يونيورسيتي بروني دارالسلام
UNIVERSITI BRUNEI DARUSSALAM

Επικίνδυνα Ορυκτά

Διάλεξη στα πλαίσια της Ειδίκευσης:
«*Ορυκτές Ύλες - Περιβάλλον*»

Βασίλης Τσικούρας
GeoSciences Programme, Faculty of Science
Universiti Brunei Darussalam

Αμιαντικά Ορυκτά - Asbestos Minerals

Introduction

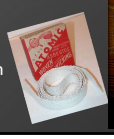
- Under certain conditions, some minerals can be hazardous for public health
- Asbestos is a typical example
- It is thought to be responsible for asbestosis, lung cancer, as well as *malignant mesothelioma*

Asbestos Minerals

- The earliest mineral used as asbestos is chrysotile (*polymorph of ?*)
- Later some amphiboles were also introduced
- Asbestos is a general commercial term referring to certain minerals with certain dimensions (asbestiform habit) that fall in two categories: the serpentine asbestos and the amphibole asbestos

Asbestos Minerals

- The term asbestos derives from the Ancient Greek "*ἄσβεστος*", meaning "unquenchable" or "inextinguishable"; it was used for wicks of lamps and it was incombustible
- In many languages roots the term "amiantos" (e.g. amiant, amianto, etc.) are used from the Greek term "*αμίαντος*", meaning undefiled; it showed no mark or stain when thrown into fire



Asbestos Minerals

- Chrysotile (white asbestos)
- Crocidolite (blue asbestos)
- Amosite (brown asbestos)
- Tremolite
- Actinolite*
- Anthophyllite *

Serpentine Asbestos

Amphibole Asbestos

- **Not used for commercial purposes*

Asbestos Minerals

- According to World Health Organisation (WHO) the previous six minerals show an asbestiform habit, which is a health risk, when they have:
  - length > 5µm
  - diameter < 3µm, and
  - aspect ratio (length/diameter) > 3

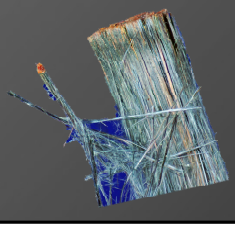
(all these properties must be fulfilled simultaneously)

Asbestos Minerals

- Chrysotile - $Mg_3Si_2O_5(OH)_4$

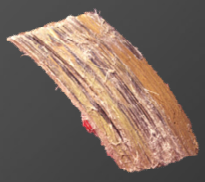
Asbestos Minerals

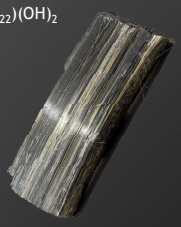
- Crocidolite (Riebeckite) - $Na_2Fe_5(Si_8O_{22})(OH)_2$



Asbestos Minerals

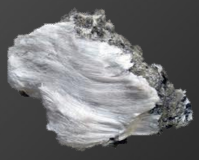
- Amosite (Cummingtonite-Grunerite) - $(Mg,Fe)_7(Si_8O_{22})(OH)_2$





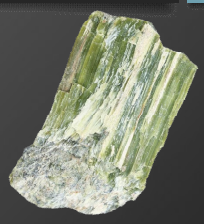
Asbestos Minerals

- Tremolite - $CaMg_5(Si_8O_{22})(OH)_2$



Asbestos Minerals

- Actinolite - $Ca(Mg,Fe)_5(Si_8O_{22})(OH)_2$



Asbestos Minerals

- Anthophyllite -$Mg_7(Si_8O_{22})(OH)_2$

Properties of Asbestos

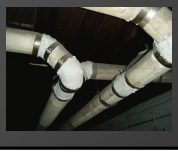
- The exploited raw material comprises fibre bundles
- The fibres are flexible showing high tensile stress, hence they can be woven to form asbestos clothes or ropes
- Asbestos fibres show excellent resistance to tension, to heat and to acid attack
- Chrysotile asbestos clothes resemble wool fabrics whereas the amphibolite asbestos materials resemble fiberglass

