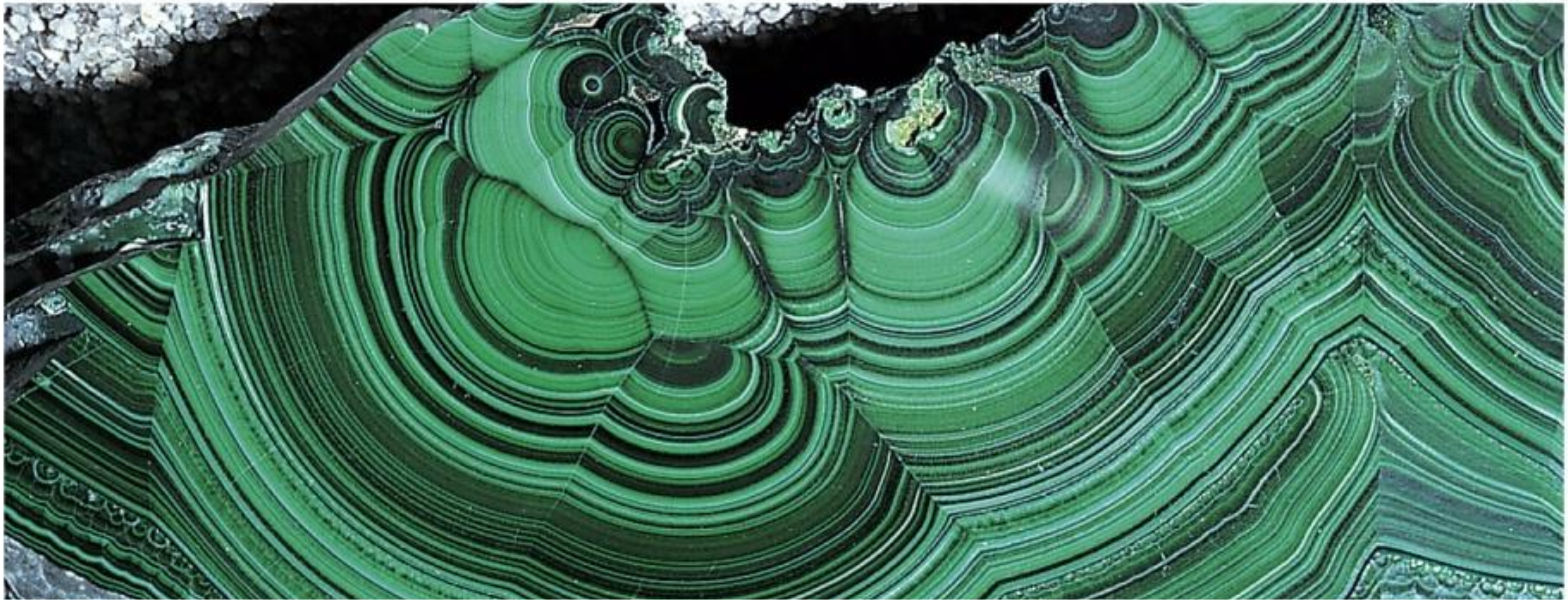


Lecture 1B
Mineral properties and identification

Dr Tom Raimondo

UniSA

See Marshak pg. 106–123

Figures taken from Earth: Portrait of a Planet, WW Norton & Co.

Sweet weekly homework

Every week, there are regular tasks that must be completed. There are clear expectations about the amount of time you should spend studying this course.

	Contact time per week	**Non-contact time per week**
Lectures	2 hours	1–2 hours pre-reading and revision
Practicals	2 hours	1 hour pre-reading
Weekly quizzes	-	30 mins to 1 hour
eModules	-	30 mins to 1 hour
Textbook online resources	-	30 mins to 1 hour
Total	**4 hours**	**4–5 hours**

Why do I need to know about minerals?

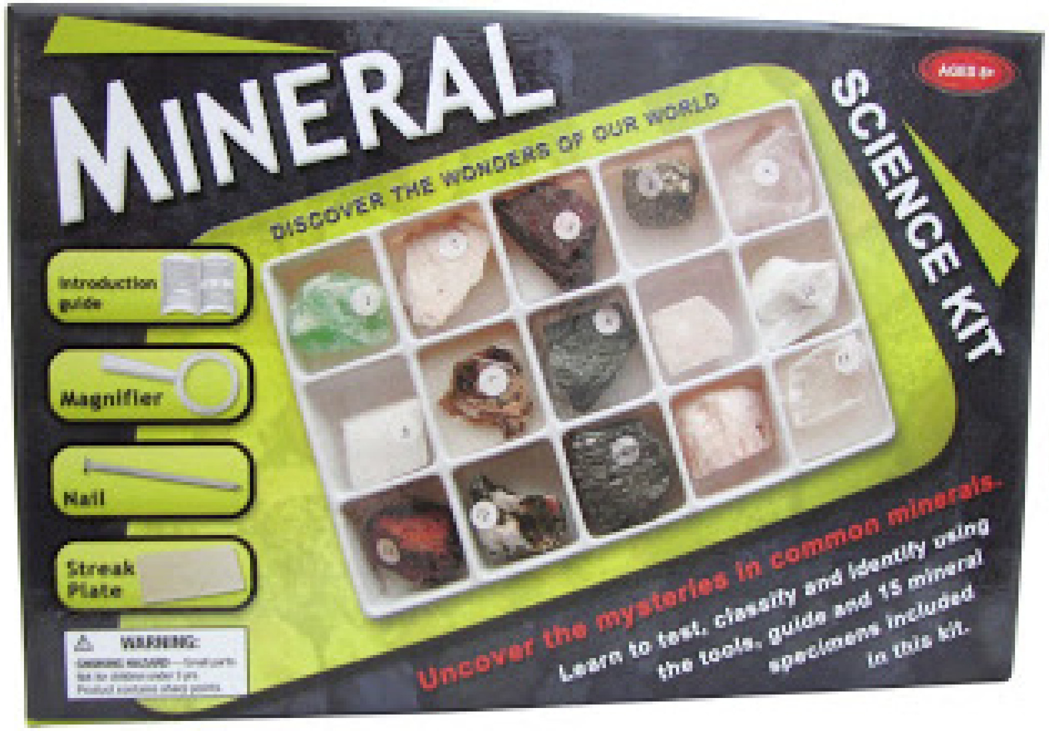
- Quite literally, the Earth is **built from minerals** – so a proper understanding of the Earth System and its behaviour must include detailed knowledge of them
- Minerals also form the raw materials for manufacturing a variety of chemicals and industrial materials
- Ore minerals are important sources of metals, and can provide energy resources (e.g. uranium for nuclear power)
- Some minerals can also pose significant environmental hazards
- An understanding of **mineral properties** is critical to our understanding of how rocks behave and how our environment is shaped – this forms a **key ingredient** of proper site evaluation and the application of tailored engineering solutions

Why do I need to know about minerals?

http://www.gigapan.com/gigapans/24054

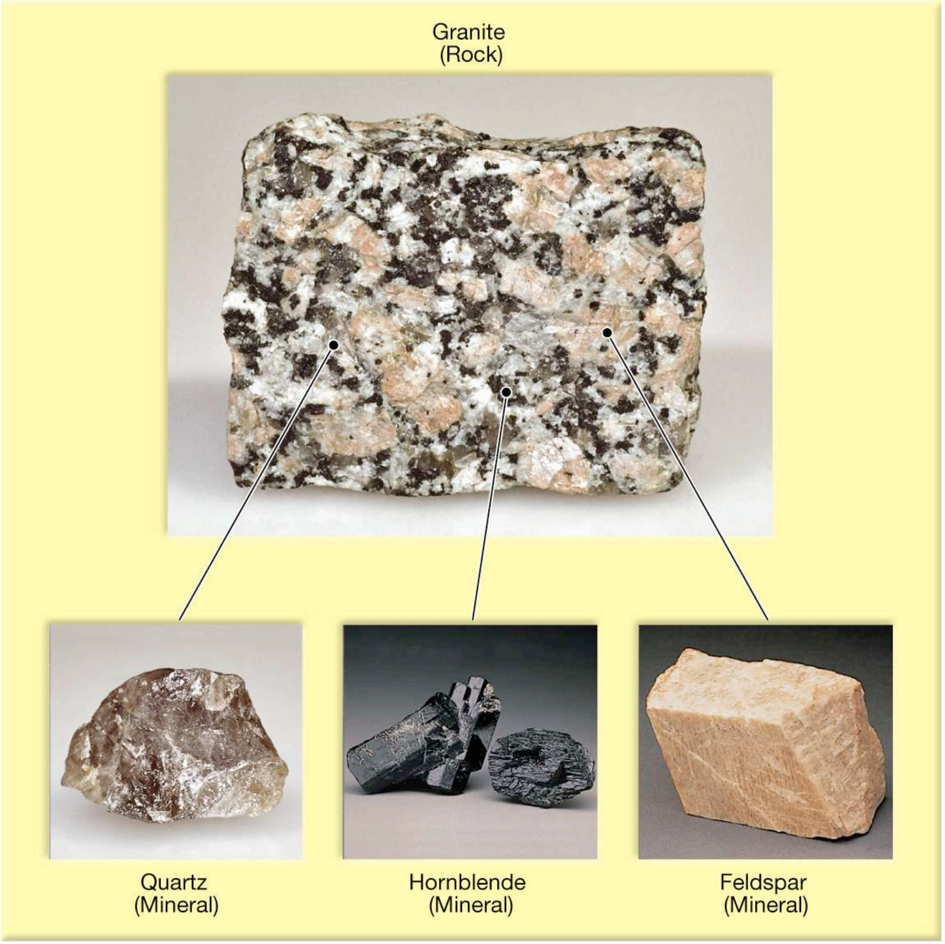
Lecture outline

- **What is a mineral?**
- Mineral properties and identification
- Mineral classes



What is a mineral? How is it different to a rock?

