U3A

Australian Geological Phenomena

Lecture 1

Tasmania

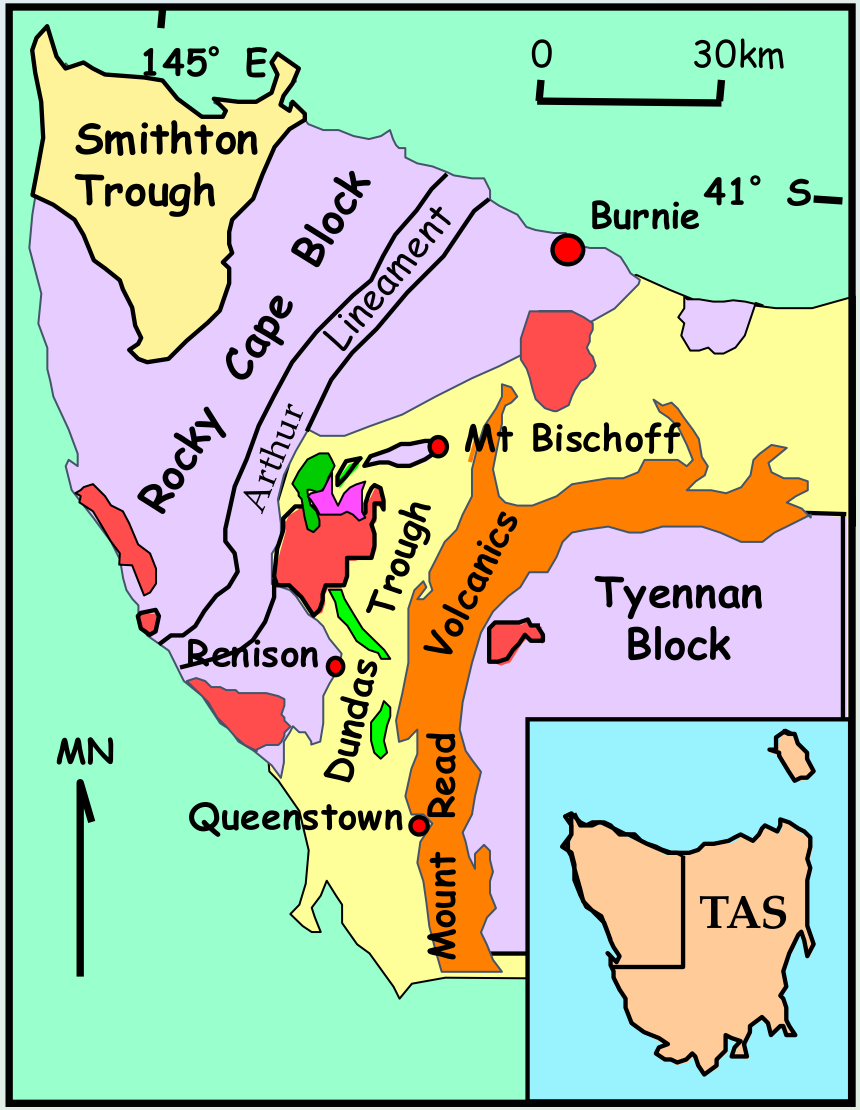
Tasmanian geological phenomena

1. Mt Read Volcanic Belt
2. Tasmanian Sn deposits
3. Tasmanian Jurassic dolerites
4. Pleistocene glacial features

Mt Read Volcanics Belt

- The Mt Read volcanics in western Tasmania is an arcuate belt 10-15km wide of Middle-Late Cambrian volcanic-volcaniclastic rocks
- located on the eastern margin of the Dundas Trough
- composed of felsic, intermediate and minor mafic volcanic and volcaniclastic rocks → predominantly rhyolite and dacite with rare basalt. Granites outcrop at Mt Murchison, Mt Darwin
- the rocks are structurally deformed and hydrothermally altered*
- belt renowned worldwide for the abundance and richness of base metal deposits including Rosebery, Mt Lyell, Hellyer, Que River, Hercules and Henty

Regional geology of northwest Tasmania



Devonian granite

Cambrian calc-alkaline volcanics

Neoproterozoic-Cambrian sediments with some mafic volcanics

Ultramafic complexes

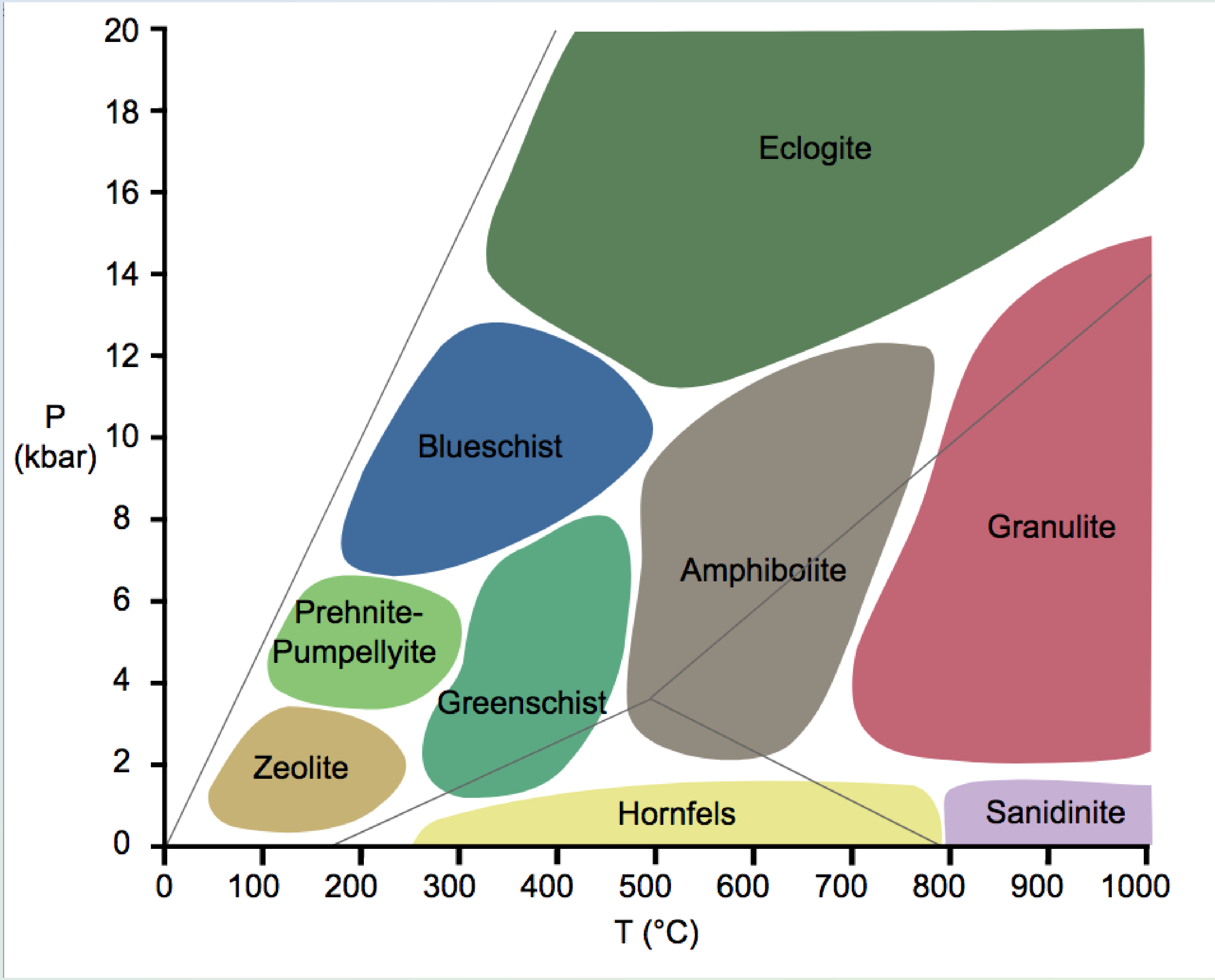
Proterozoic

Mafic volcanics

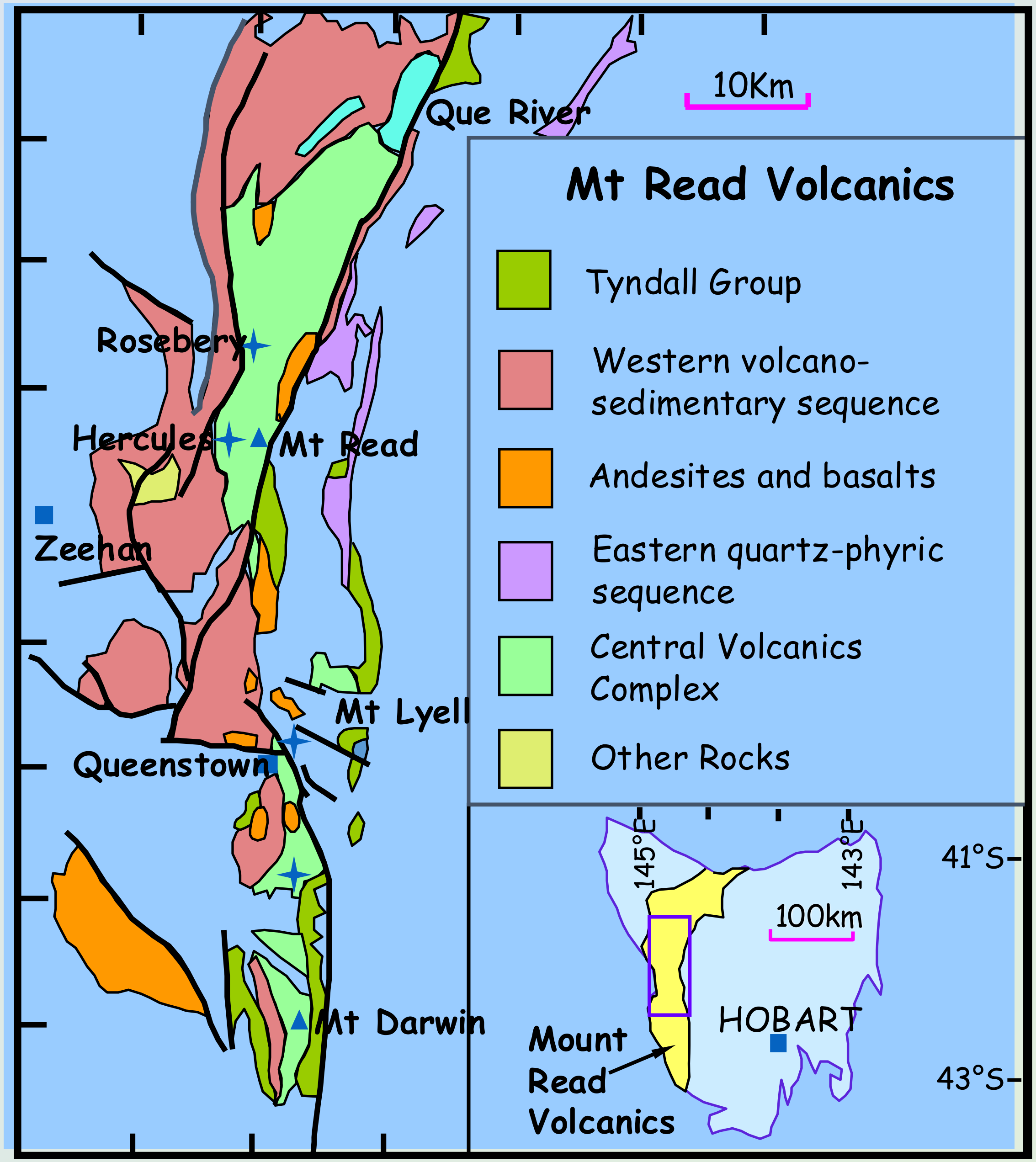
Lithological features of the volcanic belt

