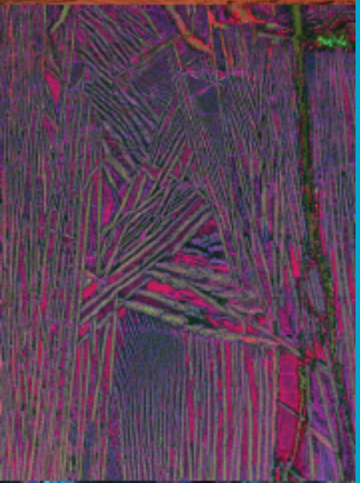
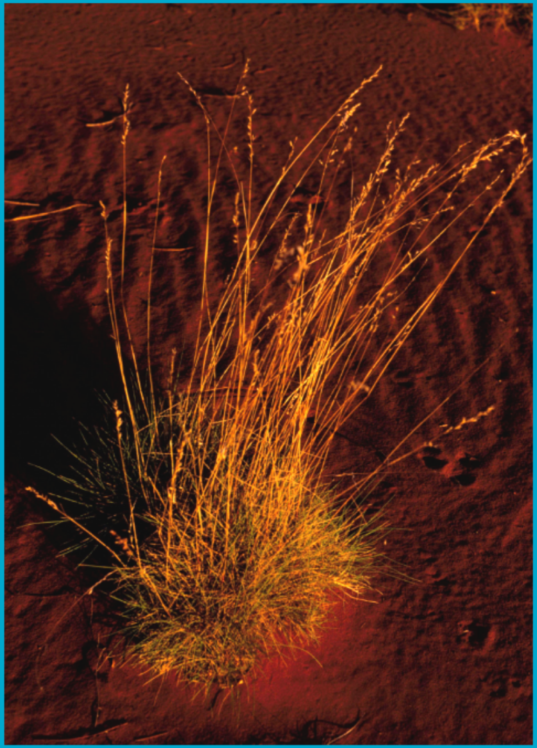


Komatiites of the East Yilgarn

In which we find out what komatiites are, look into the strange world of komatiite volcanology, and consider why the world's third largest nickel sulfide ore province is where it is…

…and meet this guy:

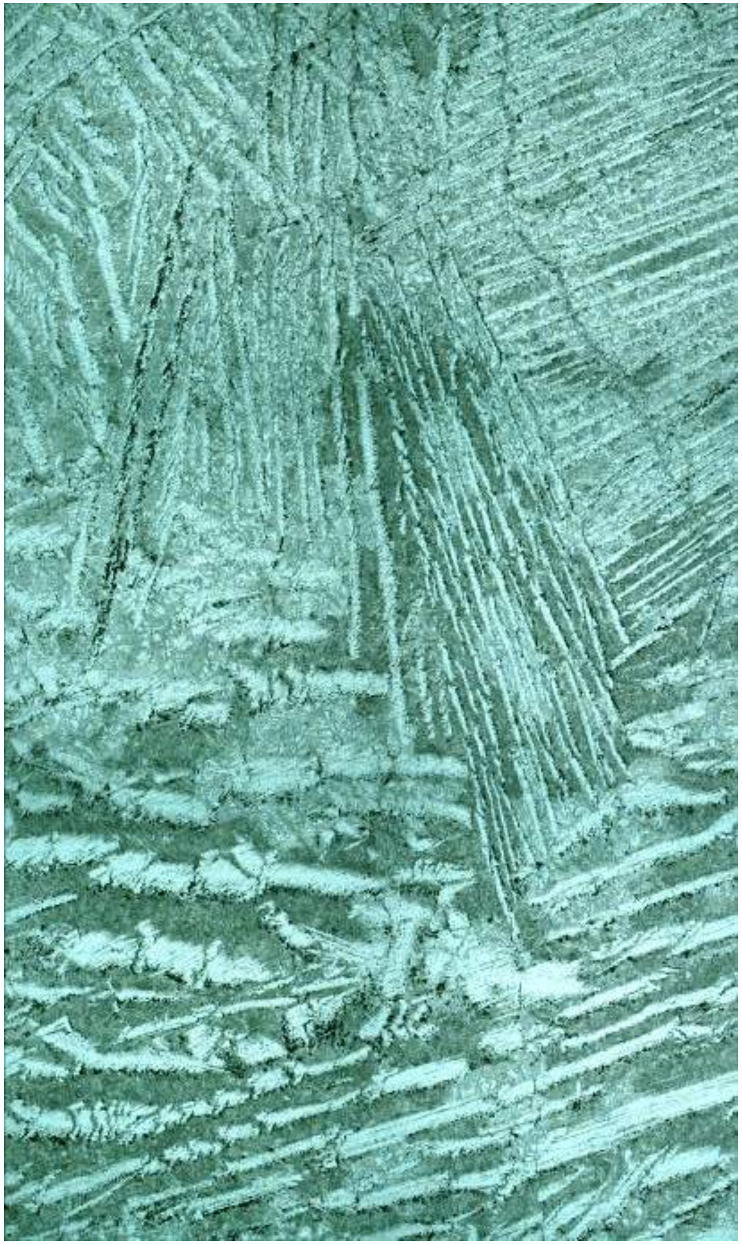


CSIRO MINERAL RESOURCES

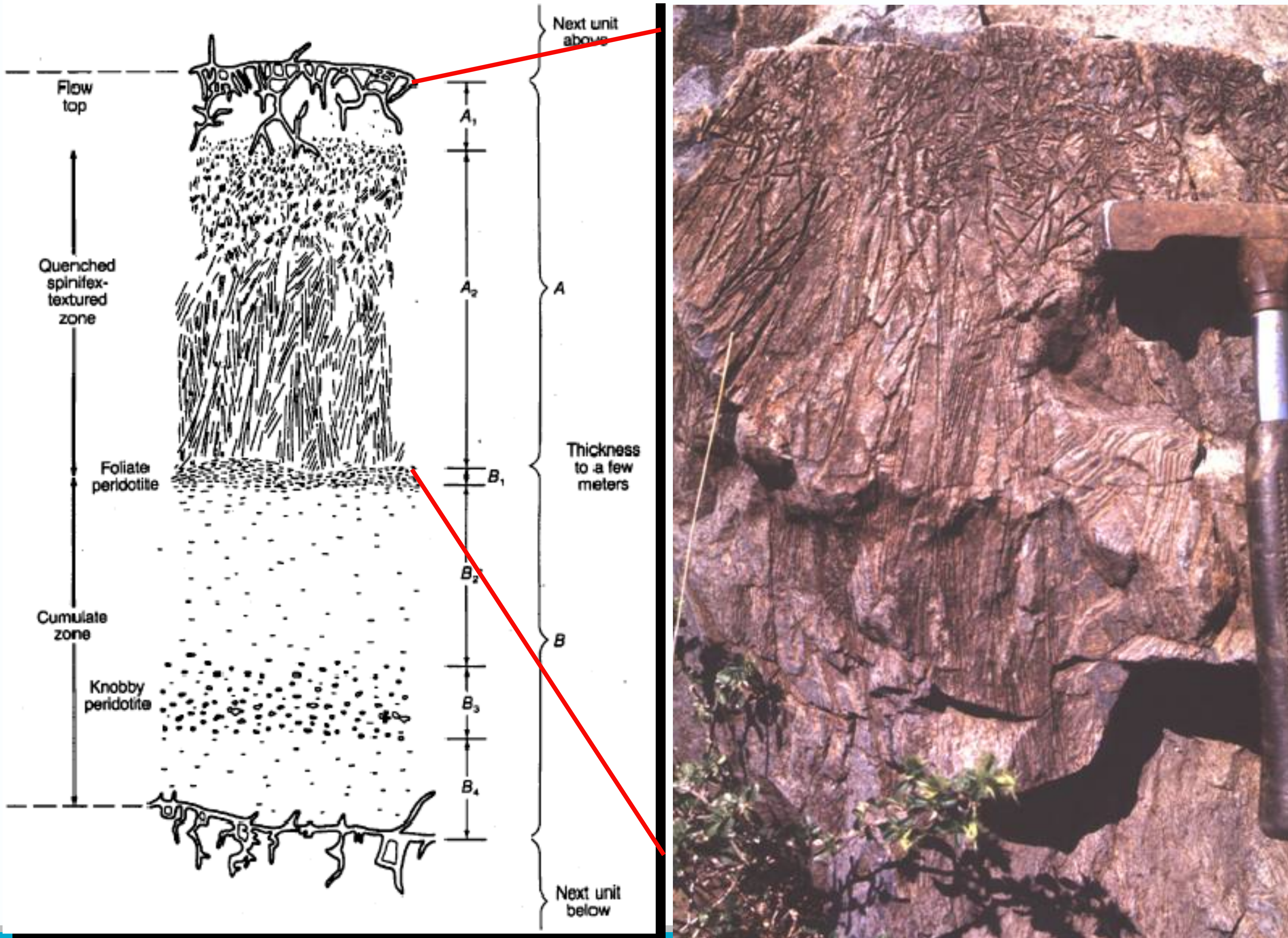
Steve Barnes @SteveBFreo
steve.barnes@csiro.au

What are Komatiites?

- Volcanic rocks with >18% MgO in the liquid: ultramafic lavas
- Characteristic dendritic olivine and pyroxene textures - “spinifex”
- Mainly Archaean, rarely Proterozoic
- Eruption temperatures up to 1600C

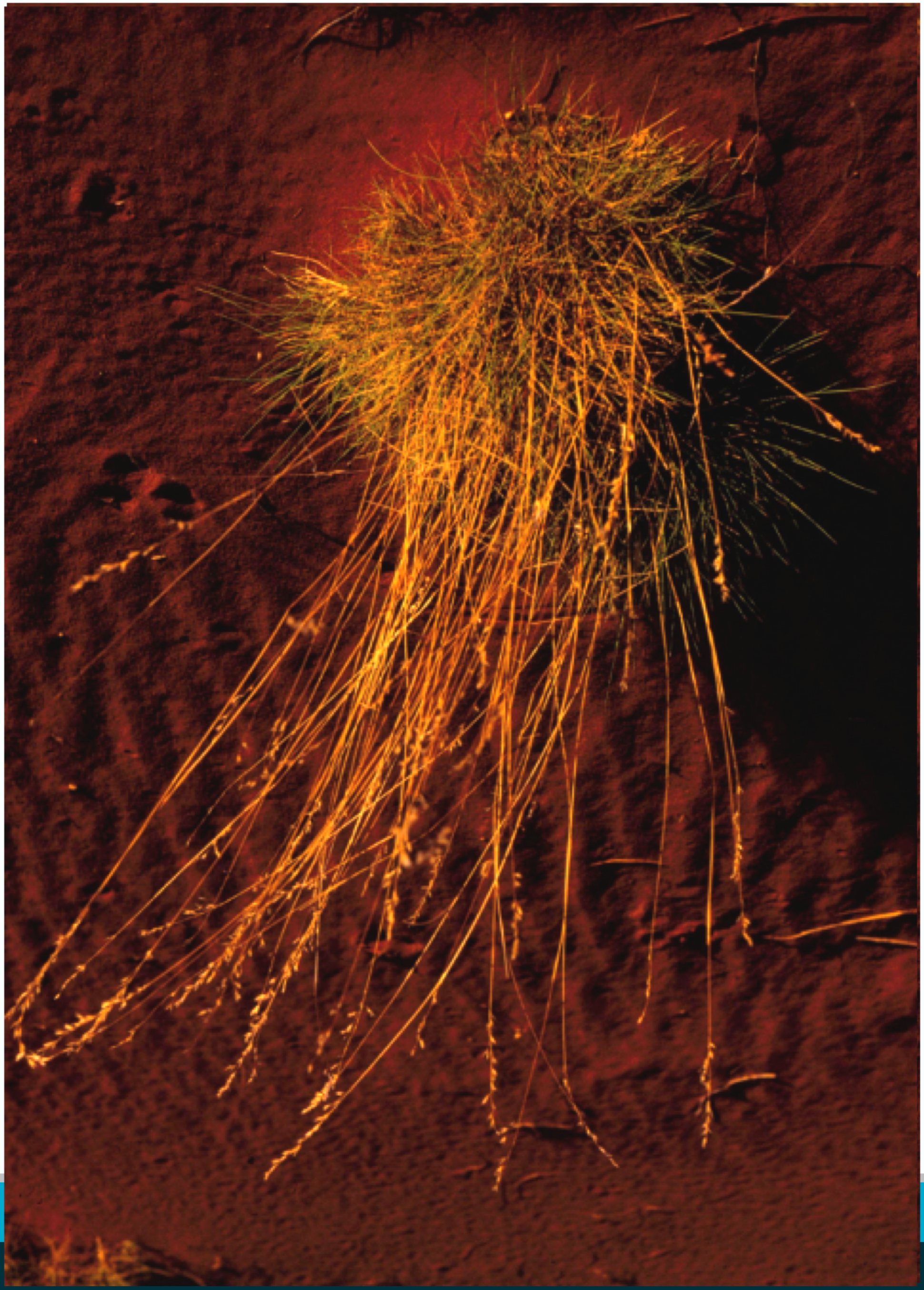


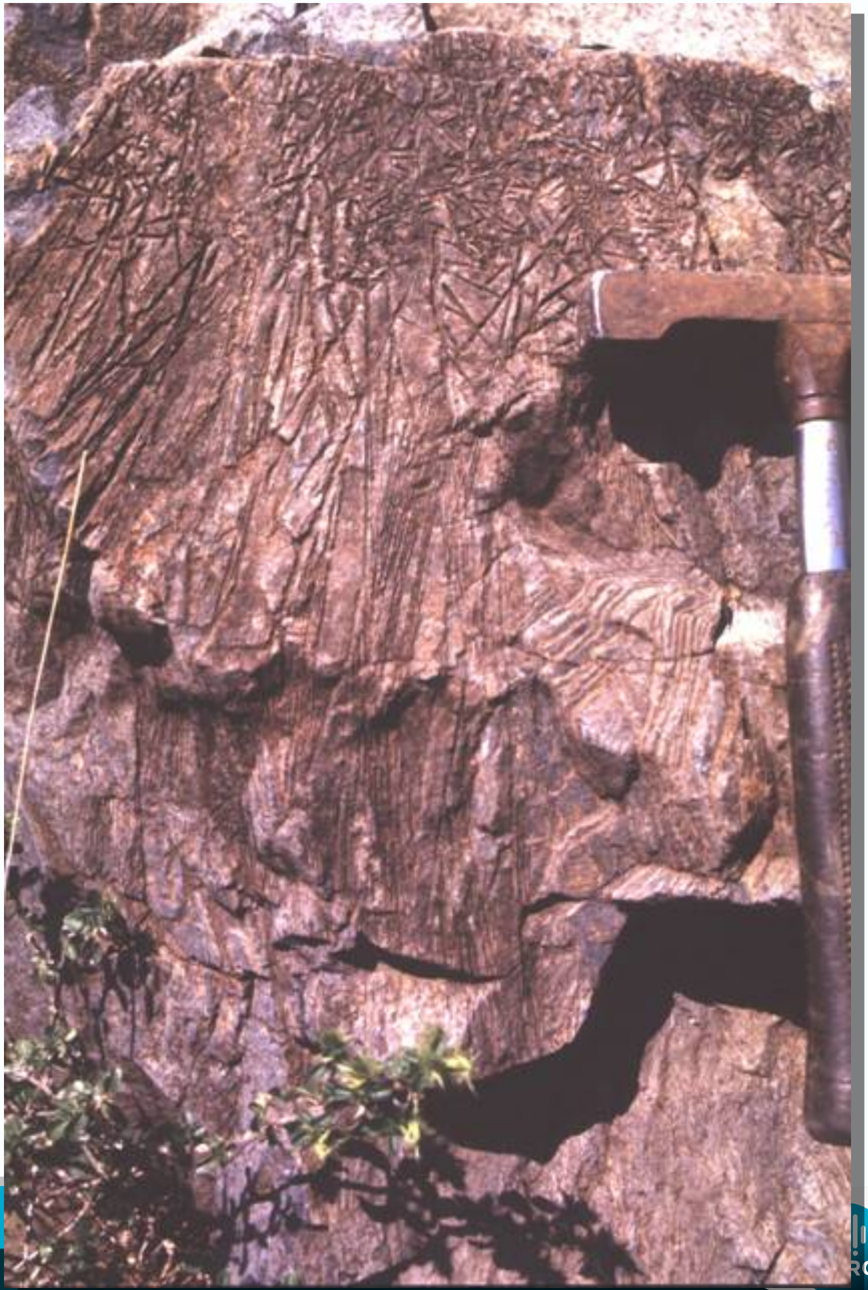
Extremely high T (1600C) – white hot, extreme low viscosity lavas
Low-aspect shield volcanoes and large lava fields



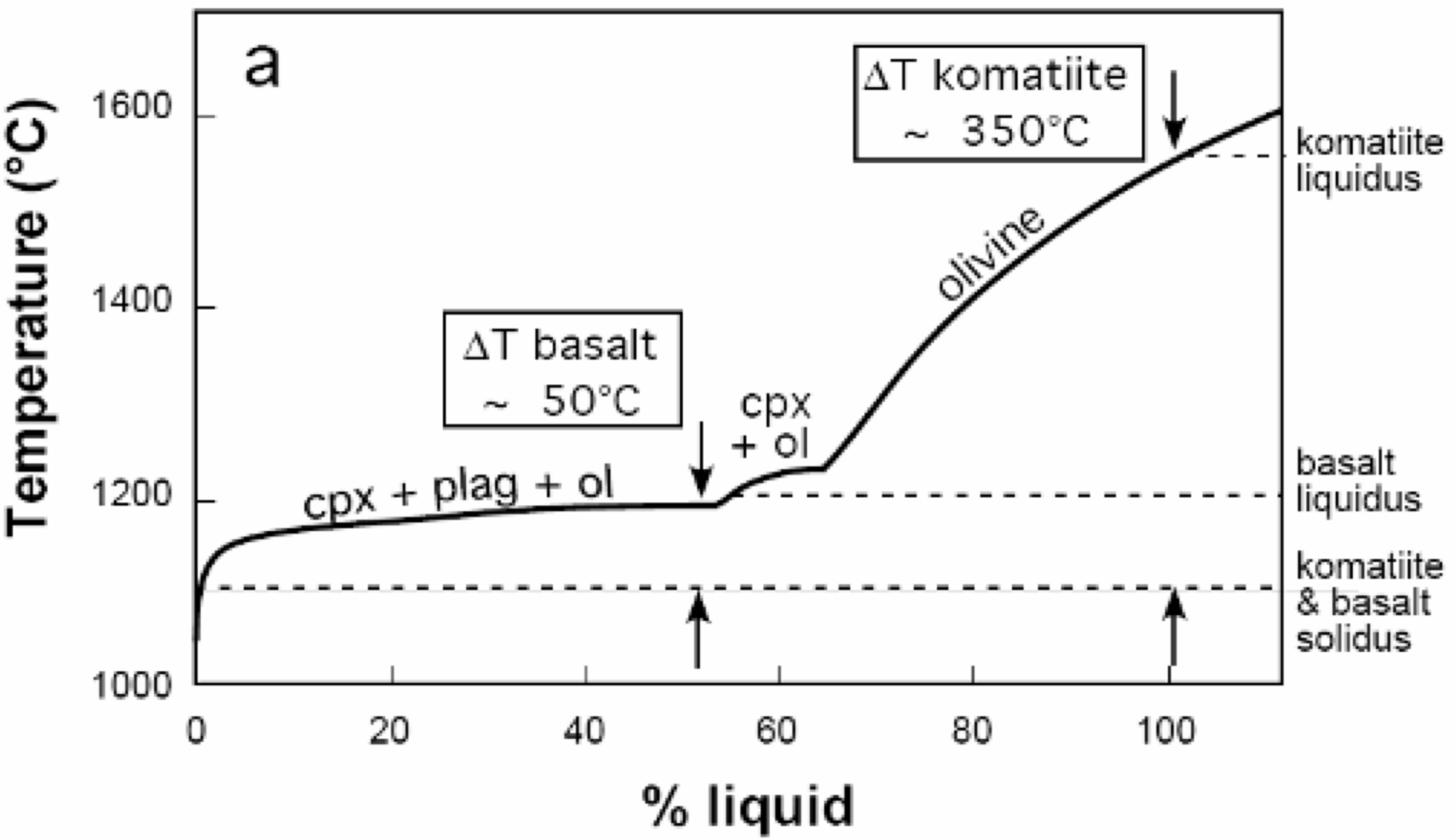
Next unit above
Flow top
A_1
Quenched spinifex-textured zone
A_2
A
Foliate peridotite
B_1
Thickness to a few meters
B_2
Cumulate zone
B
Knobby peridotite
B_3
B_4
Next unit below

Spinifex (Triodia)

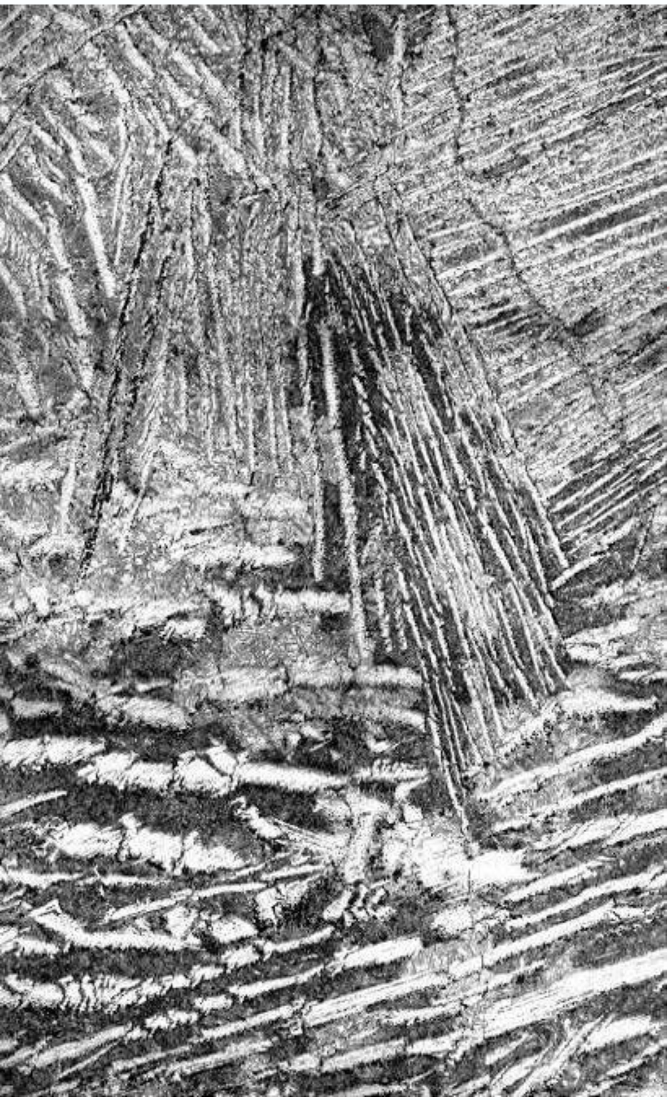




Komatiite phase equilibria



Komatiites crystallise olivine (+/- chromite) over a large part of their cooling history
Small amount of olivine crystallises over a large temperature drop
Komatiites can easily assimilate very large proportions of country rock



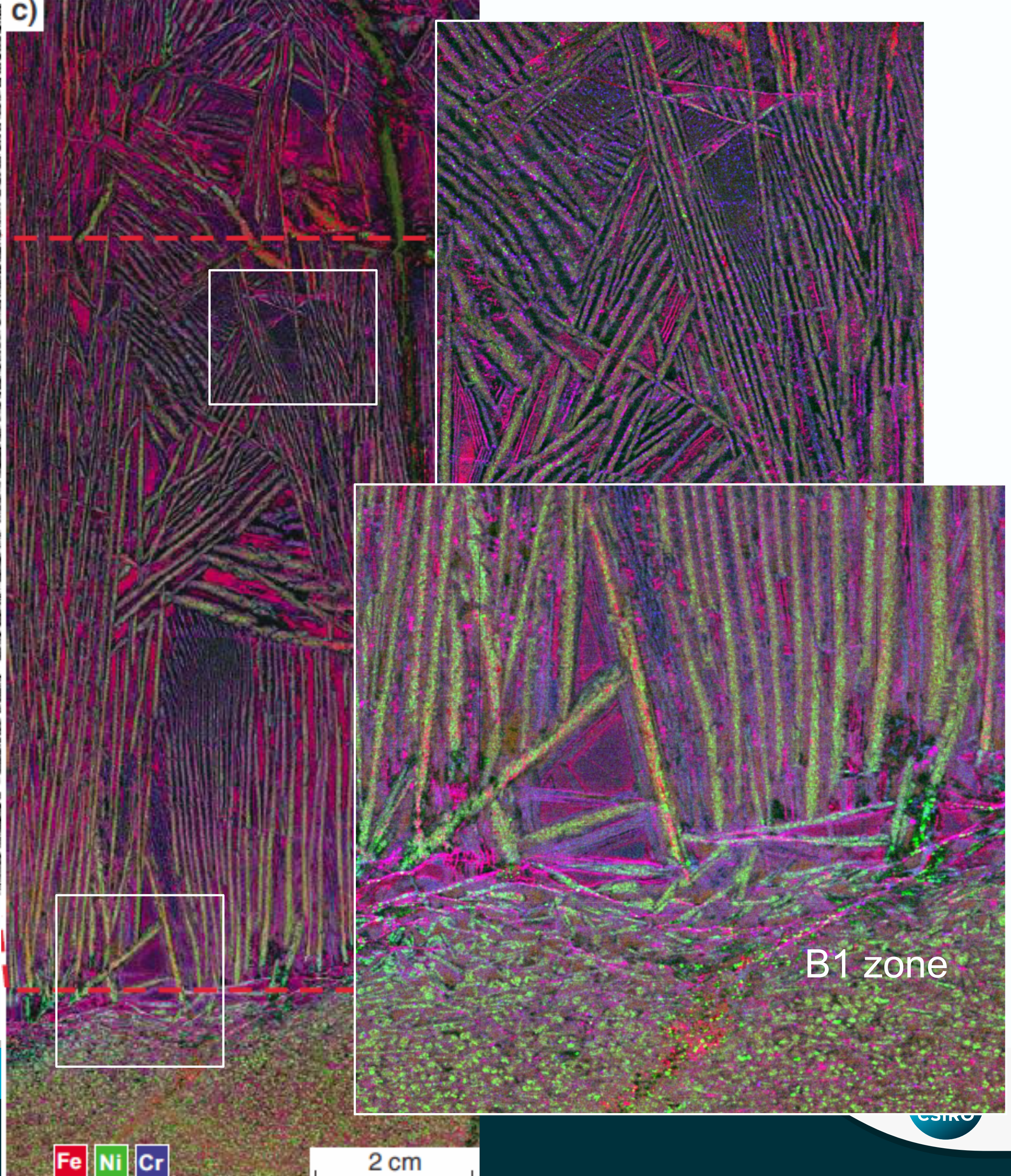
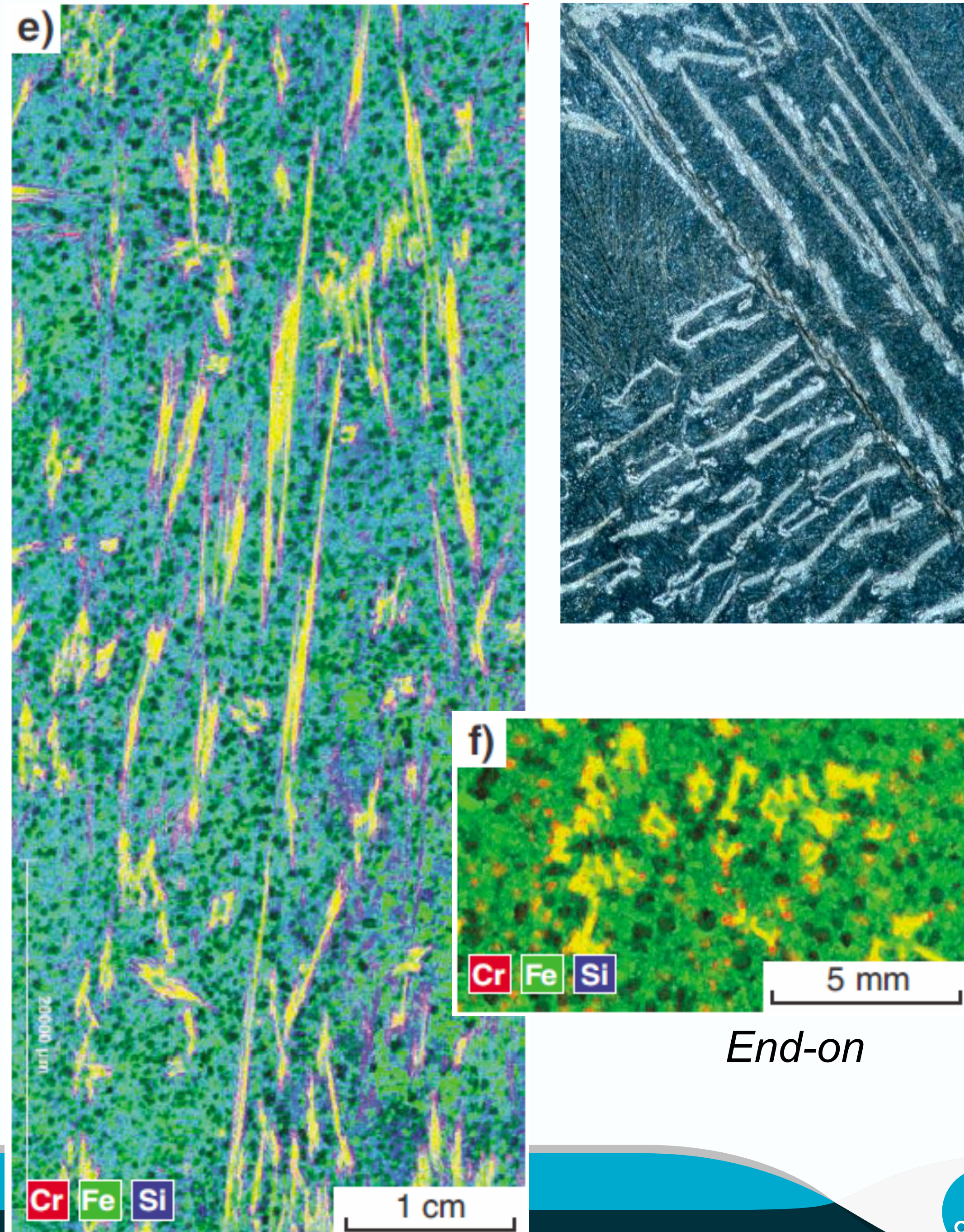