- Minerals are the 'building blocks' of rocks
- Rocks are **aggregates** of minerals
- By itself, a mineral is not a rock! Do not get the two confused
- Most rocks are composed of more than one type of mineral (e.g. granite contains quartz, biotite and feldspar)
- But some are **monomineralic** (e.g. limestone and marble contain 100% calcite)



The definition of a mineral

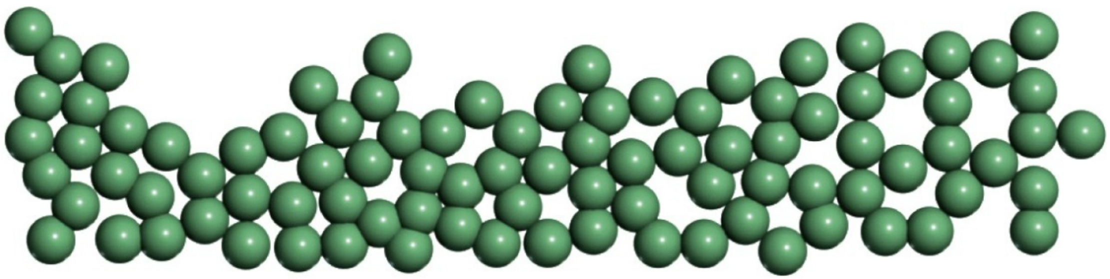
- Naturally occurring
- Solid and crystalline
- Orderly arrangement of atoms
- Definable chemical composition
- Usually inorganic

The mineral test: which ones are minerals?

Quartz
Ice
Water
Diamond
Gold
Coal
Volcanic glass
Table salt

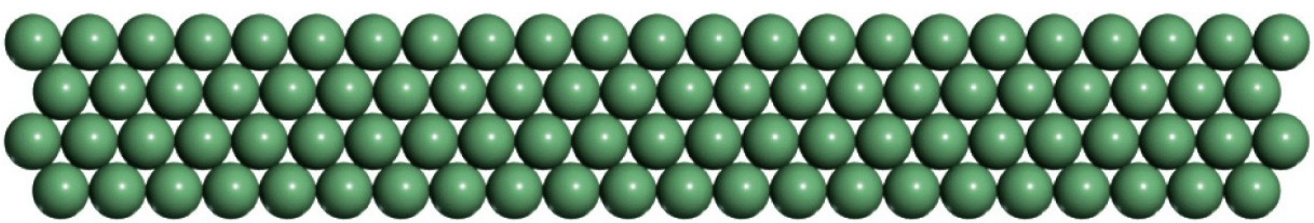
Minerals have a crystalline structure

- Minerals are composed of atoms and/or ions and/or molecules
- These particles are bound together in an **orderly, repeated three dimensional pattern** – specific chemical arrangement
- A solid with disordered atoms is called a **glass**
- Minerals have an ordered crystalline structure based on atomic patterns



Disordered: **GLASS**

Ordered: **MINERAL**



Minerals have a crystalline structure

- Crystals are solids which have naturally-formed flat surfaces called **faces**
- Some mineral specimens have multiple faces and solid geometric form that are expressions of the atomic, ionic or molecular **structural pattern**
- Crystalline minerals do not necessarily exhibit crystal faces – well formed crystals are rare

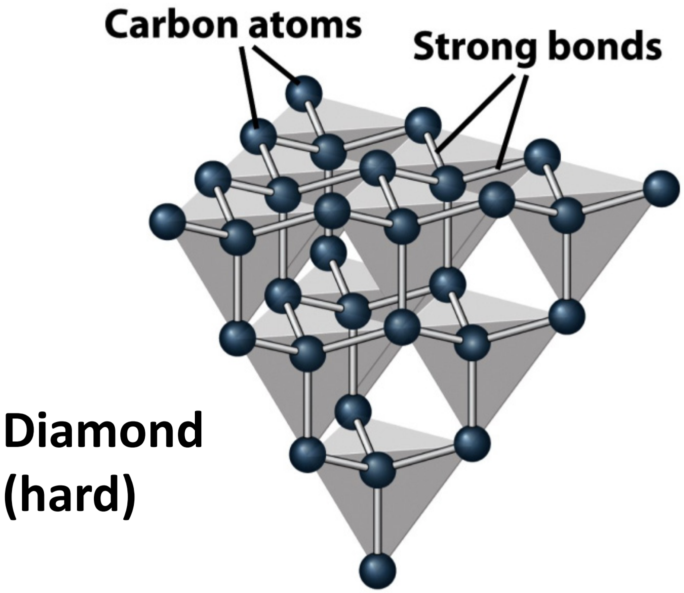
Beryl

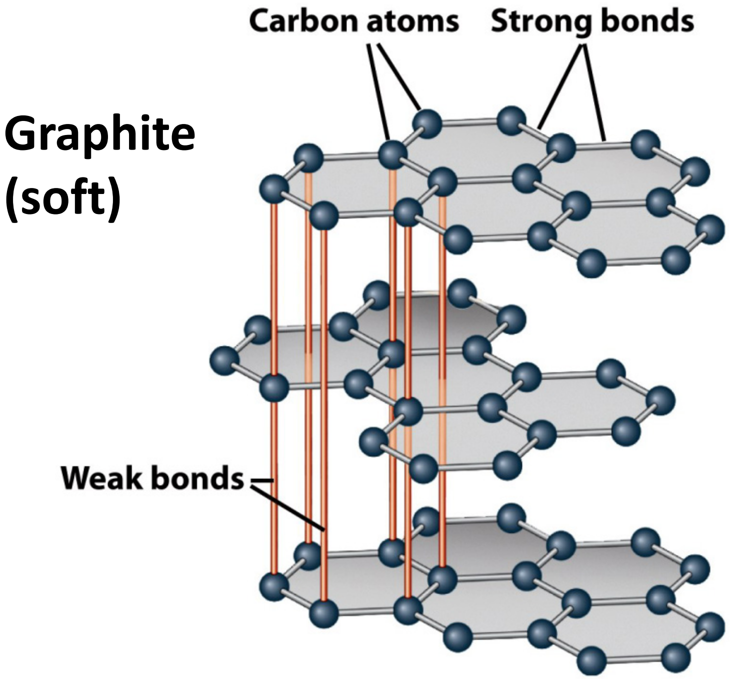
Tourmaline

Quartz

Minerals have a crystalline structure

- Ordered arrangement of atoms is known as a crystal **lattice**
- Lattices are patterns (or **structural frameworks**) that repeat in three dimensions
- Lattice atoms are held in place by atomic bonds – the chemical characteristics of these bonds determine mineral properties (e.g. graphite vs. diamond)

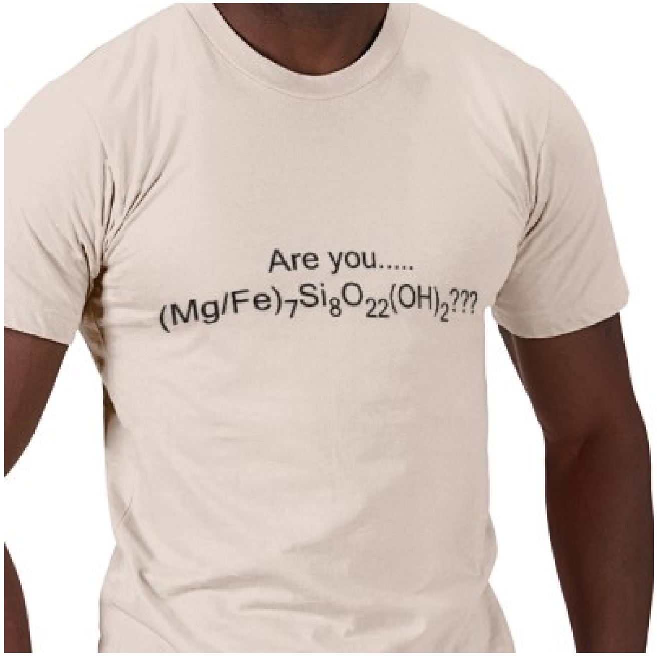




Minerals have a specific chemical composition

- Some minerals contain only one element; e.g. gold (Au), copper (Cu), graphite (C) and diamond (C)
- But most are **compounds** of two or more elements
- Must be able to write a chemical formula for a mineral; cannot be a mixture of different elements or compounds

$(Mg,Fe)_7Si_8O_{22}(OH)_2$



Minerals have a specific chemical composition

- Many minerals are actually mineral **groups**
- Members of a group conform to a general type of structure, have similar physical properties, and are chemically closely related, but they have some specific **chemical differences**
- Hence, individuals that make up a group are defined as separate minerals. For simplicity, it is convenient to call them by a group name (e.g. pyroxene, **garnet**, feldspar)

Almandine
$Fe_3Al_2Si_3O_{12}$

Spessartine
$Mn_3Al_2Si_3O_{12}$

Grossular
$Ca_3Al_2Si_3O_{12}$

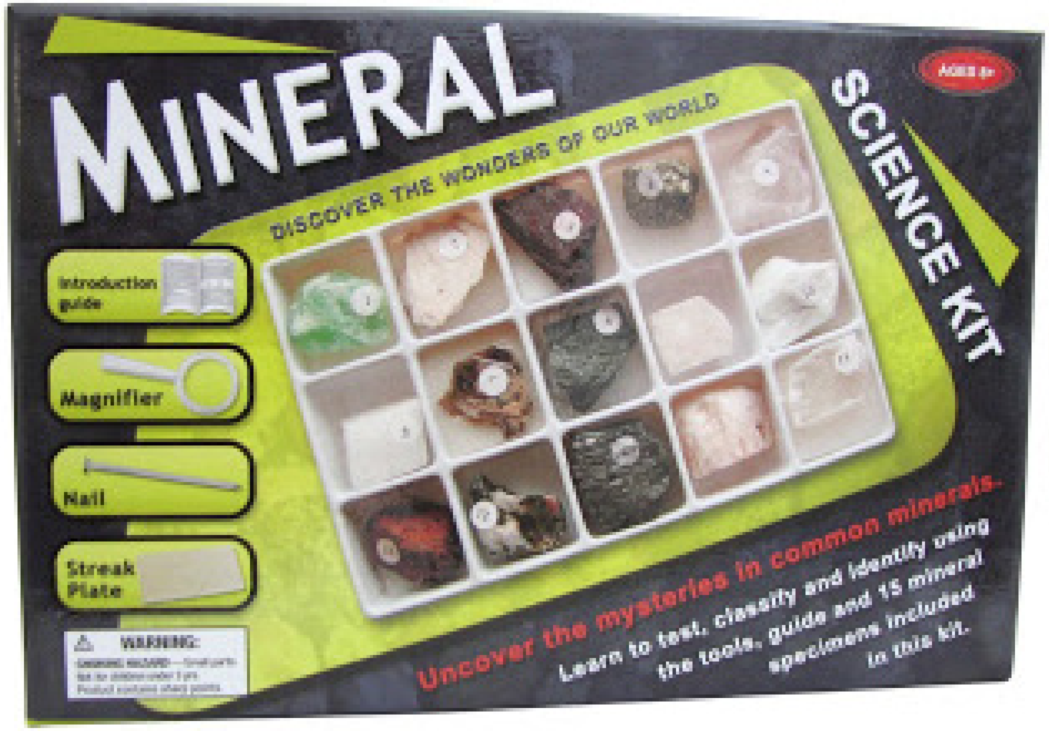
http://www.gigapan.com/gigapans/93593

Minerals are usually of inorganic origin

- **Organic** substances contain carbon–hydrogen bonds; all others are referred to as **inorganic**
- Organic materials are generally formed by living organisms, but may also be formed in the laboratory (e.g. plastics)
- Inorganic materials such as minerals are generally formed by **geological processes**, not by the action of organisms
- Some organic substances can be formed in this way, hence there are a limited number of organic minerals