Uses of Asbestos

- Heat and electrical insulations
- Building material
- Constituent of cements for reinforced concrete
- Asbestos clothing
- Roof and non-roof coatings
- Friction materials

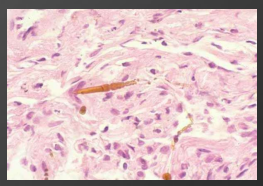
Uses of Asbestos

- Clutch facings
- Automatic transmission components
- Coating of car brake pads
- Drum brake linings
- Gaskets
- Asbestos-cement pipe and pipeline wrap
- Many other industrial applications



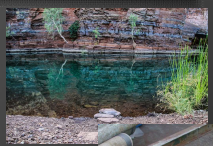
Health Effects of Asbestos

- Health problems are due to the crystal habit of the asbestos minerals
- Asbestos fibres are friable, thus with their destruction they continue to produce smaller fibres even in microscopic sizes
- Hence, the fibres become inhalable and subsequently penetrate the epithelial cells



Health Effects of Asbestos

- They may cause serious damage due to the fact that they cannot be eliminated by the immune system
- They can be easily incorporated into drinking water (rivers, water pipes, etc.)
- These fibres are insoluble and can travel for long distances
- Eventually they can enter human body by drinking water

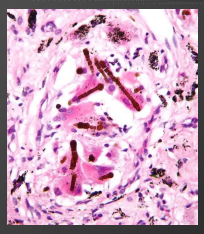


Health Effects of Asbestos

- Asbestos is considered today as a high cancer-risk factor
- It is thought to cause asbestosis, mesothelioma and other types of cancer of lungs, oesophagus and rectum
- Latency periods of asbestos related diseases are usually 10 to 40 years

Health Effects of Asbestos

- Infected patients are thus diagnosed with these diseases several to many years after their exposure to asbestos
- Most of those diagnosed with occupational asbestos-related diseases had worked in asbestos mines or processing during the 1970's and 1980's



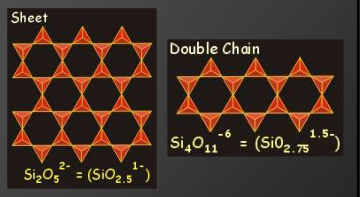
Are there substitutes?

- Some common substitutes (but for a limited range of applications)

✓Polyurethane foam
✓Thermoset plastic
✓Fiberglass
✓Mineral wool
✓Cellulose
✓Flour fillers (pecan shells, wheat flour, rice flour, rice hulls)
✓Plastic
✓Hemp
✓Sheep's wool
✓Straw
✓Natural cotton
✓Polybenzimidazole (PBI)

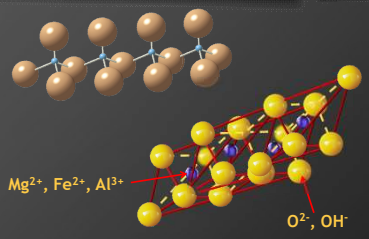
Serpentine *vs.* Amphibole Asbestos

- Physical properties of chrysotile asbestos are much different than amphibolite asbestos fibres
- Chrysotile belongs to the sheet silicate (phyllosilicate) subclass of minerals
- Amphiboles belong to double chain silicates (inosilicates)



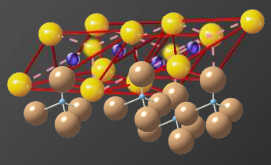
Why a Sheet Silicate is Fibrous?

- Phyllosilicate minerals are comprised of two sheets:
- a Tetrahedral (T), and
- an Octahedral (O)



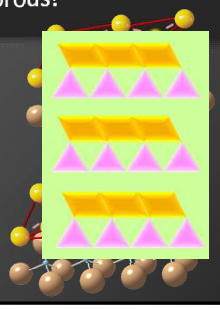
Why a Sheet Silicate is Fibrous?