Plate-shaped dendrites
Like pages in a book
18-30% MgO

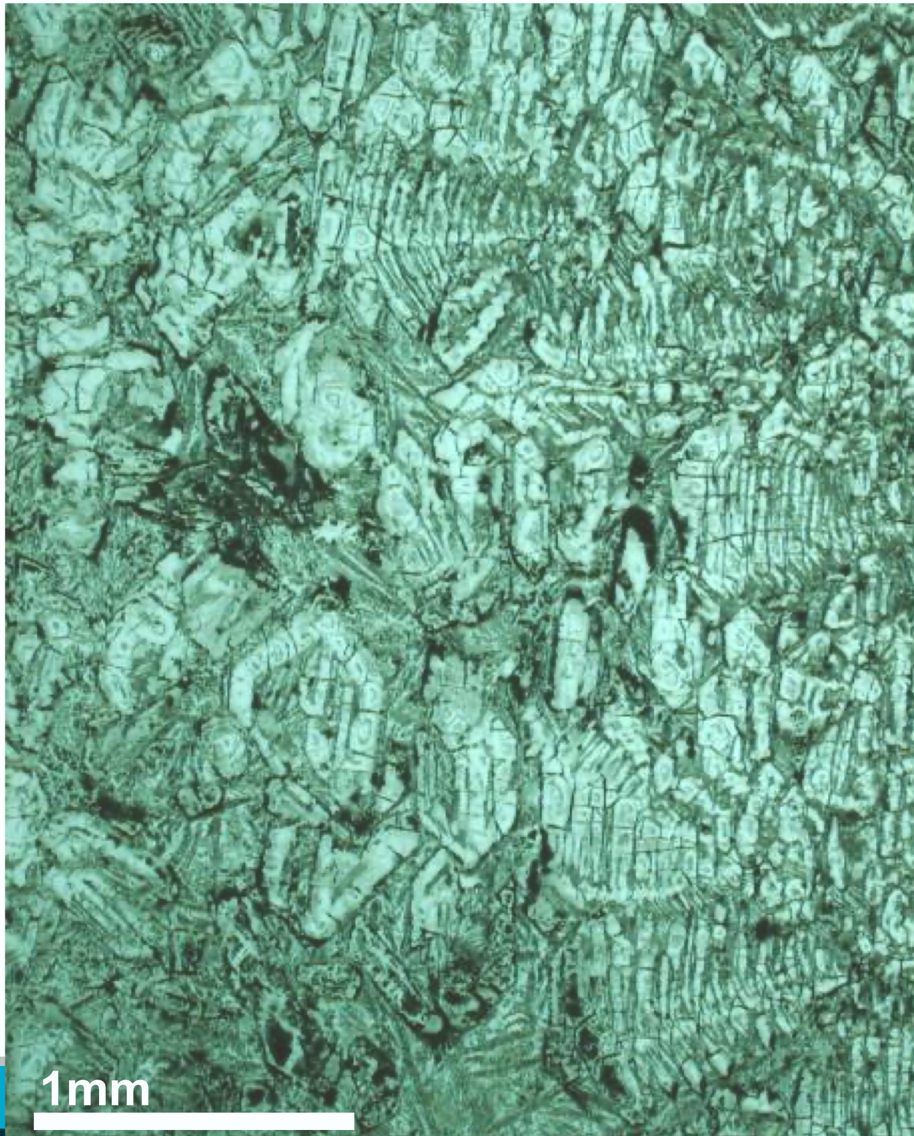
Olivine spinifex

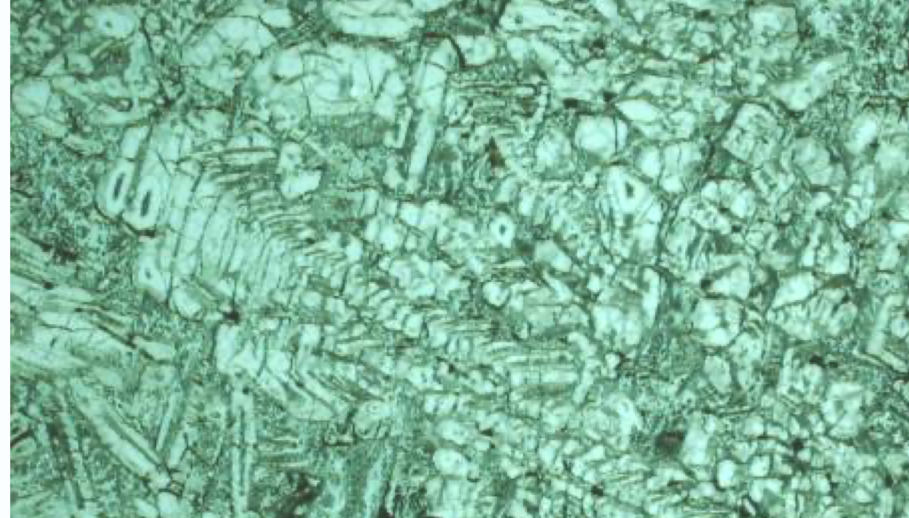
Pyroxene spinifex

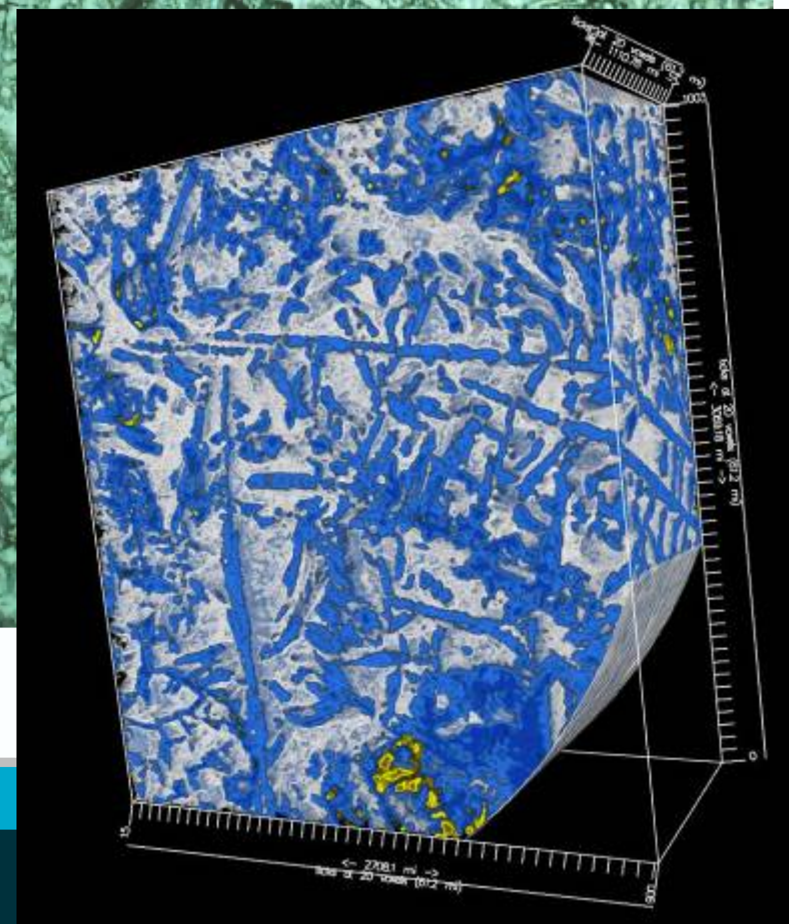
Needles – 8-18% MgO



Curiouser and curiouser… (Murphy Well)

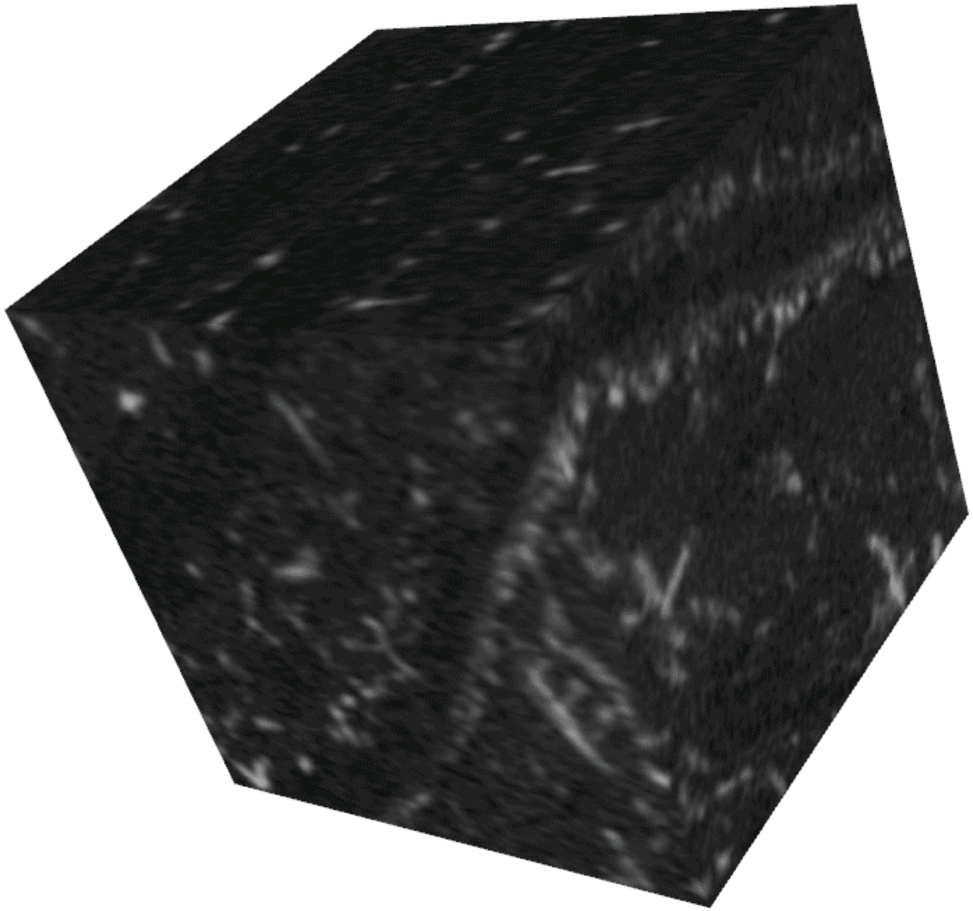


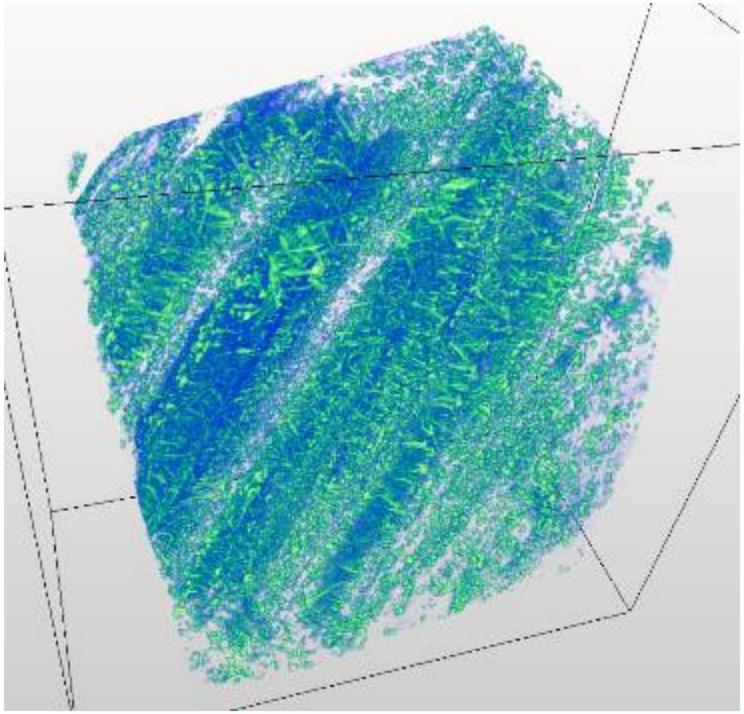




Olivine harrisite, Victor Shoot, Kambalda

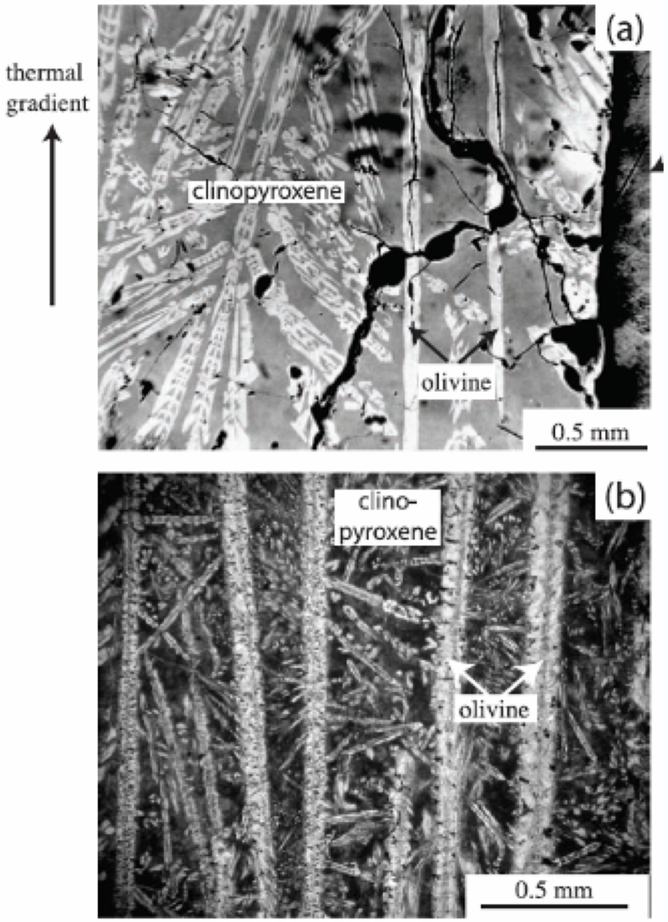
Skeletal chromite in spinifex –textured A zone

