Silica minerals

- Quartz (alpha <573°C <beta <870). Change is total but the shape of the beta form is preserved in lavas
- Cristobalite & Tridymite are high temp forms but most common as devitrification products of obsidian (e.g. spherulites)
- Coesite, the high pressure form, occurs in impact-site rocks
- Opal is a cryptocrystalline form of cristobalite with sub-microscopic water-filled pores that make up 5-10%
Carbonates

- Calcite $\text{CaCO}_3$ Limestone and carbonatites
- Aragonite $\text{CaCO}_3$ (orthorhombic) High P, low T mm
- Dolomite $\text{CaCO}_3 \cdot \text{MgCO}_3$ Limestone
- Ankerite $\text{CaCO}_3 \cdot (\text{Fe,Mg})\text{CO}_3$ Ore deposits in limestone
- Siderite $\text{FeCO}_3$ Rare sedimentary rocks

Calcite cement in sandstone  
Ultra thin-polished section of calcite showing twinning
Garnet $X_3Y_2Si_3O_{12}$

- $Ca_3Al_3$ grossular calc-silicate metamorphic rocks
- $Fe_3Al_3$ almandine meta-mudstones, med-high grade
- $Mn_3Al_3$ spessartine meta-mudstones, low grade
- $Ca_3Fe_3$ andradite skarns
- $Mg_3Al_3$ pyrope meta-basalts especially high-P

- A few granites/rhyolites have almandine/spessartine garnet. Some mantle peridotites have pyrope-rich garnet

Garnet in S-type granite

Garnet with inclusions in gneiss
Apatite and zircon

- Apatite $\text{Ca}_5(\text{PO}_4)_3(\text{OH},\text{F},\text{Cl})$ Holds most of the P in rocks. Forms needles in many igneous rocks. Small triangular grains in metamorphic. Some shells and some marine pttes in sedimentary rocks

- Zircon $\text{ZrSiO}_4$ Holds most of the Zr in most rocks. Very stable so concentrates in sand. Very high melting point and many granites have “restitic” (unmelted) zircon that has retained an earlier U/Pb isotopic age. 420 Ma Lachlan Fold Belt Granites have zircons that can be as old as 3000Ma
Andalusite Sillimanite Kyanite

- In meta-shales (excess of Al over that needed to form feldspar. Muscovite + quartz --> andalusite + K-feldspar + water is one common reaction.
Cordierite/Staurolite

- Cordierite
  - $\text{Al}_2(\text{Mg,Fe})_2\text{Si}_5\text{AlO}_18$
  - Meta-shales at low pressure, replaced by almandine at high pressure. Looks a bit like feldspar. Cyclic twins, inclusions and pleochroic haloes
- Staurolite
  - $(\text{Fe,Mg})_2(\text{Al,Fe})_9\text{O}_6(\text{SiO}_4)(\text{OH})_2$
  - Likes Al, Fe$^{3+}$ and Zn
- Meta-shales

Cyclic twins and a myriad of inclusions in cordierite

Staurolite porphyroblast
Nepheline - Leucite

- Nepheline: $\text{NaAlSiO}_4$
- Leucite: $\text{KAISi}_2\text{O}_6$
- The feldspathoids are a silica-poor mineral group chemically related to the feldspars.
- Nepheline occurs in silica-deficient alkaline rocks (gabbros, syenites, basalts, trachytes, phonolites) and in igneous rocks that have reacted with limestone.
- Leucite occurs in K-rich, silica-poor basalts and ultra-mafic lavas. Unstable at moderate pressure & does not occur in plutonic rocks.
Tourmaline

- Tourmaline is an Al-rich ferromagnesian mineral that contains 10% boron. It occurs in S-type granites, pegmatites and indeed any rock with boron. Does not occur with hornblende.
- Because it is resistant to abrasion and chemical attack it occurs in many sandstones.
- Hexagonal with darkest colour with C-axis normal to polariser.
CHLORITE \((\text{Mg,Al,Fe})_{12}(\text{Si,Al})_{8}\text{O}_{20}(\text{OH})_{16}\)

- Layer silicate that occurs in many low-grade metamorphic rocks. Also occurs as a sub-solidus alteration minerals in igneous rocks (commonly replacing biotite)

- Chlorite and the clay mineral montmorillonite have very similar compositions and on burial the clay changes to chlorite
Titanite \( \text{CaTi(SiO}_4\text{)(O,OH,F)} \)

- Titanite (sphene) occurs in many I-type monzonites, granodiorites and granites that have magnetite as the Fe/Ti oxide (generally have pink K-feldspar)
- Also forms in metamorphic rocks (e.g. meta-basalts) but is not easy to identify when very fine grained

Epidote: \( \text{Ca}_2(\text{Al,Fe}^{3+})_3\text{Si}_3\text{O}_{12}(\text{OH}) \)

- If Fe-free it is clinozoisite, Never more than one of the three
- Atoms is Fe. Epidote is generally pale yellow in thin section
- High relief and bright interference colours. In meta-basalts
- At low and intermediate grade. In altered igneous rocks
- Plagioclase can have fine epidote in the Ca-rich core
- In skarns with hedenbergite
- Mn epidote called piedmontite is pleochroic (red-black-pink)