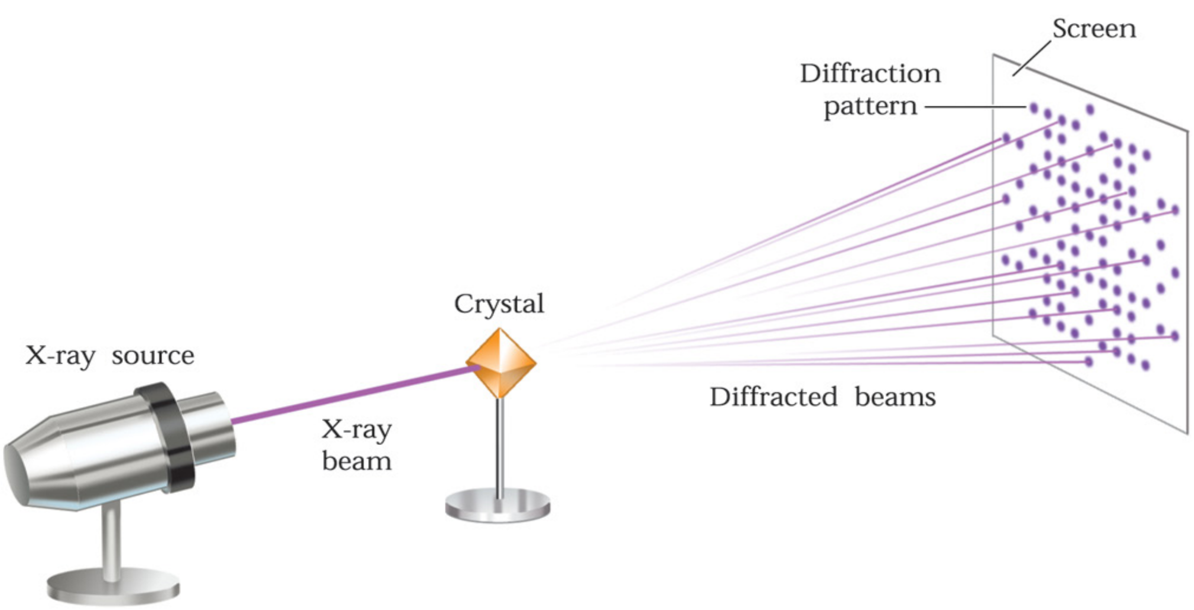
Lecture outline

- What is a mineral?
- **Mineral properties and identification**
- Mineral classes



Mineral identification

- Different mineral types are specifically defined by their **crystal structure** and **chemical composition**
- These properties can be determined by a variety of analytical techniques (e.g. X-ray diffraction, optical microscopy)
- But these methods are clearly not practical for mineral ID in the field!



Unless you are a little bit obsessed

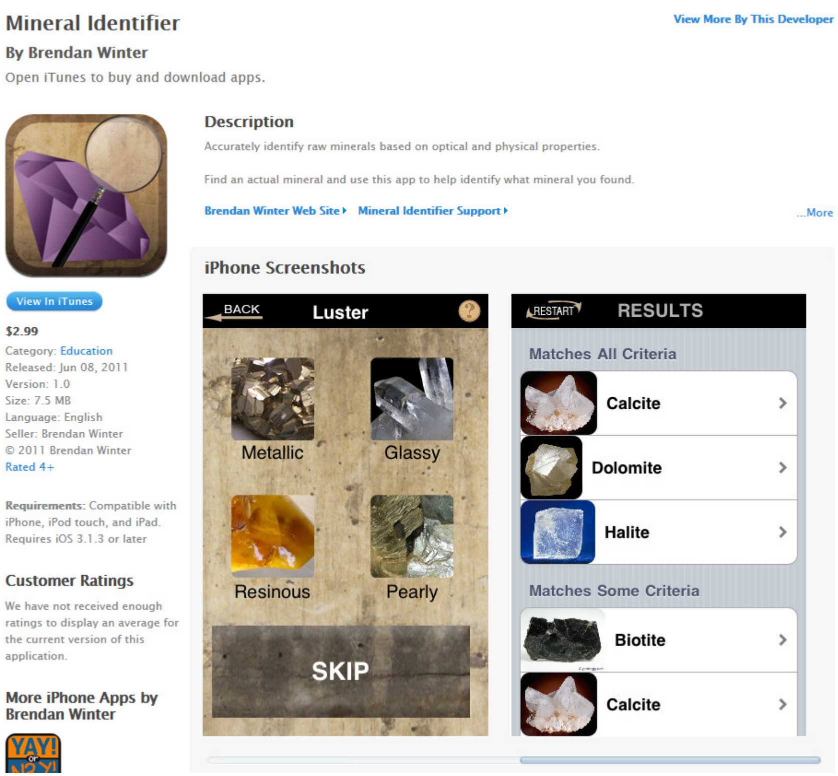
So how do we recognise minerals?

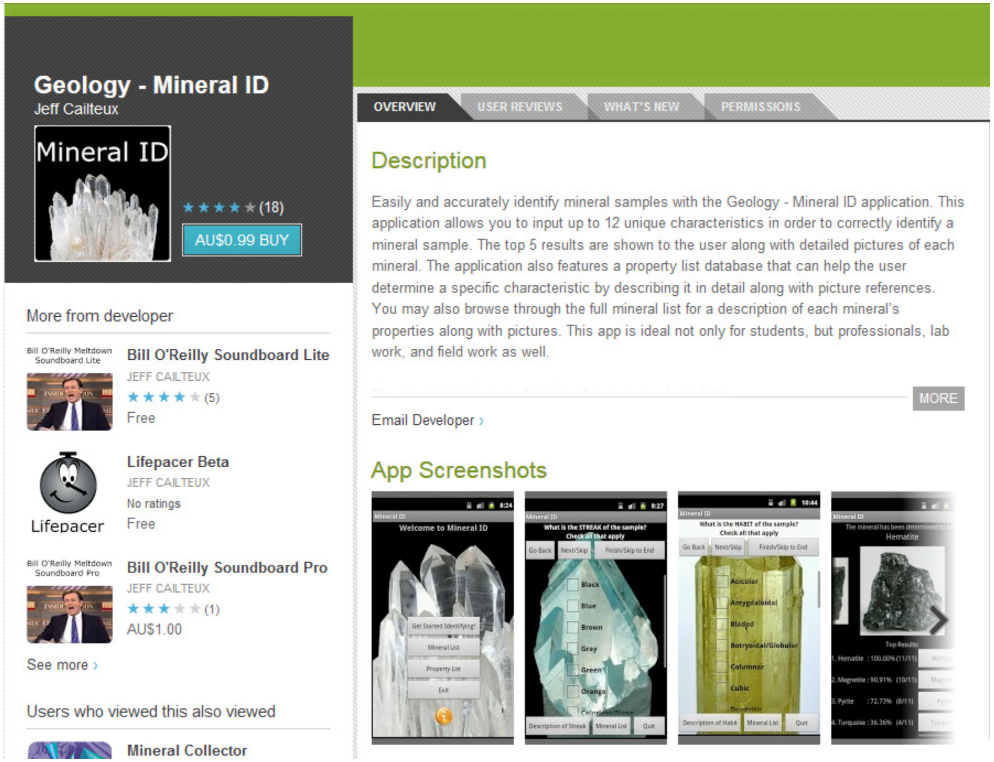
We rely on the physical properties of a mineral to aid identification. Together, two or three properties may be diagnostic for a given mineral. Some of the most commonly used properties are:

- Colour
- Streak
- Lustre
- Hardness
- Specific gravity (density)
- Crystal habit/form
- Cleavage/fracture
- Magnetism
- Taste/touch

Physical properties are controlled by mineral composition and structure. Hence, by examining these properties in detail, we learn important information about the nature of minerals.

So how do we recognise minerals?





https://itunes.apple.com/us/app/mineral-identifier/id441424808?mt=8

https://play.google.com/store/apps/details?id=jeffcailteux.rockidentifier&hl=en

https://itunes.apple.com/au/app/minerals-gemstones/id462199583?mt=8

https://play.google.com/store/apps/details?id=com.bim.key.mineral3&hl=en

Colour

- Colour is perhaps the least reliable physical property of minerals
- It can often vary considerably (e.g. quartz can be white, purple, black, etc.), but is very diagnostic for certain minerals
- Subtle colour changes can tell you a lot about **chemical composition**
- The overall colour of a mineral can also be used as an indicator of its chemistry