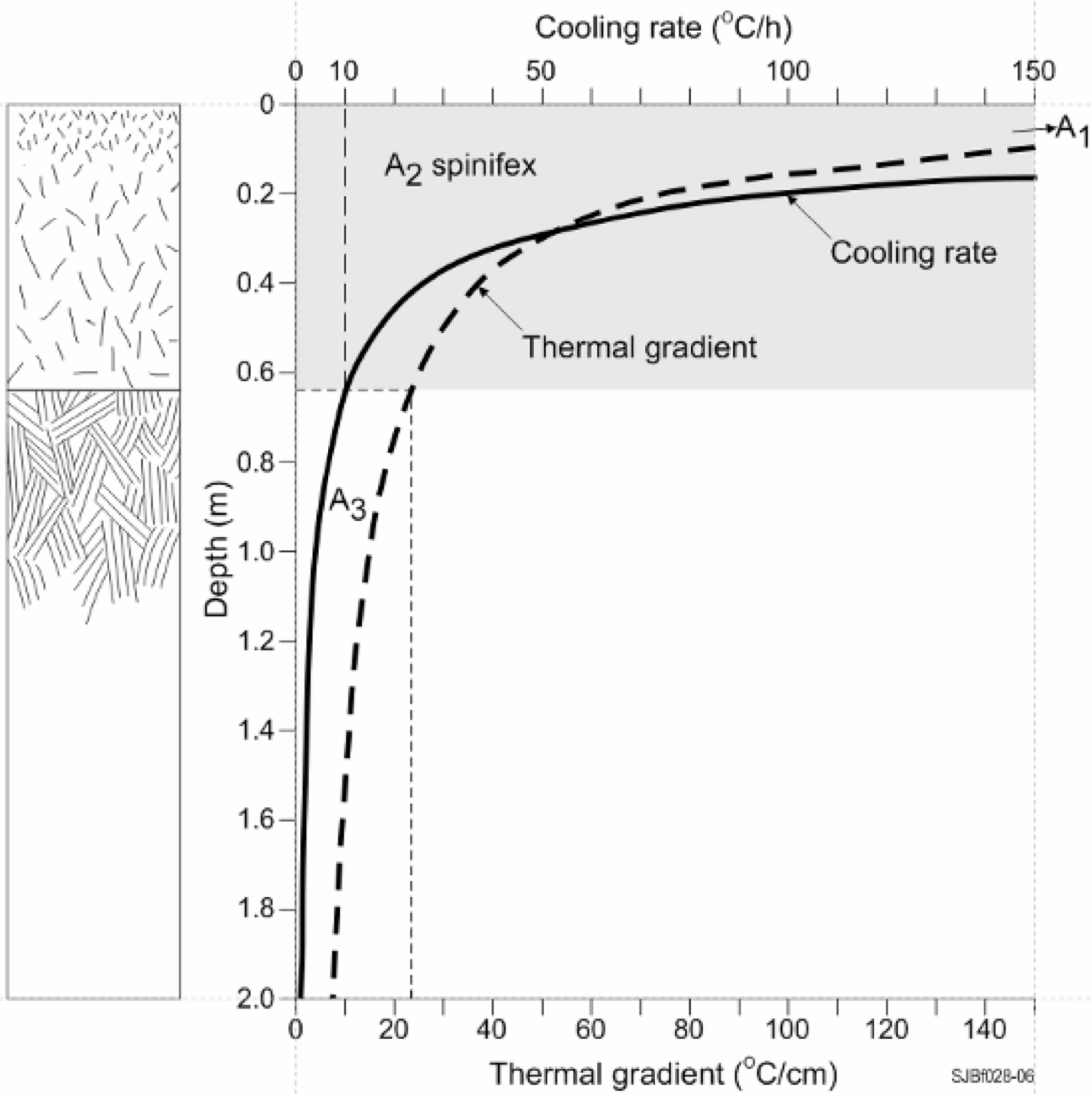




Origin of spinifex – Faure et al experiments

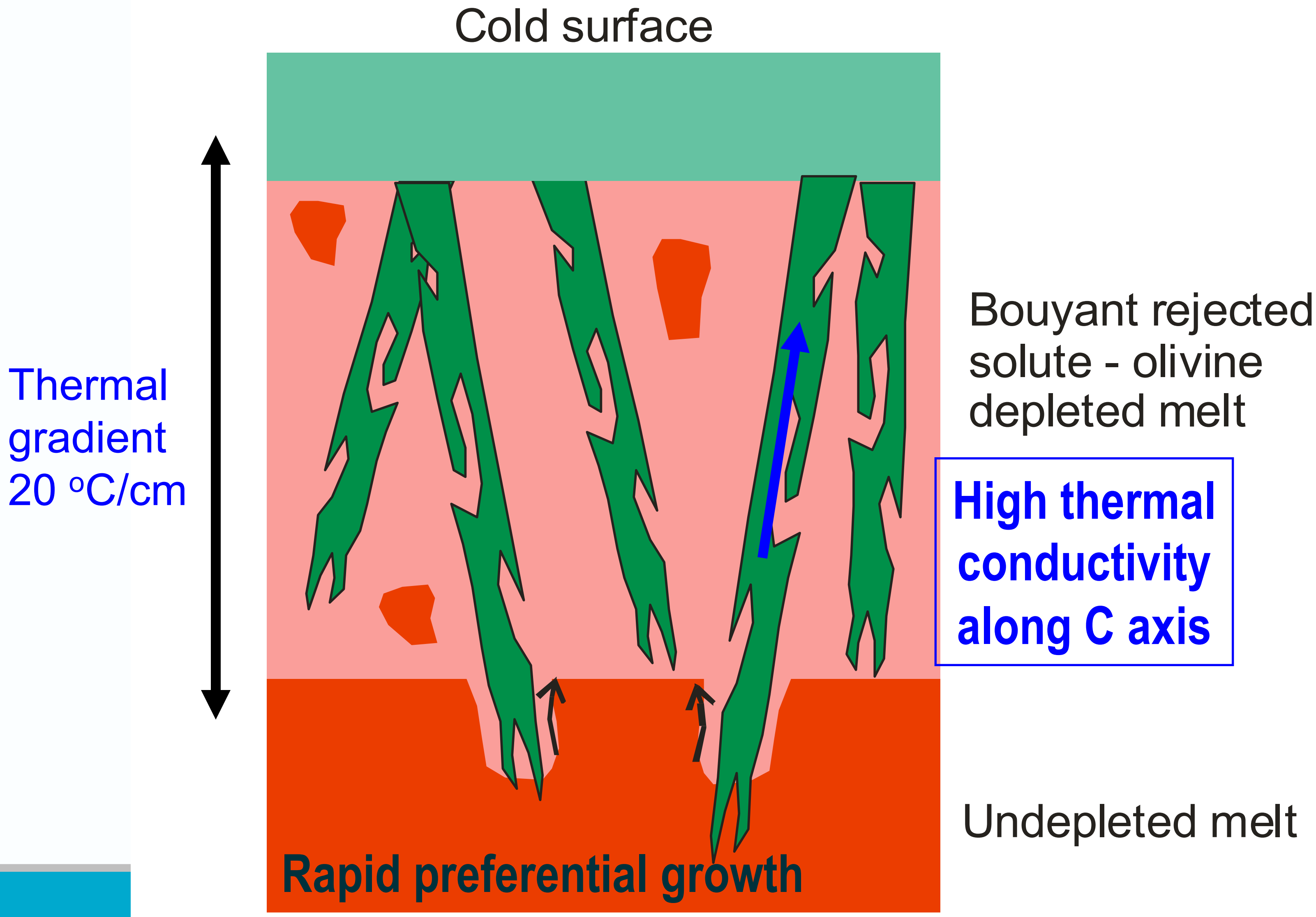
Experiment



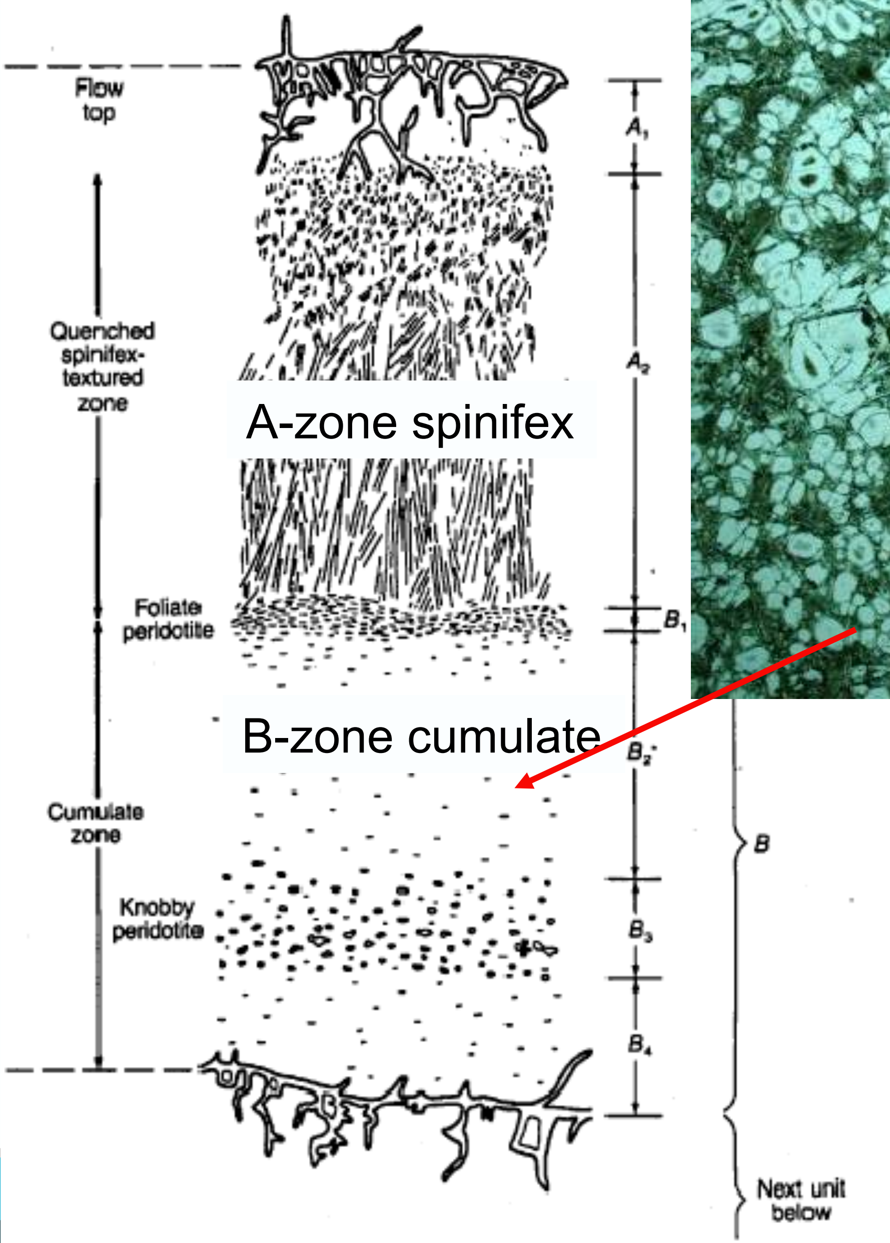


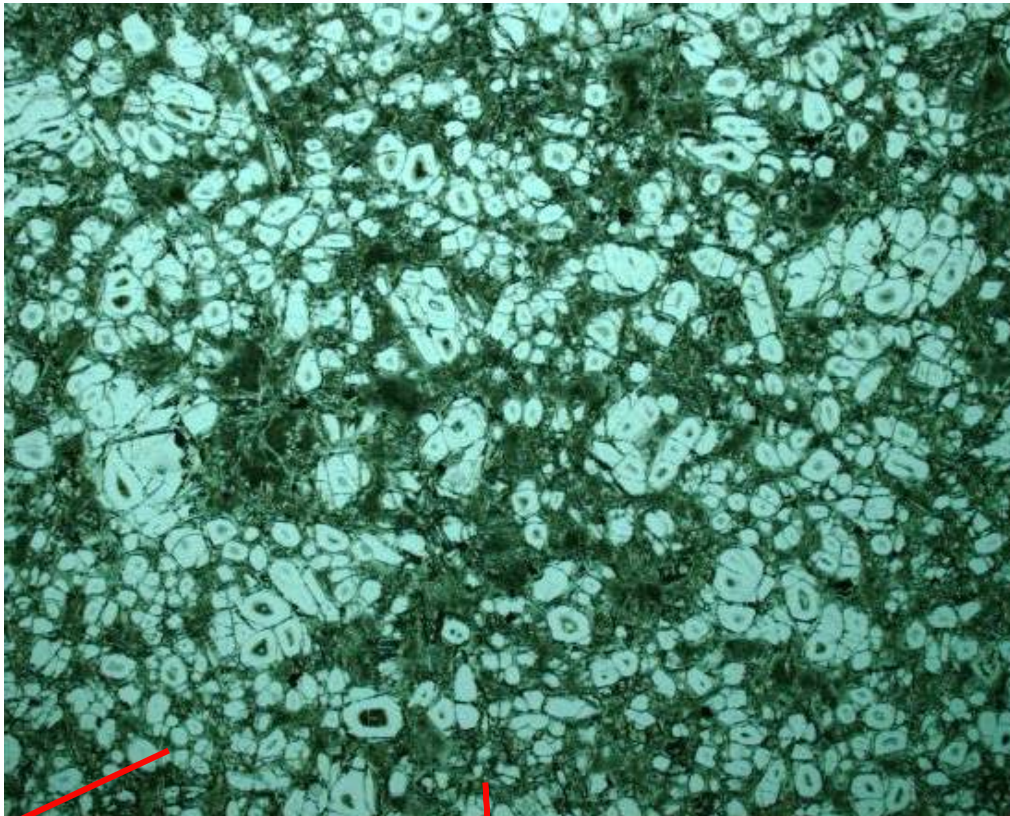
Alexo flow

Crystallisation kinetics and spinifex texture

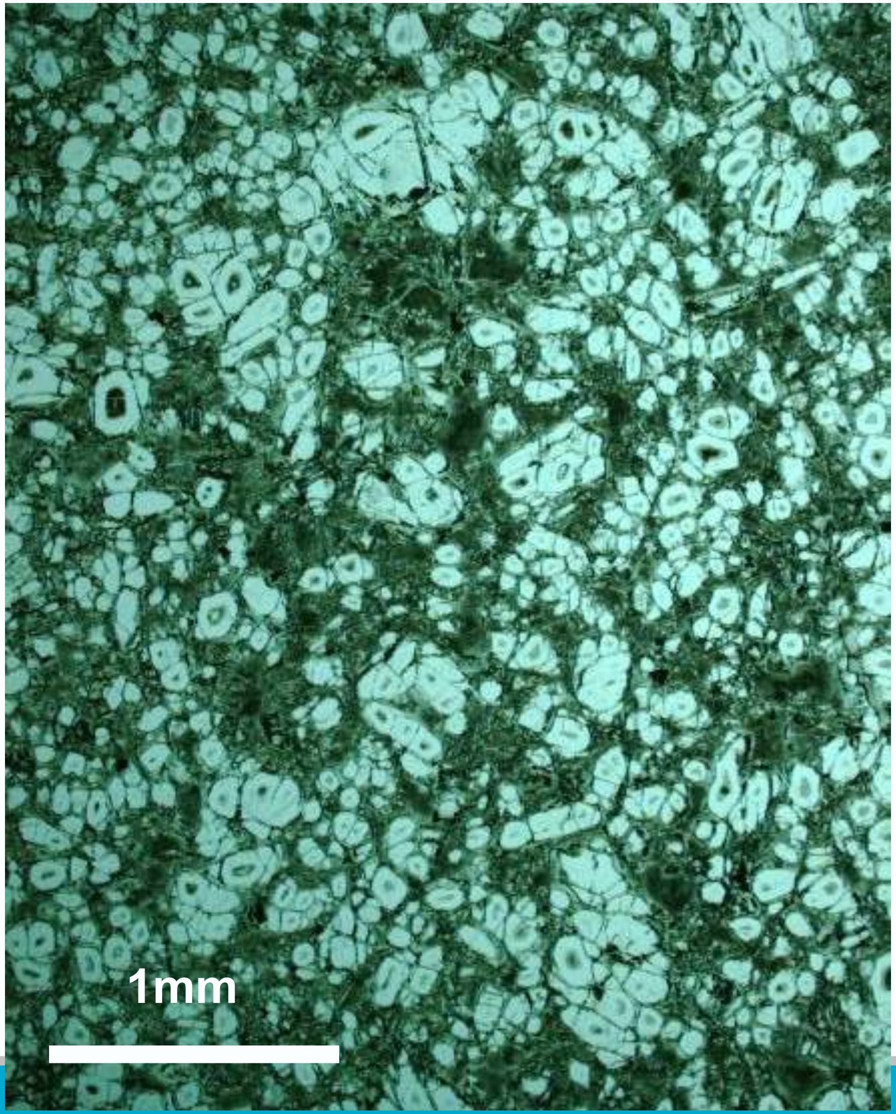


Olivine cumulates in lower layer



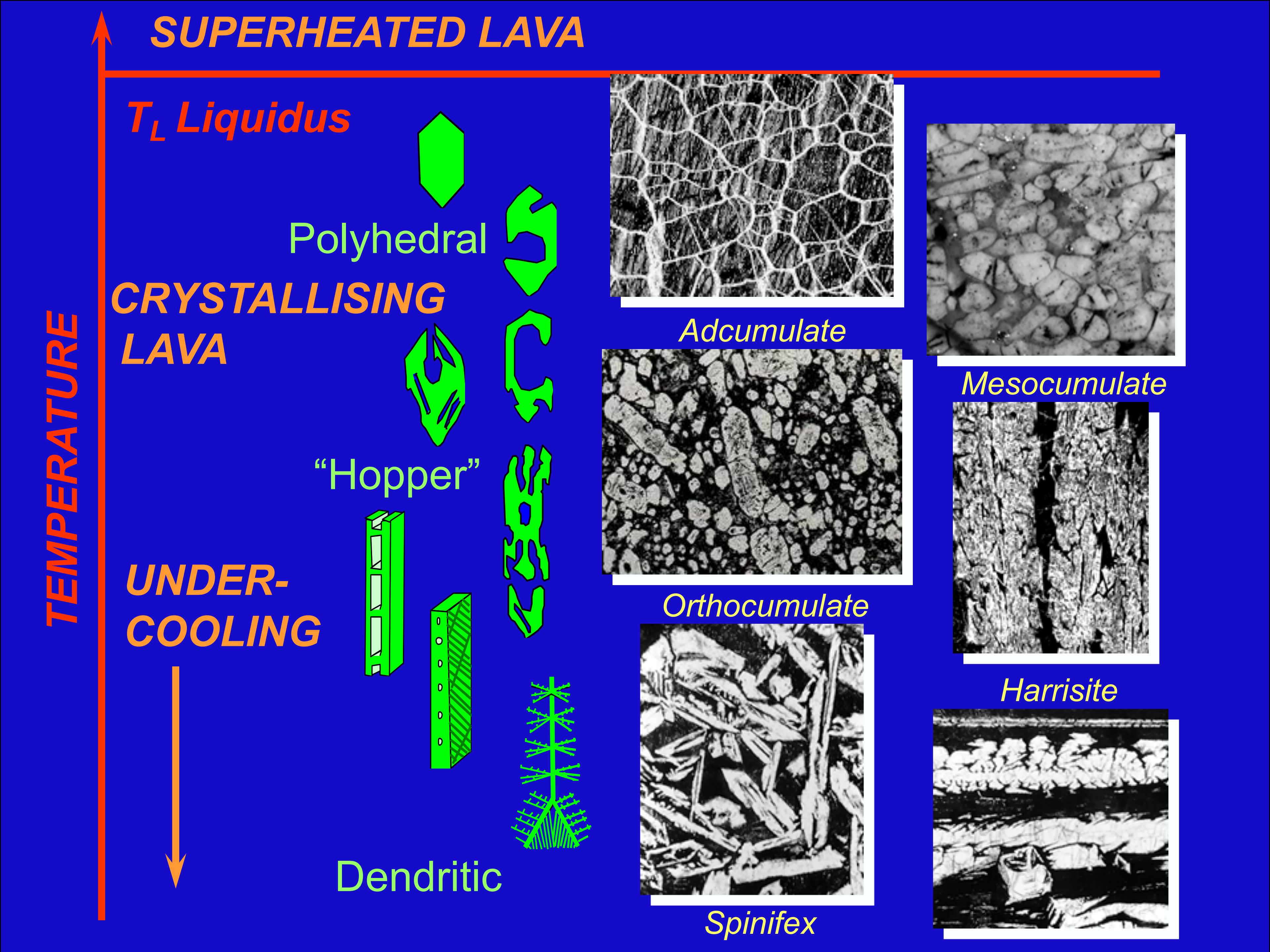


Olivine cumulate textures

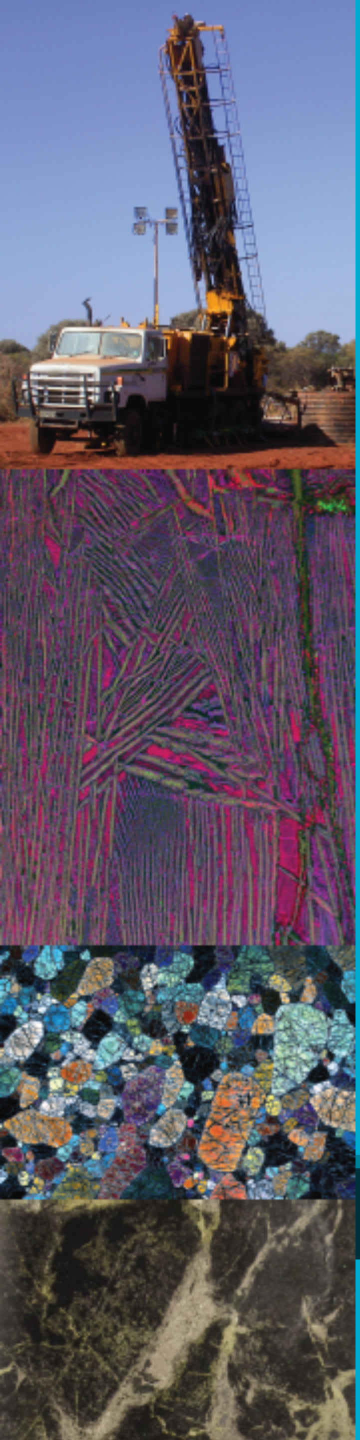


Orthocumulate

Adcumulate



SUPERHEATED LAVA
T_L Liquidus
Polyhedral
CRYSTALLISING LAVA
"Hopper"
UNDER-COOLING
Dendritic
TEMPERATURE
Adcumulate
Mesocumulate
Orthocumulate
Harrisite
Spinifex



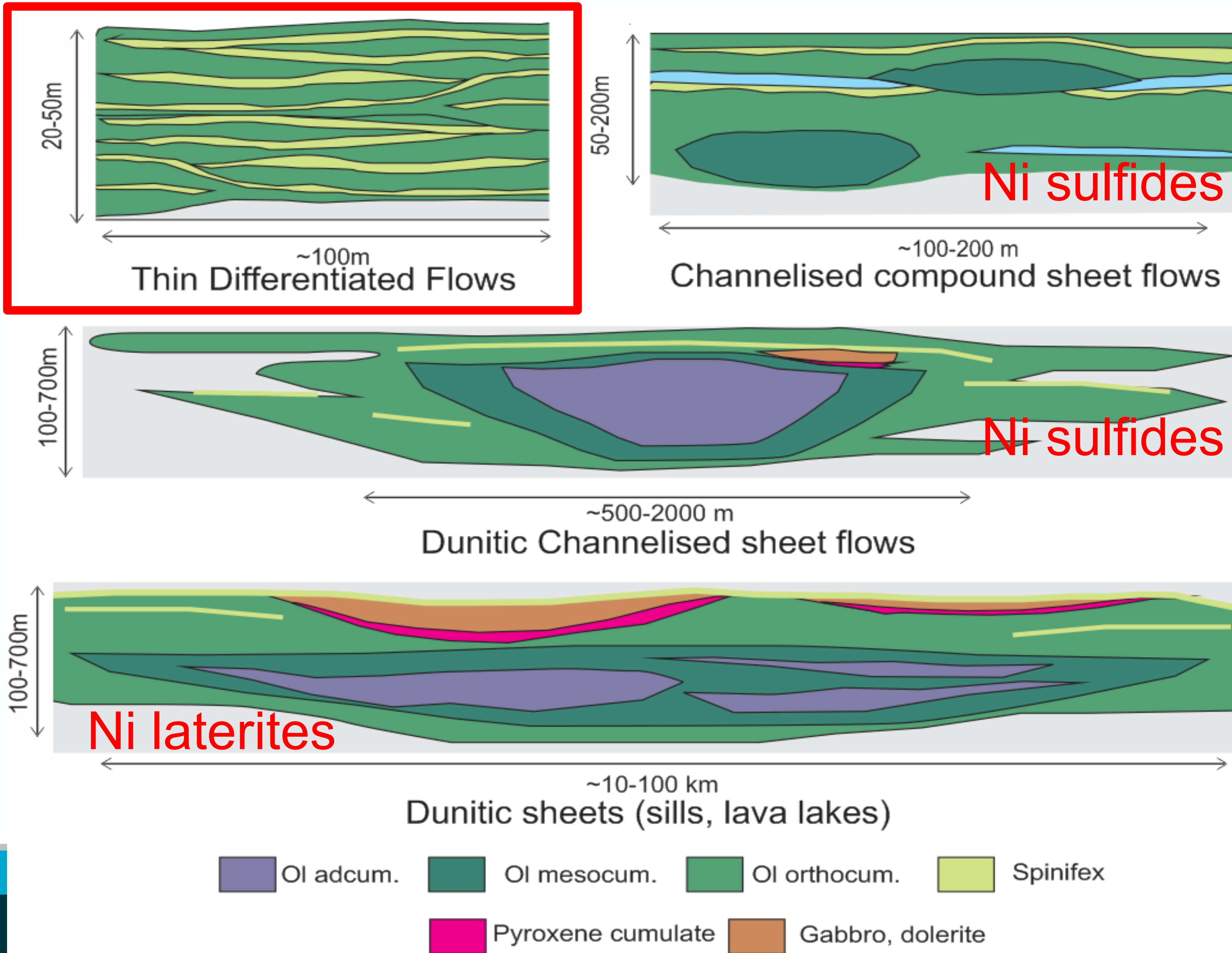
Komatiite flow field complexes

Mapping volcanic facies using igneous textures

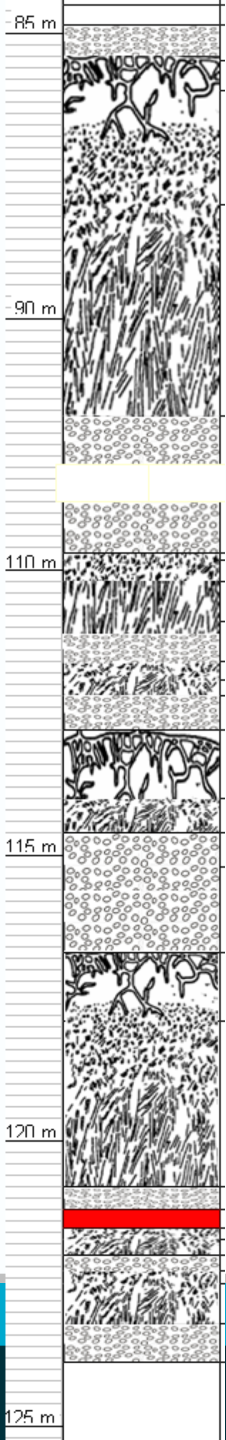
Volcanic Facies = part of a compound lava flow field defined by a set of igneous rock types

Rock types are distinguished by igneous textures (or by chemical composition where textures are not preserved)

Komatiite facies model

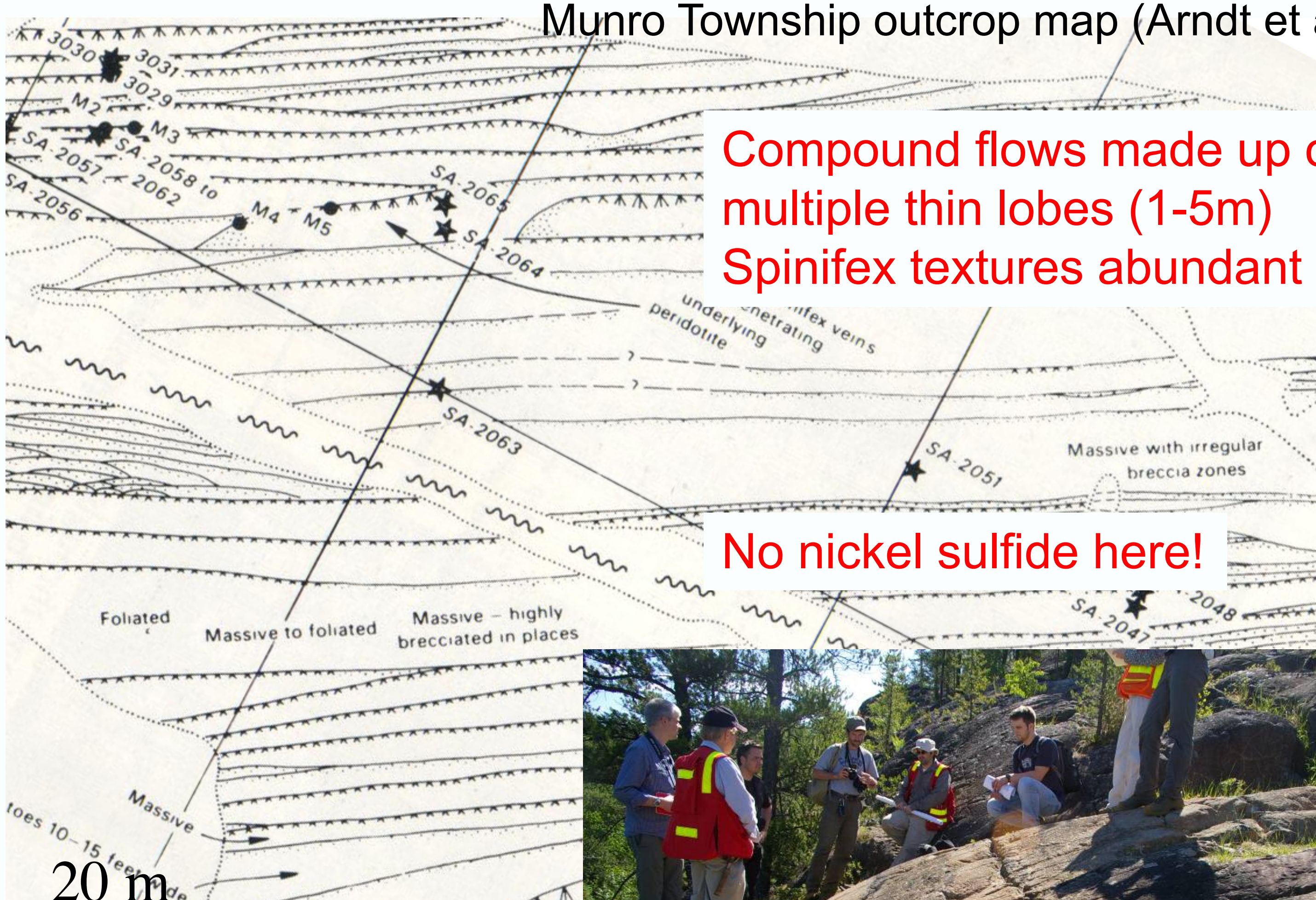


Thin Differentiated Flow Facies



Black Swan drill hole BSD86

Munro Township outcrop map (Arndt et al)



Compound flows made up of multiple thin lobes (1-5m)

Spinifex textures abundant

No nickel sulfide here!

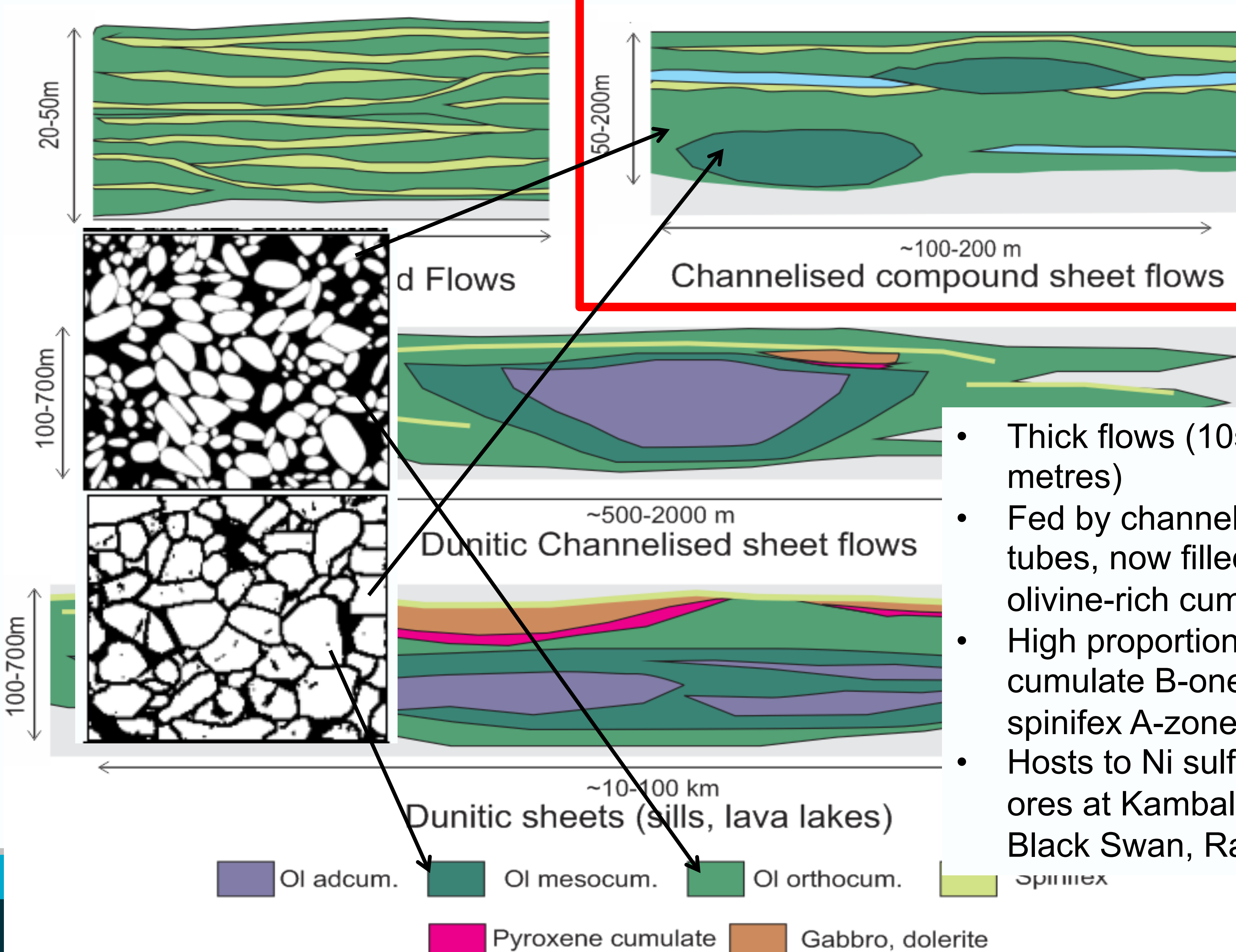
Pyke Hill, Ontario

How are compound lava flows formed?

