This handout is an example of an alternative exercise used on the Access Anglesey field course. It was laminated and taken into the field for use by those who were unable to fully visit the outcrops themselves as a relevant parallel experience. For more details see https://accessanglesey.leeds.ac.uk/
Note: the students had access to hand specimens that are not shown here.

UNIVERSITY OF LEEDS

Exercise: Blueschists

Llanfair PG monument

UNIVERSITY OF PLYMOUTH
School of Geography, Earth and Environmental Sciences

The Open University

IncSTEM

Access Anglesey was designed and delivered as part of the Embedding and Sustaining Inclusive STEM Practices (IncSTEM) project, funded by the Office for Students (OfS).

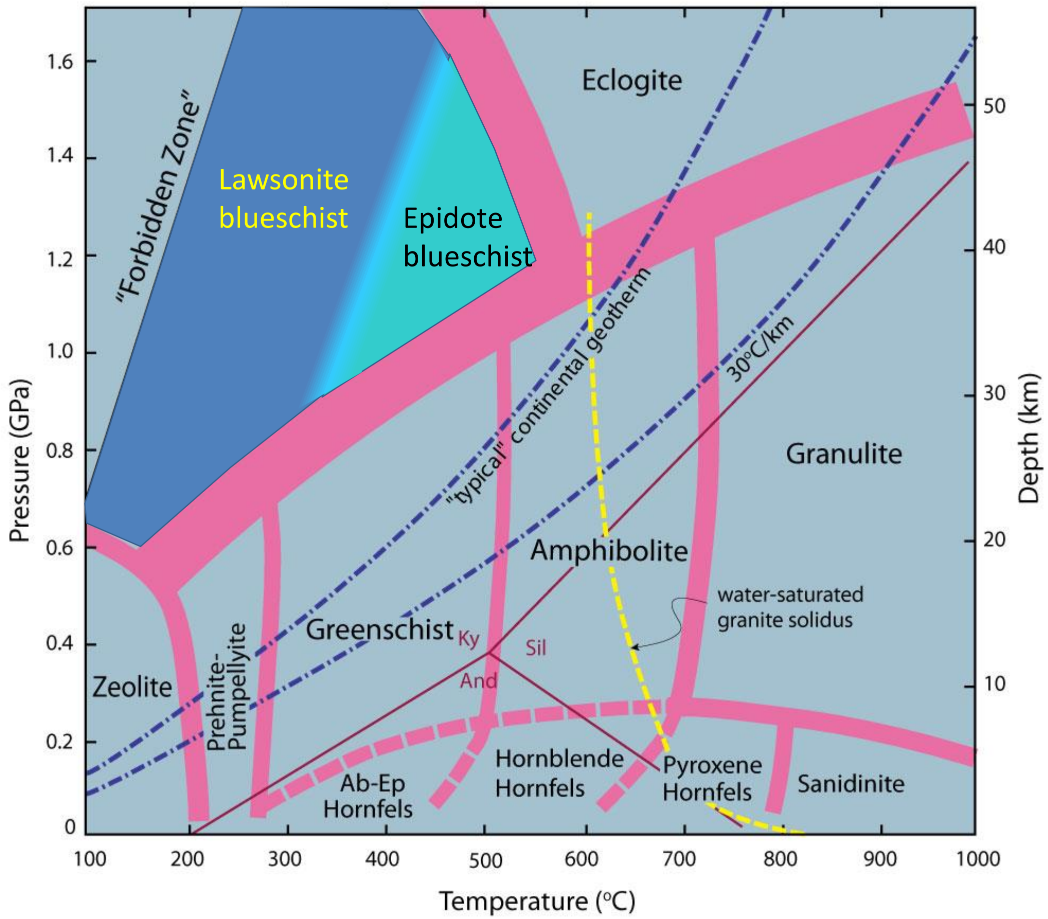
Background

- Blueschists are high-pressure, low-temperature metamorphic rocks, typically produced by metamorphism of basaltic igneous protoliths in a subduction zone setting.
- Blueschists obtain their blue colour from the mineral **glaucophane** ($Na_2(Mg_3Al_2)Si_8O_{22}(OH)_2$), a blue amphibole. In addition, they commonly contain **epidote** (a pistachio-green orthosilicate), **lawsonite**, and **quartz**. Other possibilities include the minerals **zoisite** and **clinozoisite**, which are related to epidote, but are colourless.
- Often seen altering to ***greenschist***, which has a characteristic assemblage of green amphibole (**actinolite**), **epidote**, **chlorite** and sodic **plagioclase**.
- Greenschists are lower-grade metamorphic rocks than blueschists, formed at lower P but similar T, and are also more hydrated (as you go up grade, rocks tend to get drier, formed from minerals with progressively less water in their structures).
- The presence of blueschists is often taken to imply rapid exhumation (rate of ascent back to the surface) from the conditions of formation.