- Every tetrahedral sheet is connected to an octahedral sheet
- A OH^- anion from an octahedron is removed from the apical oxygen of a tetrahedron and the latter is bonded in this position



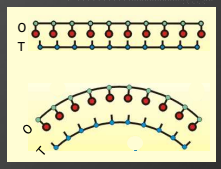
Why a Sheet Silicate is Fibrous?

- Chrysotile (and all the serpentine polymorphs) are TO Phyllosilicate minerals
- A Tetrahedral (T), and an Octahedral (O) sheets combine to form TO layers



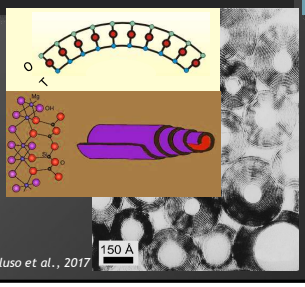
Chrysotile Asbestiform Structure

- The ionic distances in a sheet of chrysotile have the peculiar feature to be shorter than those of its opposite sheet
- Therefore, both sheets bend in order the opposite ionic distances to fit and the opposite ions to bend



Chrysotile Asbestiform Structure

- This bending of sheets is continuous resulting in wrapping like a carpet
- Therefore, chrysotile shows a fibrous habit, unlike the rest serpentine polymorphs (*which are …?*) and sheet silicates



Belluso et al., 2017

Serpentine *vs.* Amphibole Asbestos

Chrysotile	Amphiboles
Wavy-curly fibres	Straight fibres
More soluble	Less soluble (practically insoluble)
Contains little or no Fe	Contains much Fe
Hydrophilic (fibres may attach water)	Hydrophobic (fibres repel water)

Serpentine *vs.* Amphibole Asbestos

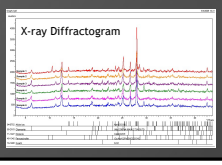
- Wavy-curly fibres of chrysotile show lower resistance to flexure and wrapping than the needle-like asbestos fibres with high resistance to flexure and wrapping
- Amphibole asbestos fibres are shorter, straight and razor-sharp, hence they are capable of penetrating easier and deeper into the lung's air sacs and alveoli
- Amphibole asbestos fibres are preserved longer in the lungs, due to their insolubility
- Considerable Fe contents in the amphibolite asbestos fibres react with oxygen forming hazardous products, which destroy the tissues and even the cell DNA

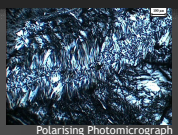
Serpentine *vs.* Amphibole Asbestos

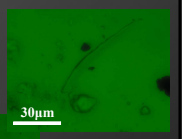
- When asbestos fibres are recognised, the immune system employs the mechanisms to isolate and eliminate them
- However, macrophages are unable to destroy the asbestos fibres (highly resistant materials)
- When the immune system is alerted it also produces mucus to isolate the "enemy"
- However, the amphibole asbestos repel the mucus due to its hydrophobic nature counteracting the immune system