- Volcanic rocks in the belt show a wide variety of primary and secondary features → massive, vesicular, flowbanding, columnar -jointed lava flows, autobrecciation*
- rocks are typically porphyritic* and have undergone lower greenschist facies metamorphism and hydrothermal alteration
- the rocks were regionally deformed in the Devonian and locally in the Cambrian
- deformation in Devonian → secondary metamorphic minerals → sericite, chlorite, epidote, actinolite–tremolite

Metamorphic facies



Mt Read volcanics



Mt Read Volcanics sequence

Tyndall Group

- Quartz-phyric* felsic and intermediate extrusive and volcaniclastic rocks. Volcaniclastic agglomerates* and breccias.
- forming at the base is a discontinuous unit up to 500m thick of clastic sediments (sandstones, siltstones, conglomerate)
- all of the rocks were deposited in a marine environment

Eastern quartz-phyric sequence (EQPS)

- Quartz-phyric felsic lavas (rhyolites) and volcaniclastic rocks with numerous intrusives
- the EQPS is intruded by the Murchison granite

Mt Read Volcanics sequence

Central volcanics complex (CVC)

- Mainly rhyolite to dacite (flowbanded, autobrecciated) minor andesite, sedimentary and mafic units. Basalt and gabbro dykes intrude the felsic rocks

Western volcano-sedimentary sequence (WVSS)

- Interbedded mixtures of sandstone, siltstone, shale, quartzose and volcaniclastic turbidites and porphyry intrusions
- most of the volcanic rocks and intrusions are quartz-phyric in contrast to CVC rocks that are predominantly feldspar-phyric

Mt Read Volcanics

WTF021 dacite

WTF023 sheared plag-phyric lava

WTF042 Volcaniclastic greywacke

WTF029 plag-phyric lava

Ore deposits in the Mount Read Volcanic belt

- Deposits are syngenetic*, Volcanic Massive Sulphide (VMS) deposits
- VMS deposits → predominantly accumulations of metal sulphide deposits that form on or below the seafloor
- ore deposits form in association with submarine volcanism → hydrothermal circulation and exhalation of sulphides*
- lenticular to sheet-like, stratiform bodies develop at interfaces between volcanic units or at interfaces between volcanic and sedimentary units

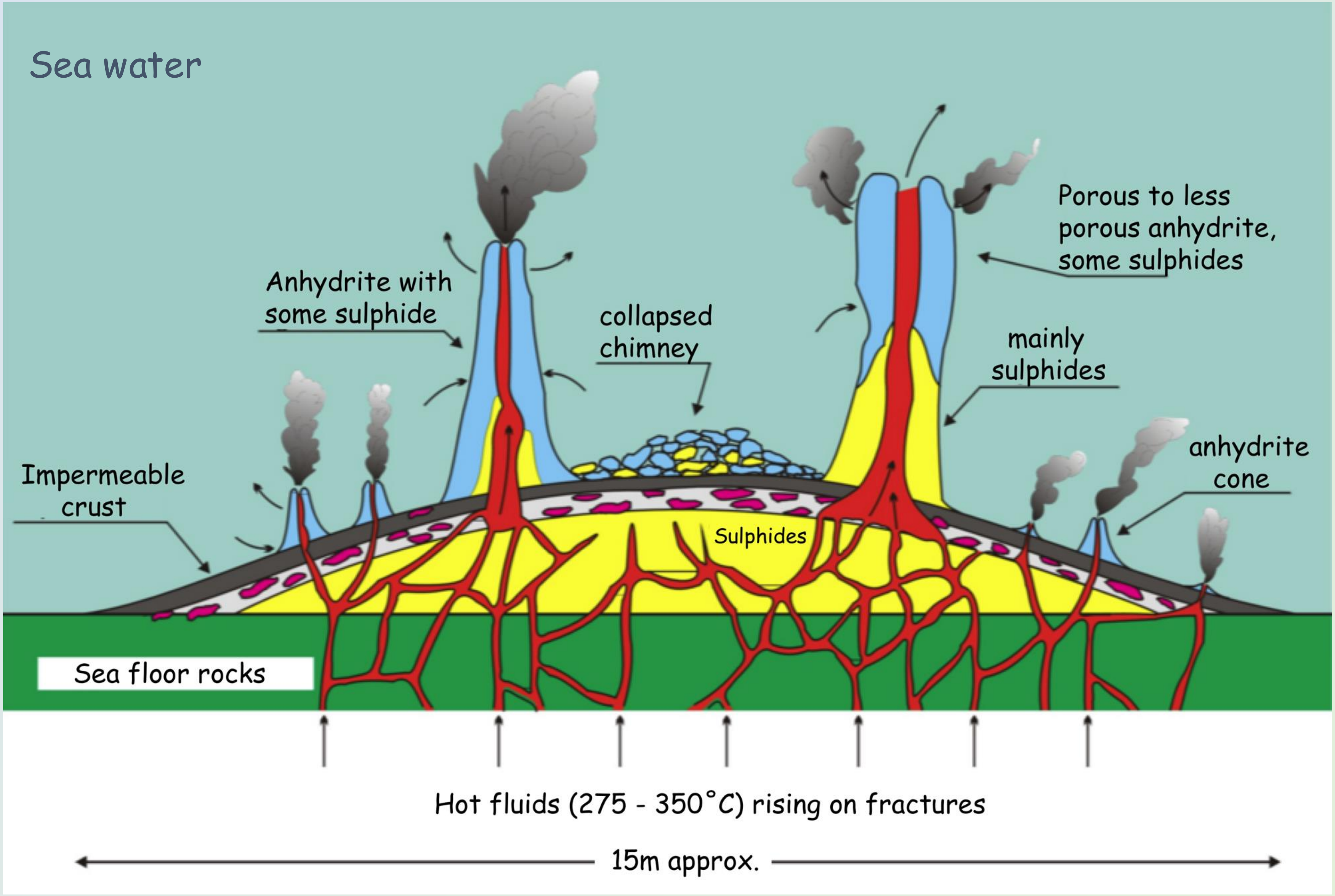
Genesis of VMS deposits

- Ores precipitate through interaction of hot S plumes & cold seawater
- exhalative vents commonly form chimney growth on the seafloor
- chimney growth commences with precipitation of anhydrite ($CaSO_4$)
- hydrothermal fluid passes out partly through porous chimney walls

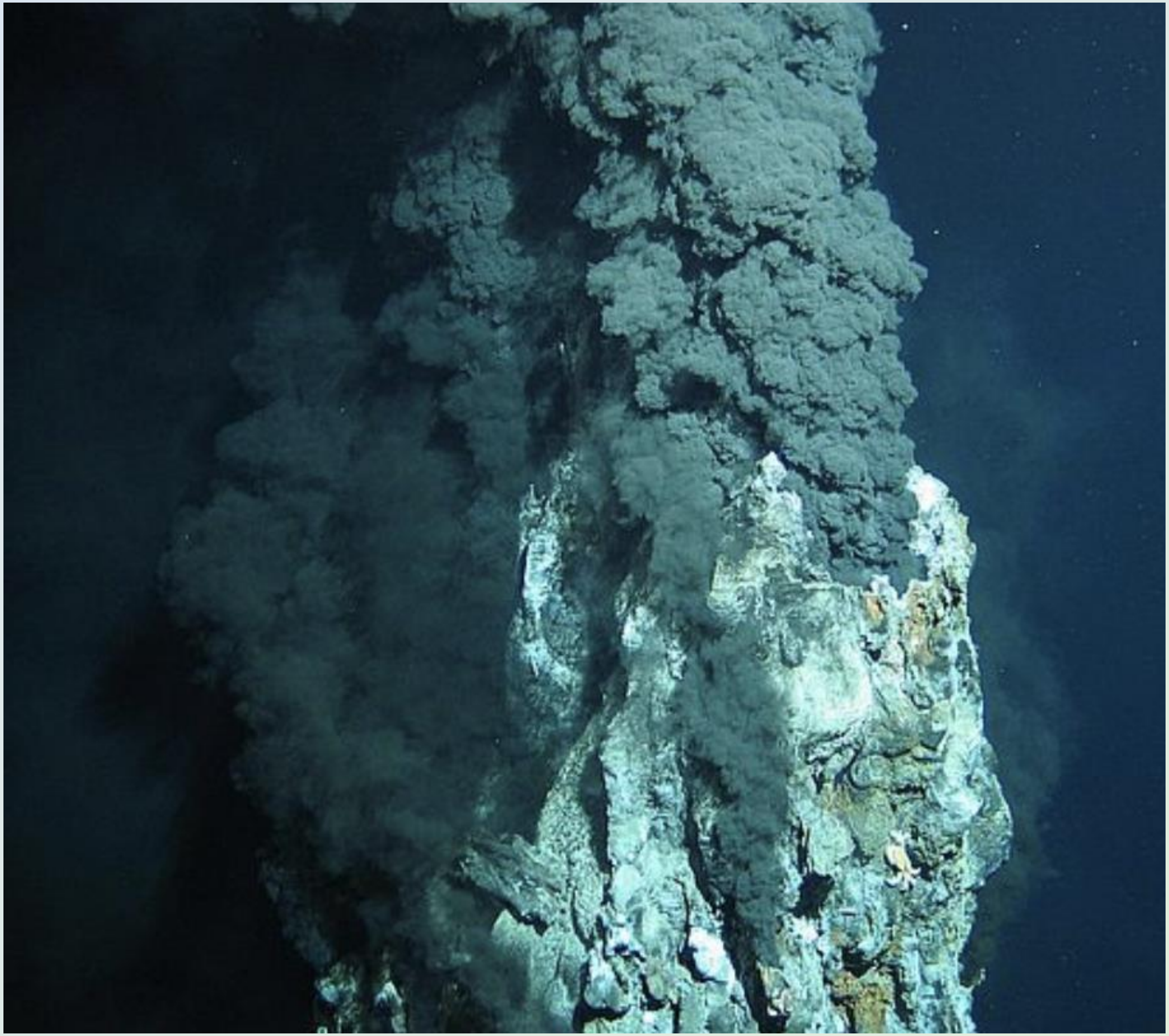
Hydrothermal fluid:	Temp. >300°C
	pH ~3.5
	Reduced ($H_2S \gg H_2SO_4$)
Seawater:	Temp. 2°C
	pH ~7.8
	Oxidised ($H_2S \ll H_2SO_4$)

- as chimney grows upwards lower part thickens → sulphides precipitate
- unstable chimneys collapse* → debris accumulates on seafloor together with chemical precipitates → form sulphide mounds