PT diagram

Dealing with complexity:

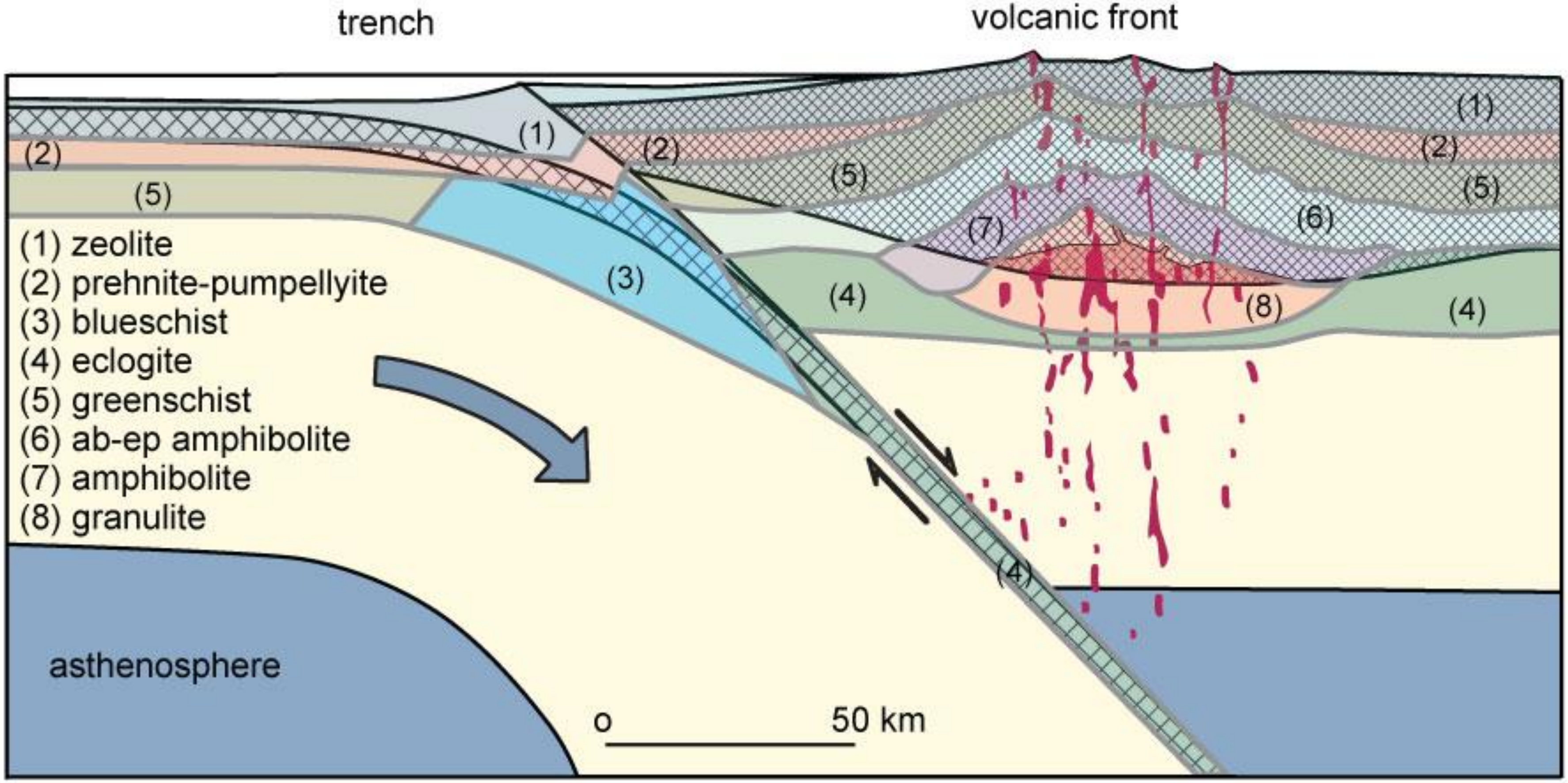
There's a lot going on on this diagram. Focus only on what is needed to answer the questions. We're looking at <u>blueschists</u> and <u>greenschists</u> and the different <u>pressures/depths</u> and <u>temperatures</u> at which they form.



Temperature-pressure diagram showing the generally accepted limits of the various facies used in this text. Boundaries are approximate and gradational. The "typical" or average continental geotherm is from Brown and Mussett (1993).

Image and above caption taken from powerpoints supplied by Winter, J.D. (2010), from the textbook: Winter (2010) An Introduction to Igneous and Metamorphic Petrology. Prentice Hall.

- Why do you think a subduction setting is required for blueschist to form? Hint: Think about the pressure and temperature conditions.
- Why do you think blueschists can be preserved during exhumation? Why do we not see greenschists instead?
- What might the role of water be in the transition between blueschist and greenschist mineralogies?



"Schematic cross-section of an island arc illustrating isotherm depression along the outer belt and elevation along the inner axis of the volcanic arc. The high P/T facies series typically develops along the outer paired belt and the medium or low P/T series develop along the inner belt, depending on subduction rate, age of arc and subducted lithosphere, etc. From Ernst (1976)."
Image and above caption taken from powerpoints supplied by Winter, J.D. (2010), from the textbook: Winter (2010) An Introduction to Igneous and Metamorphic Petrology. Prentice Hall.

This diagram shows how the temperature varies across a subduction zone. Isotherms are contour lines that divide areas of different temperature. Note how the blueschist zone forms a wedge shape down the trench.