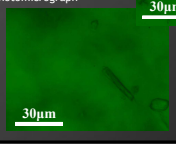
Study Methods of Asbestos

- Polarising Microscopy
- Phase Contrast Microscopy
- X-ray Diffraction




Polarising Photomicrograph

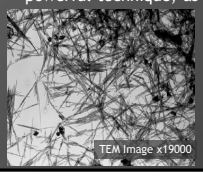


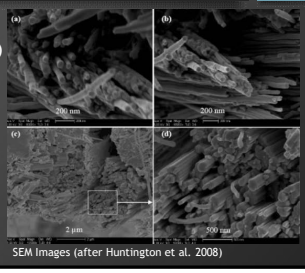


PCM Images

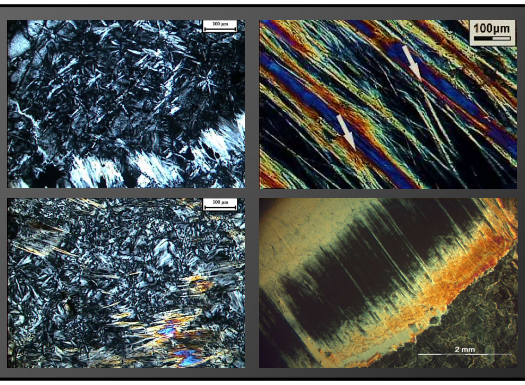
Study Methods of Asbestos

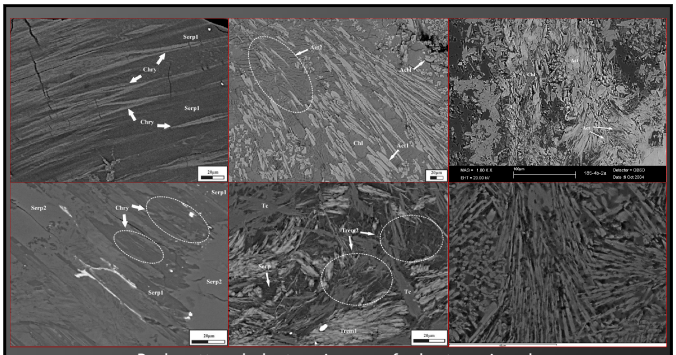
- Scanning Electron Microscopy (a powerful and very useful technique)
- Transmission Electron Microscopy (a powerful technique, as well)


TEM Image x19000


SEM Images (after Huntington et al. 2008)

Photomicrographs of asbestos minerals (XPL)




Backscattered electron images of asbestos minerals

BREAK SECTION

Ορυκτά Διοξειδίου του Πυριτίου – Silica Minerals

Silica Minerals

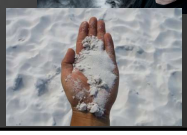
- Silica minerals (quartz, cristobalite, tridymite, chalcedony) are widespread on Earth
- They coexist with many industrial minerals (e.g. barite, bentonite, feldspars, talc, wollastonite etc.)
- They also occur in many rocks, sediments, and other construction materials (sand, granite, schists, etc.)

Exposure to Silica Minerals

- Silica occurs in significant amounts in the volcanic ash during volcanic eruptions
- Exposure may be occupational or even in our every day life (silica minerals are present even in the dust in our homes)
- Consequently most people expose to silica
- The main exposure pathway is the respiratory system

Exposure to Silica Minerals

- Occupational exposure may have significant adverse effects

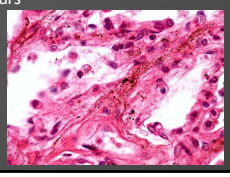


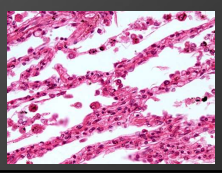
Exposure to Silica Minerals

- Occupational Exposure risk is high in employees:
  - Sandblasting
  - Rock Cutting
  - Mining and Quarries
  - Tunneling
  - Sand-casting foundry operations
  - Ceramic industry

Health Effects of Silica Minerals

- Hazardous, inhalable grains are hazardous when their average diameter is < 10μm
- In this case they can penetrate the lung sacs, where gas exchange occurs





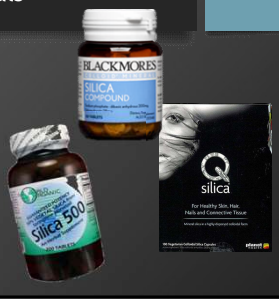
https://www.youtube.com/watch?v=vCcON72KcMA

Health Effects of Silica Minerals

- Recently, we understood that SiO_2 biominerals are necessary for good condition and health of humans (formation of collagen, elastin, cartilages and other connective tissues and contributes to the healthy appearance of skin)

Health Effects of Silica Minerals

- Silica minerals are thought to have an important contribution to the elasticity and biomineralisation capability of bones
- They prevent osteoporosis as they assist to the more effective uptake of Ca
- They are also thought to contribute to prevention of heart and arterial diseases



Health Effects of Silica Minerals

- Contribution of SiO_2 minerals to the healthy appearance of skin, hair and nails has attracted the interest of many cosmetic industries