Formation of VMS chimneys and sulphide mounds on the seafloor (after Barnes 1988)

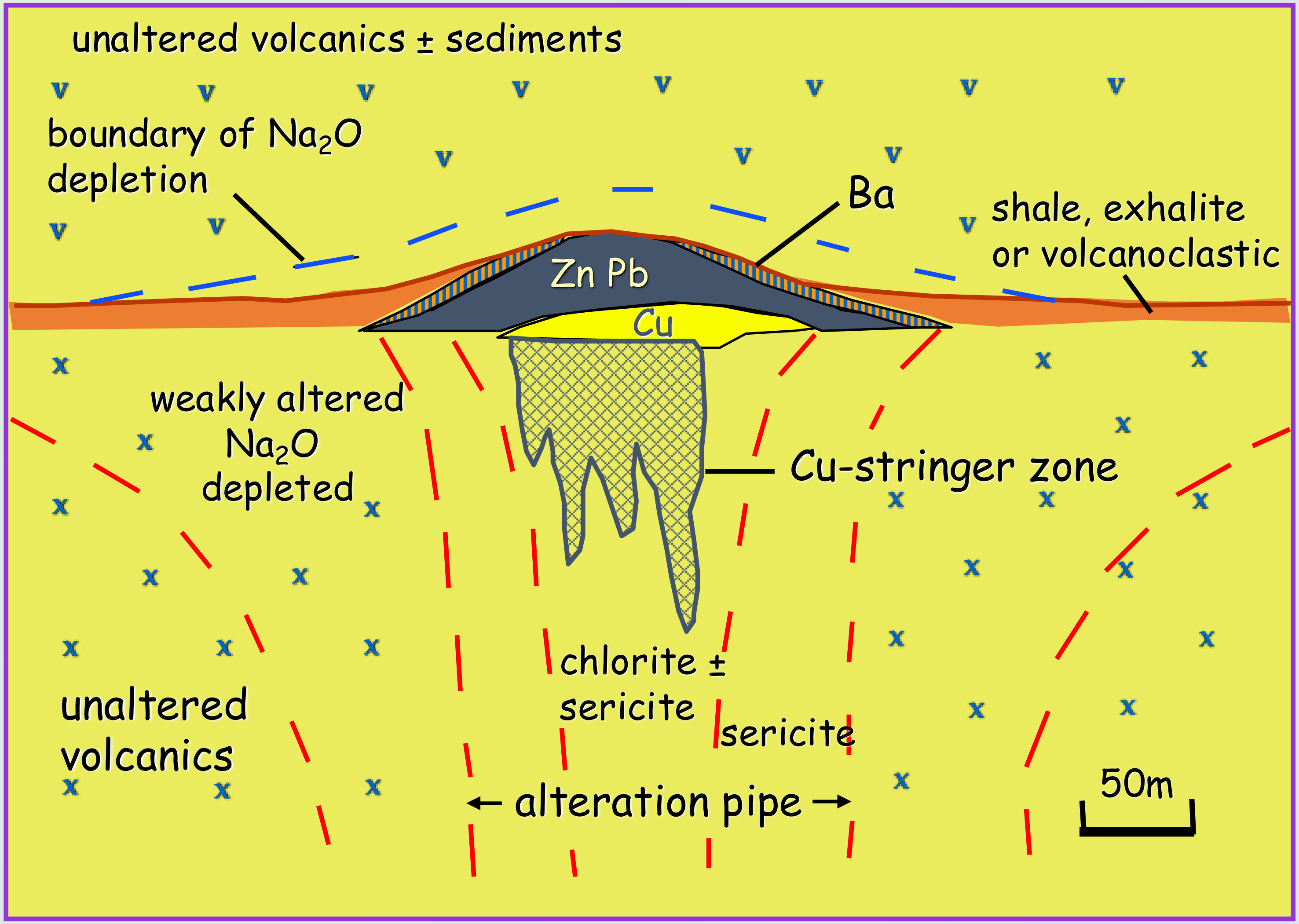


Hydrothermal vent



Typical mound style deposit

(After Large and Gemmell 1992)



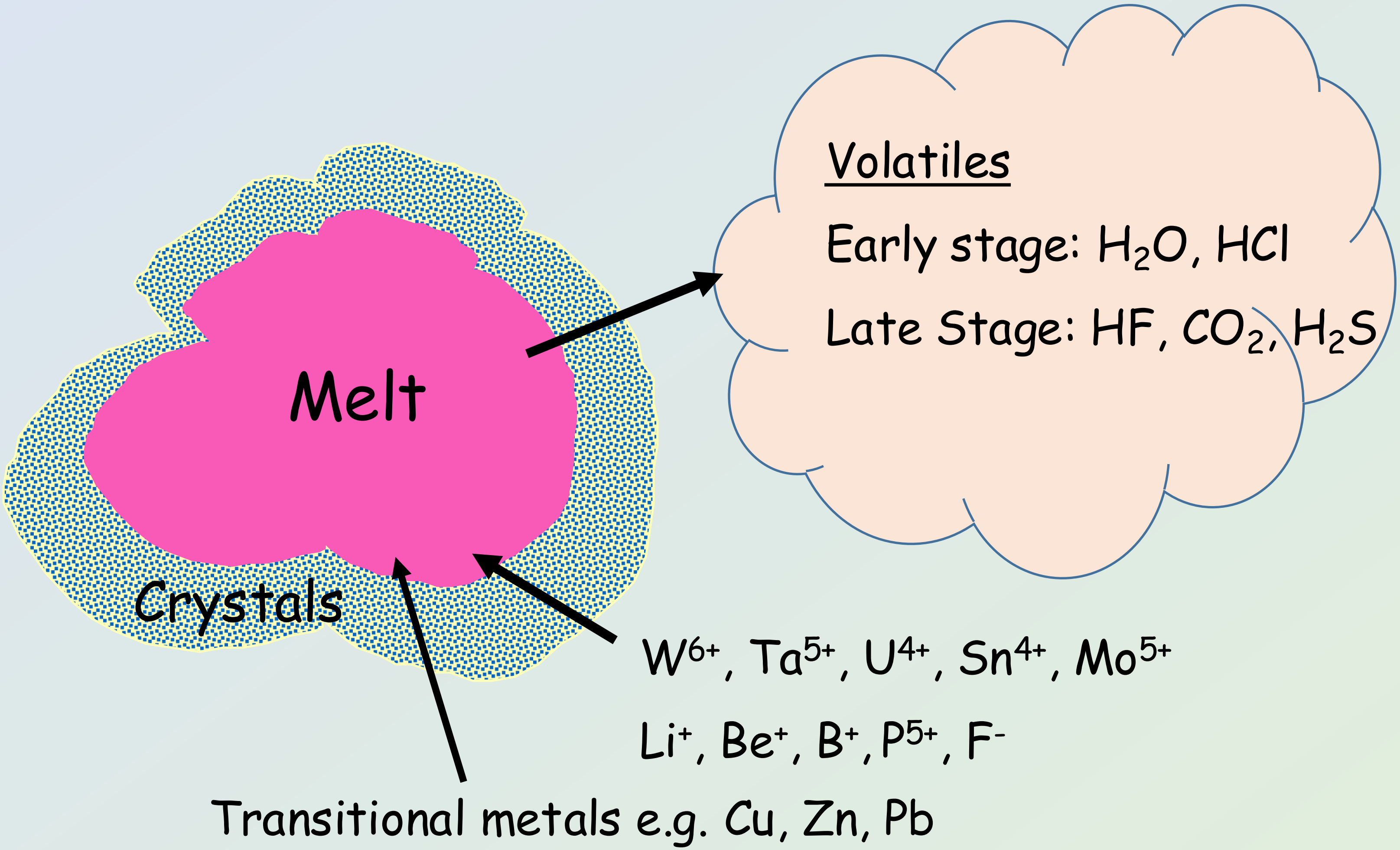
Ore characteristics

- Pyrite comprises bulk of ore in most deposits, pyrrhotite in some
- chalcopyrite ($CuFeS_2$), sphalerite (ZnS) and galena (PbS) are major ore minerals with lesser amounts of bornite (Cu_5FeS_4), arsenopyrite (FeAsS), magnetite (Fe_3O_4) and tetrahedrite [$(Cu,Fe)_{12}Sb_4S_{13}$]
- quartz is the principal gangue* mineral with carbonate, sericite and chlorite major phases in some deposits
- a majority of ore deposits are zoned with galena and sphalerite in the upper orebody and chalcopyrite increasing with depth
- Au occurs in association with Ag-Pb-Zn in some deposits, associated with Cu in stockwork at others e.g. Mt Lyell

Element partitioning in crystallization of magmas

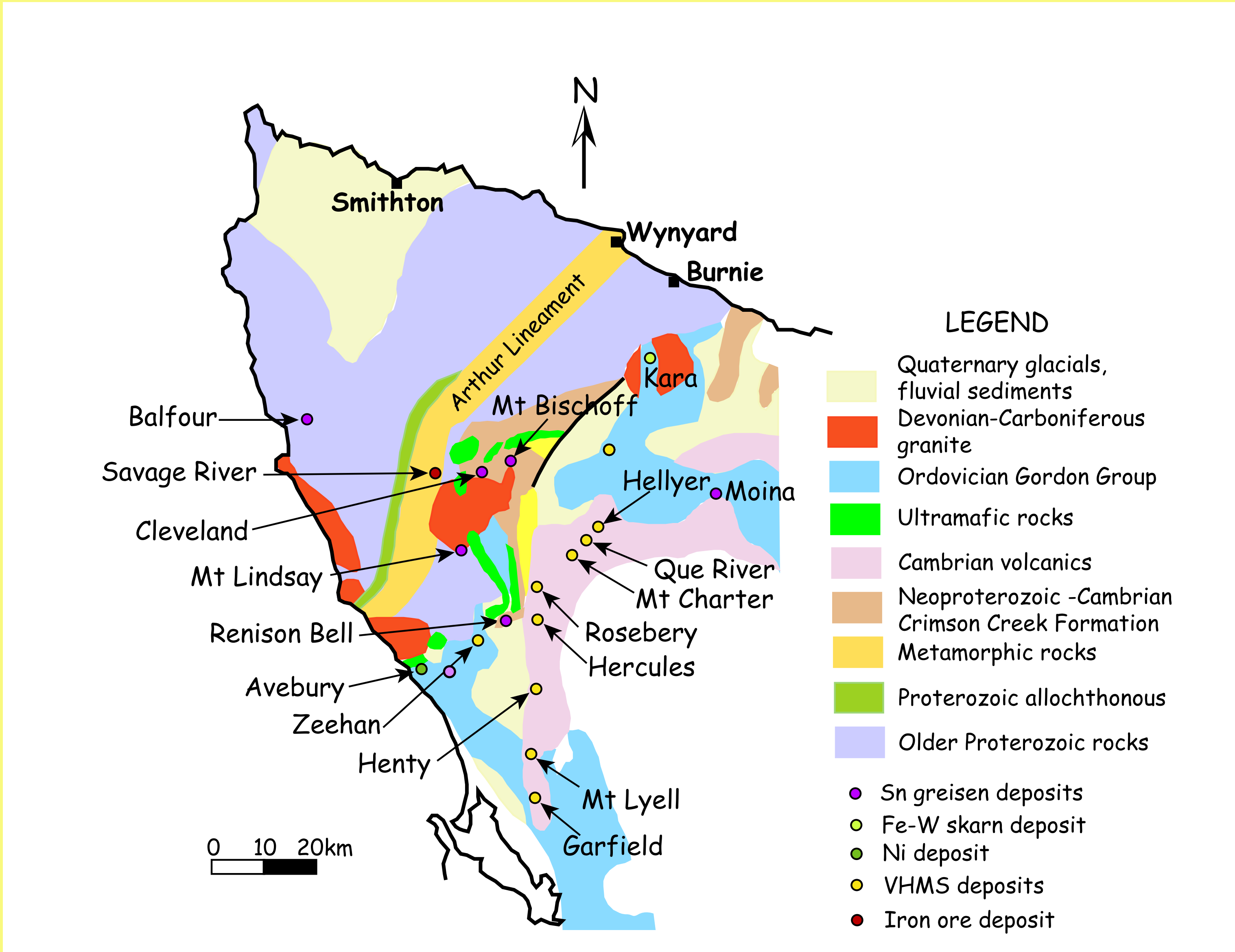
- When a body of magma containing dissolved volatiles (e.g. H_2O, CO_2, HCl, H_2S, HF) crystallises, three phases normally occur, melt, crystal and fluid
- as crystallization proceeds, some elements show preference for the crystal phase (compatible), some for the melt (incompatible), others for the fluid phase
- a consequence of crystallization is that melt reduces its capacity to dissolve fluids
- some elements in melt are readily leached by evolving fluids*
- earliest fluids to evolve are H_2O and HCl rich, incompatible elements eventually will be leached by later evolving fluids