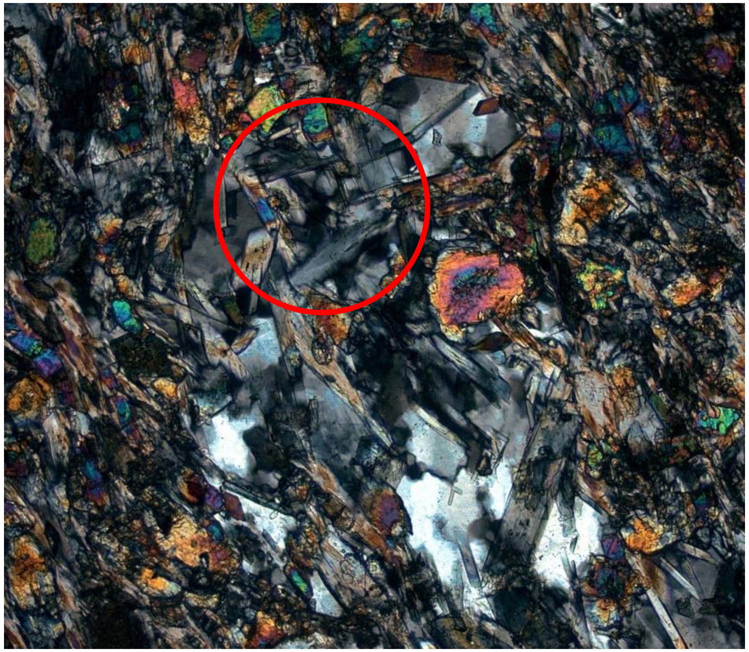
Task 1

- Have a look at the hand specimen and/or sawn slab provided. Make yourself a quick rock description.
- Note that the samples from Anglesey are ***very fine grained***; specific mineral identification will be difficult in hand specimen, but is not impossible. You may need to use a very restricted set of identifiers, such as colour.
- Look for:
  - Veins of alteration – what colour are the veins?
  - What timing relations would the veins imply, and can you link that to the PT diagram?
  - Any large metamorphic crystals (porphyroblasts)?
  - Any retrogressive textures – can you see if any of the minerals are being altered? Retrogressive minerals are of lower grade than those they replace, such as chlorite or mica replacing amphibole. This might manifest as minerals being replaced at their edges, or along cracks. It might also lead to a crystal of one mineral being replaced by one or more crystals of another, producing what is called a *pseudomorph.*
  - *Hint: in this rock, this may also result in colour changes.*

Task 2: microscopy

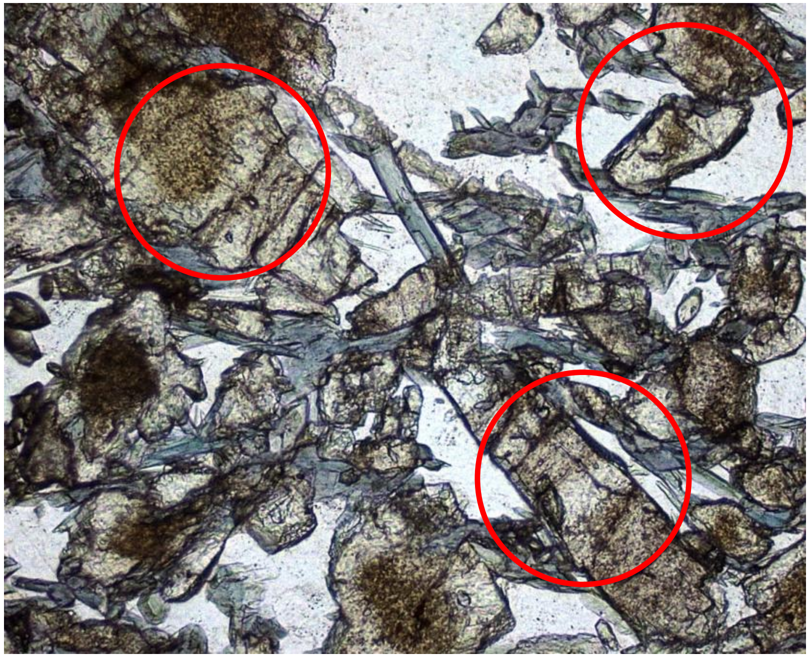
- It is not really feasible to bring a microscope to the field, but we do have a series of photomicrographs.
- If you are studying things back at base, we do have the microscopes, though!
- The next few slides cover the minerals you may see. Remember there are other minerals in the sections too e.g. quartz.

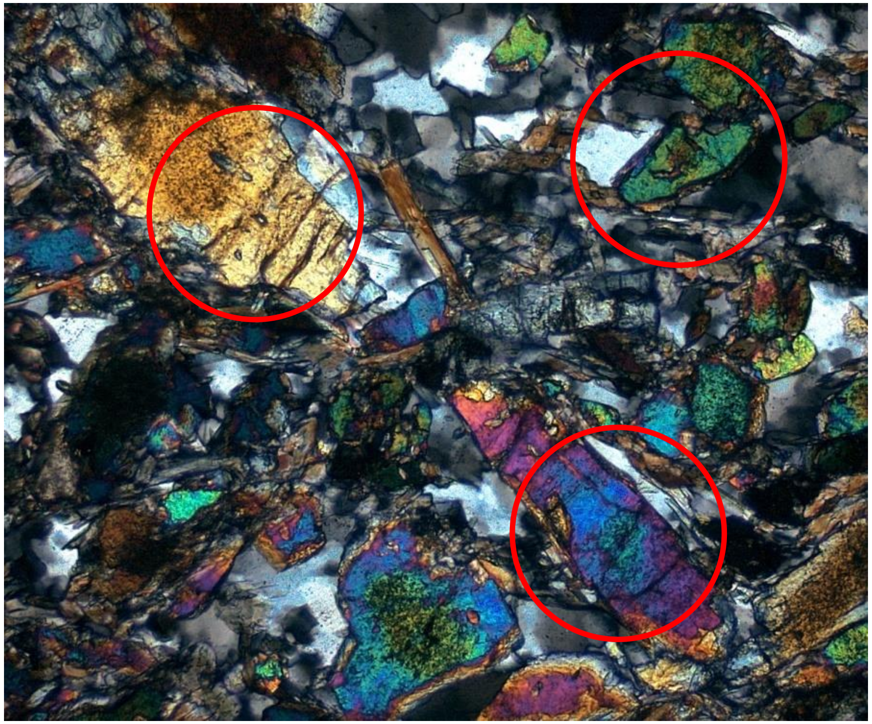
Glaucophane



Blue amphibole, medium relief, elongate, occasional rhombic sections when isolated, often forms intergrown matrix, pleochroic colourless-blue-purple. First greys and yellows for birefringence