  Mafic minerals (rich in Fe and Mg) are usually **dark**

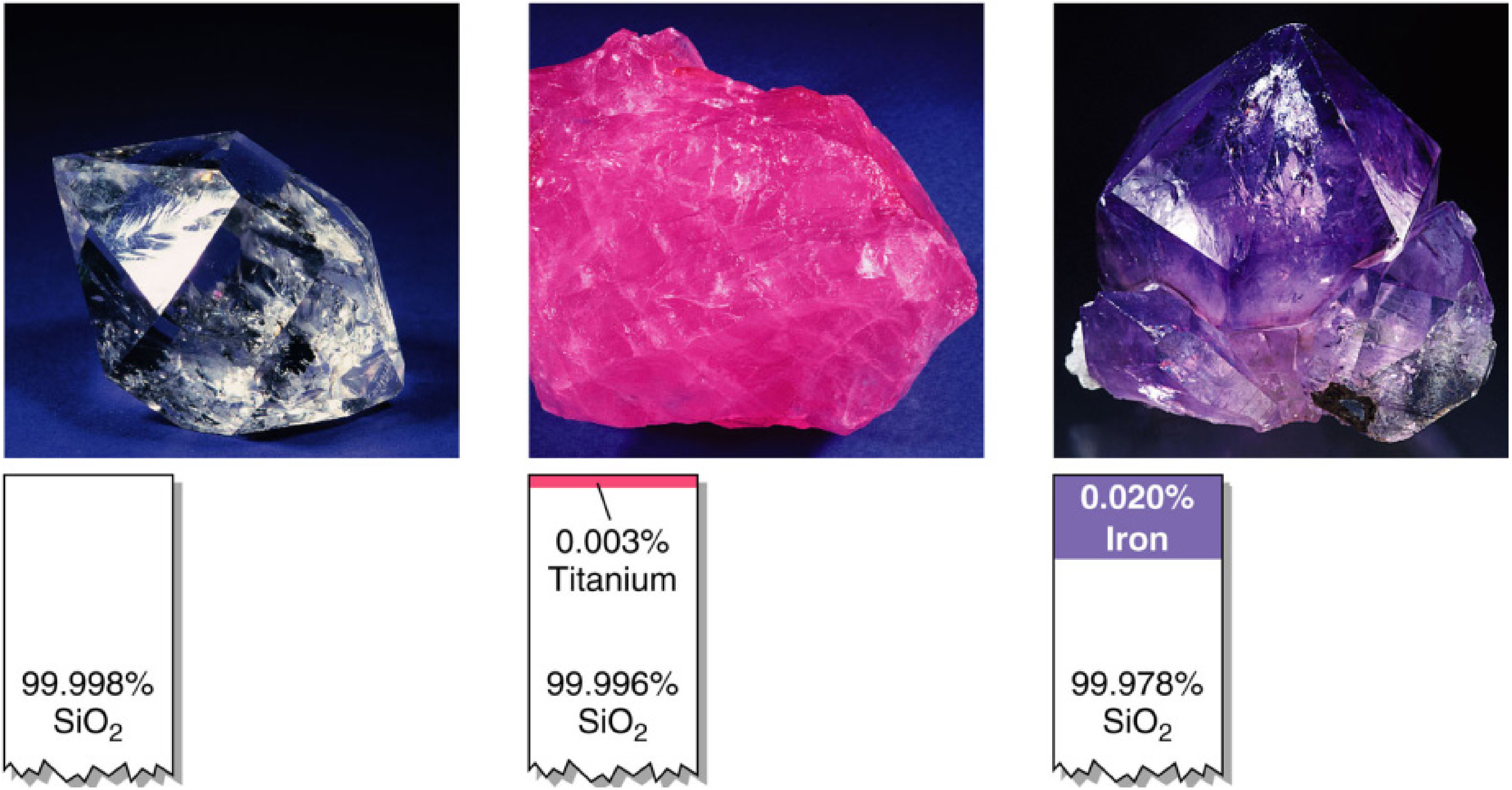
  Felsic minerals (rich in Si, Na and Ca) are usually **light**

Quartz

Olivine

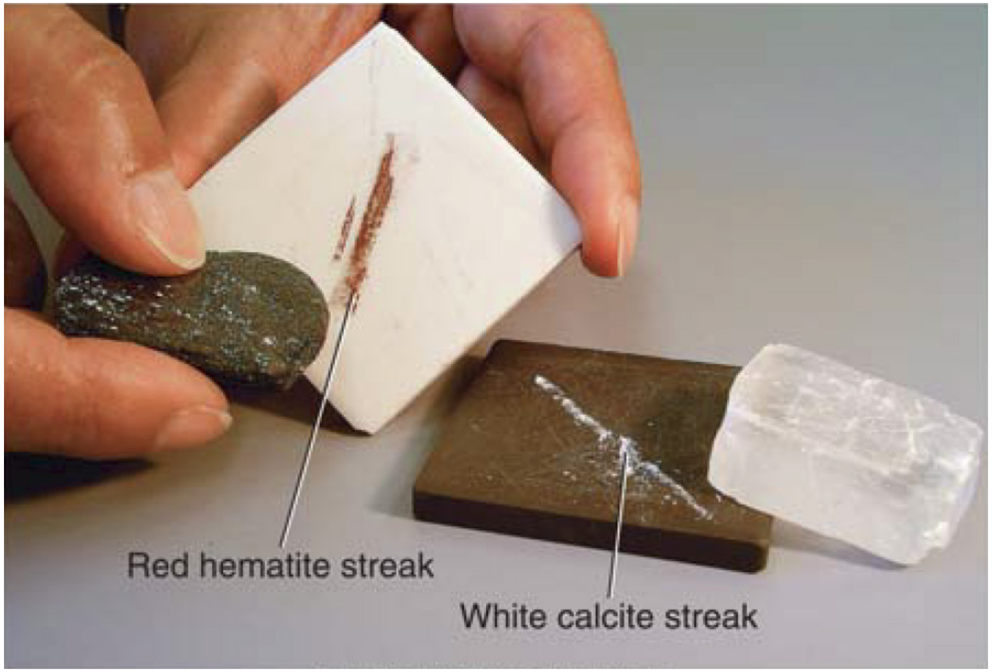
Azurite

Colour



Streak

- Streak is the colour of a powdered mineral, determined by rubbing the specimen on an unglazed ceramic tile
- Less variable than the colour of whole crystals
- It is occasionally different from the colour of the mineral itself – this is a diagnostic property
- Most useful for minerals with a **metallic lustre**



Lustre

- Lustre is a description of the reflectivity of a mineral
- Two broad subdivisions: either **metallic** (most ore minerals such as oxides and sulfides) or **non-metallic** (most silicate minerals)
- The electron cloud of metallic-bonded minerals reflects light well, whereas other types of bonds (e.g. ionic, covalent) do not
- More specific terms for a non-metallic lustre are silky, glassy (vitreous), satiny, pearly, earthy, etc.

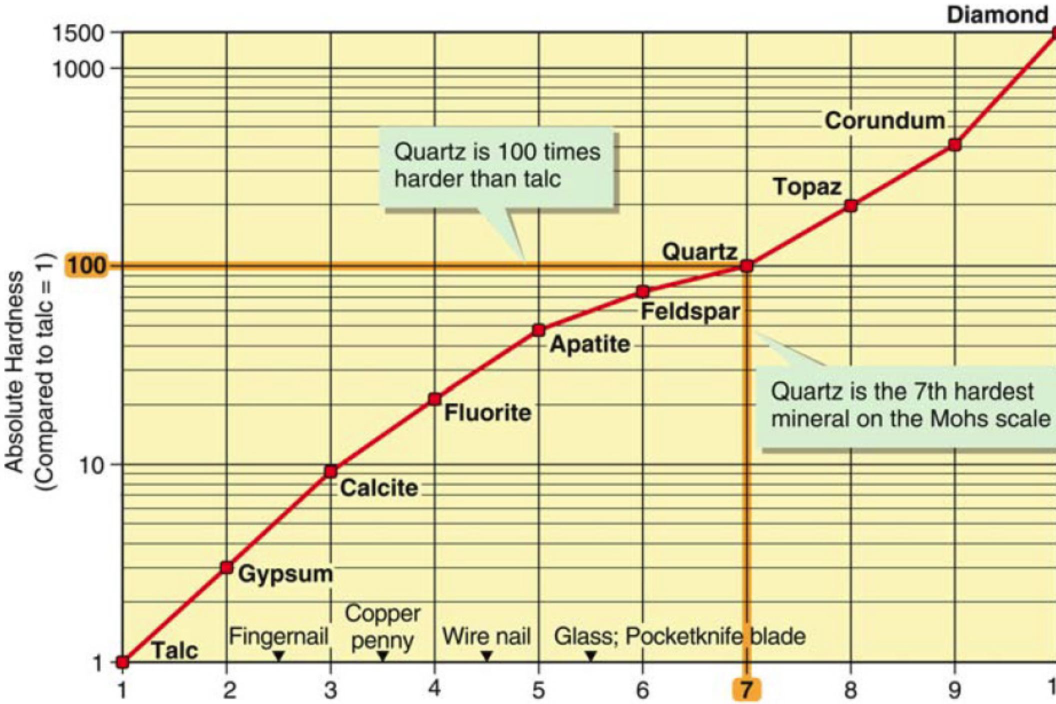
Metallic

Vitreous

Silky

Hardness

- Minerals differ in their hardness
- Hardness is dependant on the type of chemical bonding
- The degree of hardness is evaluated using the **Mohs Hardness Scale**
- Minerals with higher numbers will scratch those with lower numbers
- NOTE: this scale is only used for **MINERALS**, not ROCKS. Indiscriminately scratching the surface of a rock only tests its coherence, not hardness.



Specific gravity

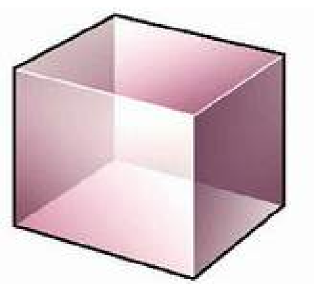
- SG = mineral weight over weight of equal water volume (dimensionless)
- Related to mineral density = weight per unit volume (g/cm^3)
- Galena (7.5) and pyrite (5.0) have a high specific gravity, whereas that of calcite (2.7), feldspar (2.6) and quartz (2.7) is low
- Usually determined in purely relative terms by hefting mineral specimens in the hand – which mineral feels heavier

Pyrite

Feldspar

Crystal habit

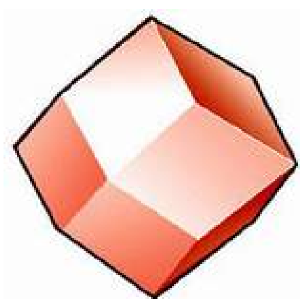
- Crystal habit refers to the ideal shape (or **morphology**) of external crystal faces
- Habit can be characterised using a range of descriptive terms