Element partitioning in crystallisation



$D = c_s/c_l \qquad D > 1 = \text{compatible}$

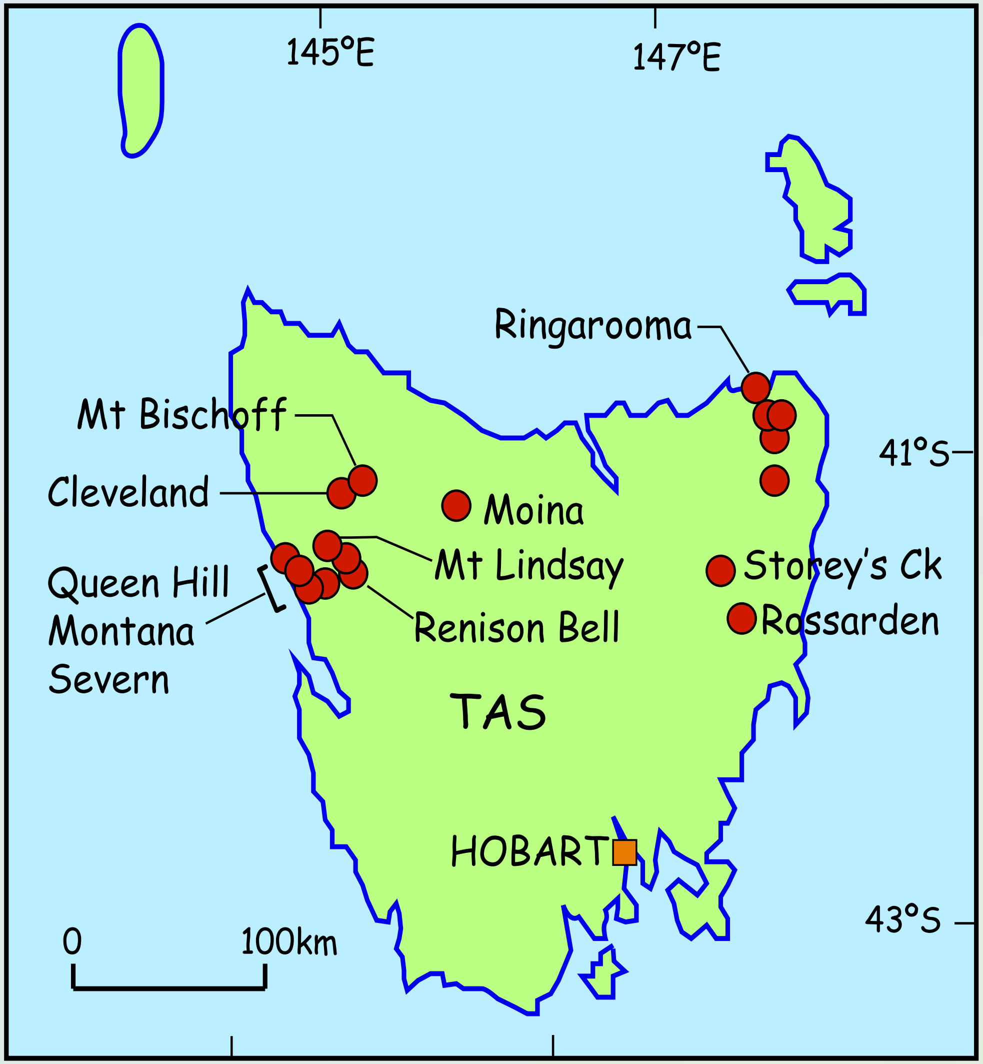
Western Tasmanian major ore deposits



Tasmanian Sn deposits

- Sn-W deposits in Tasmania → associated with Devonian and Early Carboniferous granites
- ore-bodies are contained within endogreisens*, exogreisens → greisenised carbonate replacement bodies and quartz veins
- largest deposits are in massive pyrrhotite-cassiterite greisenised carbonate replaced bodies in western Tasmania (e.g. Renison, Cleveland, Mt Bischoff and Queen Hill)
- in northeastern Tasmania, Sn mineralisation occurs in greisenised granite and dilational quartz-wolframite-cassiterite veins (e.g. Aberfoyle, Storeys Creek, Blue Tier)

Tasmanian Sn deposits



Greisens

- Greisens are autometasomatic rocks formed by the action of high temperature (300-600°C), low pH, pneumatolytic*-hydrothermal solutions high in fluorine, chlorine, lithium, water and boron
- form in apical and exocontact zones of granites.
- greisens are usually quartz-mica rocks often with topaz [$Al_2SiO_4(F,OH)_2$], tourmaline, fluorite (CaF_2) and sulphides.
- greisens commonly contain ores of tin, tungsten, beryllium, molybdenum, arsenic, bismuth, tantalum, niobium and rare earths.

Nature of greisens

Location

In apices and along flanks of shallow intrusions (1-4km depth)*, along margins of veins in endo and exocontact zones*

Geometry

Endocontact: veins, pipe-like bodies, sheets, breccia pipes, irregular, massive

Exocontact: brittle styles (veins, stockworks, pipes); replacement

Endogreisen - autometasomatic replacement

Exogreisen - greisen assemblages superimposed on rocks peripheral to the intrusion.

Greisen veins - infilled fissures by greisen fluids/leachates

Controls on mineralisation

- Contrast in host rocks → responsible for fundamental differences in the character of the Tasmanian Sn deposits

  northeastern Tasmania - lack of reactive host rocks

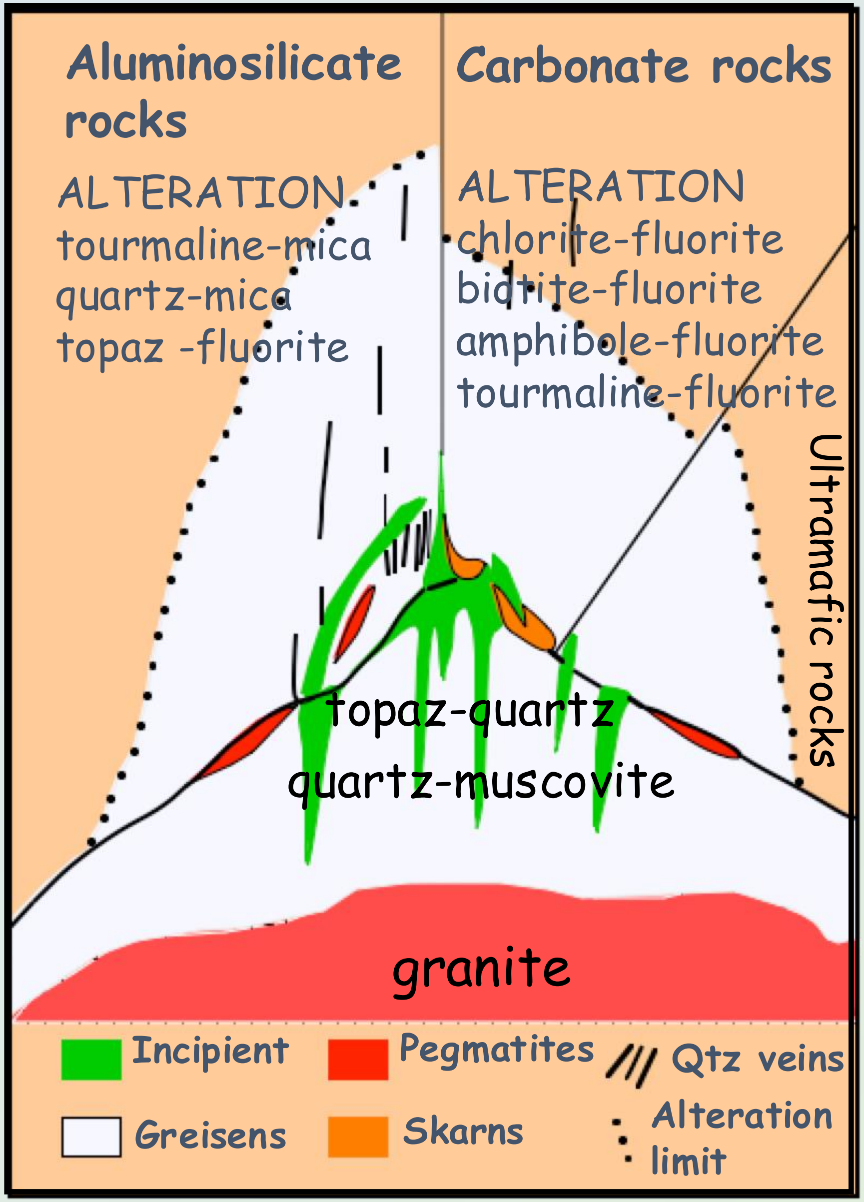
  western Tasmania – wide range of reactive rocks (dolomite, limestone, ultramafic rocks)

- Renison Bell – quartz-arsenopyrite-pyrrhotite-chalcopyrite-fluorite veins occupy faults → feeders to dolomite replacement

- Mt Bischoff – greisenised dykes, breccia pipes → conduits for metasomatic fluids → formed greisenised dolomitic skarns

- Cleveland – greisenised dyke acted as a conduit for greisen fluids → greisenised calcic skarn, greisen veins (dyke and country rocks)

Generalised greisen model (After Shcherba 1970)



Formation of primary tin deposit

(1) Source of tin → fractionating, volatile-rich, granite melt

(2) Transporting medium with transporting ligands e.g. Sn mainly transported as soluble Sn-fluoride complex