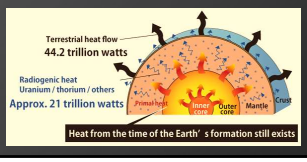
Silica - The Key To Strong Hair & Nails

Radioactivity and Radioactive Minerals

Types of Radioactive Emissions

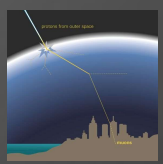
47

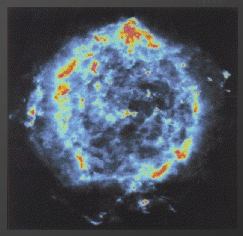
- Primordial: Occurs since the formation of Earth
- The relevant isotopes participate in the composition of minerals and rocks (^{235}U, ^{238}U, ^{232}Th, ^{236}Ra, ^{222}Rn, ^{40}K)



Types of Radioactive Emissions

- Cosmogenic: From cosmic radiation of the Universe





Types of Radioactive Emissions

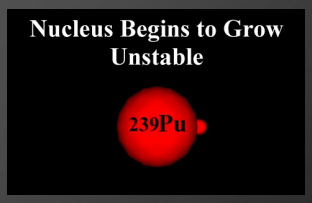
- Anthropogenic: Introduced to nature from human activities

Types of Radioactive Decays

- Alpha (α) decay
- Beta (β) decay
- Gamma (γ) decay

Alpha (α) Decay

- It is the spontaneous emission of α particles (^4_2He) from heavy radioactive nuclei



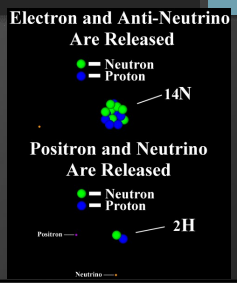
Beta (β) Decay

- It is the spontaneous emission of beta particles
- They may be either electrons (β^-) emitted from unstable nuclei during transformation of a neutron into proton:

$$n^o \rightarrow p^+ + e^- + \bar{\nu}_e$$

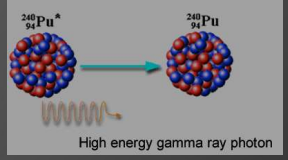
- or positrons (β^+) emitted from unstable nuclei during transformation of a proton into neutron

$$p^+ \rightarrow n^o + e^+ + \nu_e$$



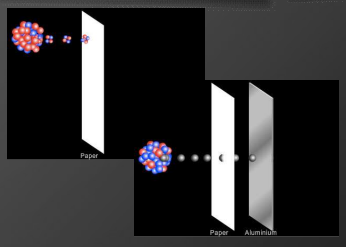
Gamma (γ) Decay

- It is the spontaneous emission of photons when radioactive nuclei drop from a high-energy state to low-energy state
- It is the only decay which does not cause transmutation



α, β and γ Radiations

- Alpha radiation can be readily stopped (absorbed) by a thin sheet of paper
- Beta radiation can be halted by a few mm aluminium plate
- It interacts with human body up to a depth of 30μm

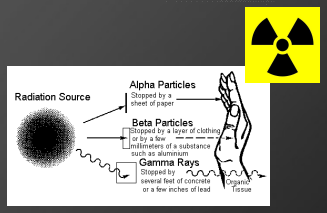


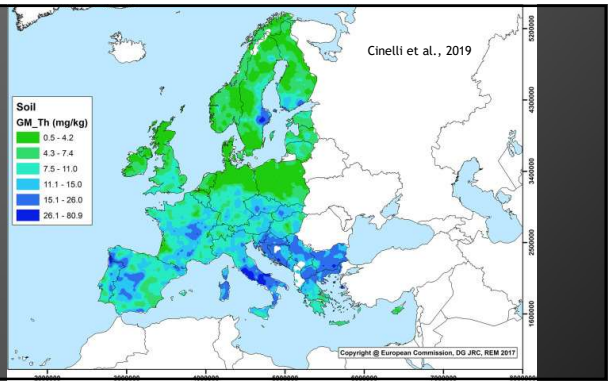
a, *B* and *y* Radiations

- Gamma radiation is the most penetrative and can be absorbed only by dense materials
- Thick lead (or several meters of concrete) can effectively absorb these highly energetic rays

a, *B* and *y* Radiations

- Gamma radiation penetrates the human body causing ionisation of the atoms of cells and tissues resulting in harmful effects and increased risks of cancer