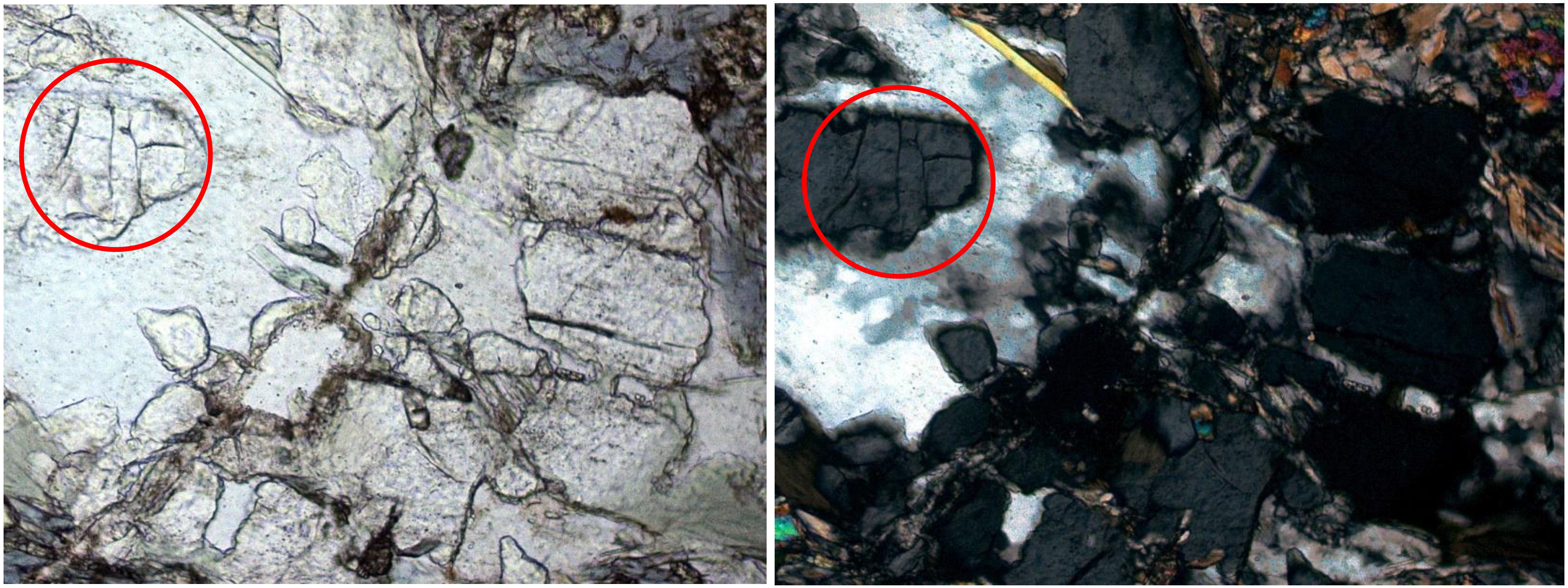
Epidote





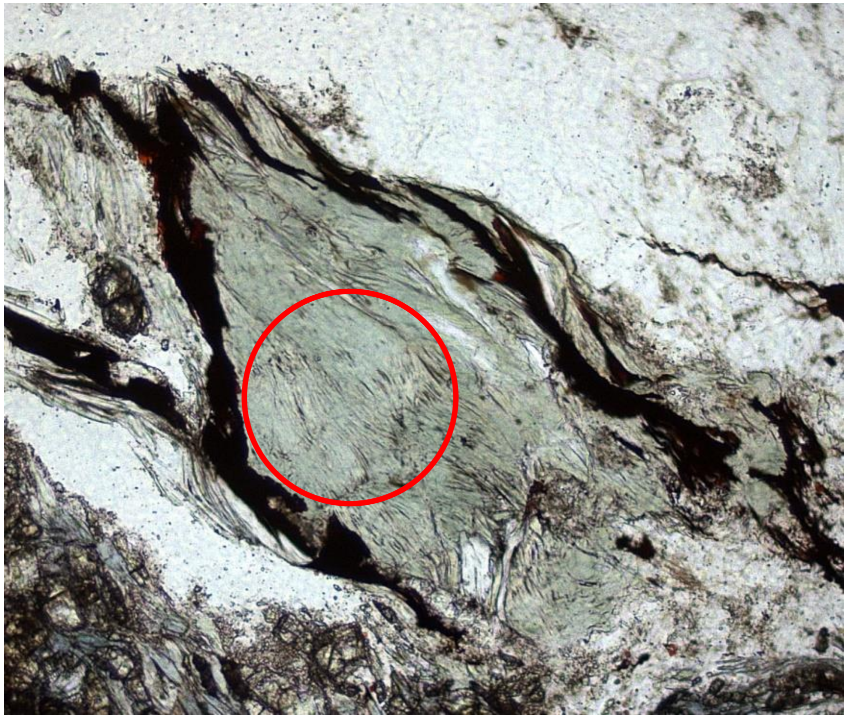
Epidote, a green-yellow, high relief phase with mild yellow-clear pleochroism, an elongate habit with transverse cracks, and high second to low third order birefringence up to purples, blues and intense green.