Cubes

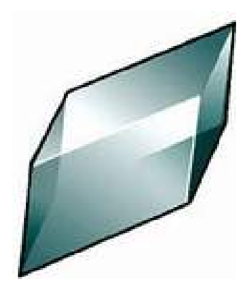

Octahedra

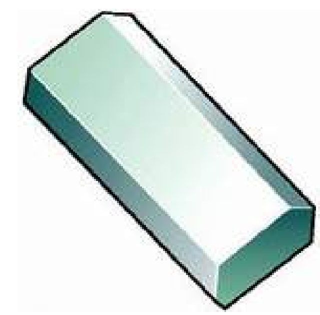

Blades


Hexagonal Prisms


Dodecahedra

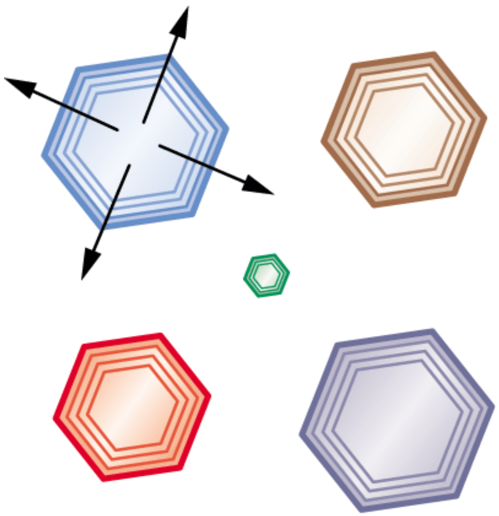

Compound Forms

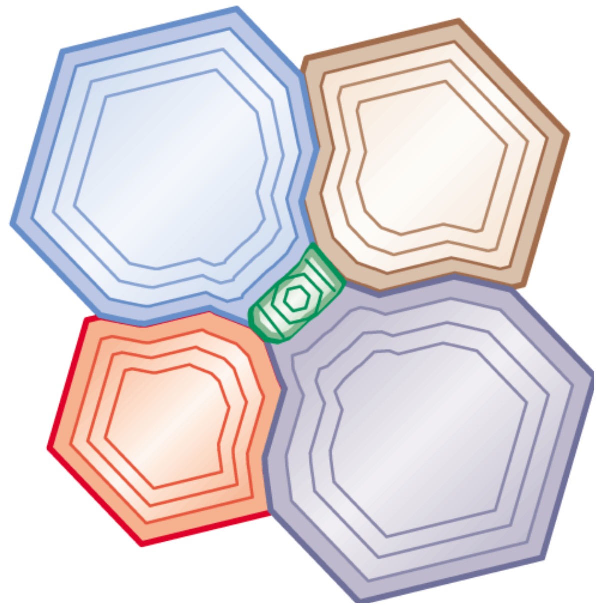

Rhombohedra


Tetragonal Prisms

Crystal form

- Crystals that grow under non-ideal conditions do not have perfectly-formed faces
- Face development is indicative of **mineral growth history**
  - **Euhedral** – Good crystal faces; grown in an open cavity
  - **Anhedral** – No crystal faces; grown in a tight space
  - **Subhedral** – Between the two





Euhedral **Anhedral**

Crystal form

Crystal growth animation:

http://www.wwnorton.com/college/geo/animations/mineral_growth.htm

Video:

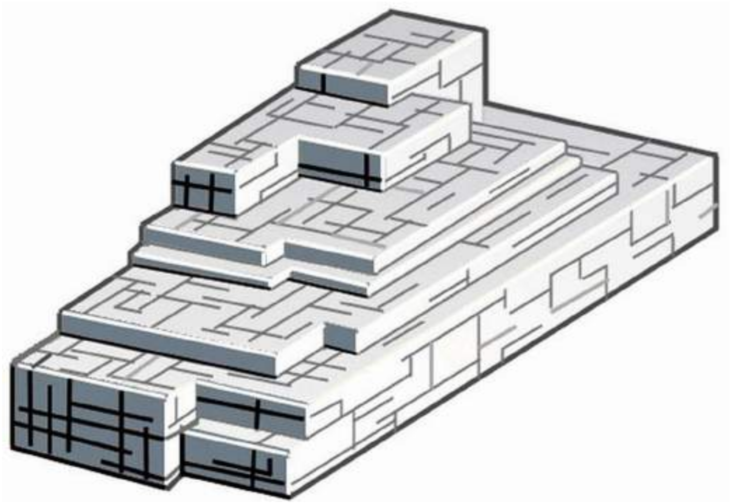
https://www.youtube.com/watch?v=-J2ZOngBfcg

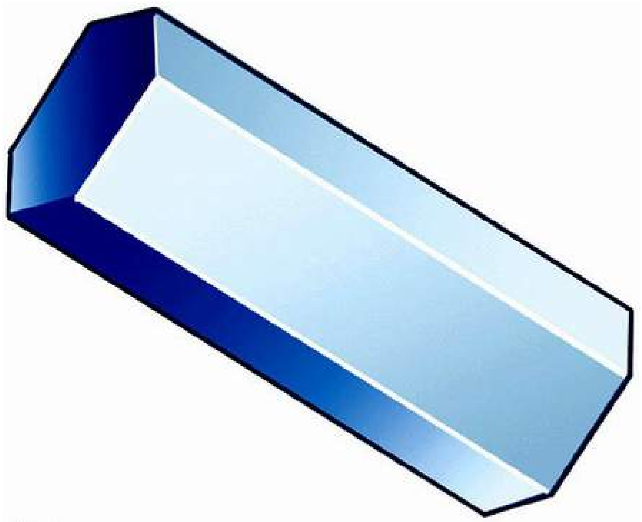
Cleavage

- Many minerals have a predisposition to break along planes of weakness that are related to the crystalline structure – the **lattice**
- Cleavage planes form flat, reflective surfaces visible in hand specimen
- Cleavage is described by the number of planes and their angles
- Do not confuse cleavage with crystal habit

  Cleavage is a **regular**, **repeated planar surface** that penetrates the **entire mineral**