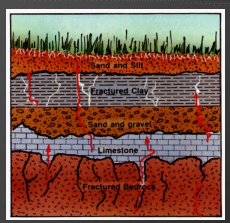


The Dangerous Radon (Rn)

- A daughter of the chain of the radioactive decay of ^{238}U
- Considerable contribution to the Earth's heat budget
- Rn and the next four daughter isotopes have short half-life periods
- It comprises an important radioactive source on Earth

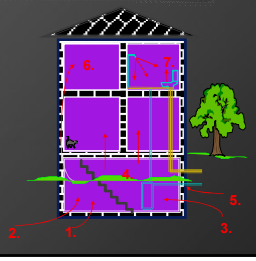
The Dangerous Radon (Rn)

- It is odourless, colourless gas, hence it escapes easily from cracks of rocks and minerals to the air (it is used as an indication for buried ores of U)
- Rn is mobile and hence it is largely liberated during earthquakes



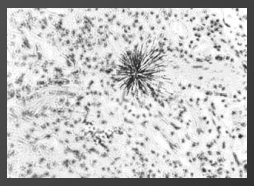
The Dangerous Radon (Rn)

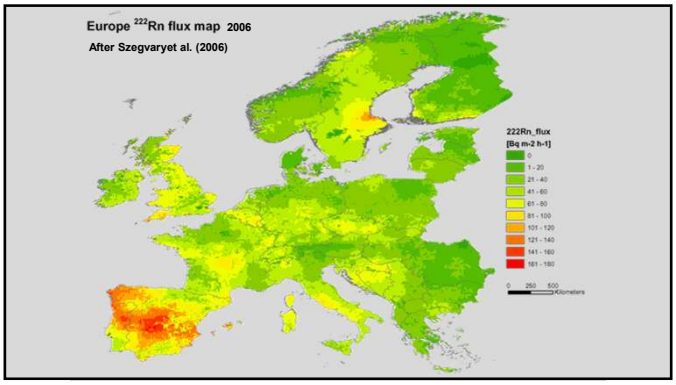
- It is abundant in rocks containing U-bearing minerals (granites, slates, coal)
- In the 1980's it was discovered that Rn participates in the construction materials, sometimes in considerable amounts

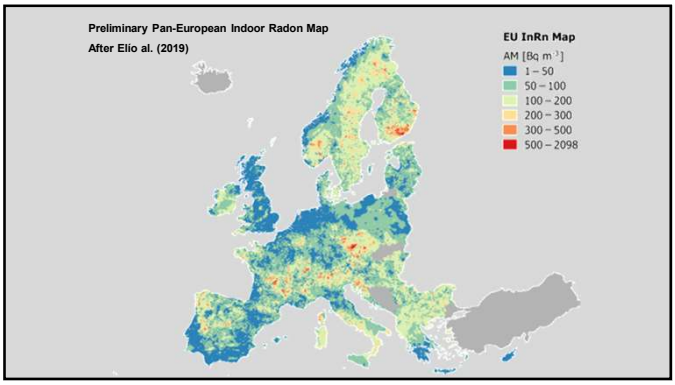


Radon and Cancer…

- Rn is related to lung carcinogenesis, as well as other forms of cancer
- Smokers show much higher health risk due to synergistic effect of smoking with radon exposure







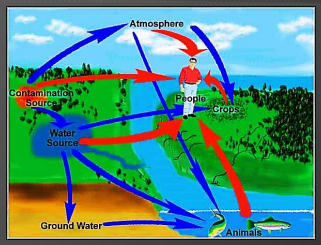
Sources of Rn

- Drinking water (lakes, rivers, groundwater, etc.)
- Rainwater (from concentration of Rn in the clouds)
- Air in the neighbouring areas of U mining activities (Rn is capable to travel along several thousands of km)