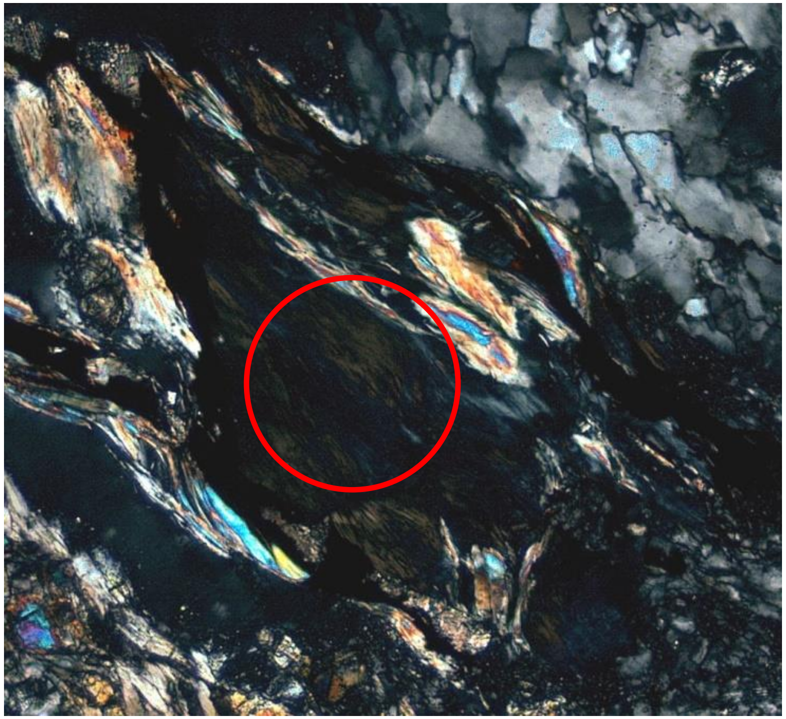
Lawsonite



Lawsonite, a colourless, medium-high relief mineral with a monoclinic (slightly rhombic) habit , 2 weak cleavages, and very low birefringence.

Chlorite





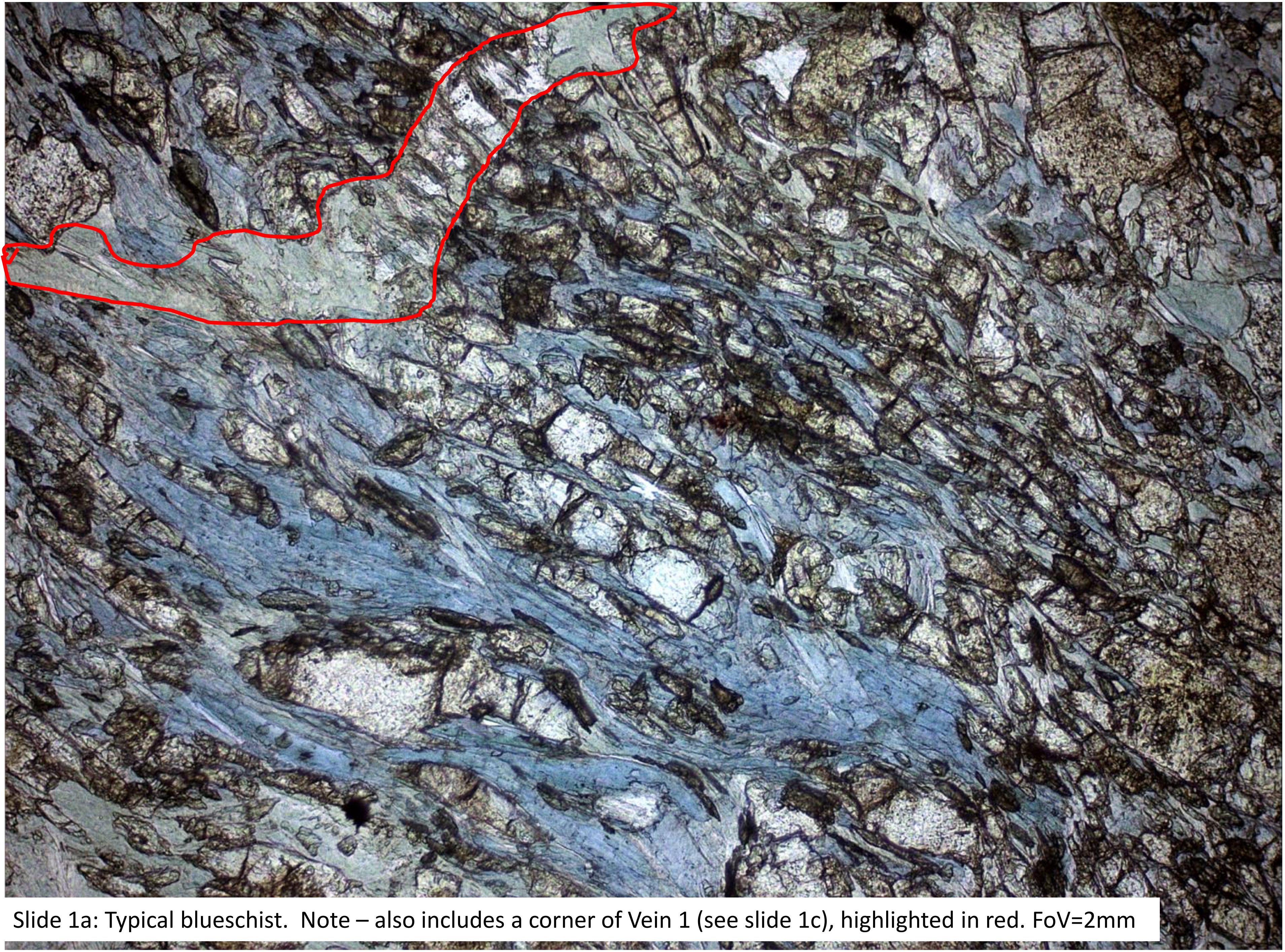
Chlorite – low relief, pale green mineral with a platy habit and a strong cleavage, pale green to colourless pleochroism, birefringence is very weak and anomalous, appearing to be very brown or blue when close to extinction (as shown)