(3) Permeability → provides plumbing for fluid movement e.g. hydraulic and/or mechanical fracturing of rocks, solution cavities in reactive rocks*

(4) Precipitating mechanism → destabilises Sn complex e.g. temperature/pressure decrease, change in oxidation state, change in pH of transporting fluids*

Skarn-carbonate exogreisen deposits

Ore formation in skarn greisen deposits show distinct stages in the paragenesis

1. Anhydrous skarn stage - Ca-garnet, diopside, wollastonite
2. Hydrous skarn stage - amphibole minerals
3. Pre-ore greisen stage - quartz mica greisens
4. Ore greisen stage - quartz-topaz, quartz-mica-fluorite, quartz-tourmaline-fluorite greisen → sulphide, cassiterite precipitation
5. Post greisen stage - carbonate, marcasite alteration

Cleveland tin deposit

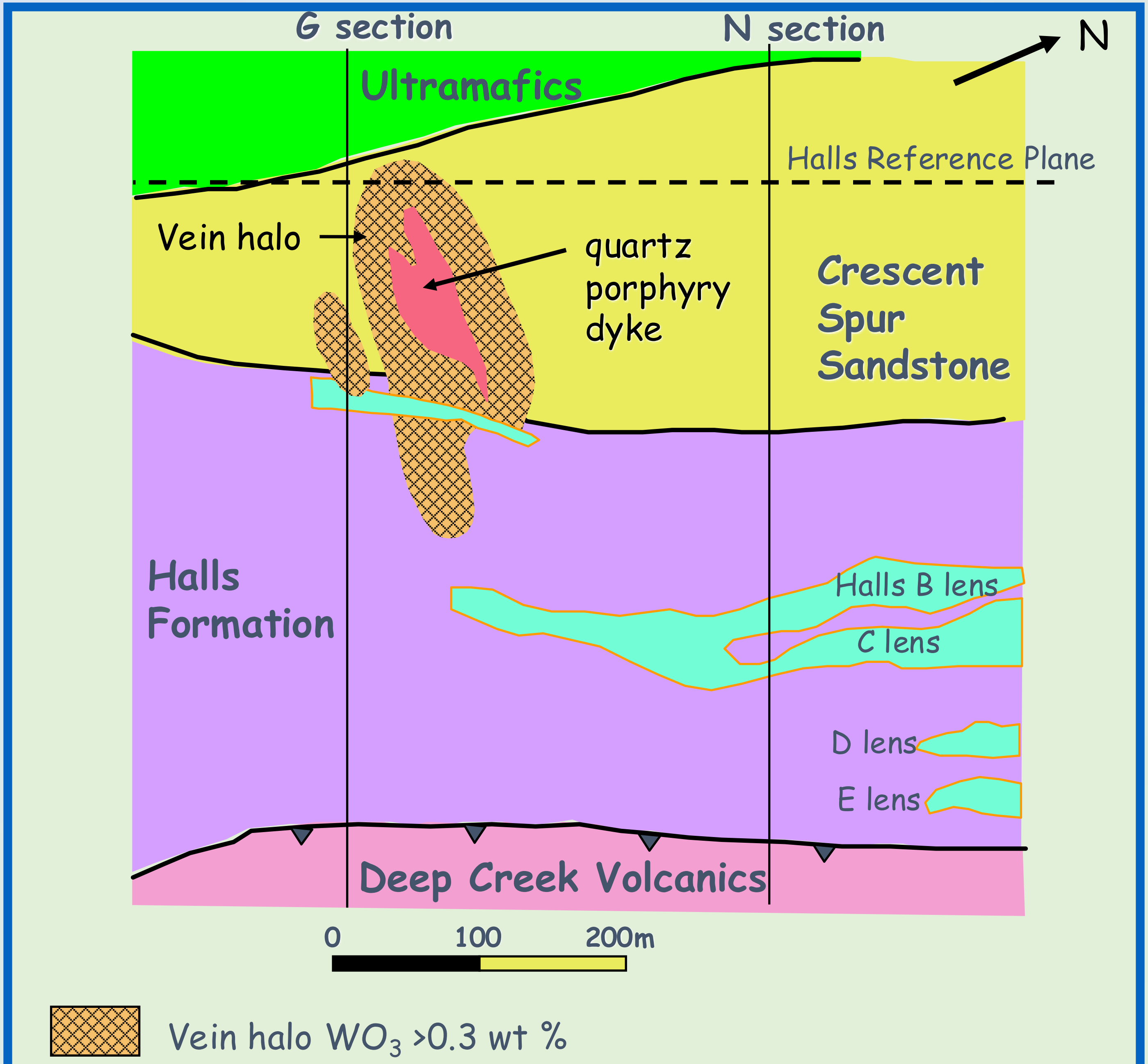
- Situated 10km W of Waratah in NW Tasmania
- hosted by steeply dipping, sedimentary, volcaniclastic and volcanic rocks of the Neoproterozoic, Crimson Ck Formation
- the ultimate source of mineralising fluids is the Meredith Granite
- three styles of mineralisation occur in the deposit:

  (1) endogreisen

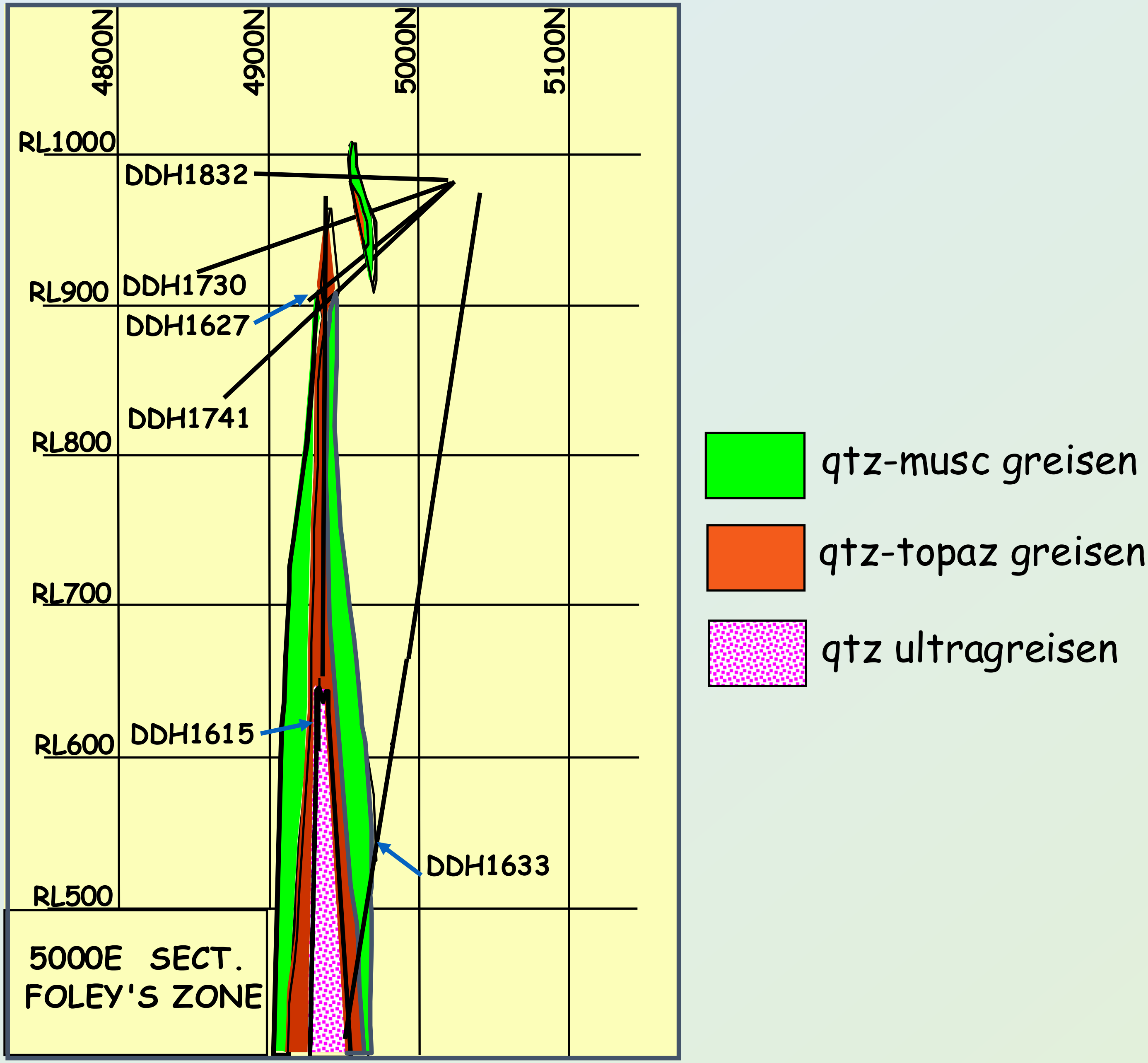
  (2) greisenised skarn

  (3) greisen veins

Plan of level RL800 Cleveland Mine



Vertical Section 5000E through Foley's Zone dyke



Alteration sequence in the quartz porphyry dyke Cleveland Mine, Western Tasmania (Jackson 1993)