Radioactivity of Rocks

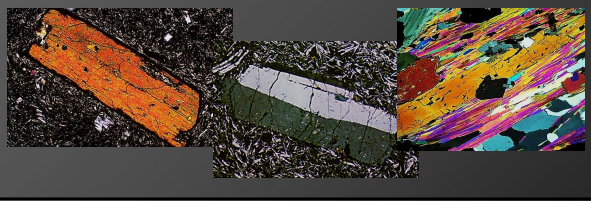
- Radioactivity of rocks (as well as all natural materials) is predominantly due to the presence of the isotopes of three elements: Uranium (^{238}U, ^{235}U), Thorium (^{232}Th) and Potassium (^{40}K)
- All of them are either main constituents of minerals or are capable to substitute for elements or ions in many minerals
- High U contents have been reported from some oil deposits (California), sandstones, acidic igneous rocks, high grade metamorphic rocks, tuffs and phosphate sediments
- High Th contents usually occurs in acidic-intermediate igneous rocks and detrital sediments (particularly clay minerals)

The “Radioactive”… Cycle



Radioactivity of Rocks

- Potassium is the main constituent of many essential minerals (K-feldspars, micas, amphiboles)



Radioactivity of Rocks

- High K contents occur in acidic to intermediate rocks, as well as in detrital sedimentary rock
- Their weathering easily liberates K, which is soluble and highly mobile and may migrate irrespective the pH conditions
- These materials can be radioactive to the degree they contain the radioactive isotope ^{40}K

Radioactivity of Rocks

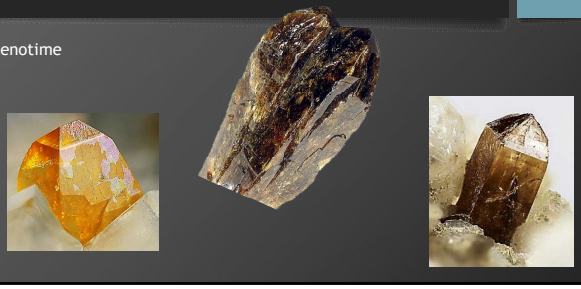
- Plutonic igneous rocks are frequently more radioactive than volcanic rocks
- Carbonate rocks contain the least, if any, amount of radioactive minerals
- Shales are considered as the most important hosts of radioactive minerals among the sedimentary rocks

Common Radioactive Minerals

- Monazite

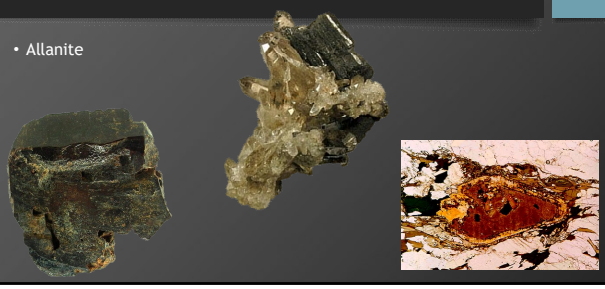
Common Radioactive Minerals

- Xenotime



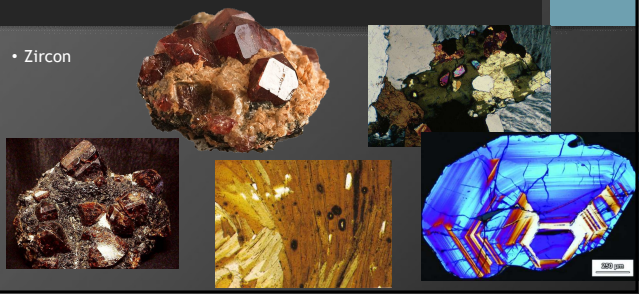
Common Radioactive Minerals

- Allanite



Common Radioactive Minerals

- Zircon

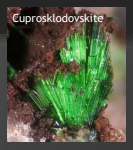


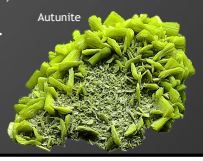
Common Radioactive Minerals

- Titanite

Radioactive Minerals

- Other rare radioactive minerals are uraninite, uranothorite, thorianite, uranophane, thorite, autunite, euxenite, cuprosklodovskite, fluorite, pyrochlore, chevkinite, bastnaesite, davidite, etc.