Task 2

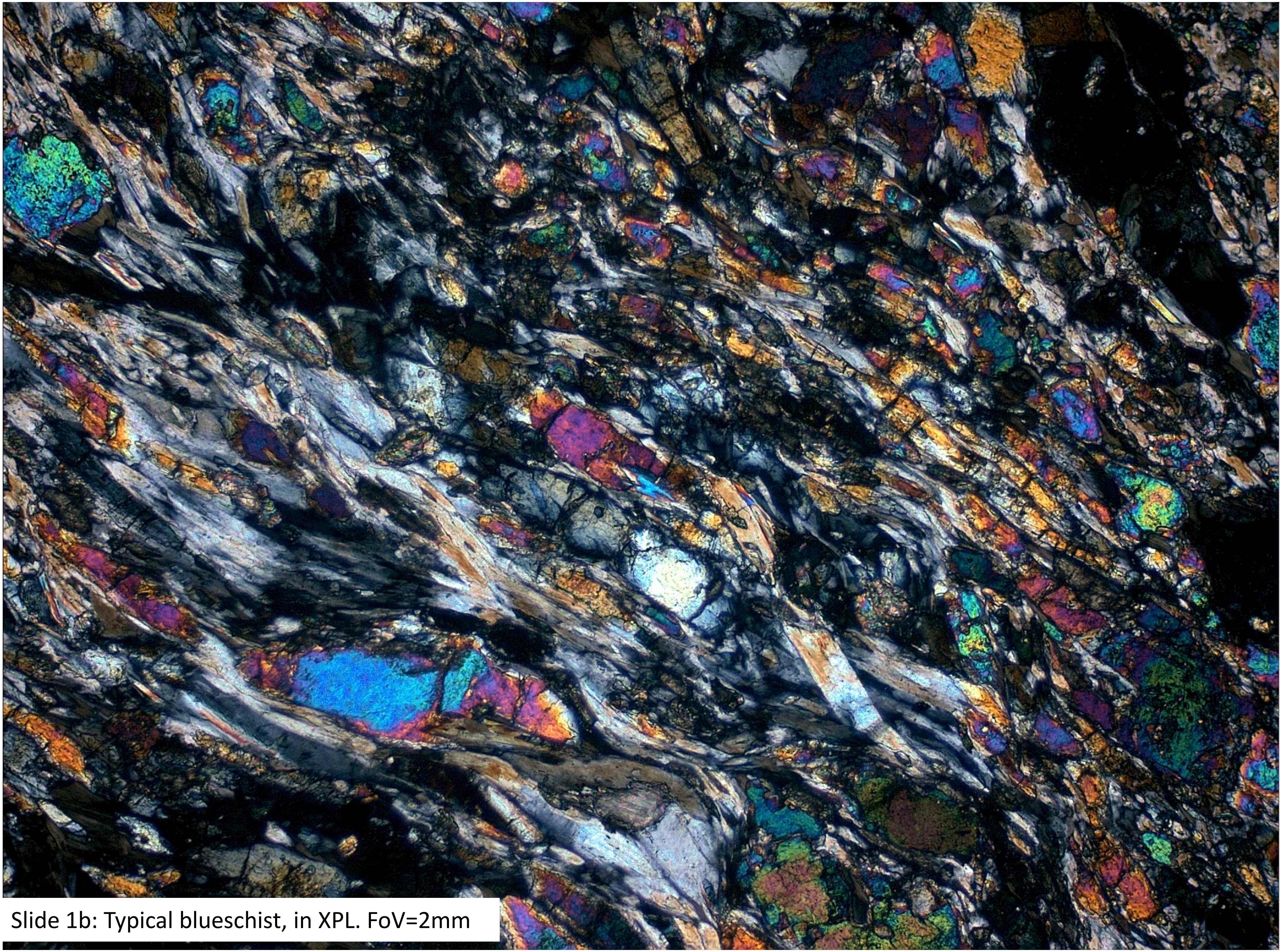
- Have a look at the photomicrographs on the following pages, or if you are back at base, study the thin sections
- Can you determine which are blueschist minerals and which are retrogressive (lower grade) minerals? (there may be some other minerals that you know of which are present, but they are not so important to the understanding of metamorphism)
- There are two generations of veins in the sample; veins 1 and 2 in slides 1c and 2c respectively. What are their mineralogies, and can you use this to infer a possible setting where they each may have formed, under what P-T conditions, and (in terms of a sequence of events), when?