  Habit is confined to only the **external faces** of a mineral – no repetition

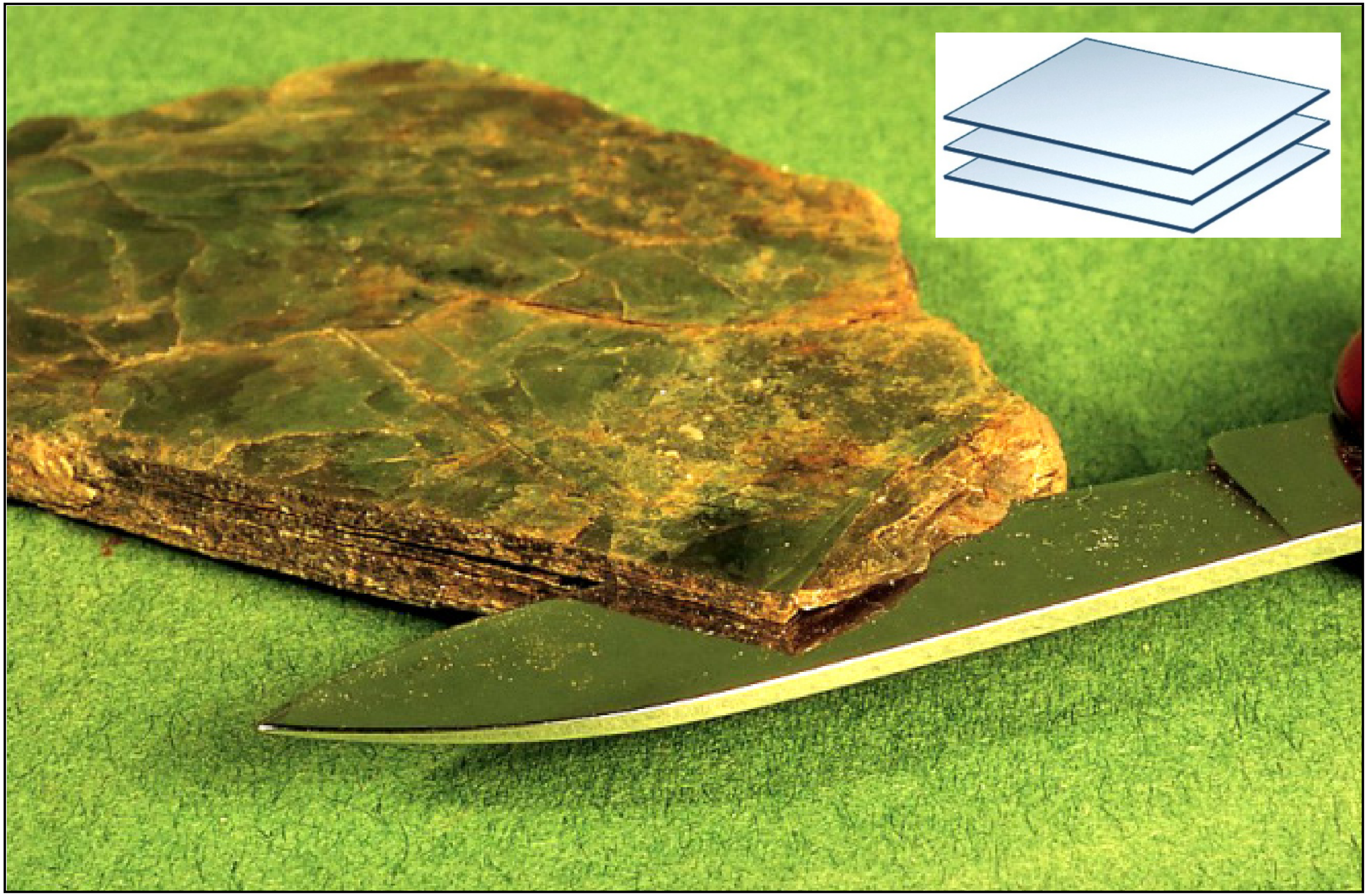




https://www.youtube.com/watch?feature=player_detailpage&v=iafahWbrK5Y#t=299s

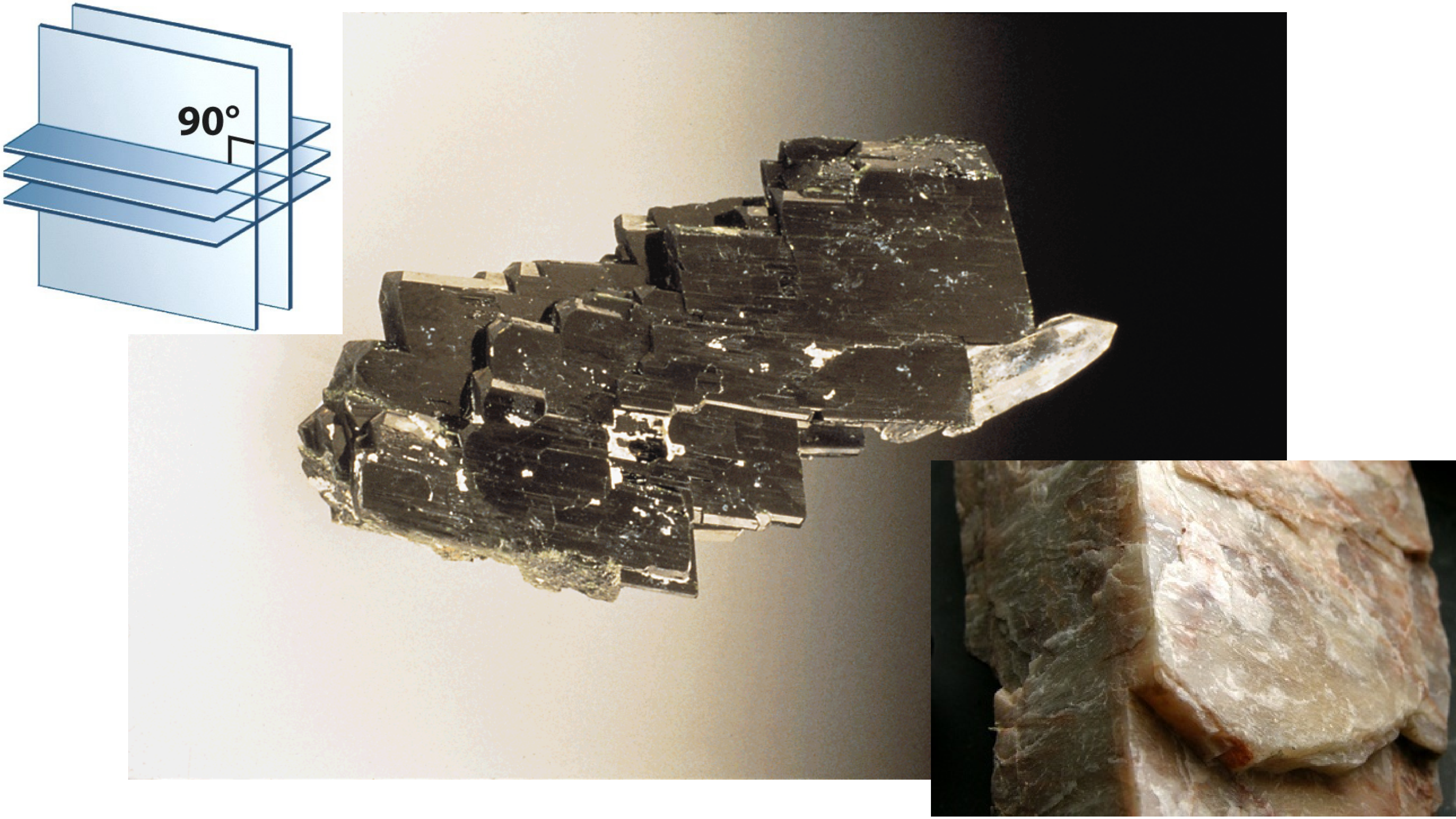
https://www.youtube.com/watch?v=hzZlfYITao0

Types of cleavage



Planar (or basal) cleavage – one direction (biotite)

Types of cleavage

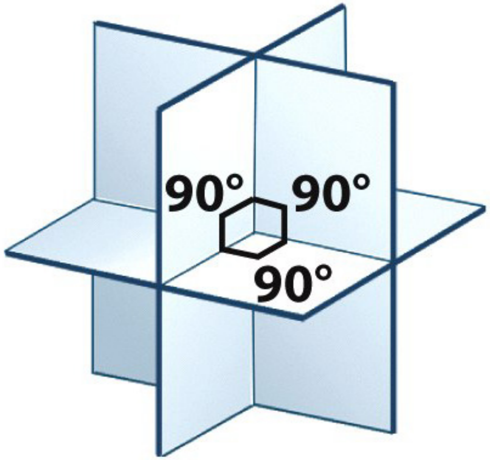


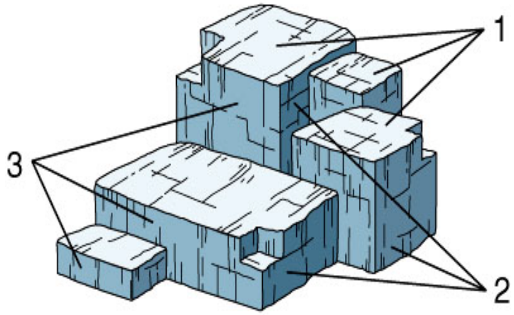
Prismatic cleavage – two directions at 90° (pyroxene/K-feldspar)

Types of cleavage

Prismatic cleavage – two directions not at 90° (amphibole)

Types of cleavage





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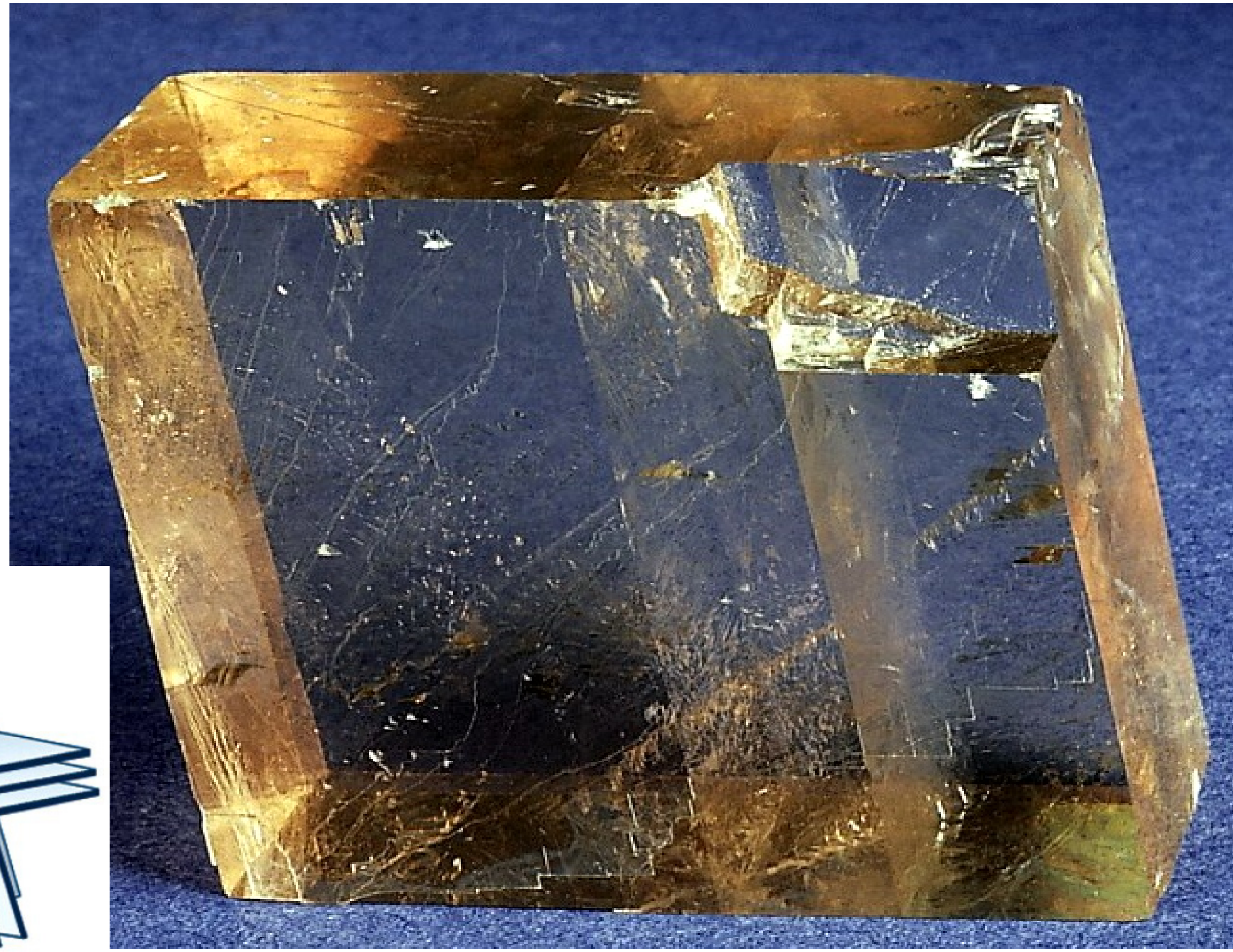
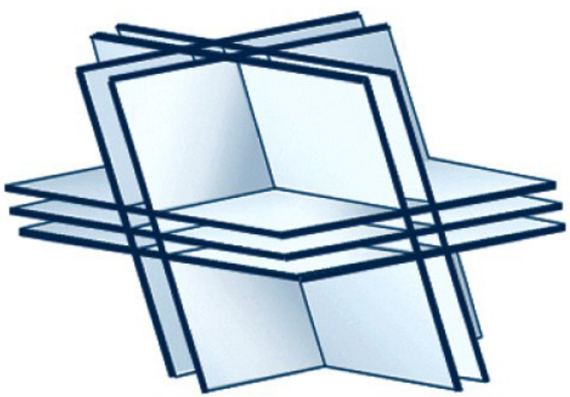
Cubic cleavage – three directions all at 90° (galena)

Types of cleavage





Orthorhombic cleavage – three directions not at 90° (calcite)

Fracture

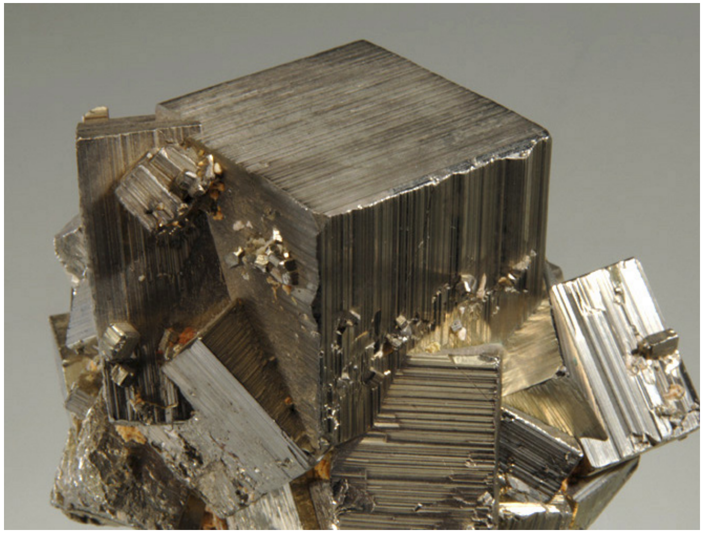
- Some minerals do not have cleavage – they lack planes of lattice weakness
- These minerals do not cleave evenly, but break or fracture unevenly instead
- Quartz has a distinctive curved fracture similar to that seen on surfaces of broken glass – **conchoidal fracture**