Pahoehoe flows, Kilauea, Hawaii

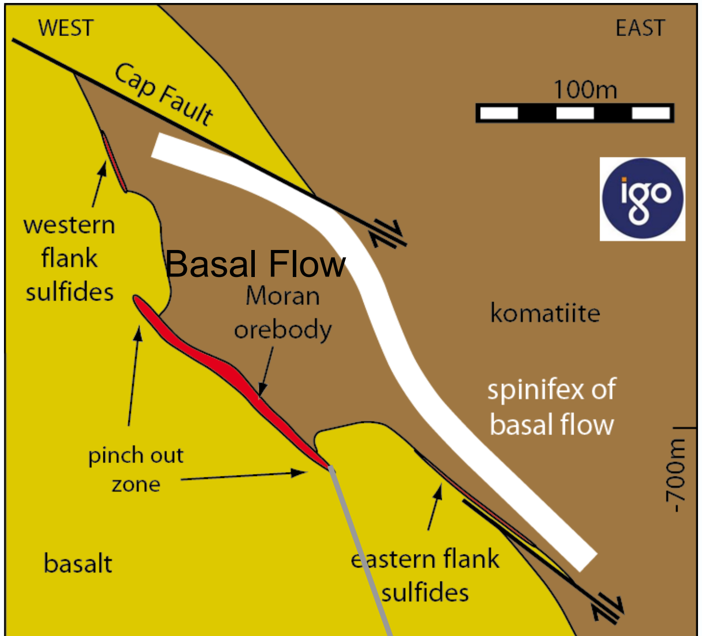
(Volcano Productions)

Komatiite facies model

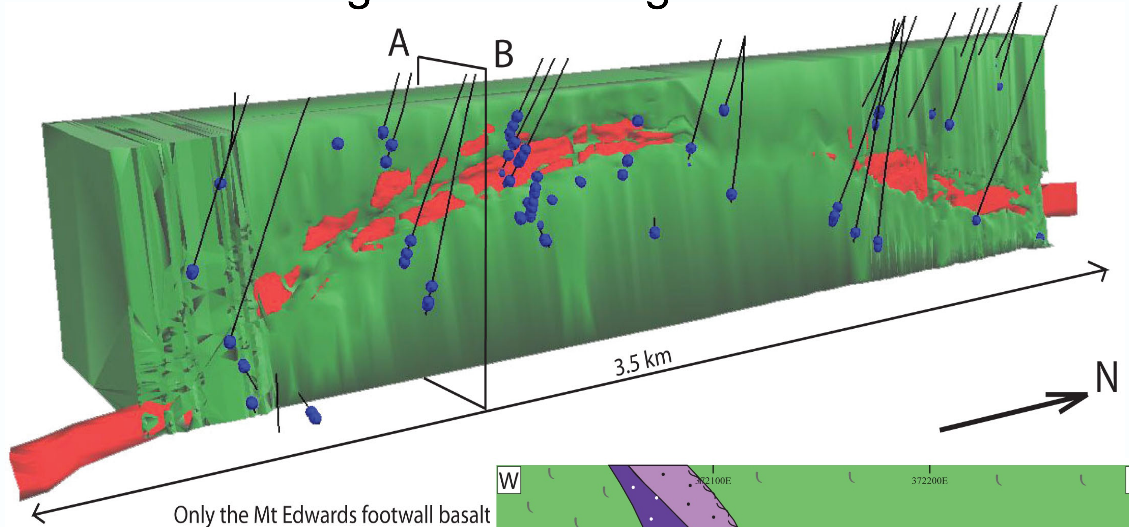


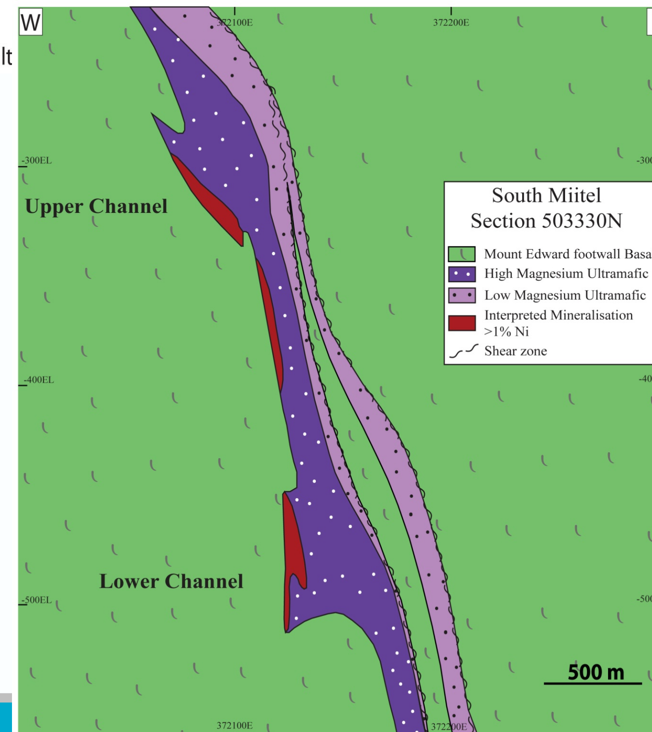
- Thick flows (10s of metres)
- Fed by channels or tubes, now filled by olivine-rich cumulates
- High proportion of cumulate B-ones to spinifex A-zones
- Hosts to Ni sulfide ores at Kambalda, Black Swan, Raglan

Moran, Kambalda



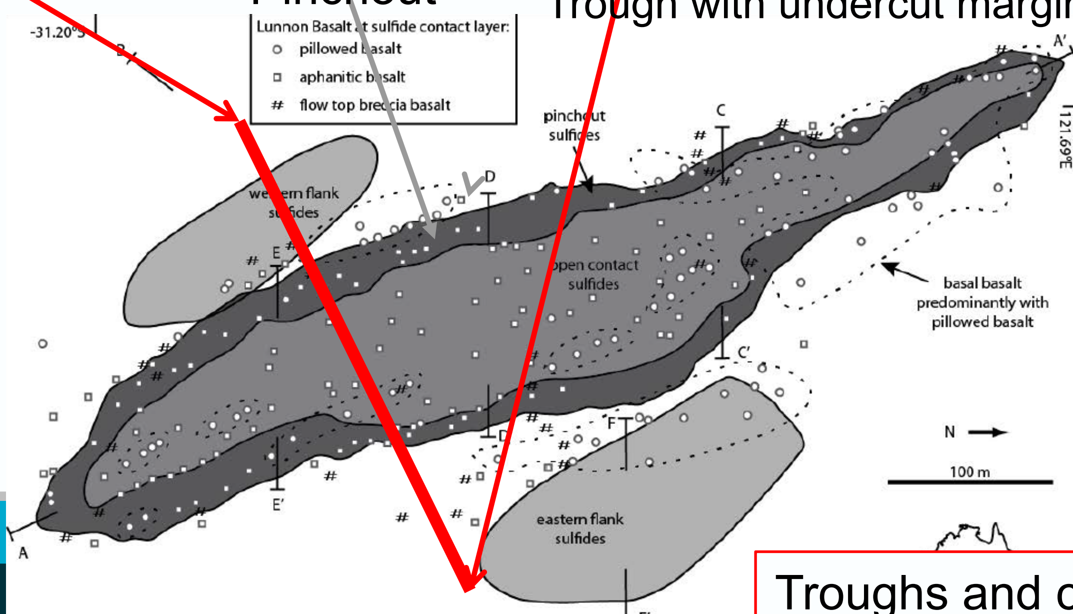
Ore-hosting footwall trough at Miitel



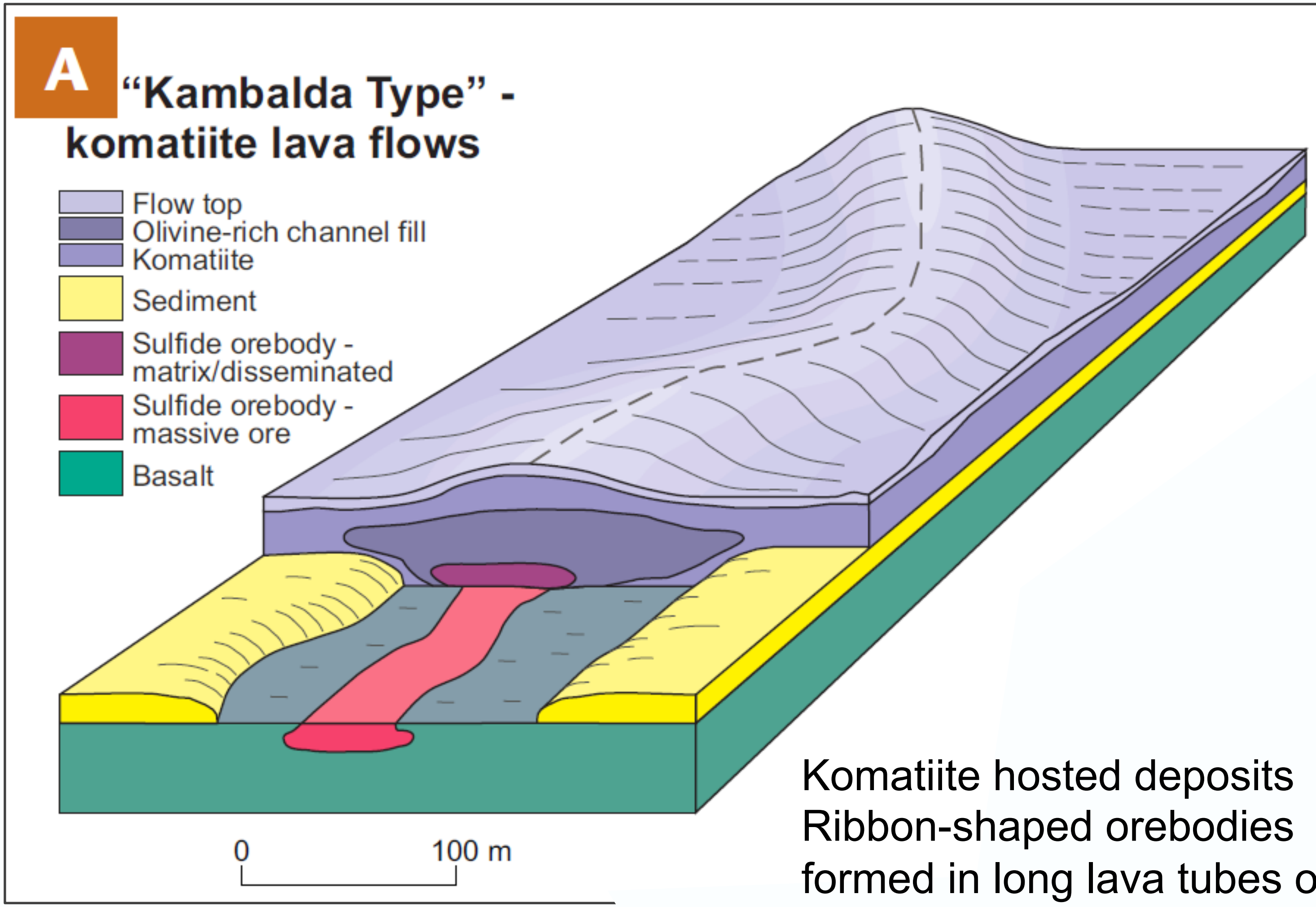


“Pinchout”

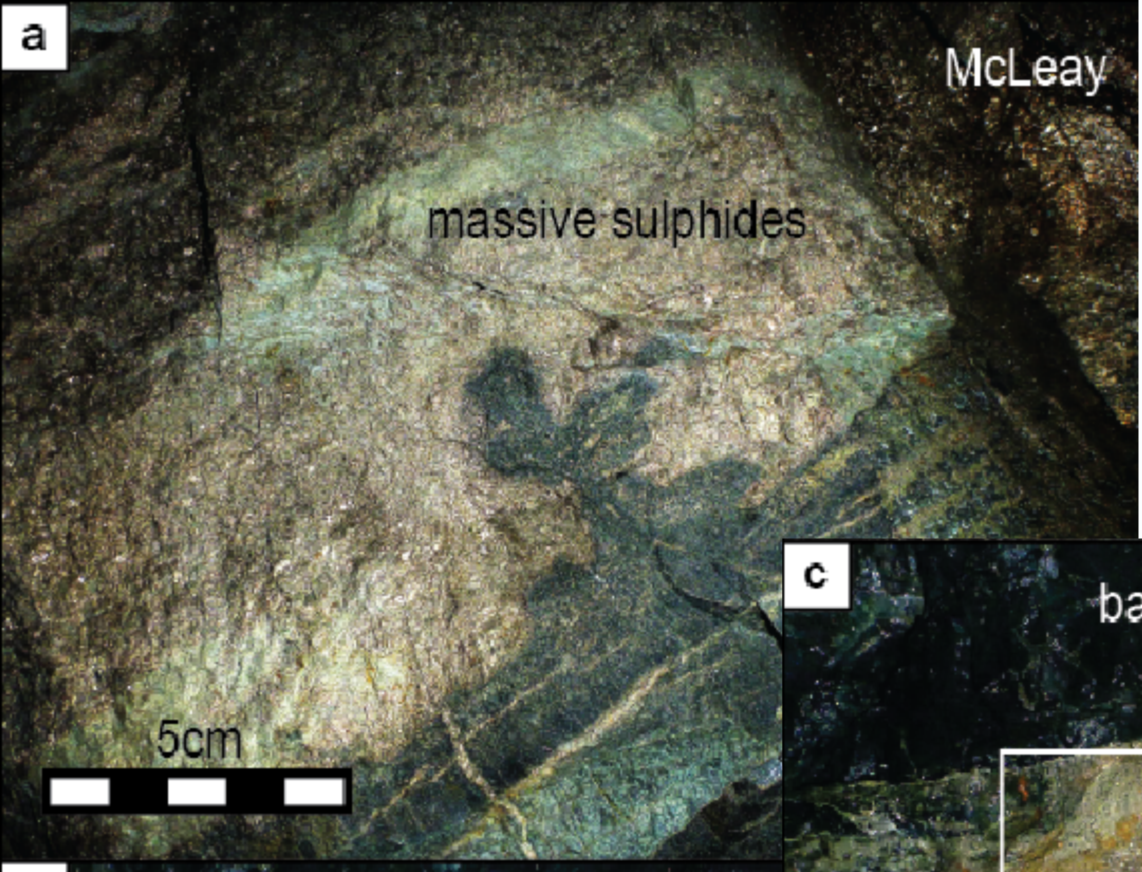
Trough with undercut margins



Troughs and channels due to thermal erosion

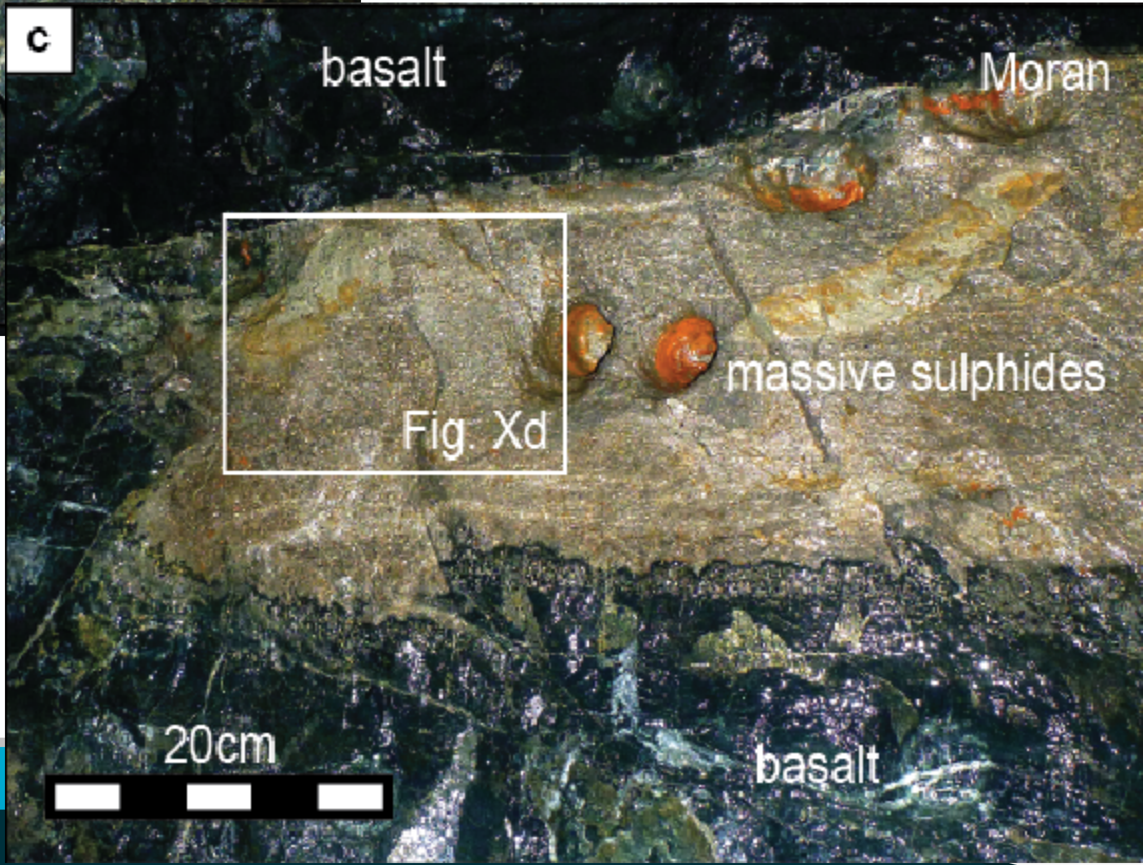


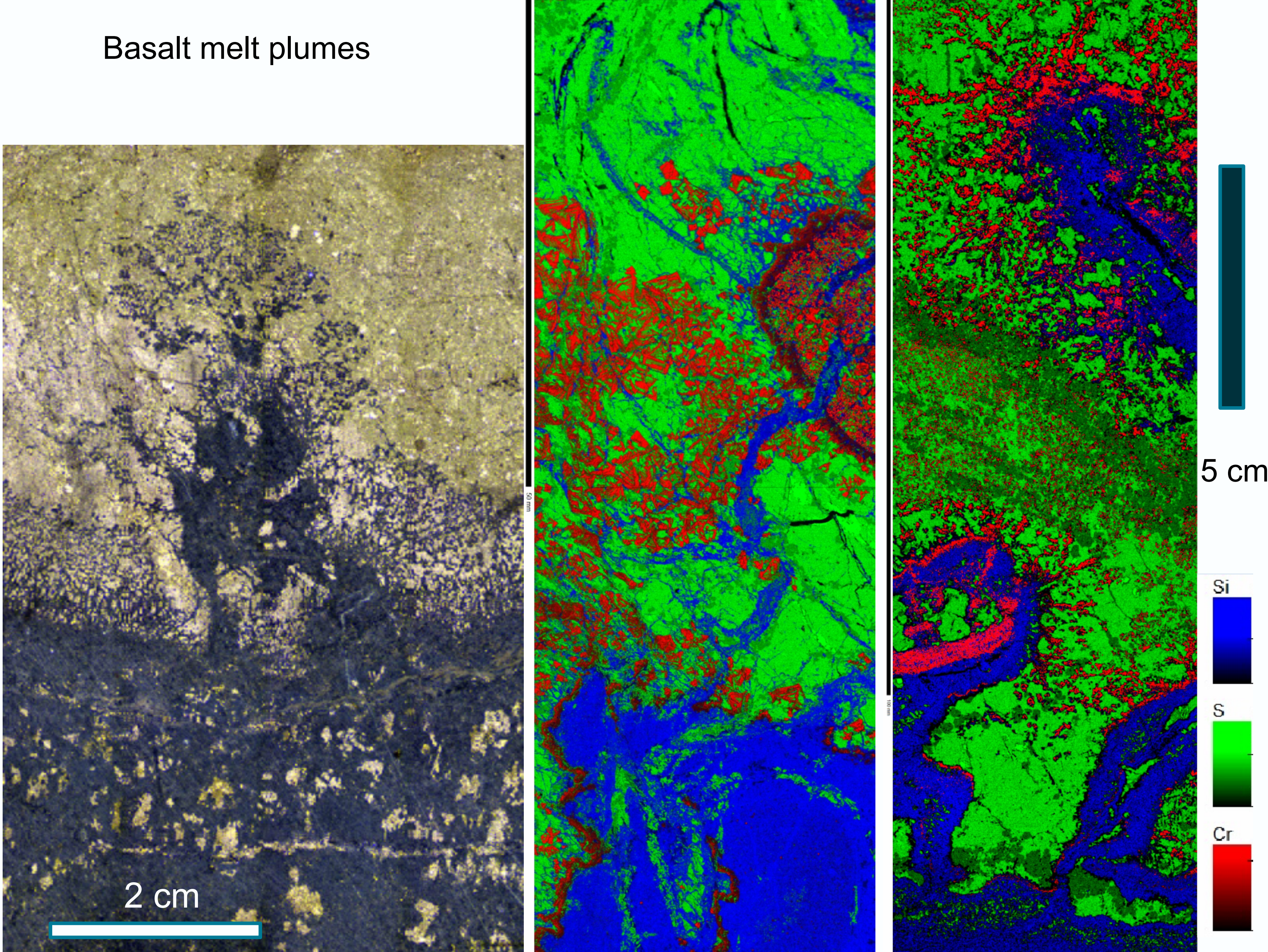
Komatiite hosted deposits
Ribbon-shaped orebodies formed in long lava tubes or channels



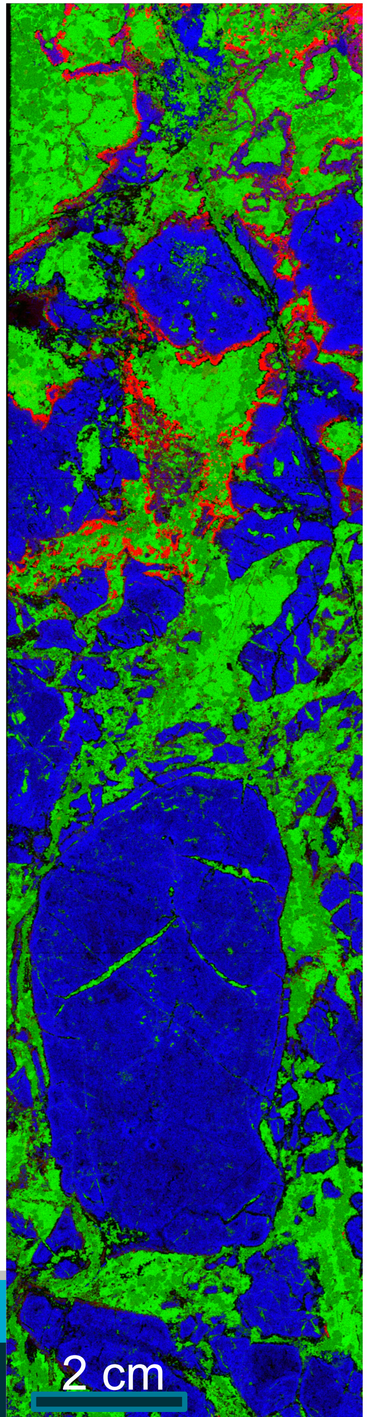
Thermomechanical erosion of footwall basalts at Kambalda

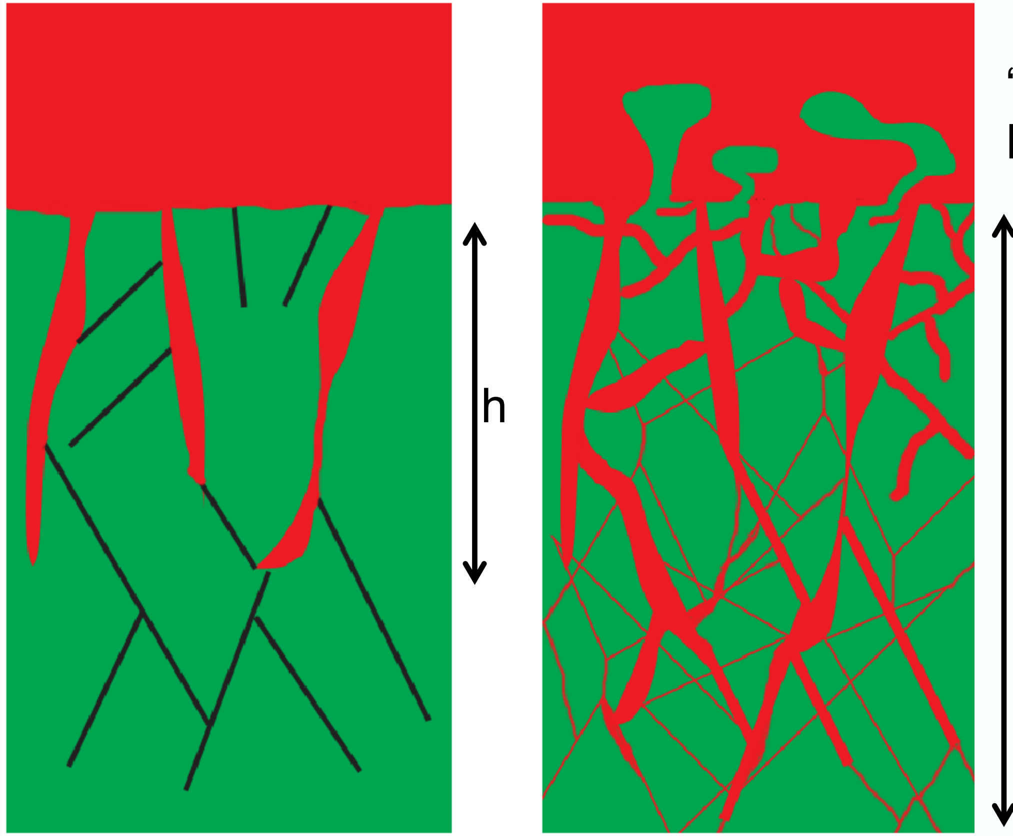
(Staude et al., 2016, 2017)




Basalt melt plumes
2 cm
5 cm
Si
S
Cr

Sulfide-silicate infiltration-melting front: Moran Shoot, Kambalda





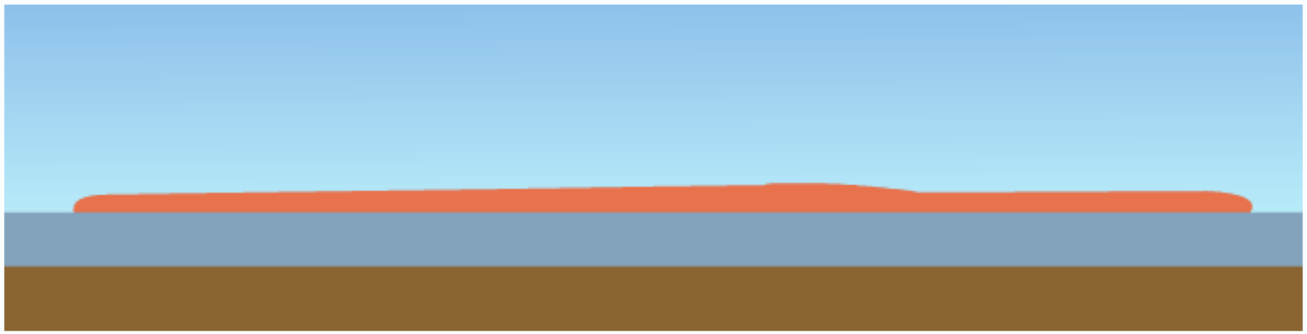
"Floating" basalt plumes

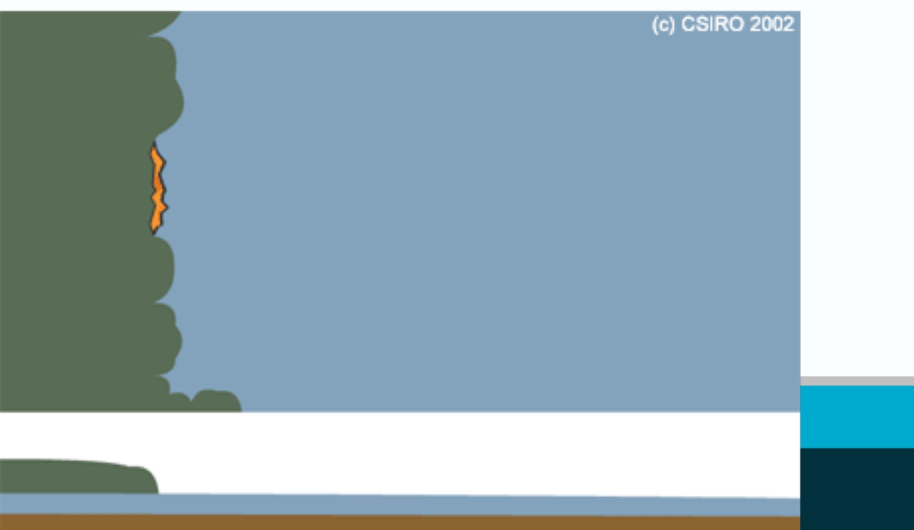
"Hydrostatic" Differential pressure at tip of sulfide network increases as veins propagate downwards