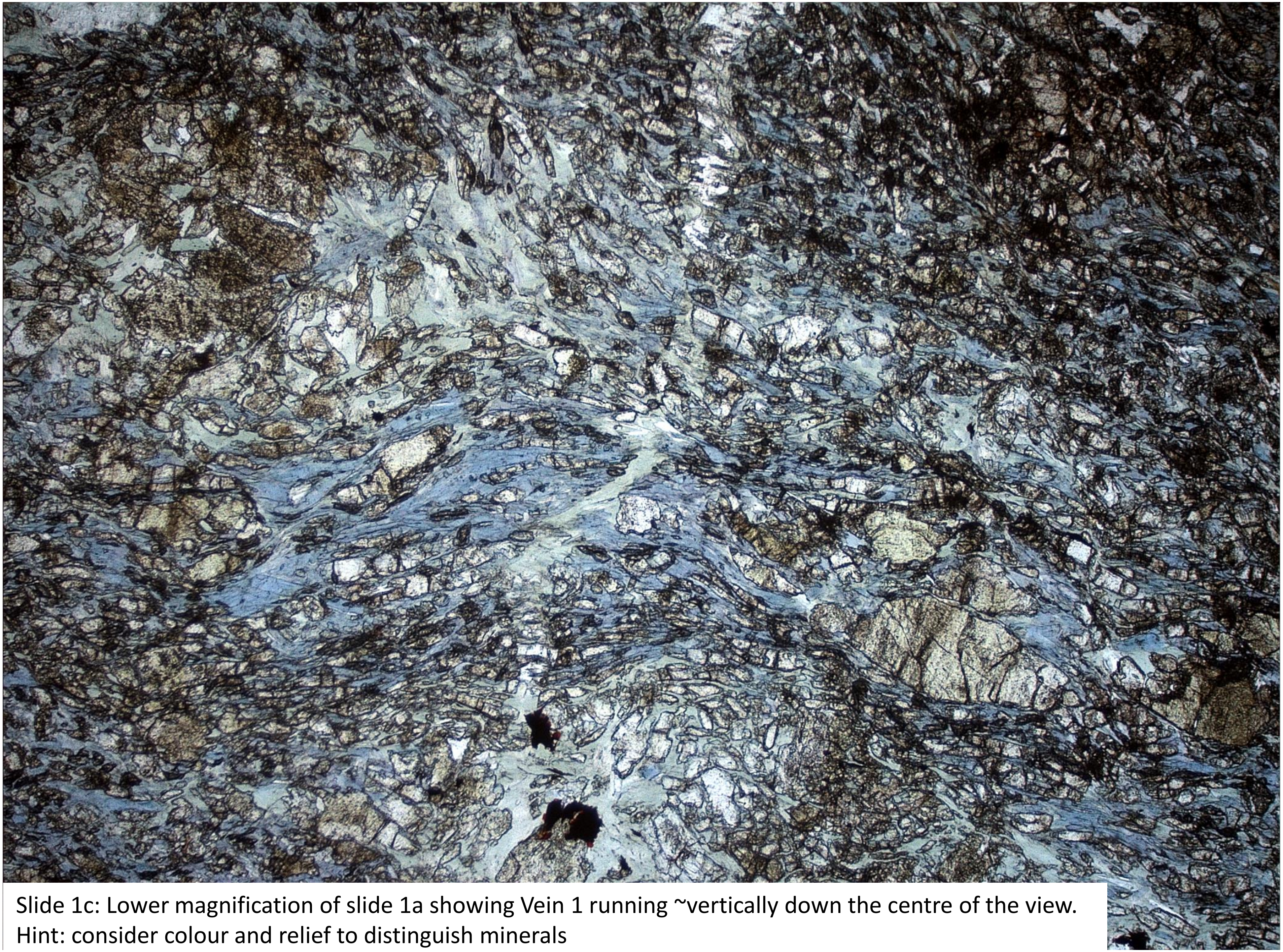
Bonus question:

- Can you plot a tentative P-T-t loop on the PT diagram, showing the route that the rock has possibly taken during blueschist metamorphism and later exhumation, and add on the times of vein formation for that sample?