Obsidian

Quartz

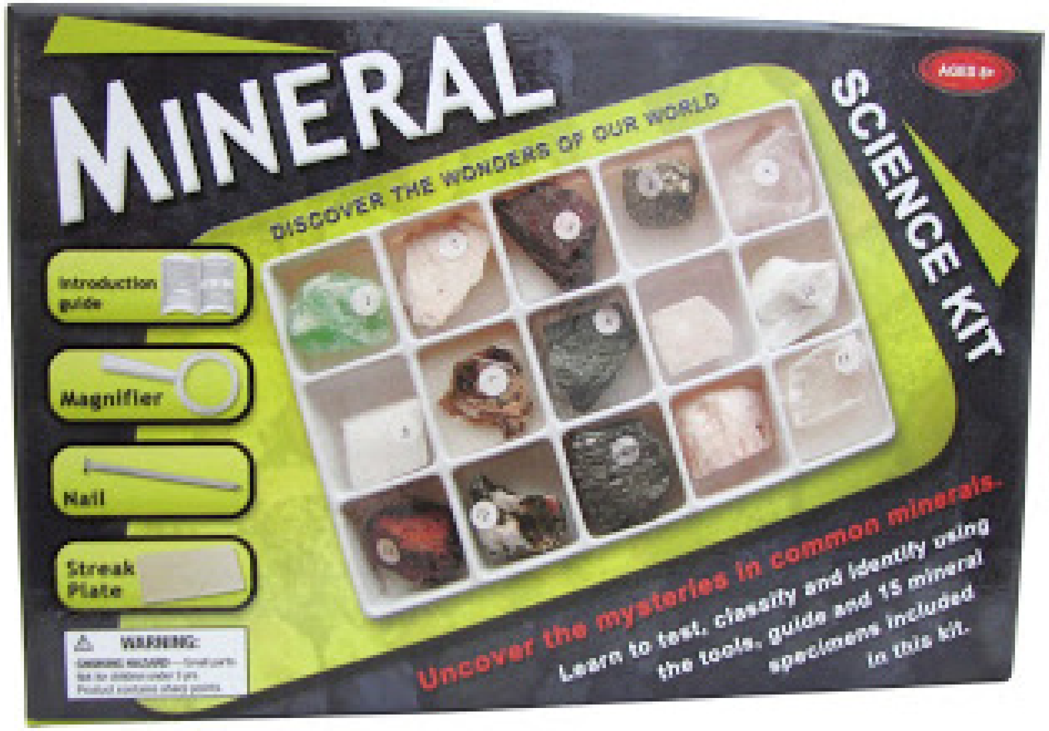
Other properties

- Magnetite (Fe_3O_4) is a mineral that is naturally strongly **magnetic**
- Native metals such as copper and gold are **conductive**
- Talc feels **greasy** to touch
- Halite (NaCl) has a **salty** taste
- Fluorite **fluoresces** in ultraviolet light
- Carbonate minerals such as calcite (CaCO3) react with HCl – **effervescence**
- Minerals such as pyrite, tourmaline and feldspar have distinctive **striations** – parallel lines on cleavage planes



Lecture outline

- What is a mineral?
- Mineral properties and identification
- **Mineral classes**



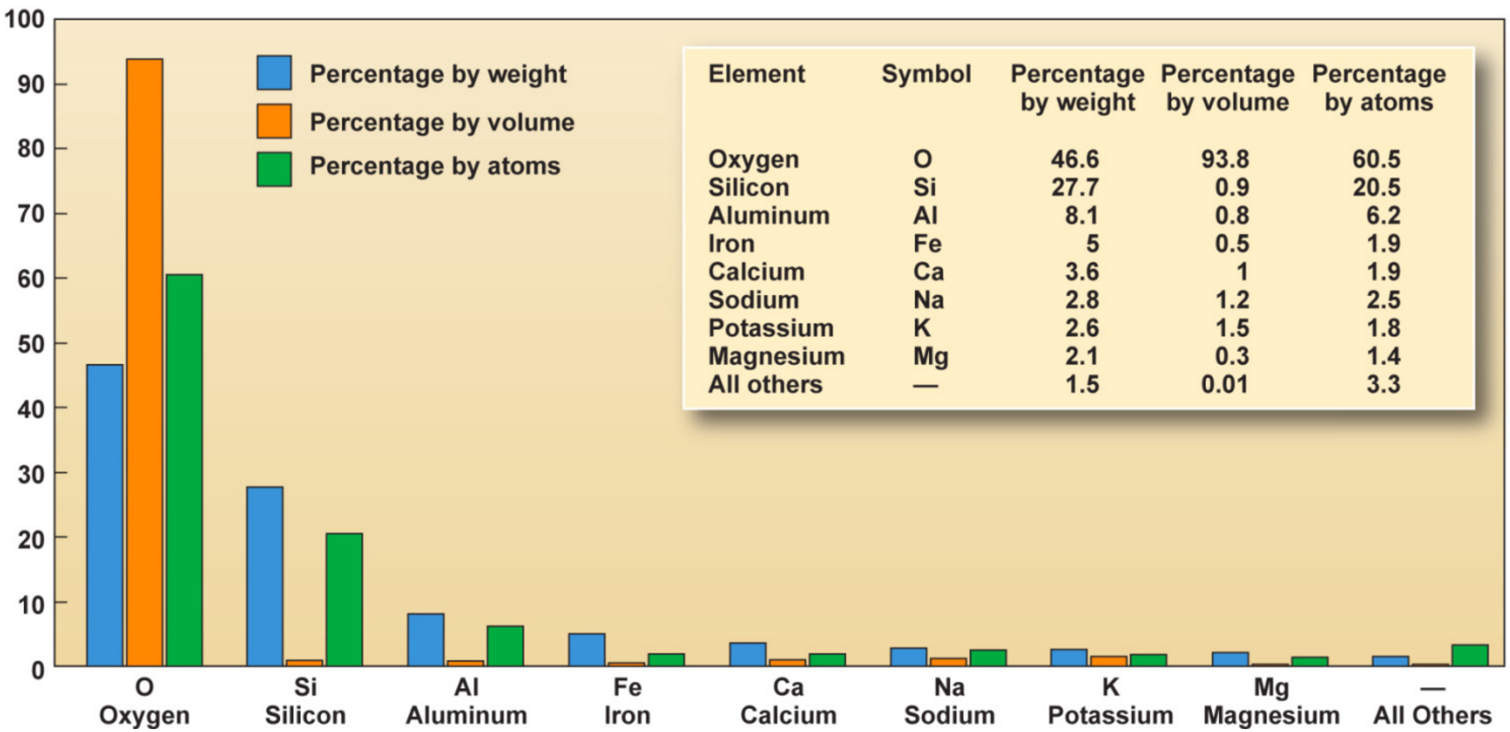
Mineral classification

- Minerals are classified based upon the dominant **anion**
- Geologists recognise 8 major mineral groups based on this chemical scheme

Mineral group	**Anion**	**Examples**
Silicates	SiO_2^{4-}	Rock-forming minerals
Oxides	O_2^{-}	Magnetite (Fe_3O_4), hematite (Fe_2O_3)
Sulfides	S^{-}	Pyrite (FeS_2), galena (PbS)
Sulfates	SO_4^{2-}	Gypsum ($CaSO_4.2H_2O$)
Halides	Cl^{-} or F^{-}	Halite (NaCl), fluorite (CaF_2)
Carbonates	CO_3^{2-}	Calcite ($CaCO_3$), dolomite [$CaMg(CO_3)_2$]
Phosphates	PO_4^{3-}	Apatite [$Ca_5(F,Cl,OH)(PO_4)_3$]
Native elements	N/A	Copper (Cu), gold (Au), graphite (C)

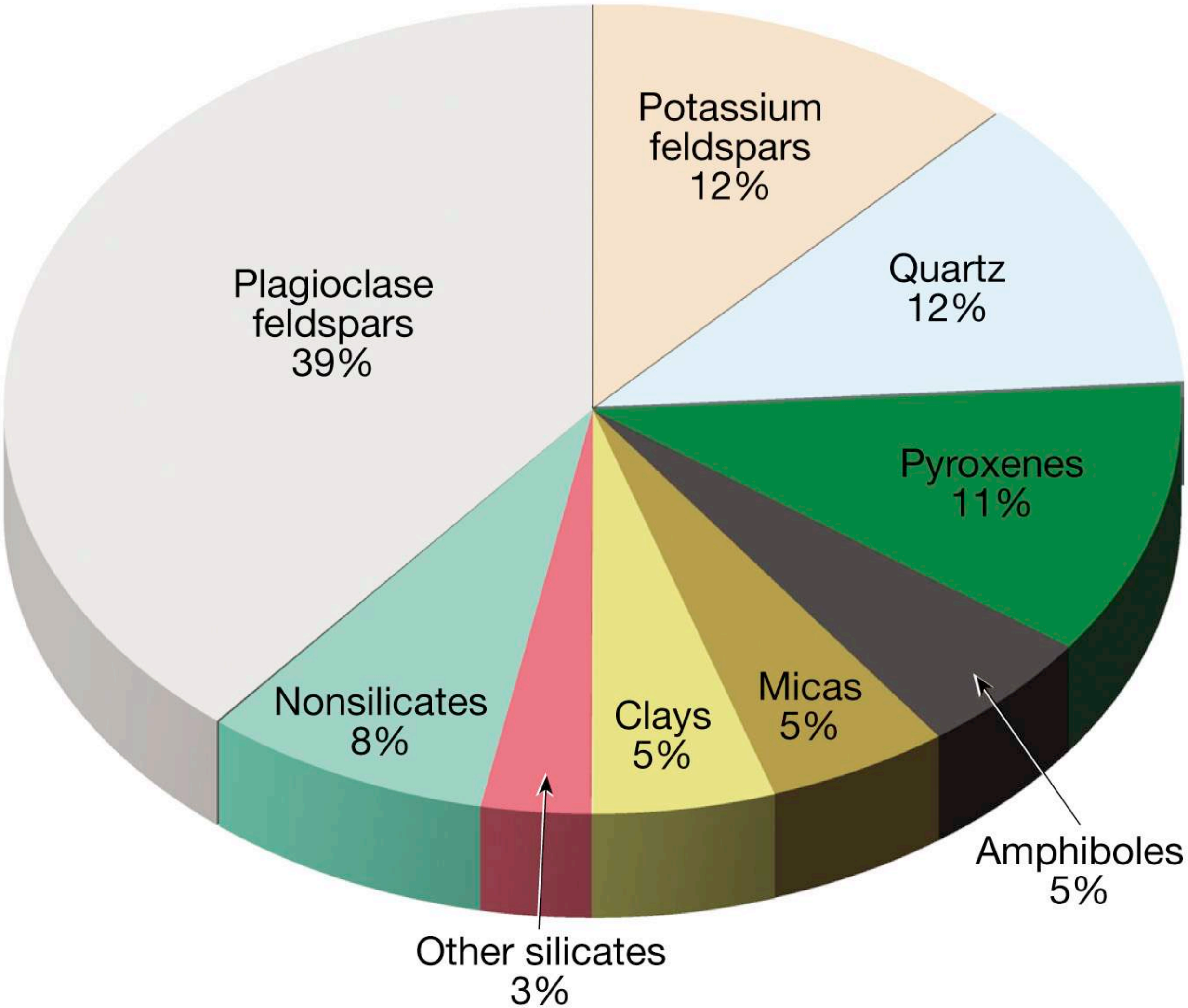
Silicates

- Oxygen and silicon make up 93.8% of crustal volume and 74.3% of crustal mass
- Silicates therefore dominate the Earth's crust
- They are known as the **rock-forming minerals**