Cuprosklodovskite


Autunite

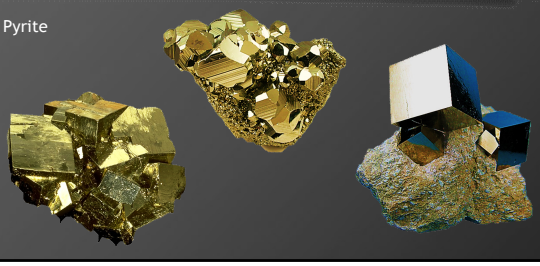

Uraninite

Potentially Radioactive Minerals

- Other minerals contribute with potentially low levels of radioactivity:
- Hematite

Potentially Radioactive Minerals

- Pyrite

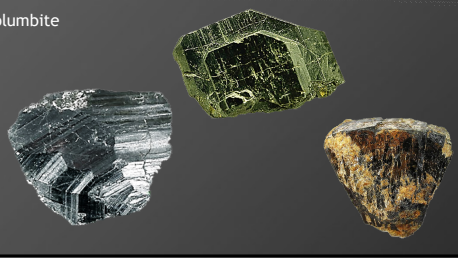


Potentially Radioactive Minerals

- Apatite

Potentially Radioactive Minerals

- Columbite



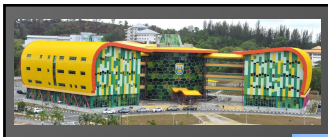
Potentially Radioactive Minerals

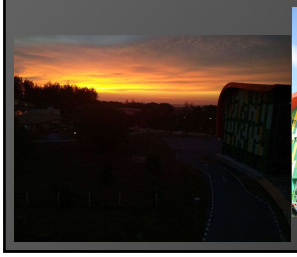
- Ilmenite

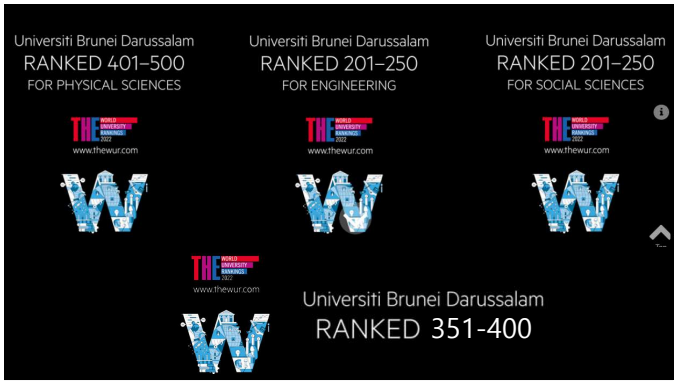
Potentially Radioactive Minerals

- Rutile

Μια σύντομη γνωριμία με το UBD







Geosciences and Faculty of Science in UBD

- https://www.youtube.com/watch?v=NhUc6Xvb5vI&t=41s
- https://www.youtube.com/watch?v=akeYx4yVbC8
- https://www.youtube.com/watch?v=lbd7wSzSNnw&t=3s

ΦΩΣ FACULTY OF SCIENCE
ubd NEWSLETTER

Geosciences in UBD

- Κάντε εγγραφή στο κανάλι μας στο YouTube:
  "*Geosciences at Universiti Brunei Darussalam*"
- Επίσης και στο κανάλι του Πανεπιστημίου στο YouTube:
  "*Universiti Brunei Darussalam*"
- Παρακολουθήστε το εταιρικό βίντεο του UBD:
  https://youtu.be/R0ax0H1Wkuo

NEXT