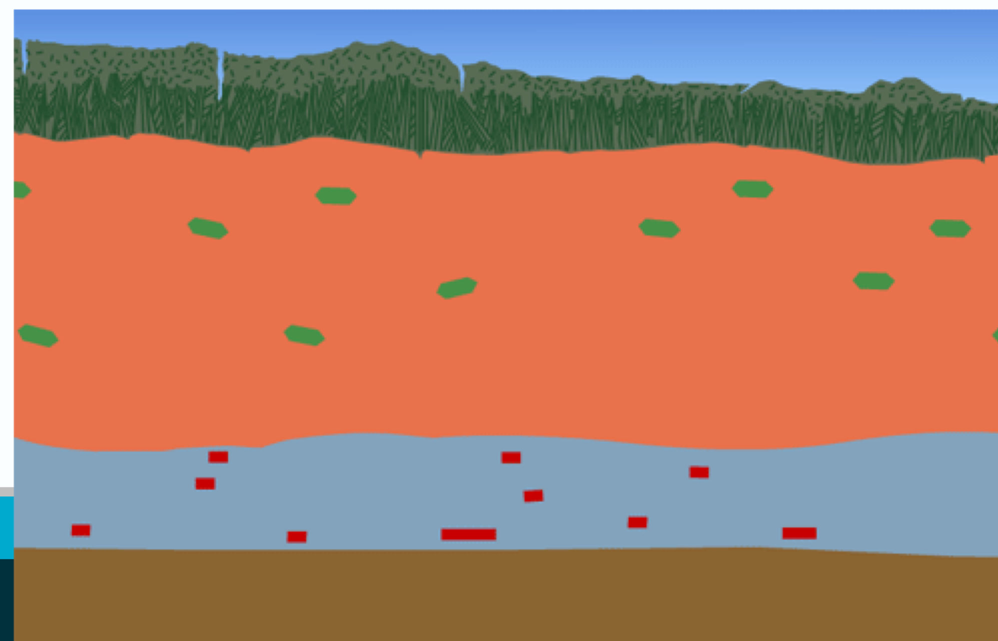
Hydrofractured basalt with sulfide penetrating along fractures

Lava tubes

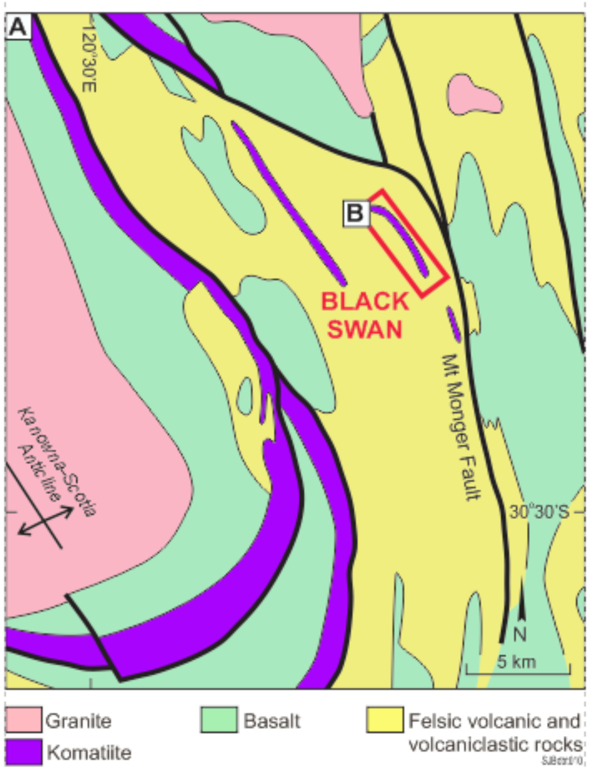
Channelised flows and komatiite-hosted ores – the substrate erosion model.
Based on observations on modern basalt lava tube formation







Black Swan (Yilgarn, WA)



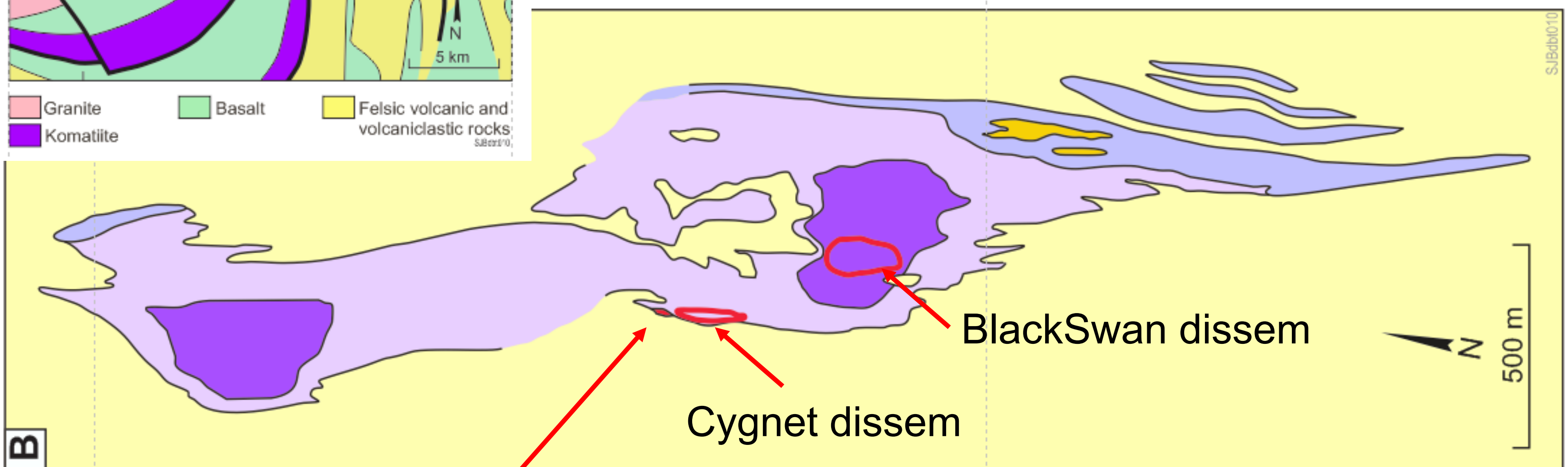
Channelised invasive flows on felsic substrate

Geometry of flows and ore-hosting channels is different where substrate is more easily melted

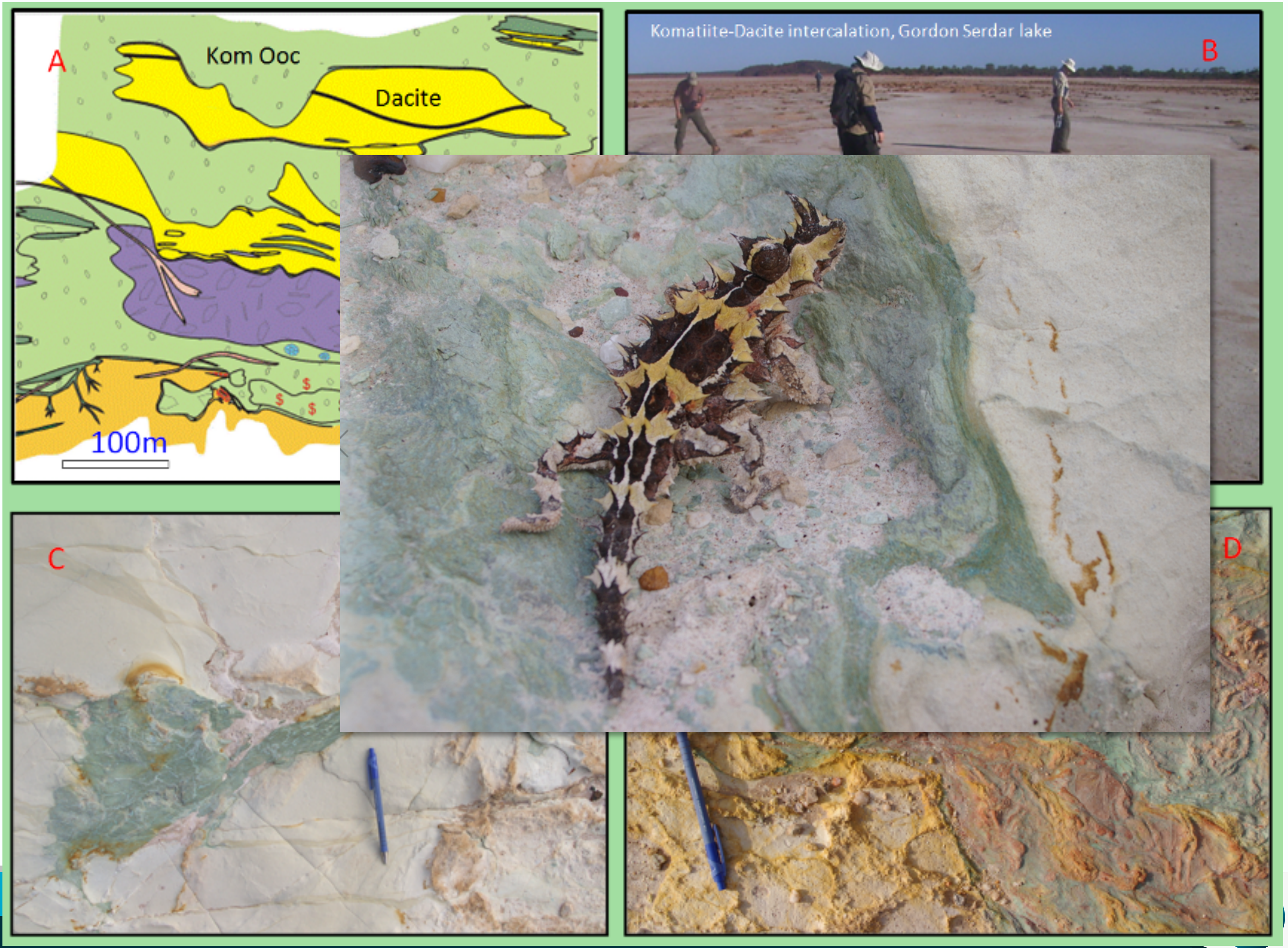
- Dacitic volcanics, volcaniclastics
- Felsic volcaniclastics and sulfidic breccias

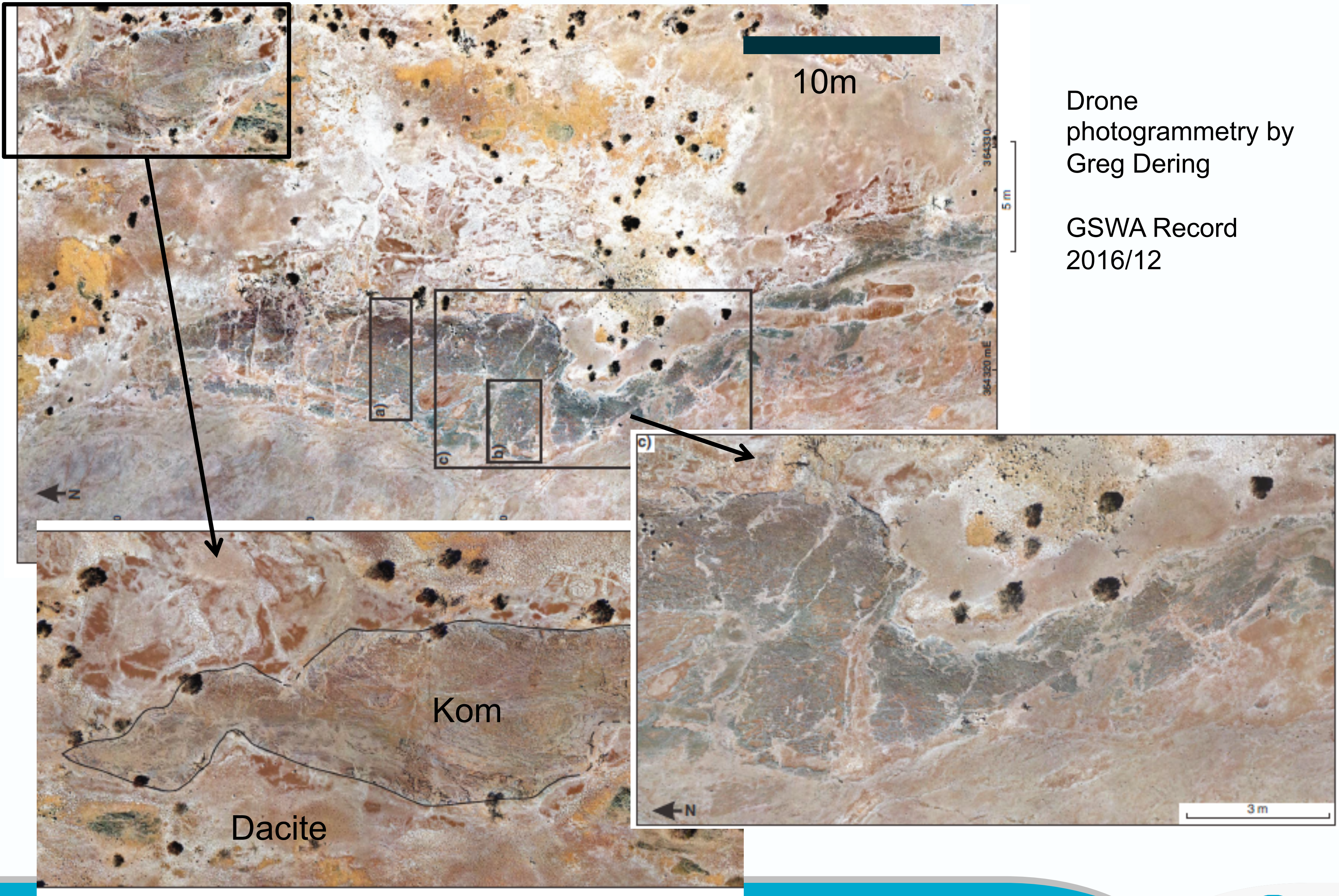
Komatiites

- Talc carbonate rocks after olivine cumulates
- Serpentinites after olivine cumulates
- Spinifex textured flows



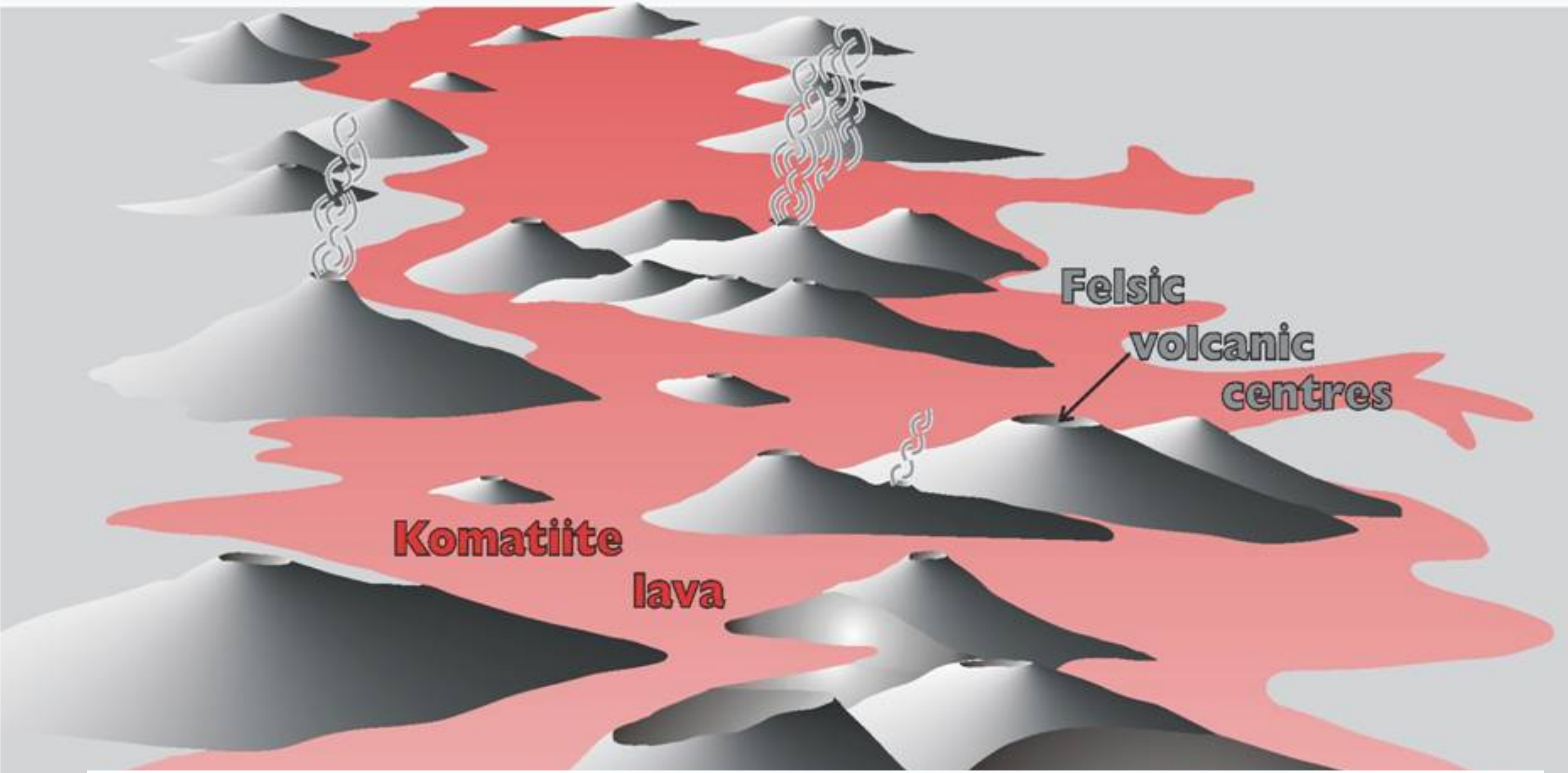
Silver Swan massive ore


A
Kom Ooc
Dacite
100m
Komatiite-Dacite intercalation, Gordon Serdar lake
B
C
D



Drone photogrammetry by Greg Dering

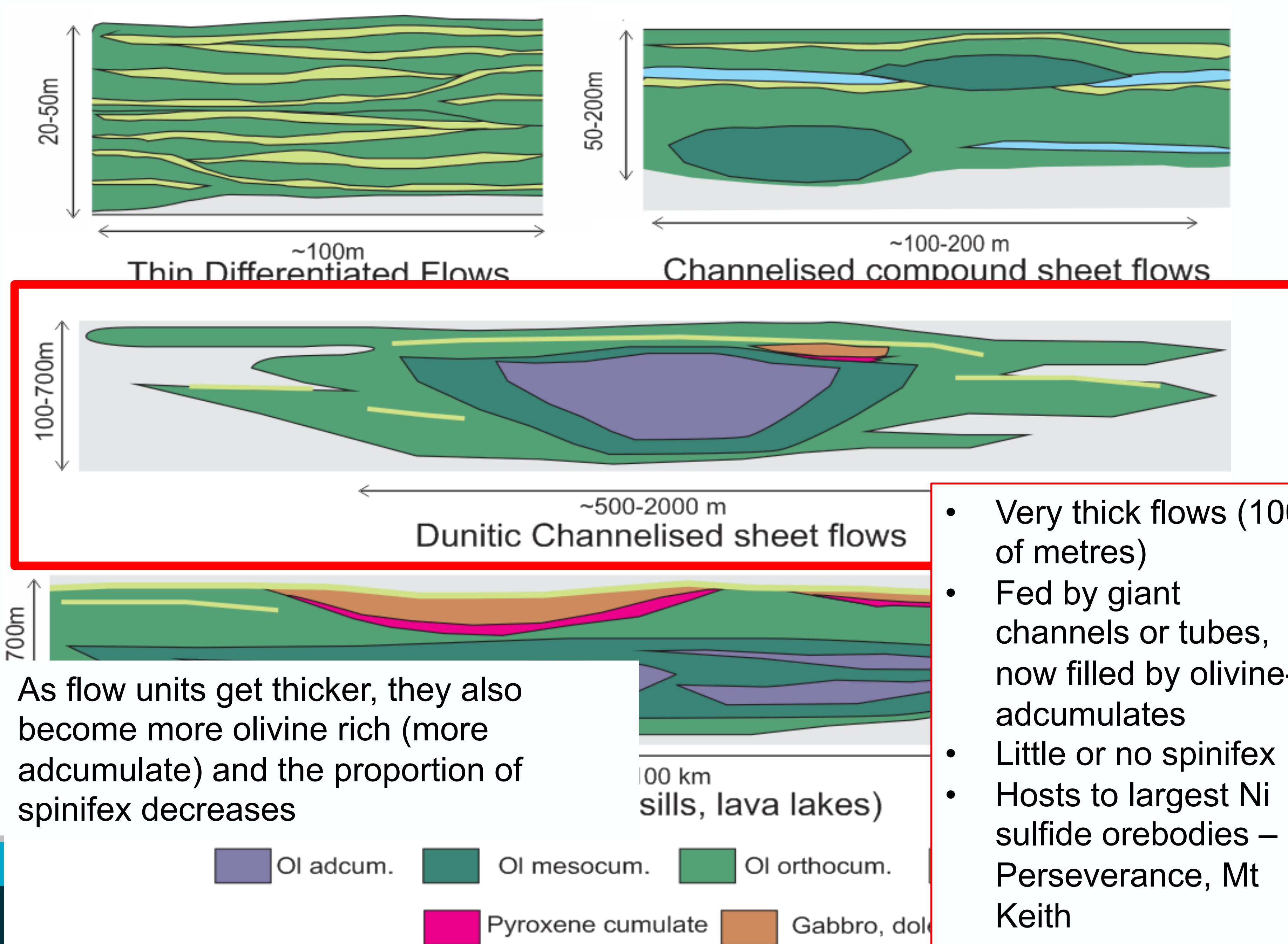
GSWA Record 2016/12



- Komatiite and dacite erupted together in linear rifts/grabens
- Abundant volcanic-exhalative sulfide in felsic rocks
- The setting for most of the very large Australian deposits (Agnew-Wiluna Belt)
- Most of the Ni deposits in the Abitibi Belt (Canada) are also in this setting

COEVAL ULTRAMAFIC-FELSIC VOLCANISM

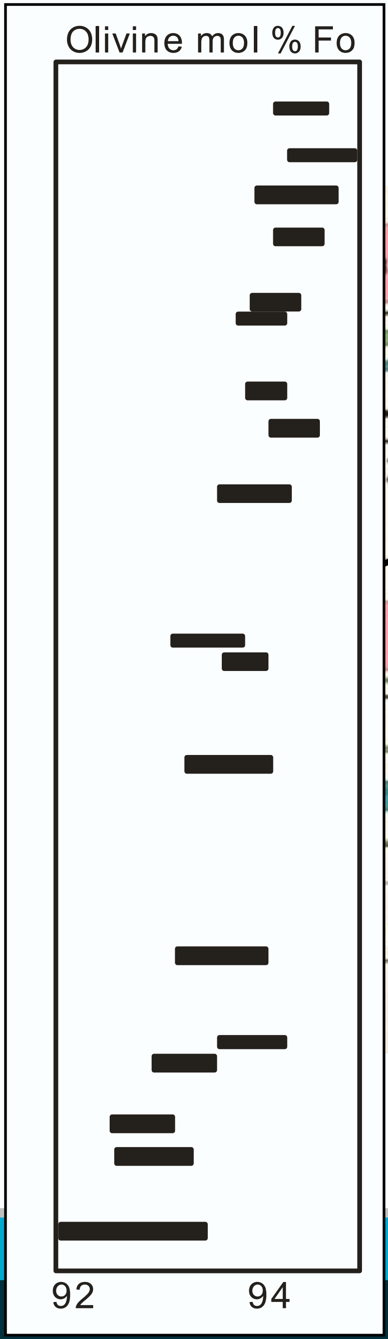
Komatiite facies model

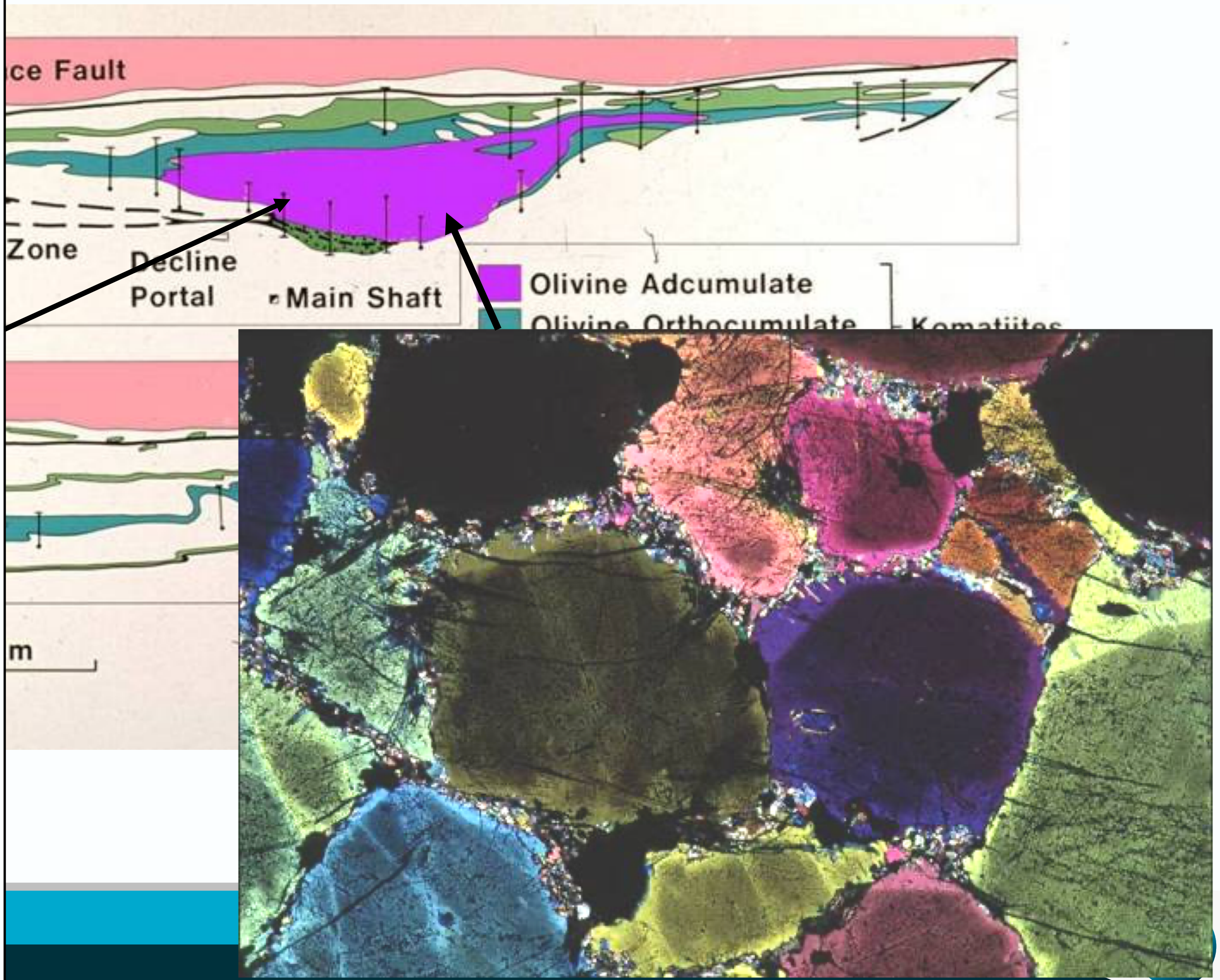


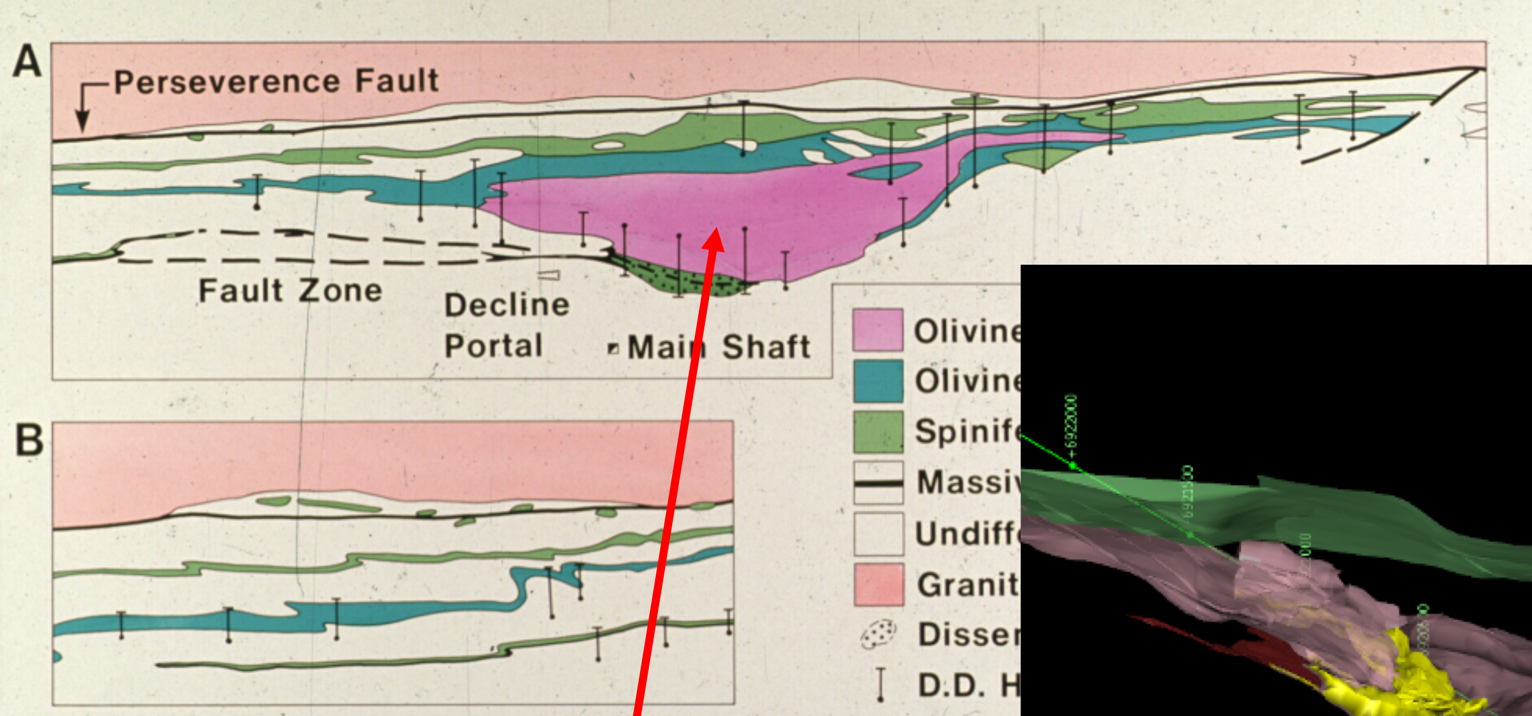
As flow units get thicker, they also become more olivine rich (more adcumulate) and the proportion of spinifex decreases