quartz-feldspar porphyry

STAGE 1 ↓

incipient greisenization

STAGE 2 ↓

quartz-muscovite greisen

STAGE 3 ↓

quartz-topaz greisen

sulphide

STAGE 4 ↓

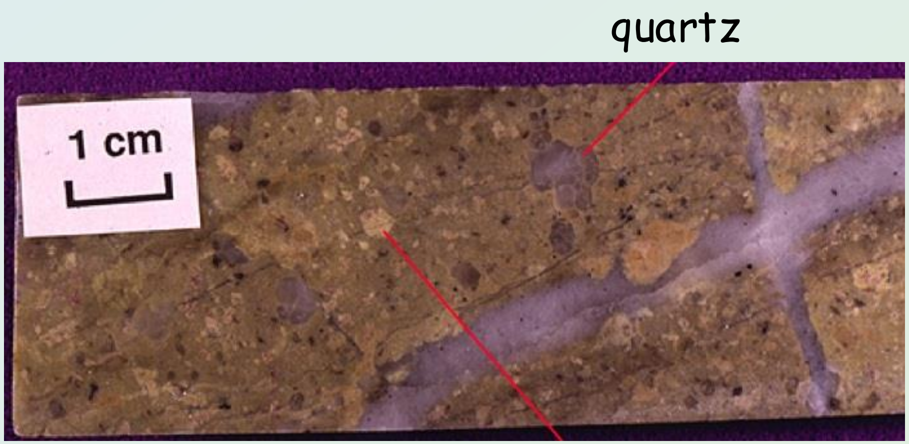
quartz ultragreisen

STAGE 5 ↓

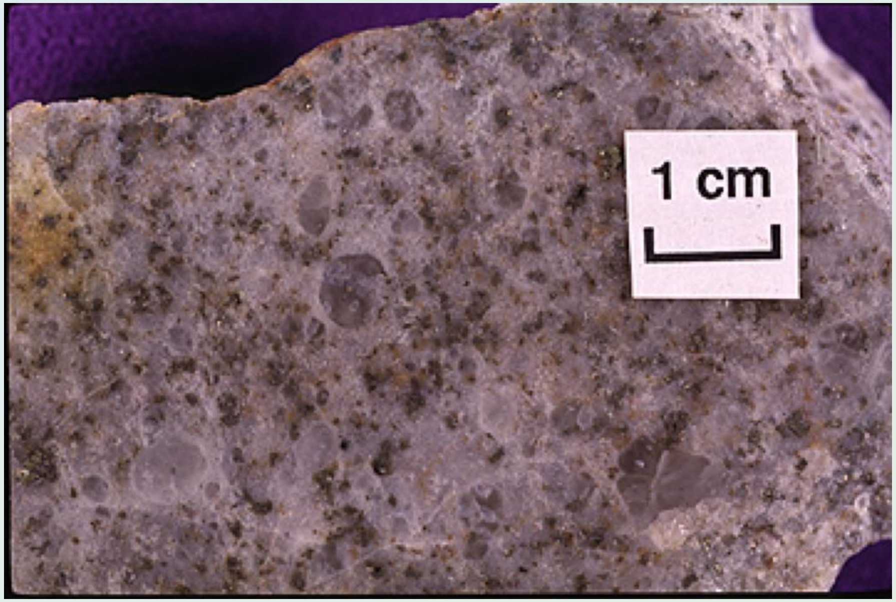
carbonate alteration

Endogreisen facies

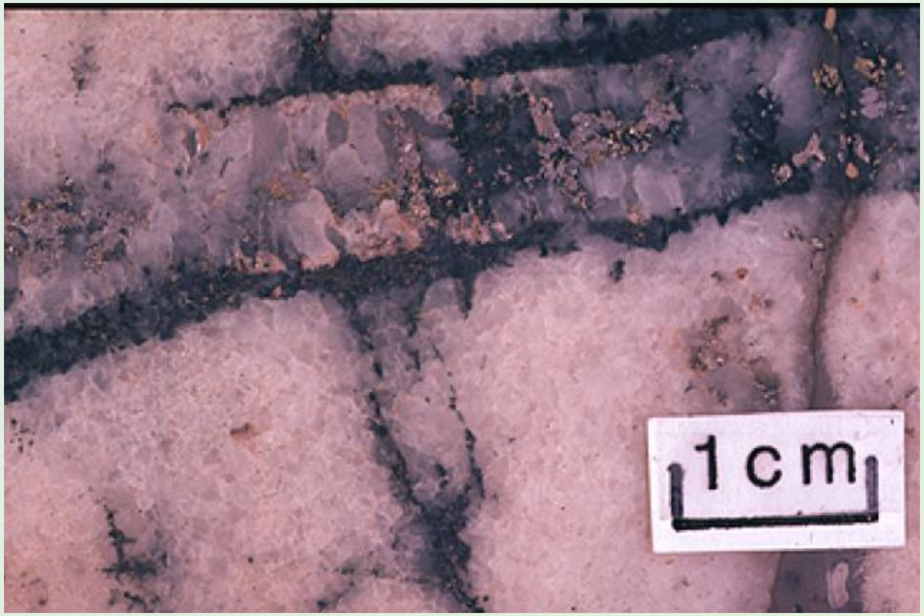
Incipient greisen



Muscovite greisen



Quartz-topaz greisen



Quartz ultragreisen

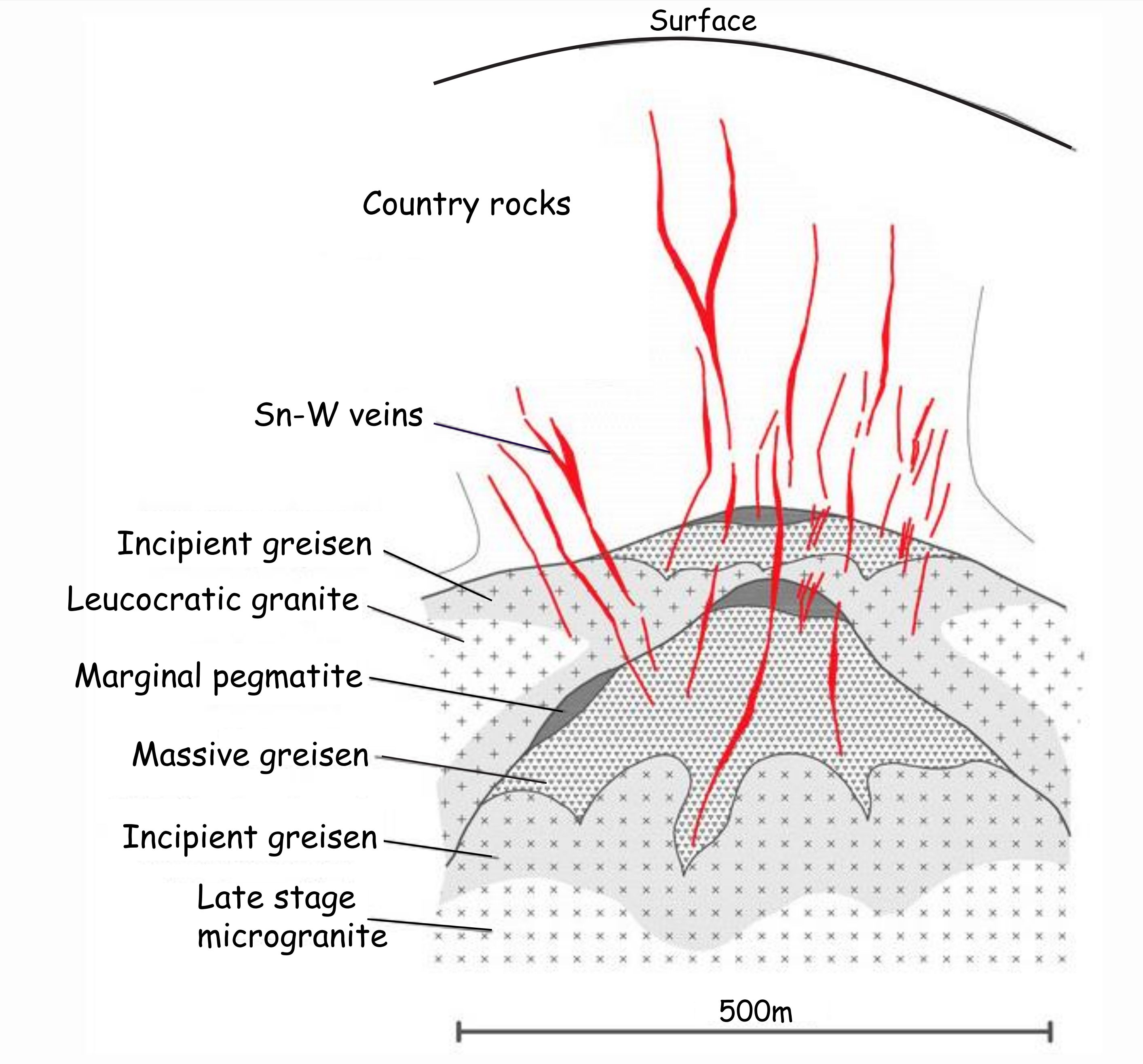
Greisenised quartz porphyry dyke

Quartz-topaz-fluorite-sulphide vein

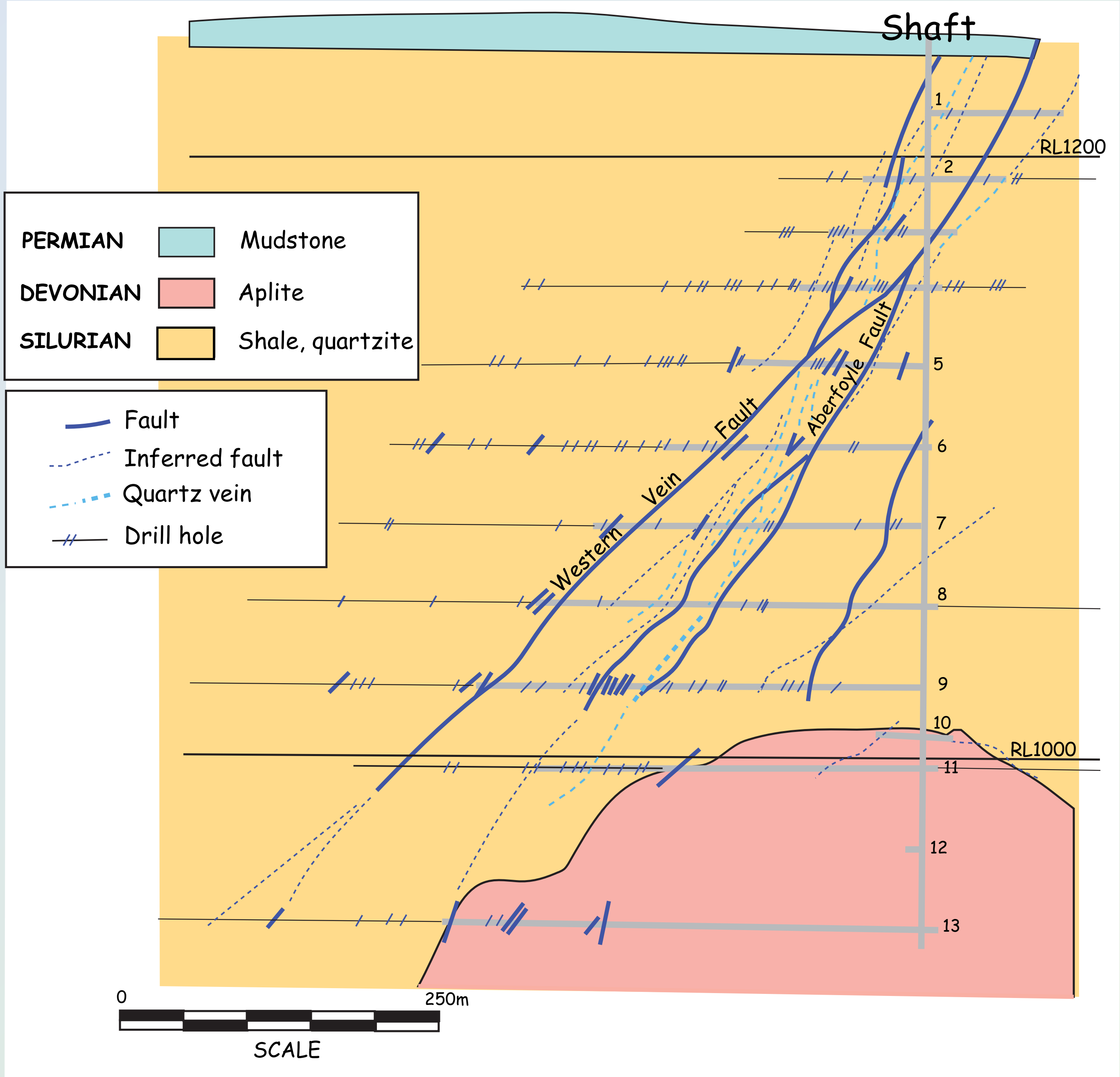
Sn-W vein deposits of NE Tasmania

- Sn-W mineralisation occurs in association with greisen in NE Tasmania
- ore occurs in a sheeted zone of quartz veins hosted by folded quartzites and slates
- granite occurring at depth below the vein system → source of mineralising fluids
- ore minerals → cassiterite (SnO_2), wolframite ($FeWO_4$), hematite, pyrite, pyrrhotite, scheelite ($CaWO_4$), stannite (Cu_2FeSnS_4), galena (PbS), sphalerite (ZnS), arsenopyrite (FeAsS)
- gangue minerals → quartz, muscovite, topaz, carbonate, fluorite