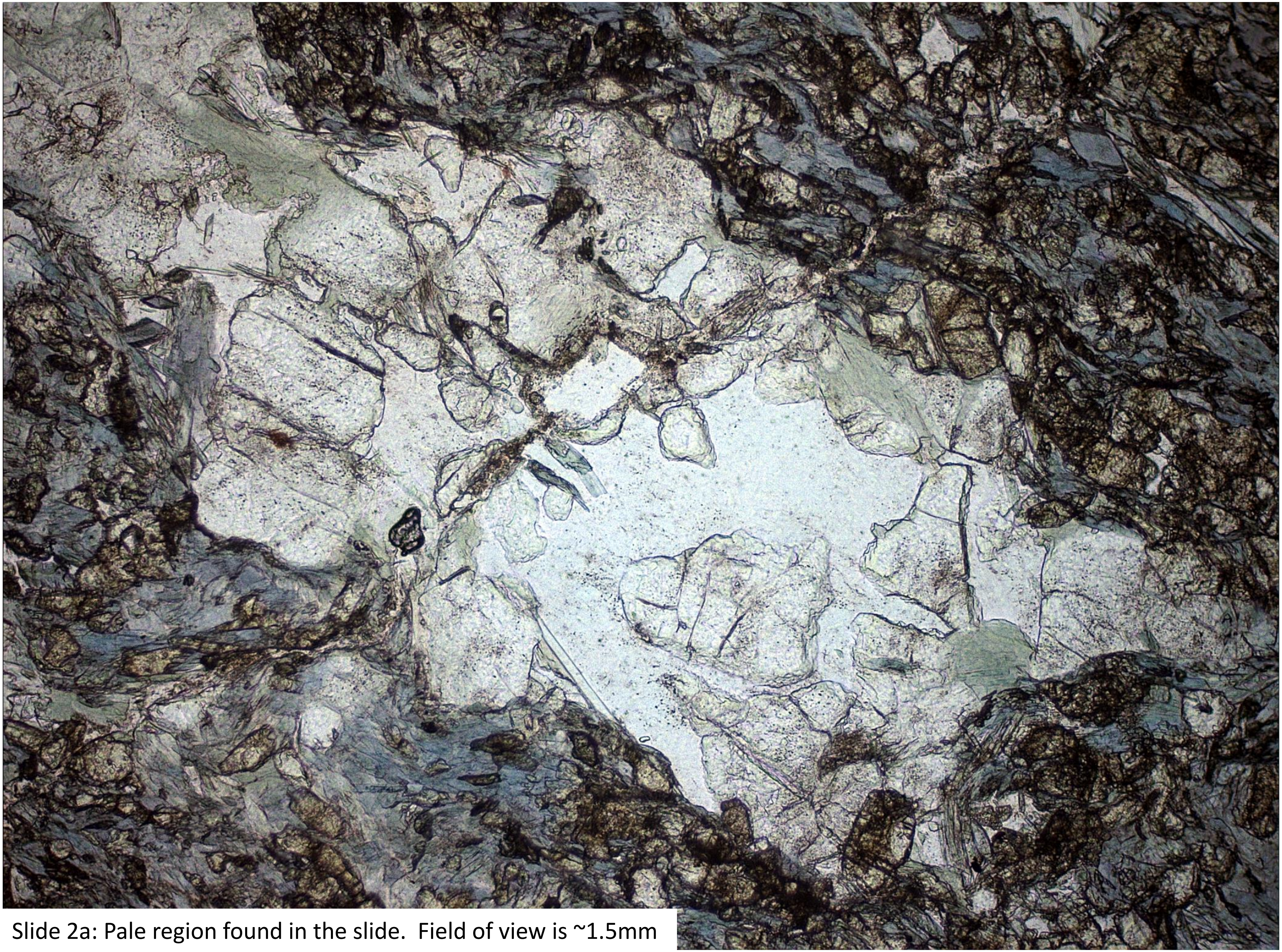


Slide 1a: Typical blueschist. Note – also includes a corner of Vein 1 (see slide 1c), highlighted in red. FoV=2mm

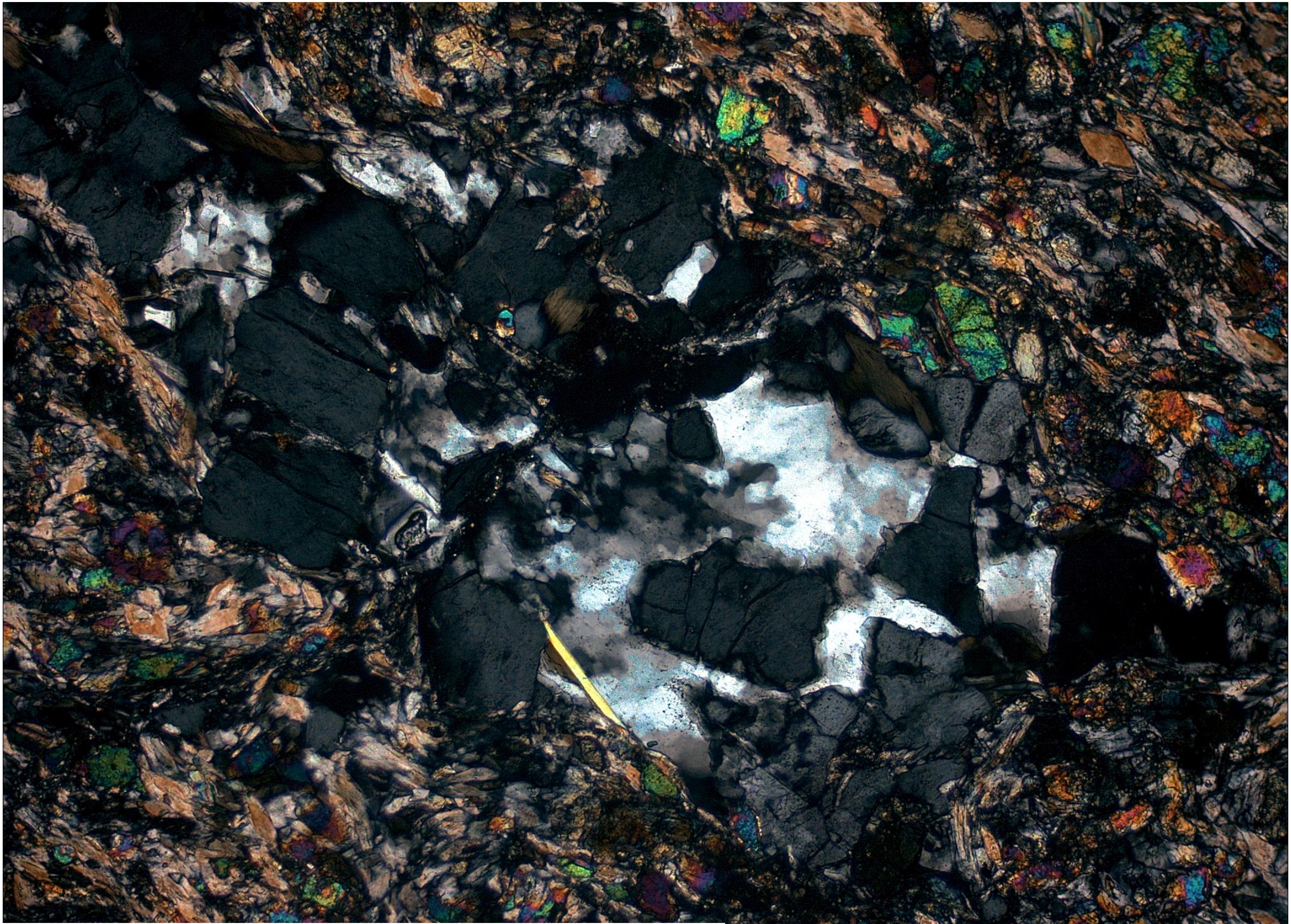

Slide 1b: Typical blueschist, in XPL. FoV=2mm



Slide 1c: Lower magnification of slide 1a showing Vein 1 running ~vertically down the centre of the view.
Hint: consider colour and relief to distinguish minerals



Slide 2a: Pale region found in the slide. Field of view is ~1.5mm



Slide 2b XPL: Pale region found in the slide. Field of view is ~1.5mm

Slide 2c: Vein 2 running ~vertically down the centre of the view. *Hint: consider colour and relief, and grain shape.*