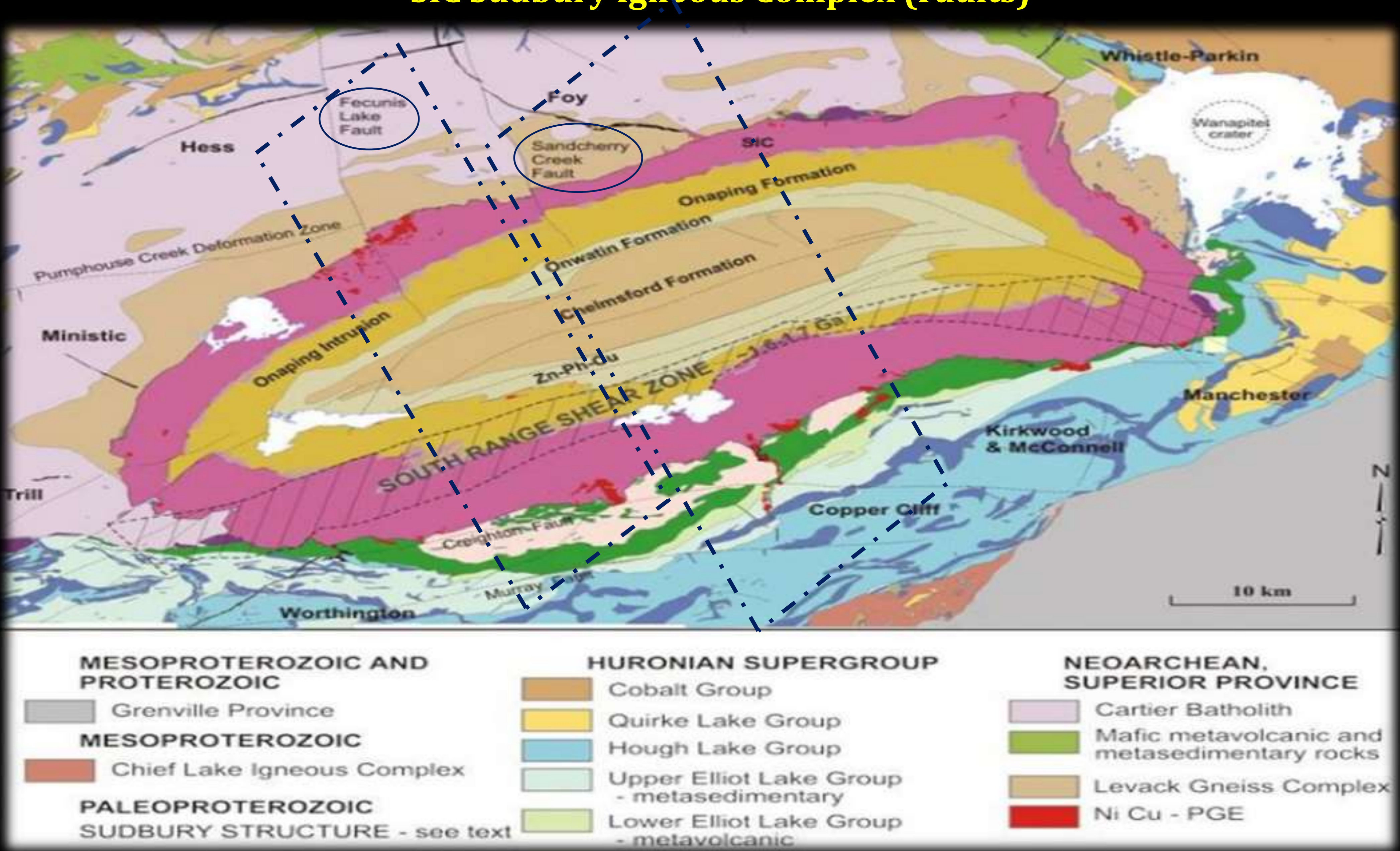
- **Contact-type Ni-rich deposits are historically the most important ore type in Sudbury and were the first to be mined in the Sudbury camp. This deposit type located at the base of the SIC within embayment structures, and is hosted in either Sublayer Norite or Footwall Breccia Ore deposits of this type comprise inclusion-rich massive to semi-massive sulphides.**

- **Sulphide assemblage is dominated by pyrrhotite (Fe+S) and minor pentlandite, (Fe+Ni+S) with Cu/Ni ratios of approximately 0.7 and Pt+Pd+Au contents of <1 g/t suggested that assimilation of SiO2 rich crustal material by the Sudbury mafic magma could lower the solubility of sulphur and led tFE+S)o sulphide saturation and settling out sulphide liquid gravitationally to from massive orebodies in trap structures at the base of the intrusion/melt sheet. Mineralogy, texture and composition of these ores are easily explained by results of experimental studies of the Cu-Fe-Ni-Cu system .**

- **Similar studies from the Srathcona mine indicate that crystallization of monosulphide solid solution (Mss) from immiscible sulphide melt would start about 1125 ºC and pyrrhotite would be joined by magnetite at about 1055 ºC. As temperature decreases, exsolution from Mss occurs with pyrite, below 700 ºC, chalcopyrite below 450 ºC, and pentlandite below 300 ºC. The vertical compositional variation of sulphide ore (increasing Cu toward depth) in many Contact Sublayer deposits has been modelled by fractional crystallization of sulphide liquid .**

- **In this model the residual Cu-rich sulphide liquid escapes from the crystallized Mss and forms Cu, Pt, Pd and Au enriched deeperzones or footwall vein deposits.**

SIC Sudbury Igneous Complex (Faults)



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  Alexander Yakubchuk Æ Anatoly Nikishin

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  A. A. Barka ; R. Reilinger