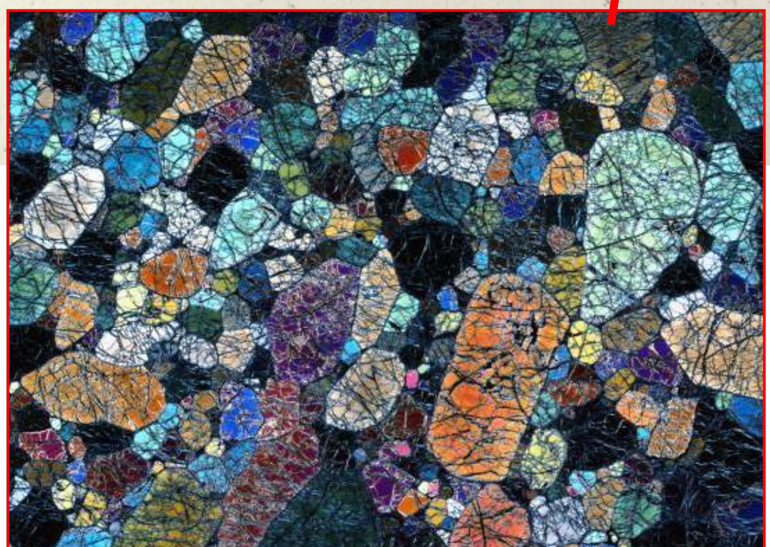
- Very thick flows (100s of metres)
- Fed by giant channels or tubes, now filled by olivine-adcumulates
- Little or no spinifex
- Hosts to largest Ni sulfide orebodies – Perseverance, Mt Keith

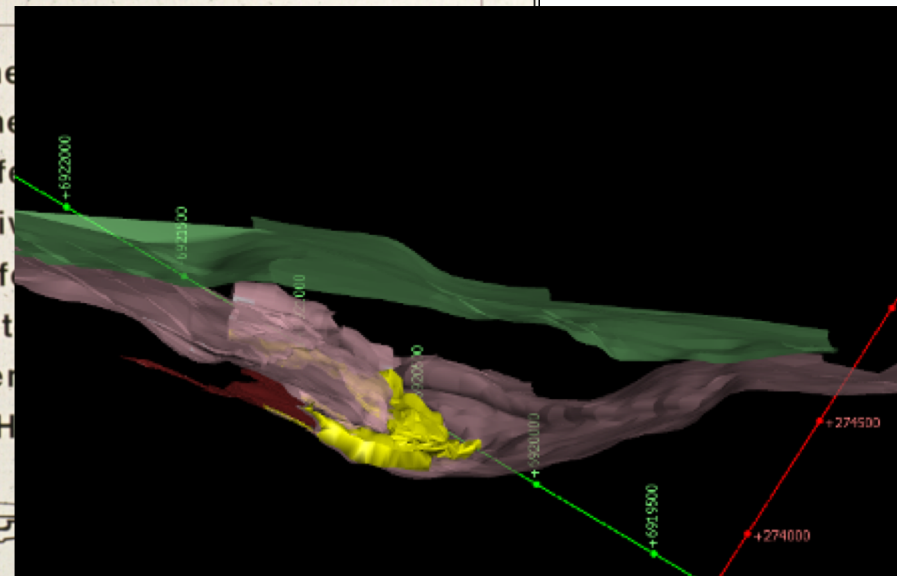
Channelised Dunite Facies - Perseverance

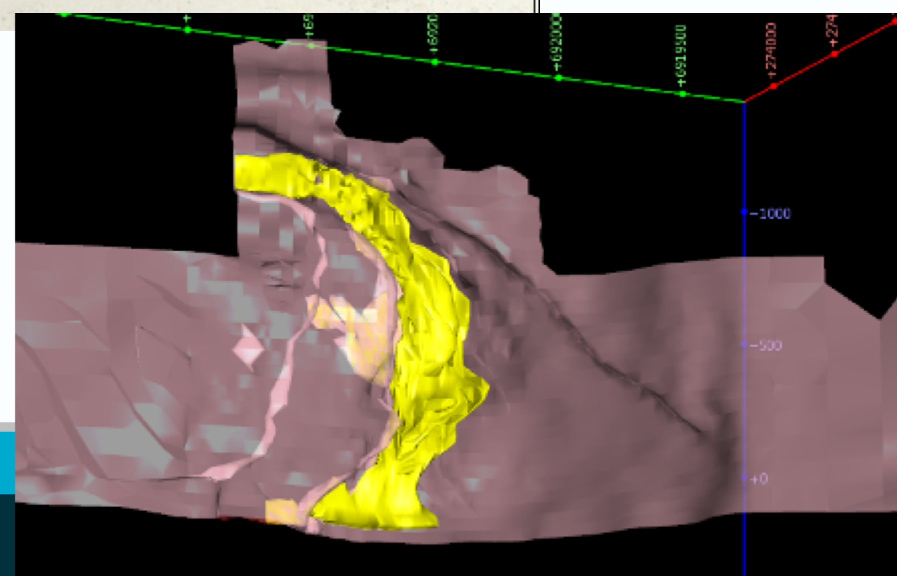








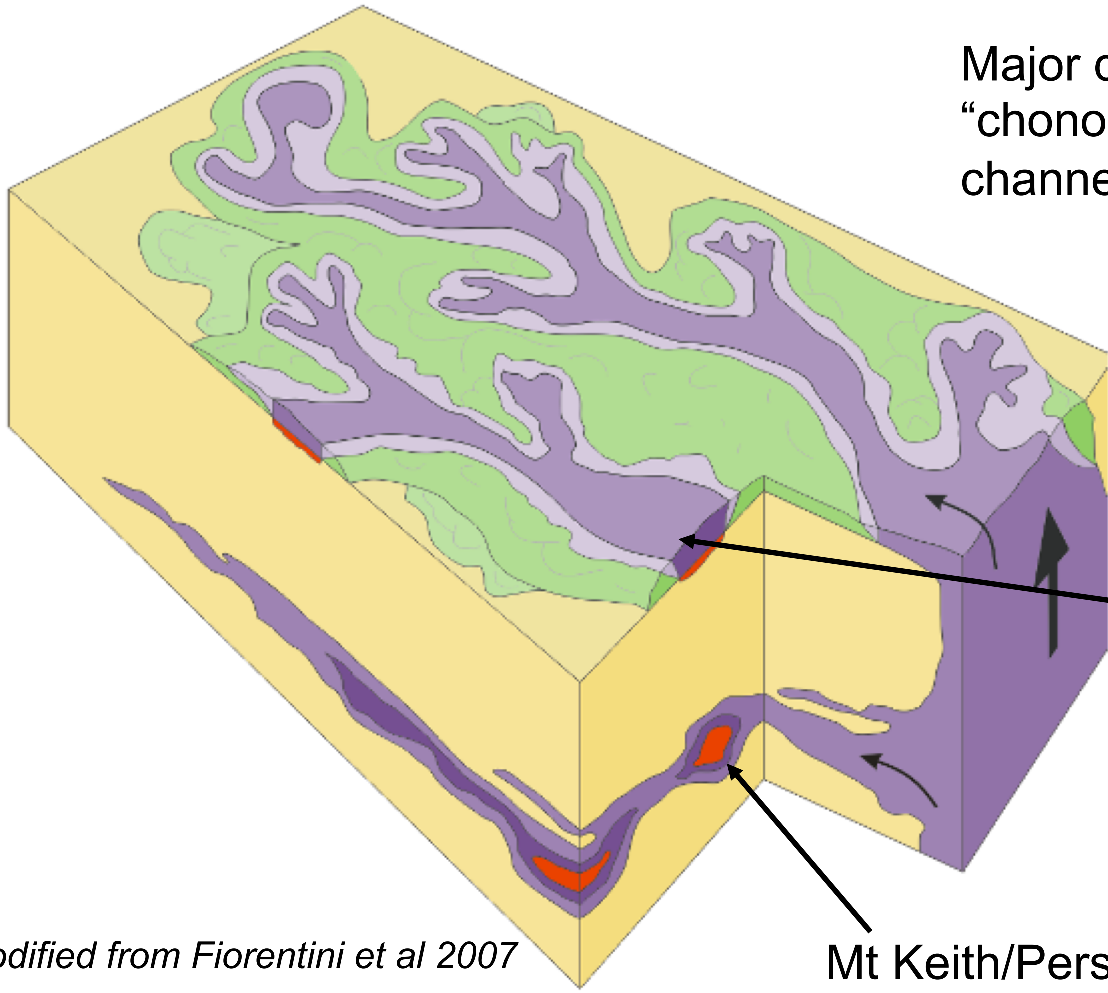




3D model by Caroline Perring, with permission of BHP-Billiton

Subvolcanic intrusion model (Rosengren, Fiorentini, Beresford et al)

Major deposits in subvolcanic "chonolith" conduits or major feeder channels in extensive flow fields



Modified from Fiorentini et al 2007

Or here?

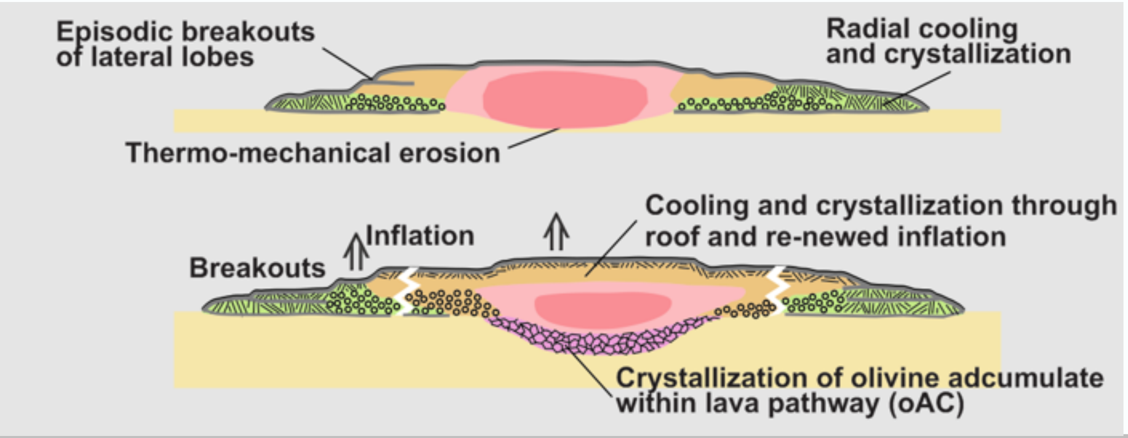
Mt Keith/Perseverance here?

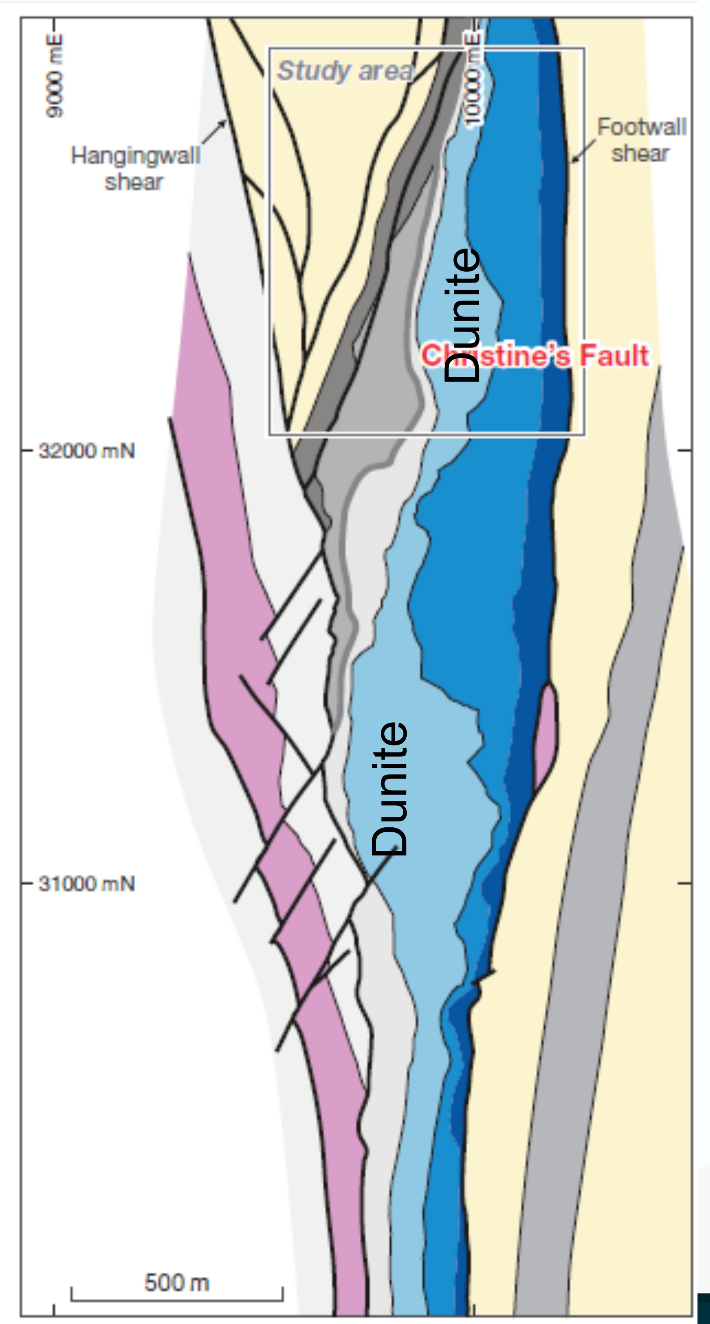
Channelised Dunite Facies – Mt Keith

Evidence for extrusive (lava flow) origin:

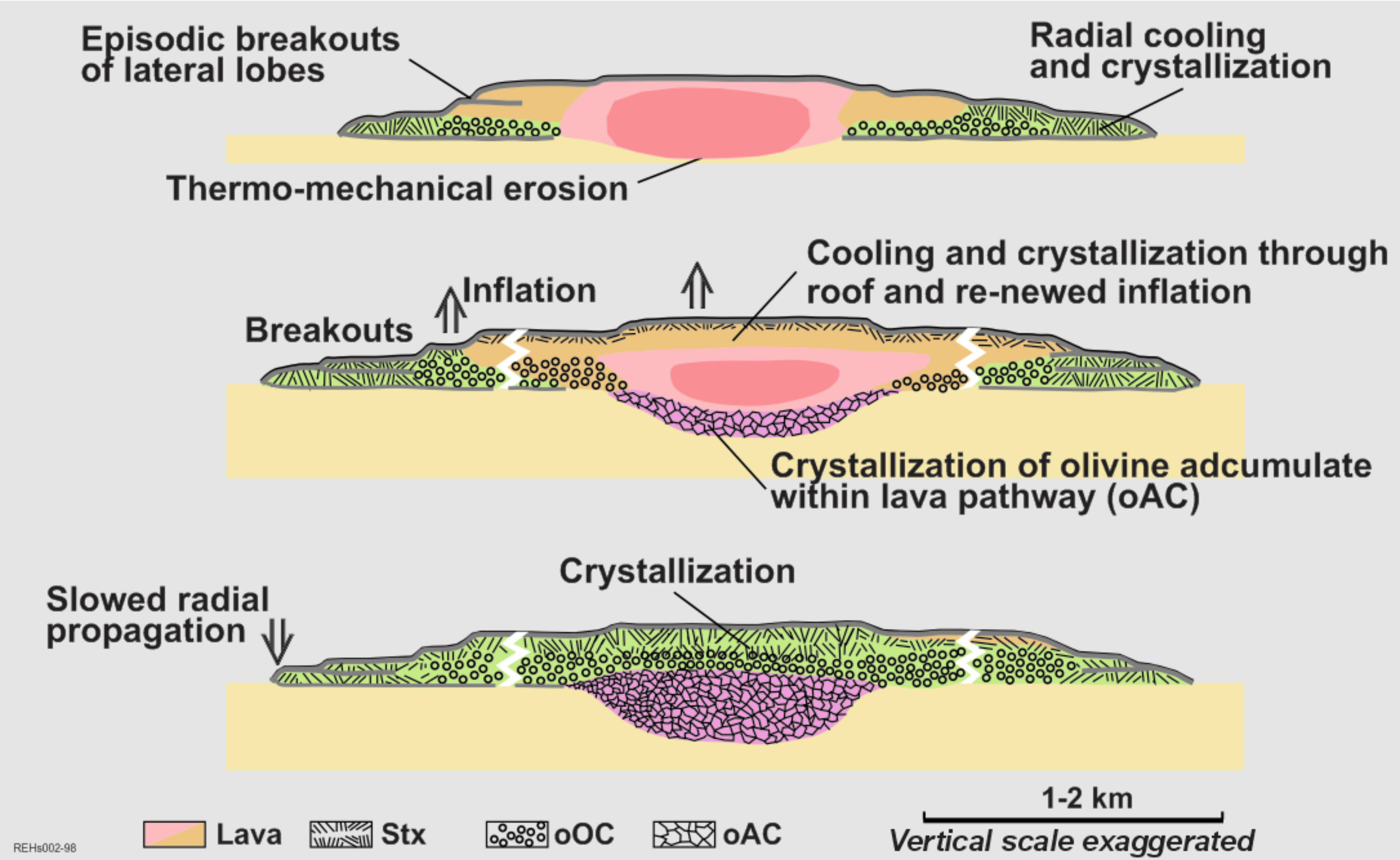
- Most fractionated cumulates (gabbros, pyroxenites) at top
- Spinifex layer at top
- Unmelted dacites directly above top contact (no roof melting)
- Thick adcumulate unit should have produced >50m thick molten dacite layer at top
- Adcumulate bodies commonly on strike with other facies

(Gole at al., Econ Geol., 2013)



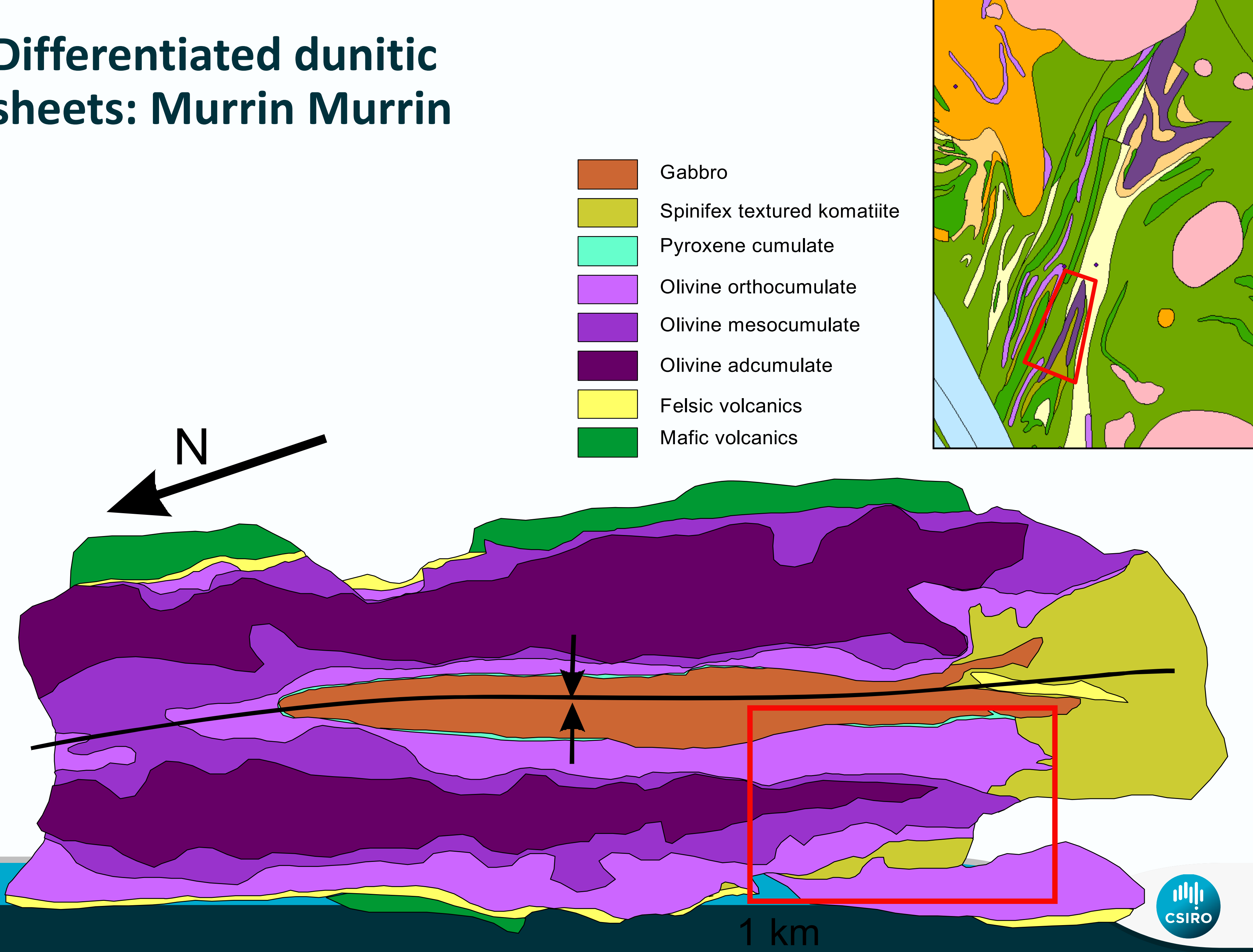


Thermal erosion on a grand scale (~100s m)