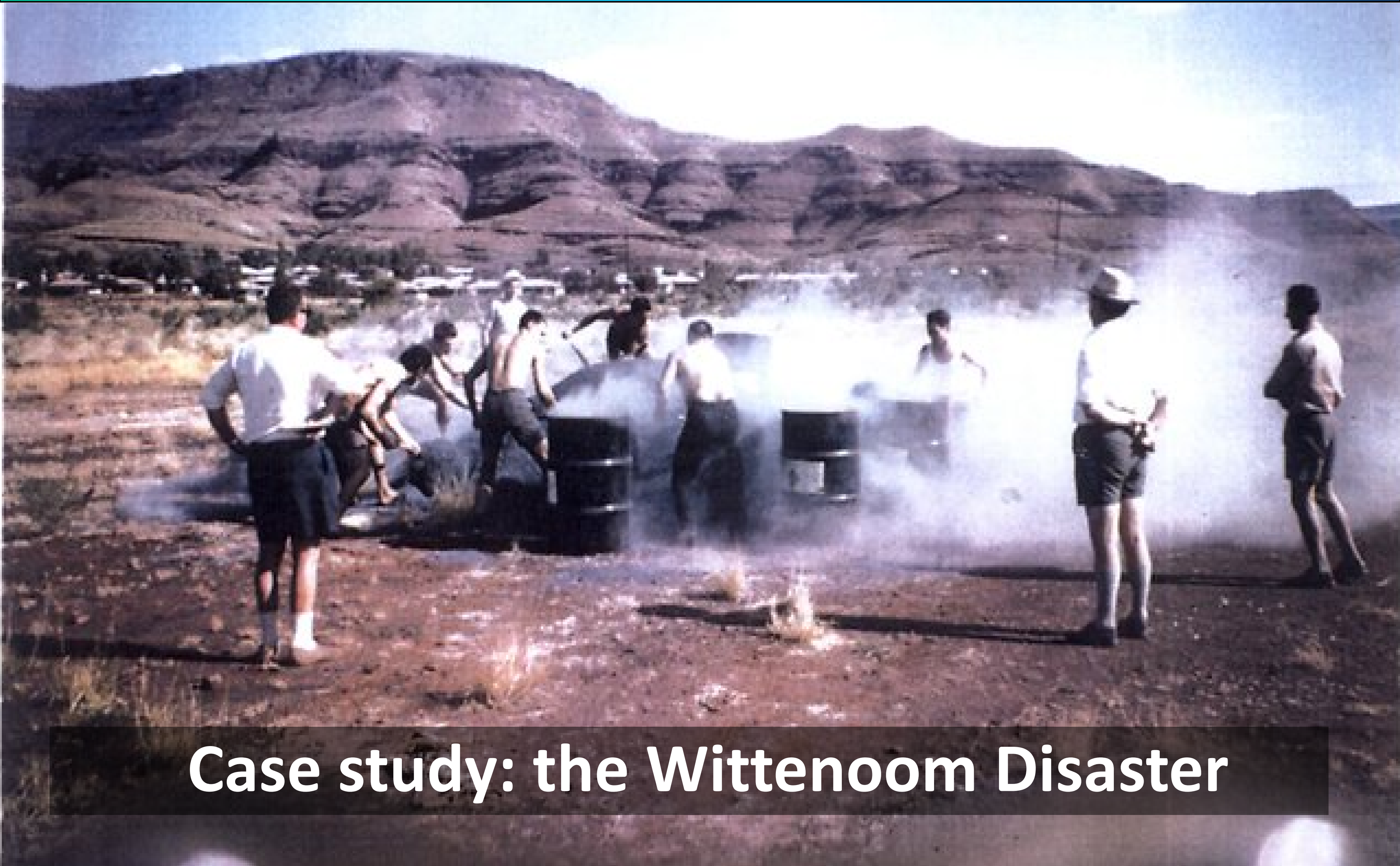


Element	Symbol	Percentage by weight	Percentage by volume	Percentage by atoms
Oxygen	O	46.6	93.8	60.5
Silicon	Si	27.7	0.9	20.5
Aluminum	Al	8.1	0.8	6.2
Iron	Fe	5	0.5	1.9
Calcium	Ca	3.6	1	1.9
Sodium	Na	2.8	1.2	2.5
Potassium	K	2.6	1.5	1.8
Magnesium	Mg	2.1	0.3	1.4
All others	—	1.5	0.01	3.3

Silicates


Potassium feldspars 12%
Quartz 12%
Pyroxenes 11%
Plagioclase feldspars 39%
Nonsilicates 8%
Clays 5%
Micas 5%
Amphiboles 5%
Other silicates 3%

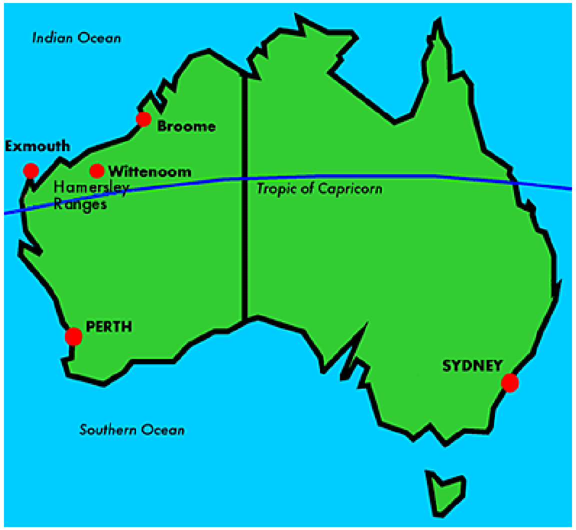
Lecture outline

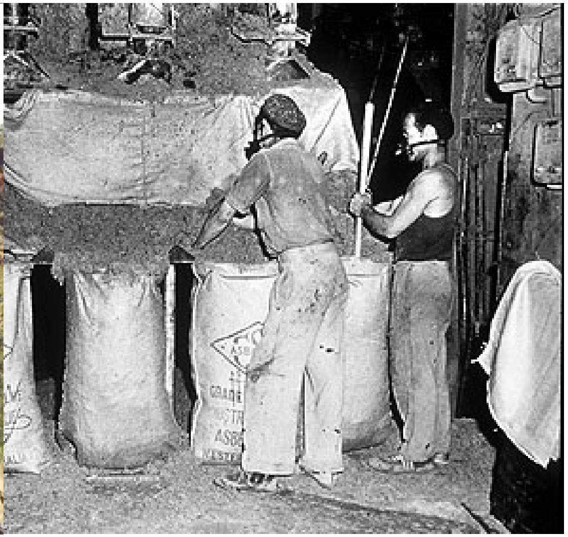


Case study: the Wittenoom Disaster

Case study: the Wittenoom Disaster

- Lang Hancock began mining blue asbestos (crocidolite) at Wittenoom in 1938
- CSR purchased Wittenoom in 1943, and soon became one of the largest manufacturers of asbestos products in Australia
- Total production (1943–1966) = 161 000 tonnes of crocidolite fibre





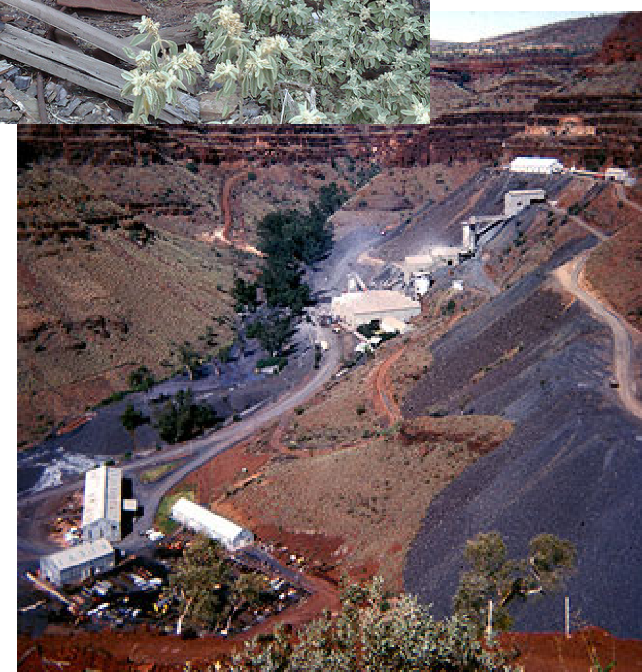
Case study: the Wittenoom Disaster

Blue asbestos (crocidolite)

Case study: the Wittenoom Disaster

- Mine layout and working conditions enhanced health risks
- First case of asbestosis in 1948
- Mesothelioma and asbestosis diagnosed throughout the 1960s and 70s
- By 1986, 85 deaths from malignant mesothelioma
- WA has the highest rate of malignant mesothelioma than any State in Australia or elsewhere in the world per capita of population

Case study: the Wittenoom Disaster



Case study: the Wittenoom Disaster

- 20,000 people lived and worked in Wittenoom while the mine was in operation
- Today, only 8 residents remain
- WA government began phasing out activity in Wittenoom in 1978
- The town of Wittenoom has been degazetted (quite literally wiped off the map) and become a ghost town