Greisen model NE Tasmania



Storey's Creek, Tas., vertical-section



Blue Tier batholith Tinfield

- Area consists almost entirely of Devonian granites
- two distinct type of granites occur:

  (1) hornblende-bearing granodiorite

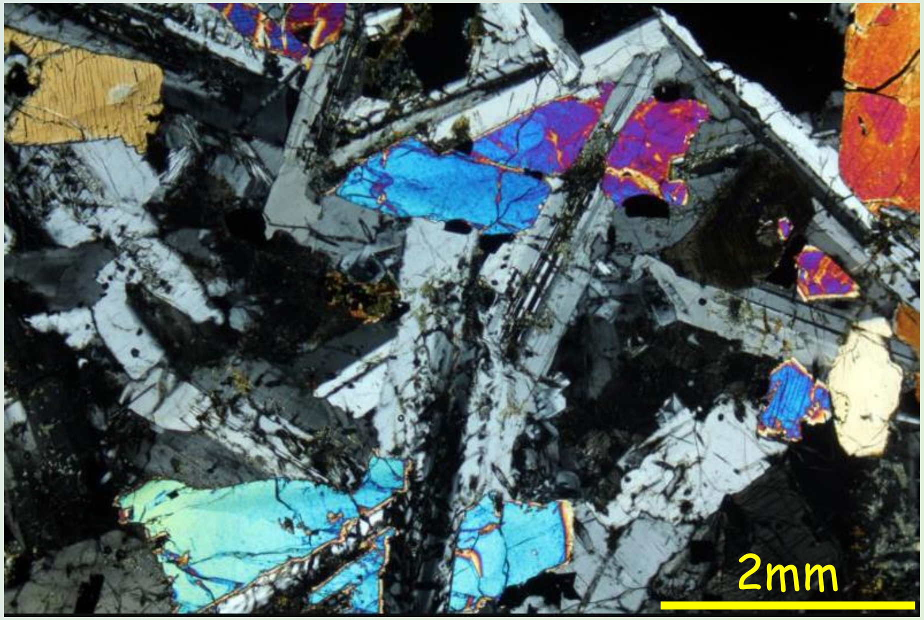
  (2) biotite-muscovite granite
- younger granite intrudes granodiorite → source of mineralising fluids
- Sn granite is partly greisenised
- Sn mineralisation occurs in flat-lying bodies in pegmatite and granite and in quartz and greisen veins

Tasmanian Jurassic dolerites

- Dolerite (diabase) → medium-grained, sub-volcanic, igneous rock of basaltic composition

- forms in relatively shallow intrusive bodies e.g. dykes, sills
- crop out over much of Central and EasternTasmania
- most of Tasmania's highest mountains → capped by dolerite

dolerite

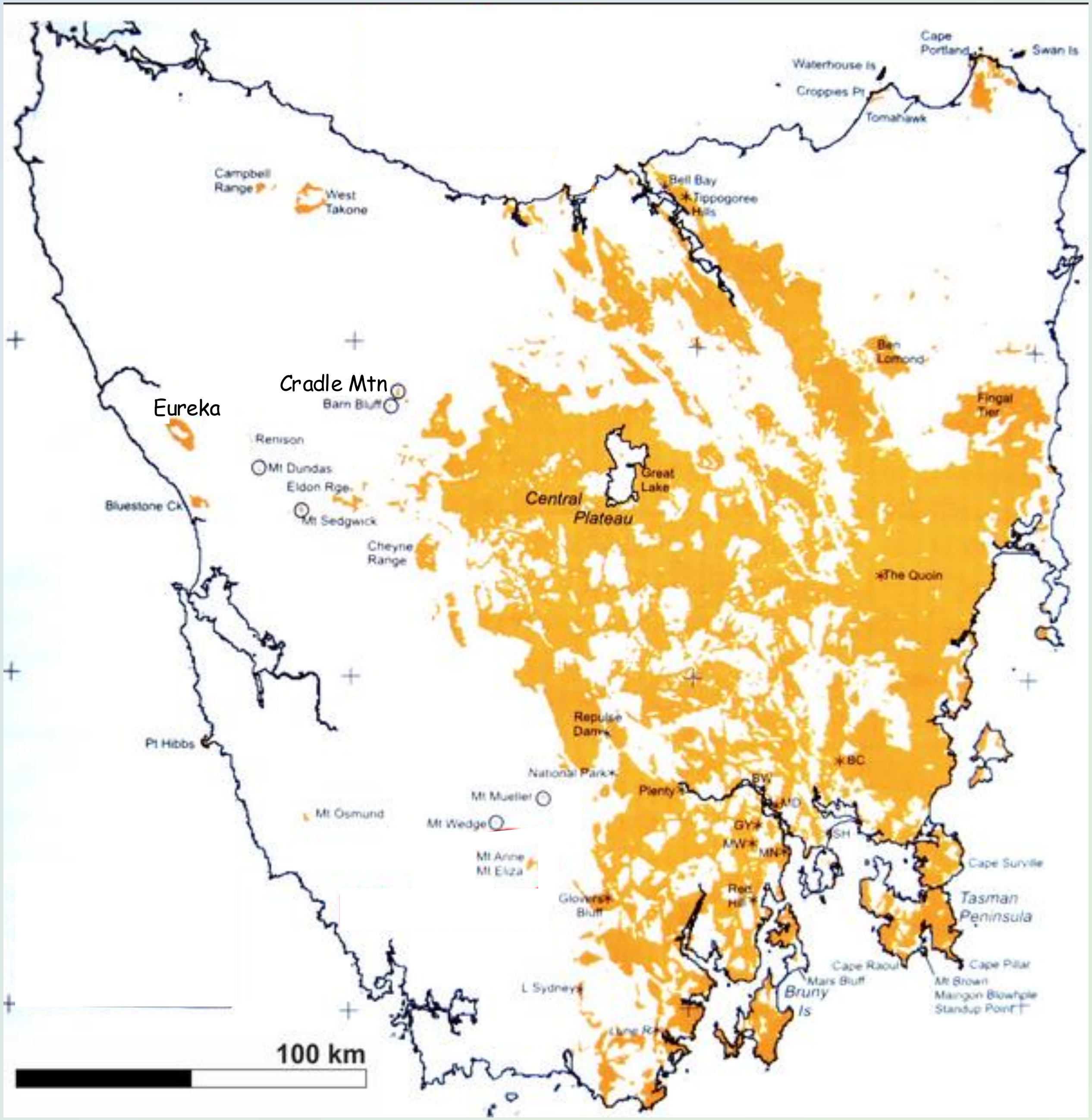


Dolerite in TS, X-polars

Tasmanian Jurassic dolerites

- Large volumes of dolerite were intruded in the Jurassic Period as sills and dykes from <0.5m up to 500m thick
- jointing is well-developed in most intrusions. Sub-vertical columnar jointing (cooling columns) are common typically (2-6m across)
- most intrusions → sill-like sheets with feeder dykes
- exposed over ~14,500km^2 of Tasmania → shallow depth elsewhere
- ages of dolerites range between 178-181Ma
- chemical composition → ~55% SiO_2, ~0.72%Ti and ~5.8%Mg → plot in field of basaltic andesites

Tasmanian Jurassic dolerites

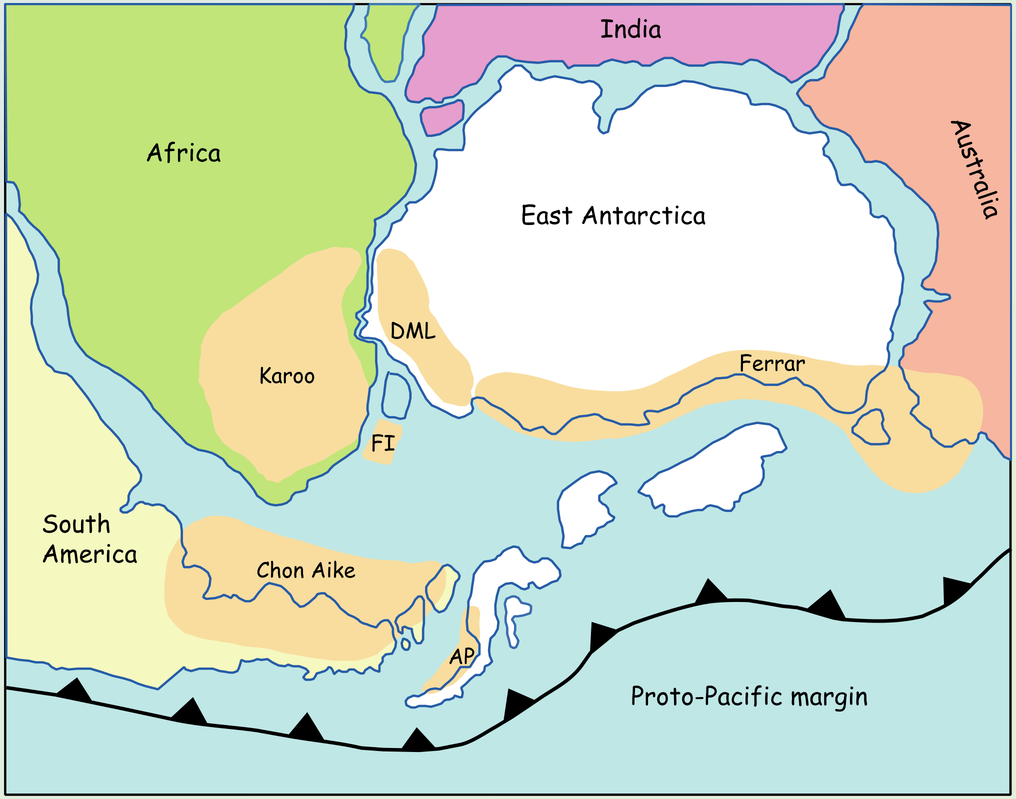


Gondwana Jurassic dolerite province

- Thick, massive, dolerite sills of Jurassic age found → Tasmania, Antarctica, South America, Southern Africa
- Tasmanian Jurassic dolerite small detachment of the Ferrar Magmatic Province (FMP)*
- dolerites → first evidence of igneous activity → precursor to break up of Gondwana