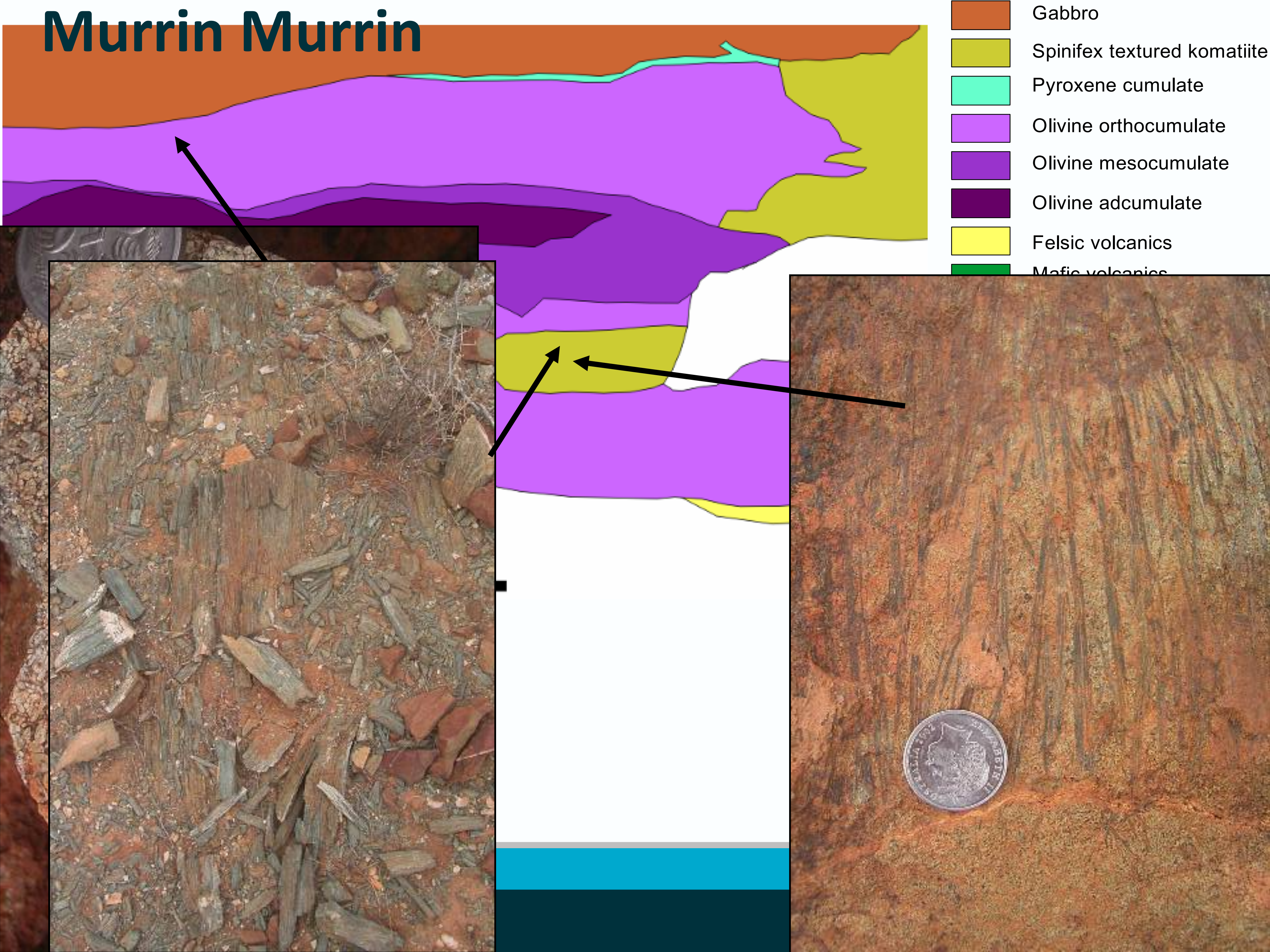
Origin of dunite channel facies

Differentiated dunitic sheets: Murrin Murrin

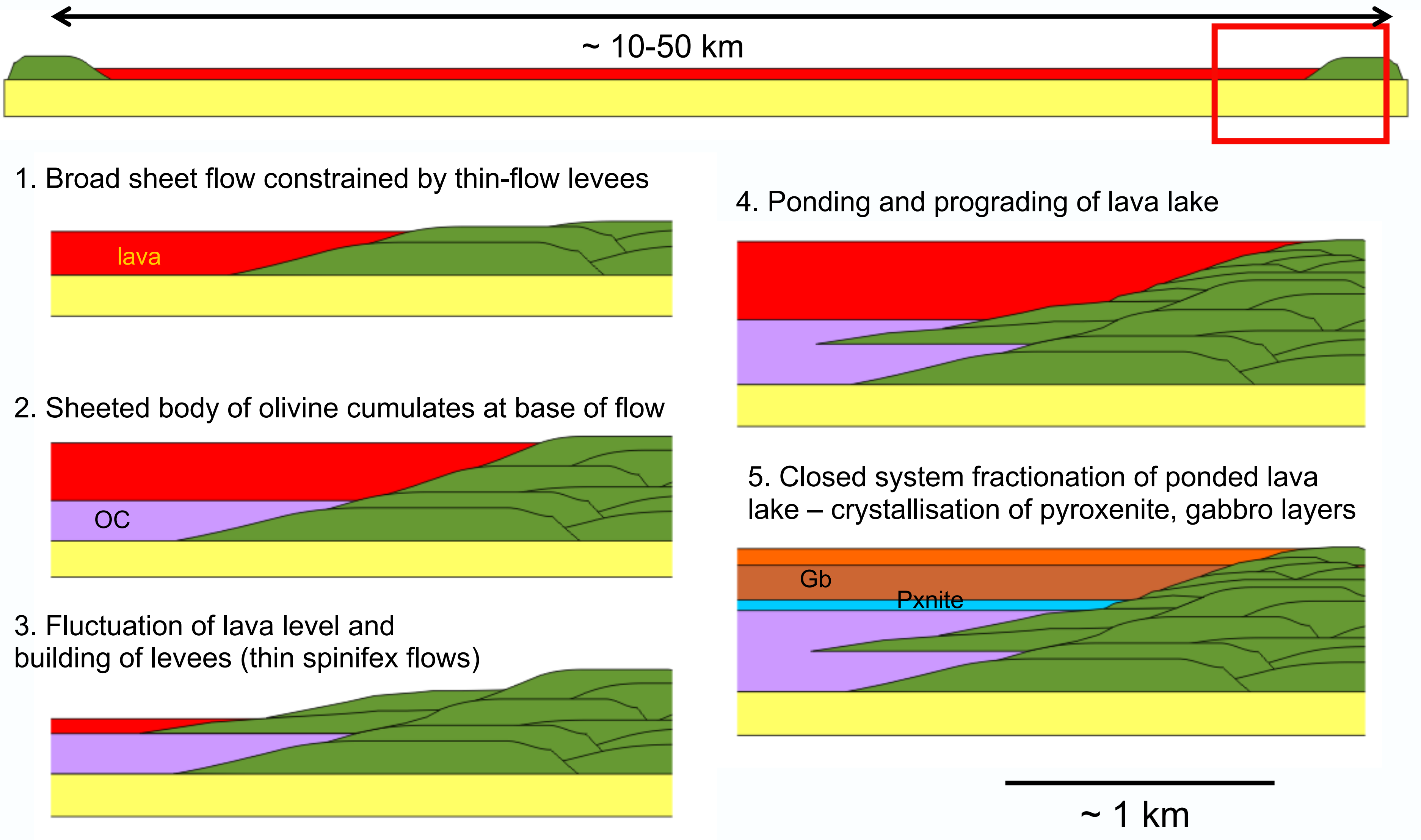


CSIRO

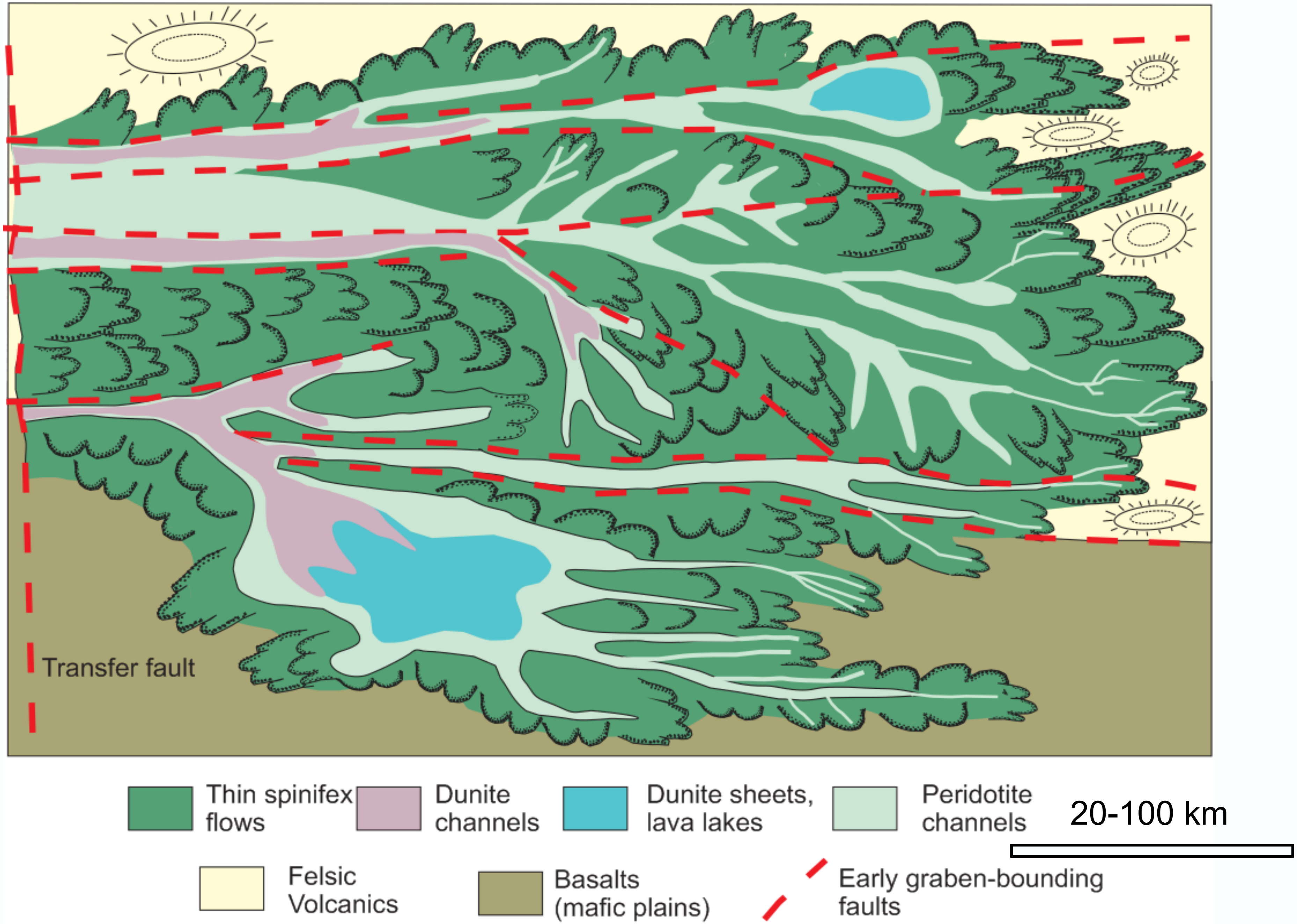
Murrin Murrin



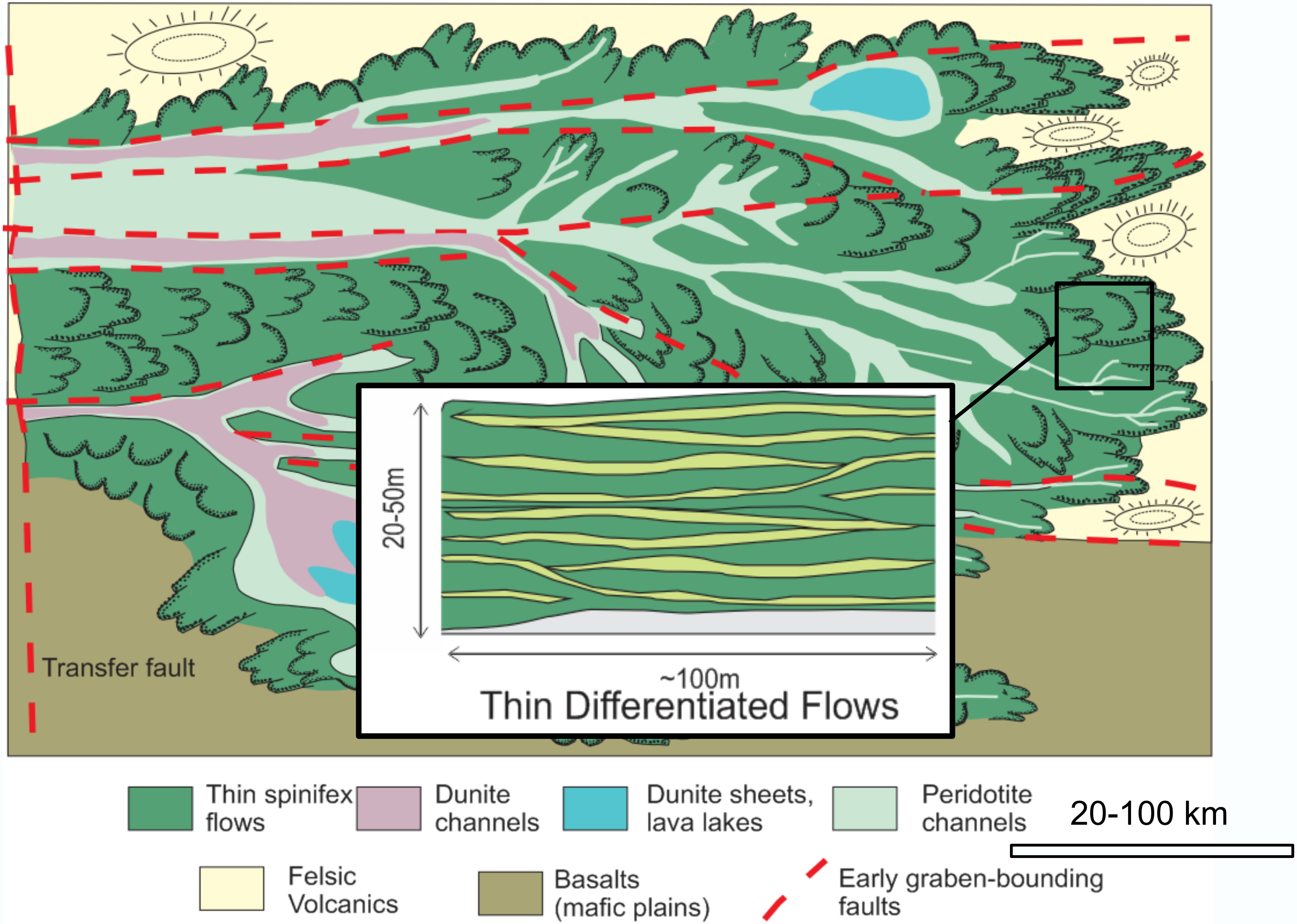
Murrin Murrin – model for development of sheet flow/lava lake



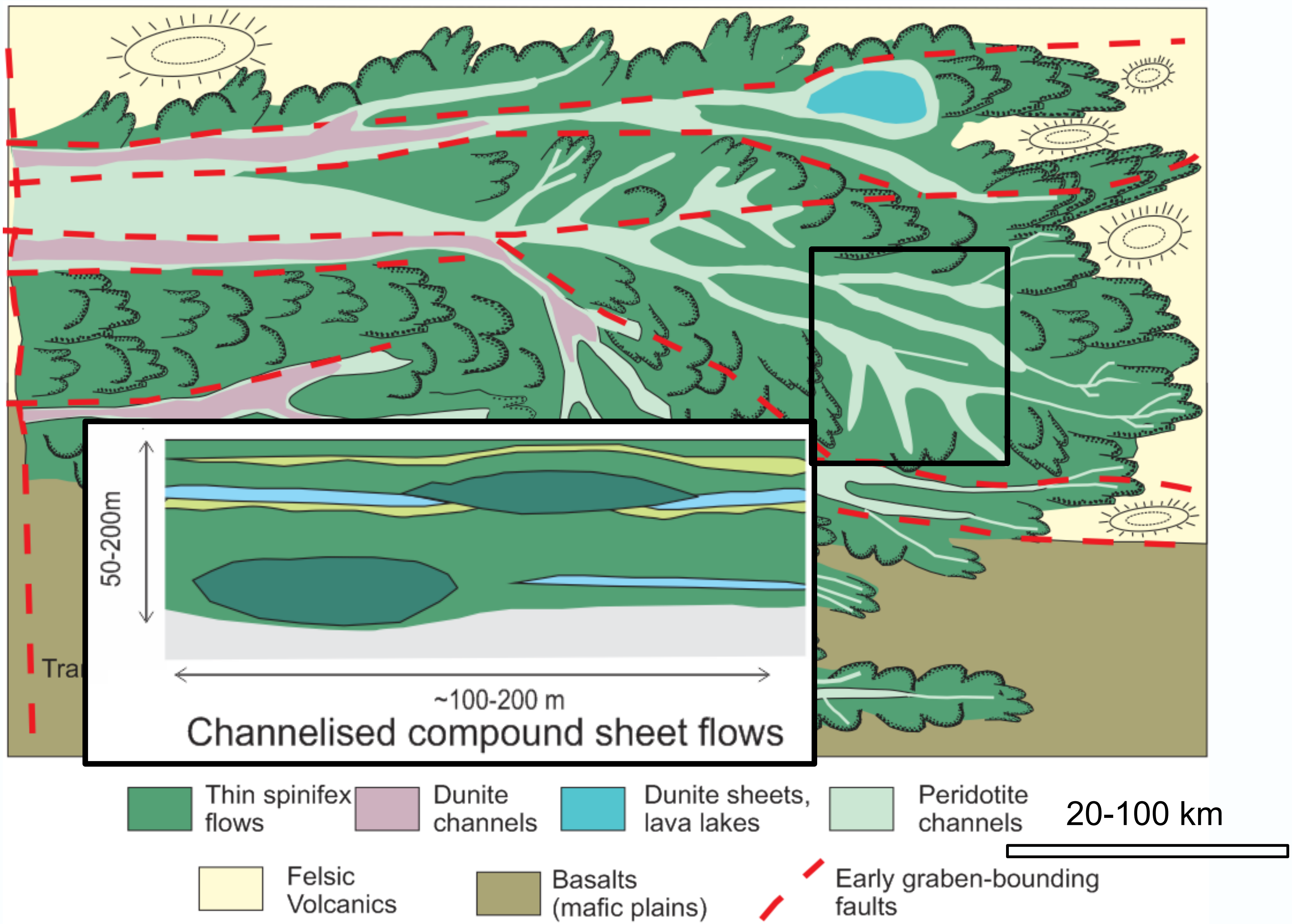
Komatiite flow field model (modified from Hill et al., 1995, Barnes and Gole in prep)



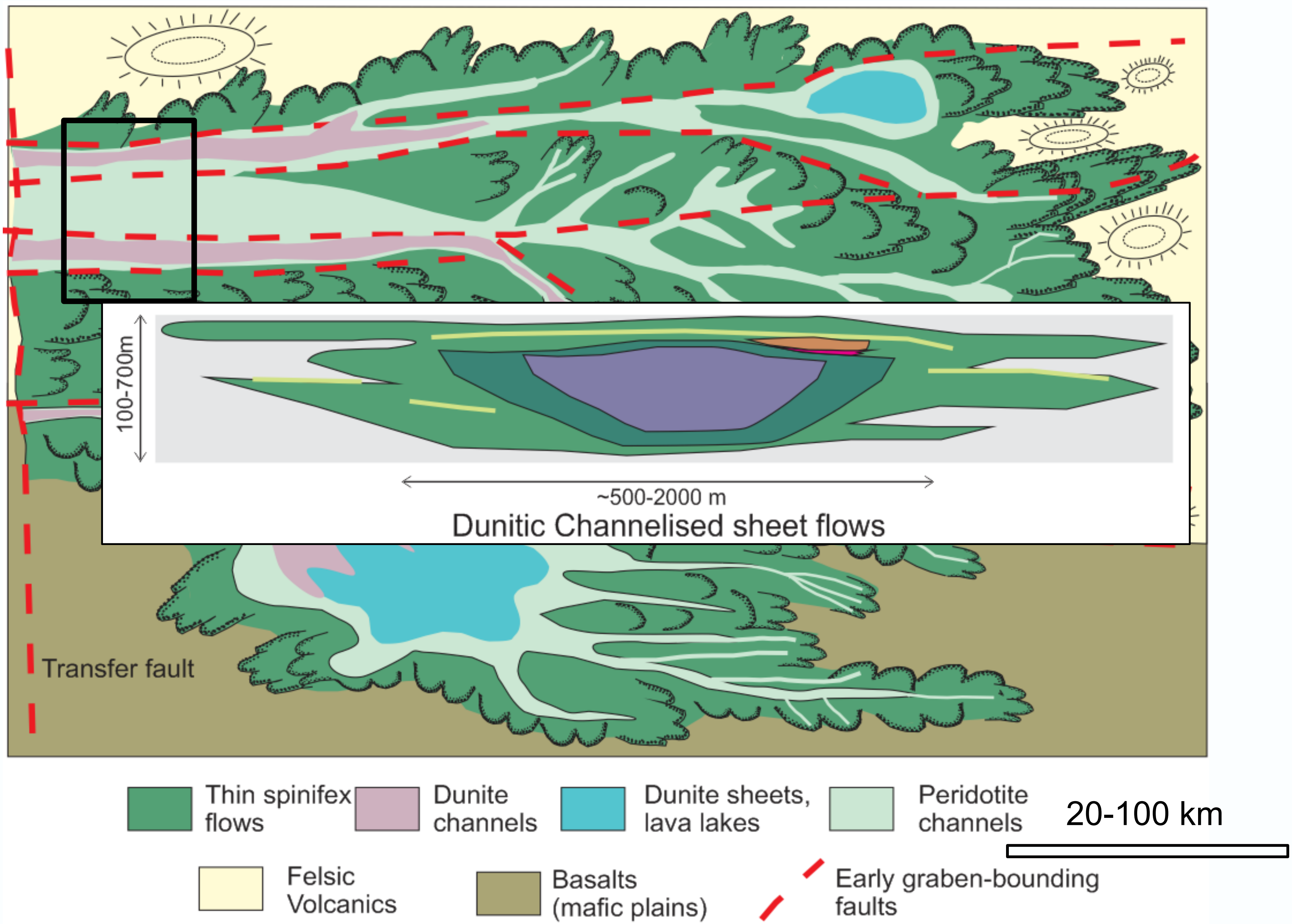
Komatiite flow field model (modified from Hill et al., 1995, Gole and Barnes in prep)



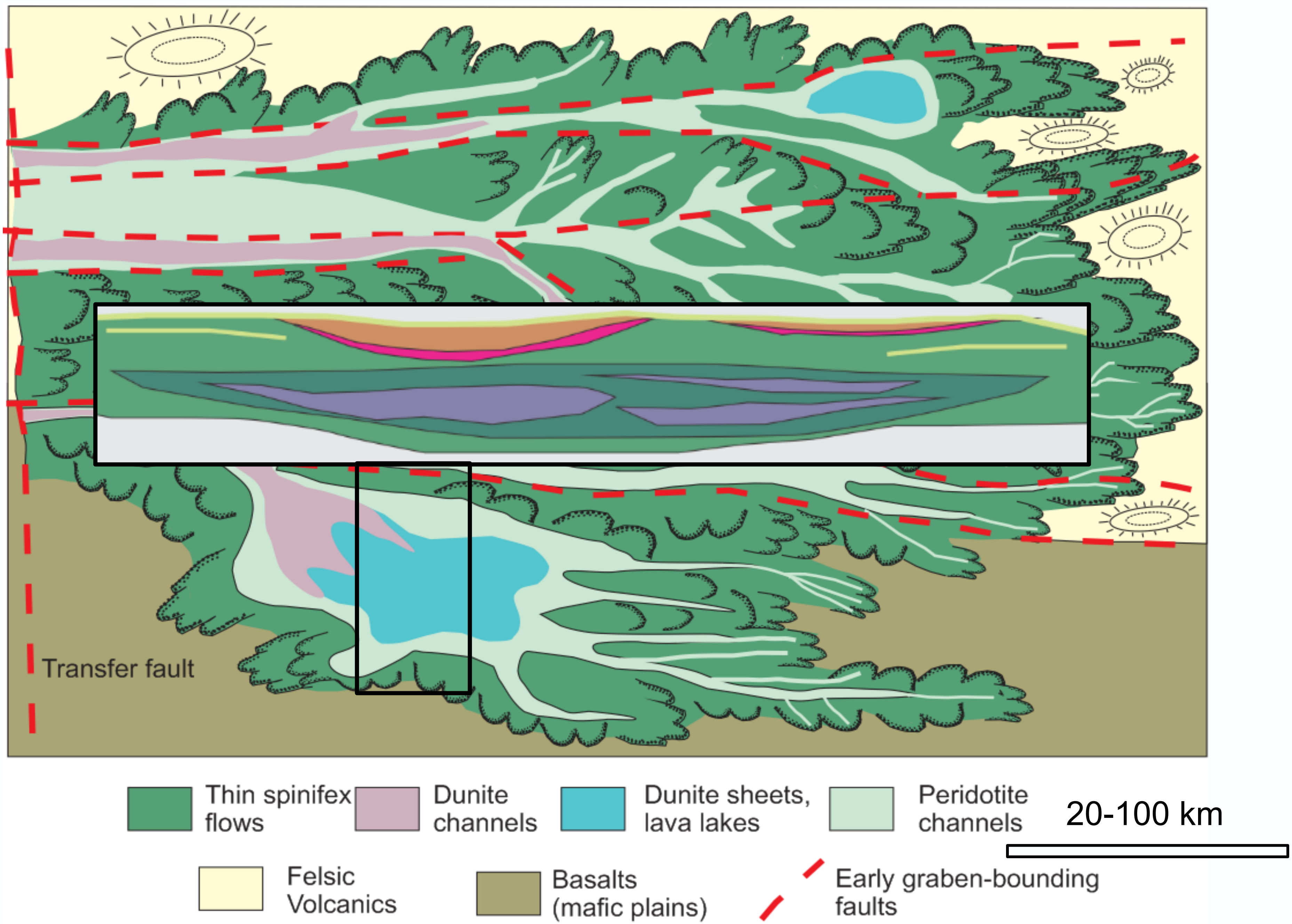
Komatiite flow field model (modified from Hill et al., 1995, Gole and Barnes in prep



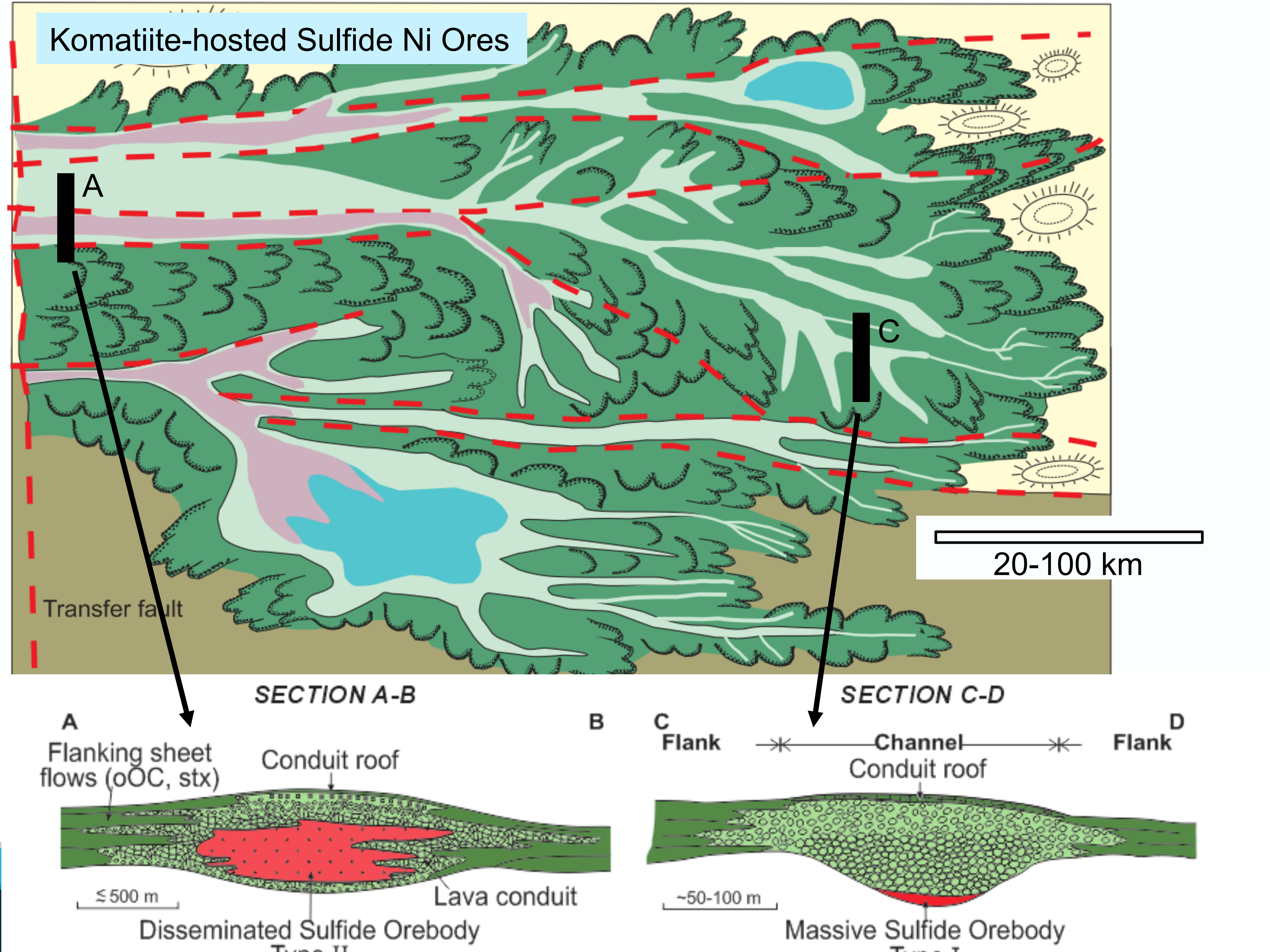
Komatiite flow field model (modified from Hill et al., 1995, Gole and Barnes in prep



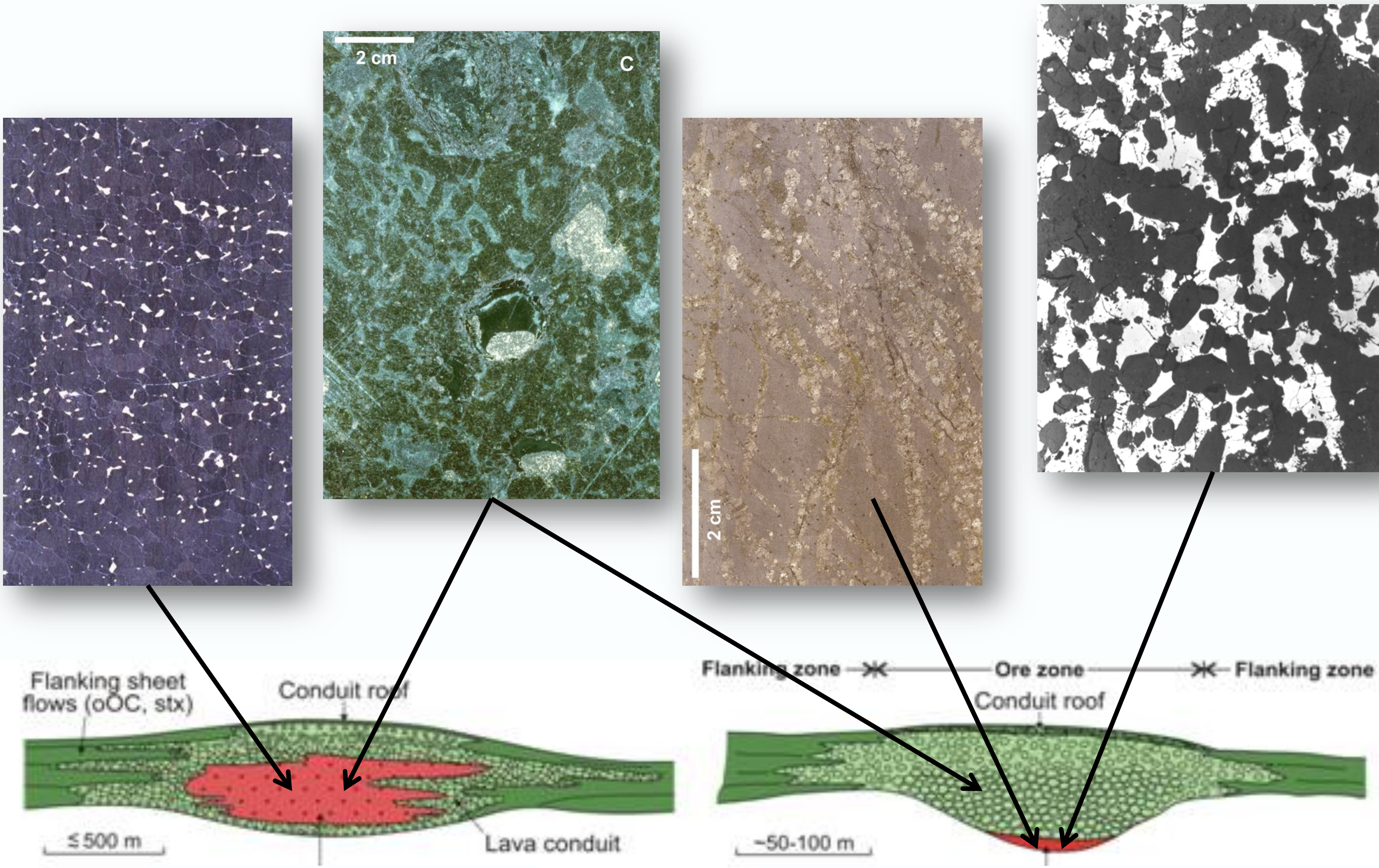
Komatiite flow field model (modified from Hill et al., 1995, Gole and Barnes in prep



Komatiite-hosted Sulfide Ni Ores

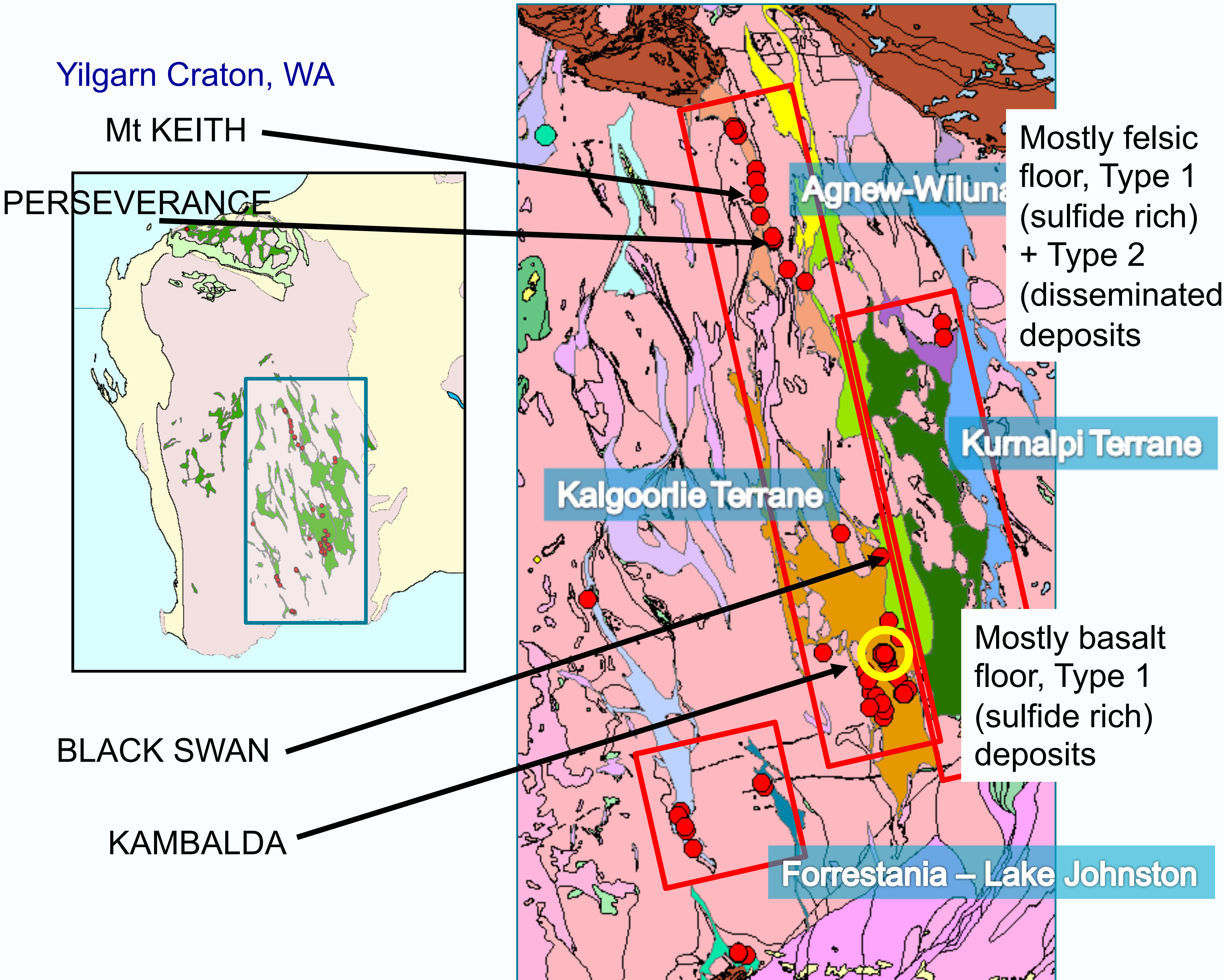


Relationship of ore deposits to komatiite flow units

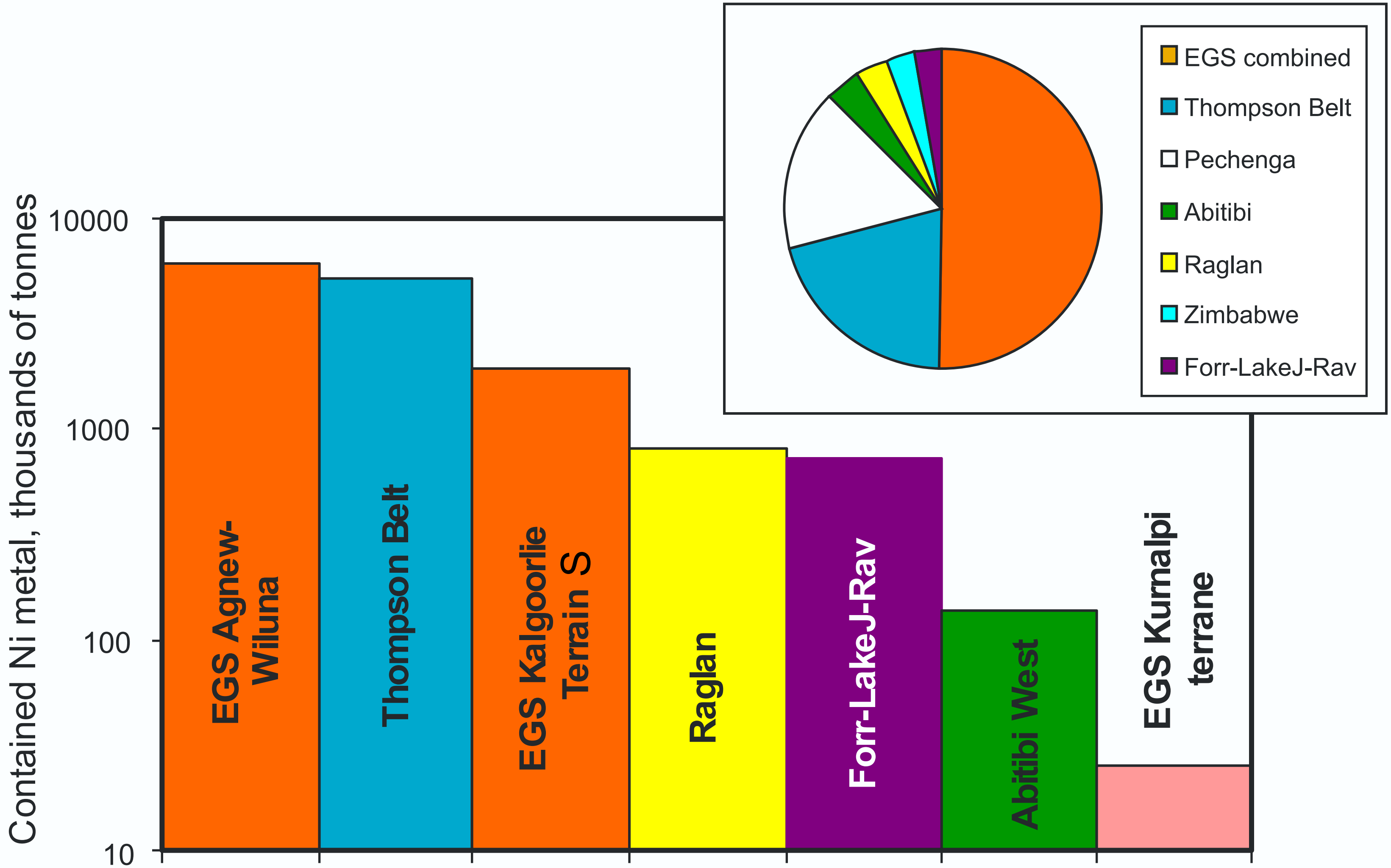


Type 2 (disseminated)

Type 1 (sulfide rich, massive+matrix)

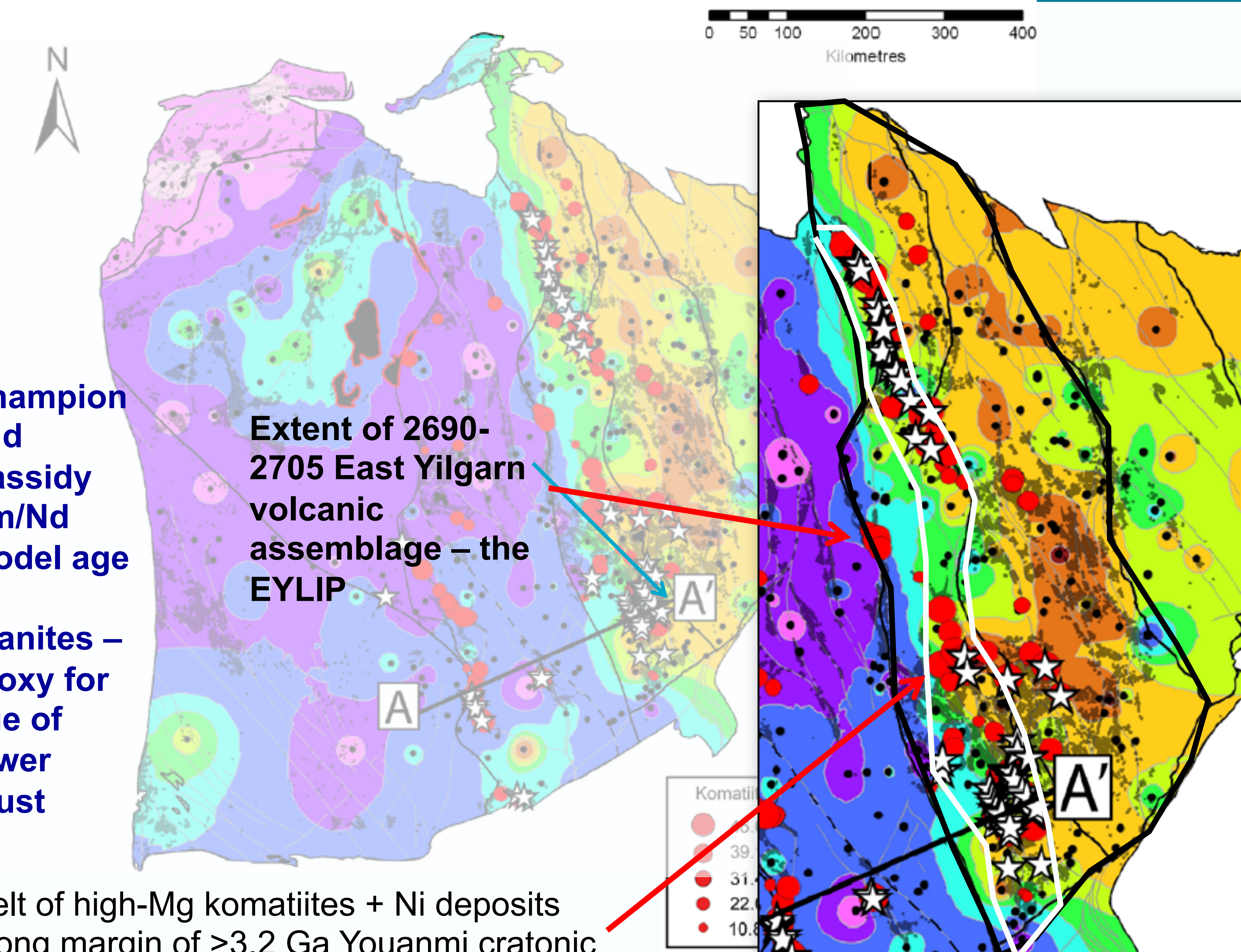

Yilgarn Craton, WA
Mt KEITH
PERSEVERANCE
BLACK SWAN
KAMBALDA
Agnew-Wiluna
Mostly felsic floor, Type 1 (sulfide rich) + Type 2 (disseminated) deposits
Kurnalpi Terrane
Kalgoorlie Terrane
Mostly basalt floor, Type 1 (sulfide rich) deposits
Forrestania – Lake Johnston

Comparative Ni endowment (ktonnes)



Barnes and Fiorentini 2011 Econ Geol

Champion and Cassidy Sm/Nd model age in granites – proxy for age of lower crust

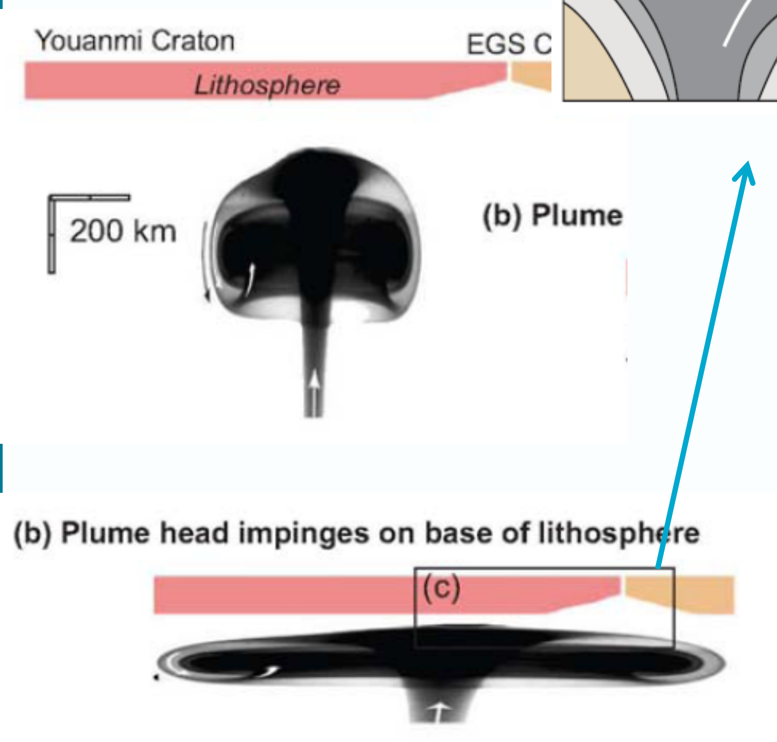


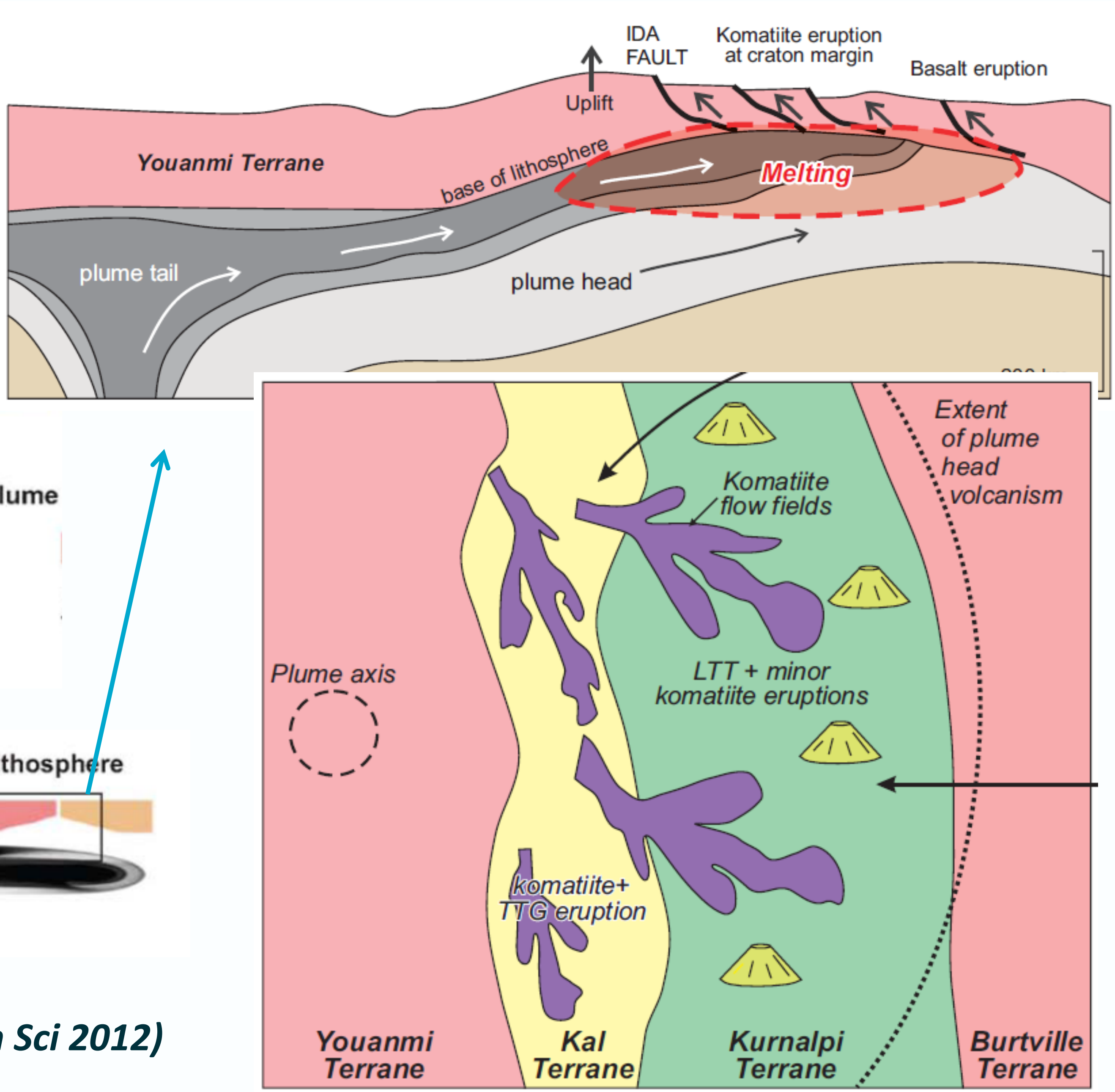
Extent of 2690-2705 East Yilgarn volcanic assemblage – the EYLIP

Belt of high-Mg komatiites + Ni deposits along margin of >3.2 Ga Youanmi cratonic nucleus or “Archon” – Kalgoorlie Terrane

Stars=Ni deposits

Plume model for ~2700 E Yilgarn “EYLIP” volcanism (East Yilgarn LIP)

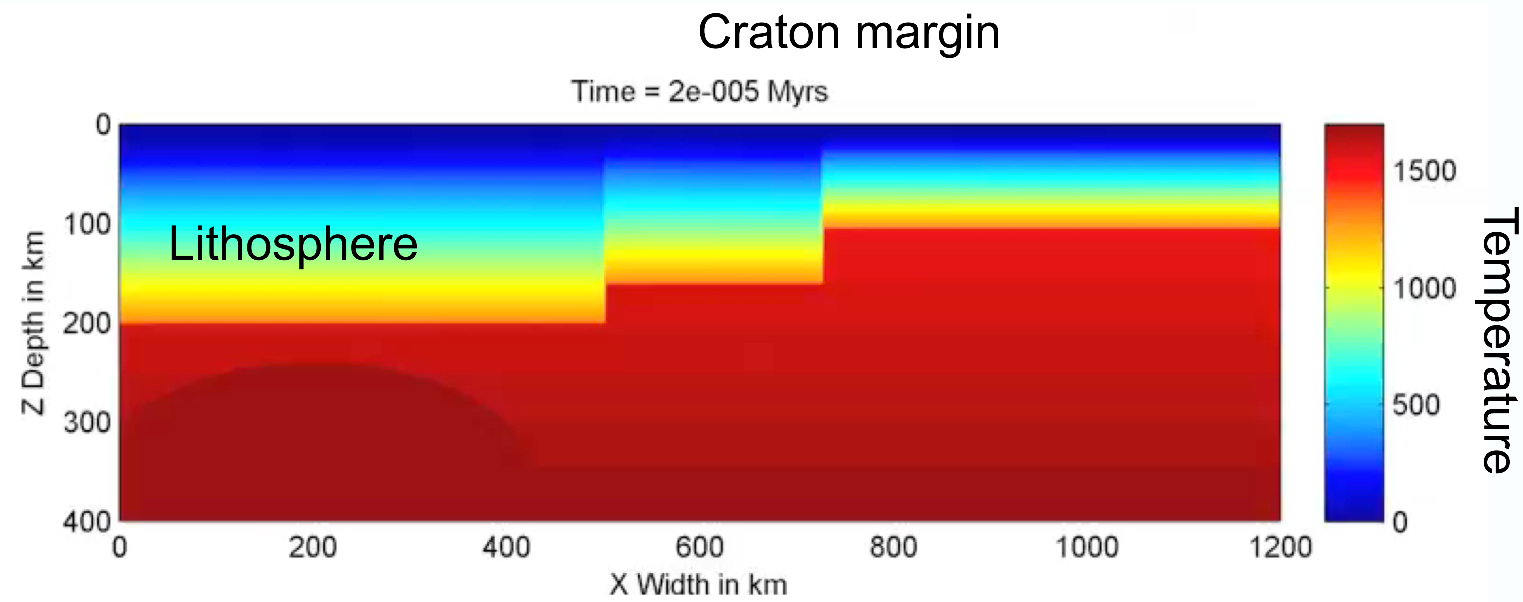


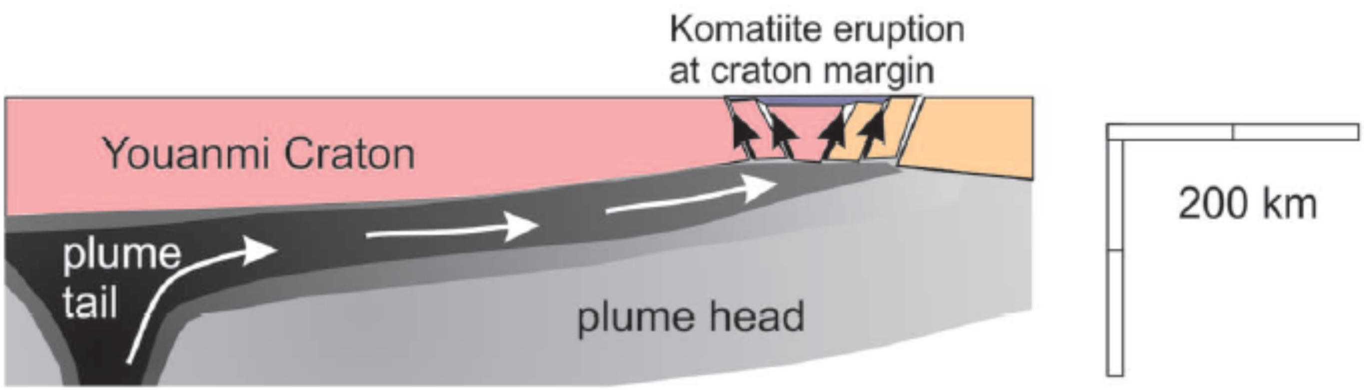


(Barnes et al, Aust J Earth Sci 2012)

EYLIP is an example of Ni-sulfide in high-volume magmatism at a craton margin

Model of a mantle plume ascending beneath a craton





Model by **Weronika Gorczyk** – University of Western Australia
Gorczyk, Barnes and Mole, Tectonophysics, doi:10.1016/j.tecto.2017.04.002

Kalgoorlie Terrane vs other greenstone settings

Richest terranes contain high proportion of very olivine-rich rocks (adcumulates) – not necessarily the host rocks

Richest terrane of all (Eastern Goldfields – Agnew Wiluna) contains most forsteritic adcumulates

Abitibi, E Goldfields have similar range of liquid compositions

All seem to have formed from depleted mantle plume source

Depth of melting (Al depletion) not crucial

The only mineralised ADK terrane (Forrestania-Lake J) contains adcumulate dunites

Similar PGE contents for same MgO – limited depletion, komatiites erupted S-undersaturated

No evidence of unusually Ni or PGE rich magmas