Jurassic dolerite distribution

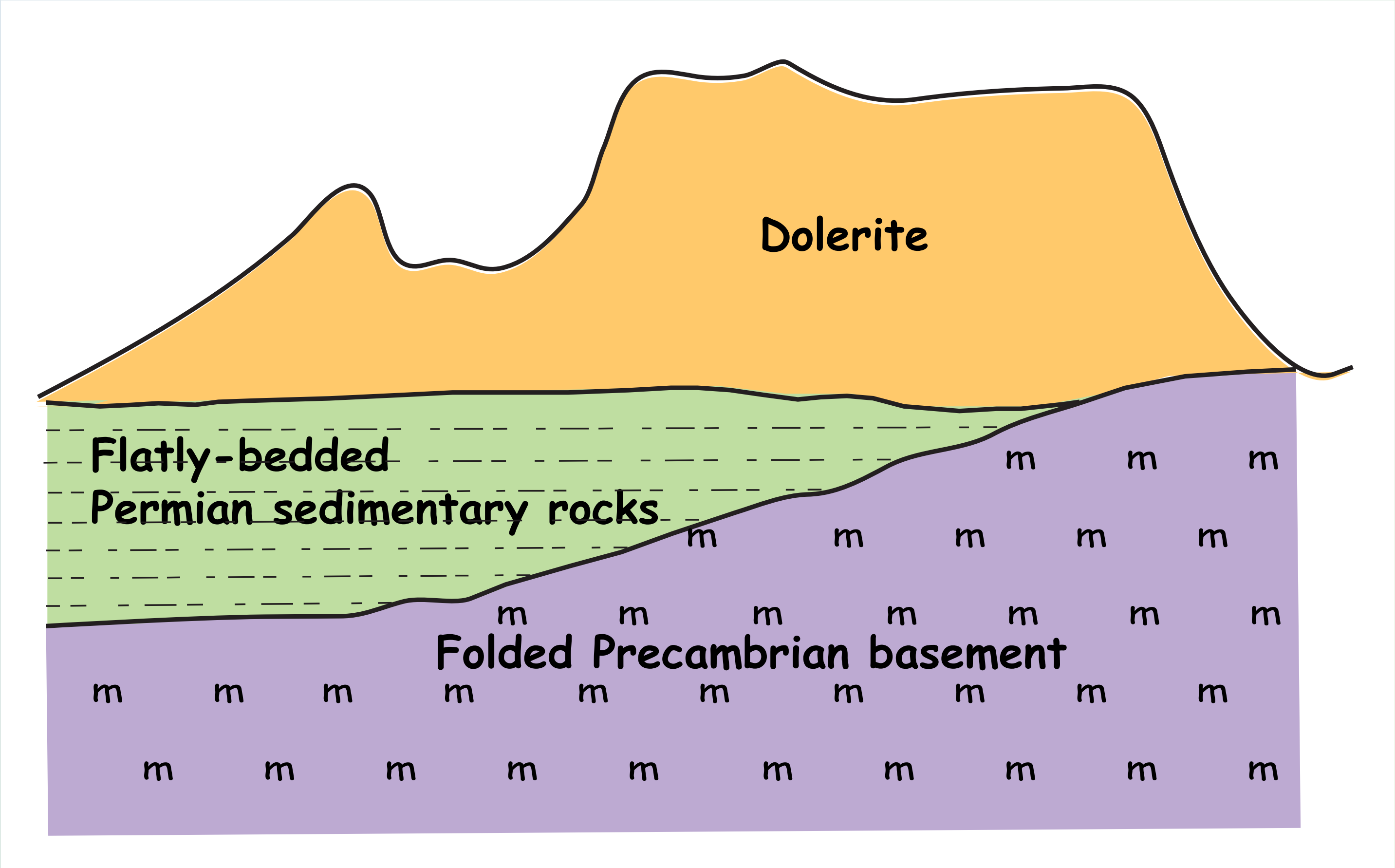
Dolerite



Dolerite capping on Cradle Mountain, Tas.

The geology of Cradle Mountain, Tas.

Cradle mountain comprises a complexly folded Proterozoic basement, overlain by gently dipping sediments of Permian and Triassic age. Later sub-horizontal sheets of dolerite were intruded into the Permo-Triassic rocks and along Permian-Proterozoic unconformity



Dolerite intrusion, Deep Glen Bluff

Columnar jointed dolerite, Mt Ossa, Tas.

Columnar jointed dolerite, summit of Mt Wellington

Pleistocene glaciation in Tasmania

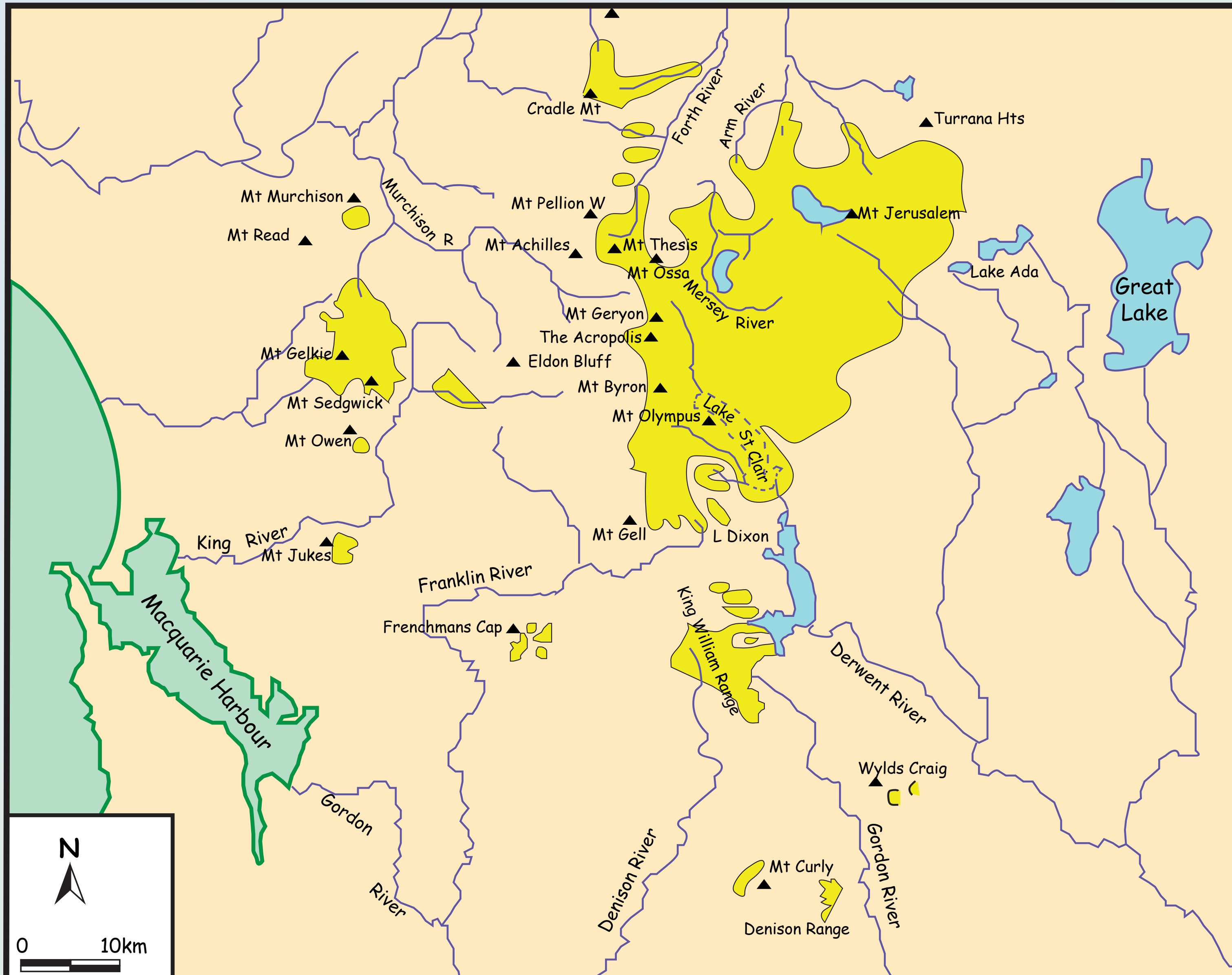
- Glacial erosional and depositional landforms are well-developed in Tasmania
- large areas of Tasmania were glaciated in the mid – Pleistocene* → ice sheets developed on plateau surfaces
- ice sheets grew to a thickness of 300m → spilled over plateau edges → ice escaped down major valleys as outlet tongues
- at least 6 glacial advances have occurred in the last 1 million years until the end of the last ice age
- during the last glacial maximum, cirque, valley and small ice cap glaciers developed on mountains of western and central Tasmania

Limits of ice in Tas. during the last glaciation

- During last glacial maximum (~19,000 years ago) → ice caps were present on the West Coast Range
- more southern and western ranges → mostly dominated by cirque glaciers (about 450 identified)
- most ice accumulated in central highlands and as ice caps on central plateau → glaciers flowed into Forth, Mersey valleys
- glacial landforms are generally larger and more deeply excavated on the West Coast Range and are reduced to the east
- ice limits generally marked by terminal moraines and outwash sheets of sand and gravel

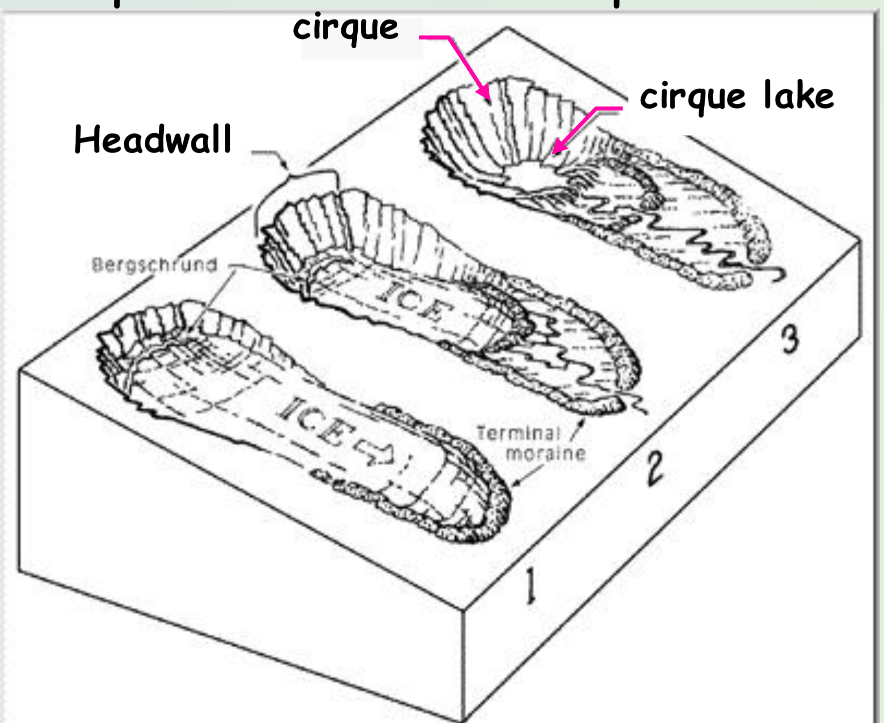
Limits of ice during last glacial maximum

(after Colhoun 1996)



Cirques

- Cirques
  - bowl-like depressions that form at head of glacier
  - steep walls on 3 sides → open on down valley side
- starts as snow hollow
  - deepened and enlarged by frost wedging and plucking
  - wedging undercuts walls → depression with steep walls



Development of a cirque at head of an alpine glacier

Murchison cirque

Glacial erratic near Zeehan, Tas.

- Rocks of varying sizes → not native in area where they are found
- transported by glaciers → dumped when glacier melted

Glacial erratic,

Henty Glacial Park,

Zeehan, Tas.

Glacial deposits, Glacial Park, Zeehan