GEOL 20170: Geomaterials and Geoenergy

MODULE COORDINATOR: Assoc. Prof. Julian Menuge

ADDITIONAL LECTURERS: Dr Conrad Childs
Dr Laia Comas Bru
Assoc. Prof. Tom Manzocchi
Prof. Frank McDermott

CREDITS: 5	**MODULE LEVEL**: 2	**SEMESTER**: II

PRE-REQUISITES/PRIOR LEARNING:

Students should have a good background in introductory Geology and familiarity with the petrological microscope is desirable. This module will be offered for the first time in academic year 2017-2018 and the content remains subject to minor change.

OVERVIEW OF MODULE:

Through closely related lectures and laboratory classes, this module outlines the processes leading to the formation and behaviour of economic geomaterials and energy resources. Geomaterials covered include groundwater and the sources of metallic and non-metallic resources. Geoenergy resources covered include coal, conventional and unconventional hydrocarbons, wind, hydroelectric, ocean, solar, geothermal and nuclear energy. The use of and demand for geomaterials and geoenergy are explored, and strategies for transitioning to a clean energy future, including carbon capture and storage technologies, are discussed.

LEARNING OUTCOMES:

On completion of this module students should be able to:

1. Describe the properties of aquifers, their performance and threats to their water quality;
2. Explain the earth processes and conditions necessary for the formation of economically viable fossil fuel, nuclear and renewable geoenergy resources;
3. Outline the role played by geoscientists in the discovery and exploitation of geomaterial and geoenergy resources, and in the disposal of their waste products (nuclear waste; carbon capture and storage)
4. Discuss how a variety of types of economic mineral deposit form, in theory and by observation of rocks and thin sections, and describe the factors influencing their economic viability.

ASSESSMENT:

Continuous Assessment: 40%
(Continuous assessment of practical work)

Examination: 60%
(2-hour end of semester written examination covering entire course)

LECTURES:

Lecture 1: Hydrogeology: some physical aspects, part 1. *(Dr C.J. Childs)*
Introduction to principles of groundwater. Hydrological cycle and controls on water table elevation and fluctuation. Overview of aquifer types; confined and unconfined aquifers. Distinction between matrix and fracture porosity. Aquifer property definition including porosity, specific yield, hydraulic conductivity and storativity. Application of Darcy's Law to calculate rates of flow in confined and unconfined aquifers.

Lecture 2: Hydrogeology: some physical aspects, part 2. *(Dr C.J. Childs)*
Ground subsidence due to groundwater extraction. Pump testing to characterize aquifer properties. Patterns of groundwater flow; flow lines and equipotential lines. Topographic and geological control on groundwater flow and scales of flow systems. Salt water intrusion in coastal aquifers. Controlling and remediation of groundwater.

Lecture 3: Hydrogeology. *(Mr David Ball, Consultant Hydrogeologist)*
An introduction to practical hydrogeology by a professional hydrogeologist of over 40 years' experience. The lecture covers topics including from how to drill and case a well for a domestic water supply in Ireland to finding water in the Sahara.

Lecture 4: Global Trends in Energy Use. *(Assoc. Prof. T. Manzocchi)*
Historical and Projected energy balance: future usage scenarios; influence on climate. Global Energy trends: Oil, Gas, Coal; Nuclear; Hydroelectric, Solar, Wind; Biofuels. The global distribution of fossil Fuels.

Lecture 5: Sedimentary basins and Fossil fuel formation. *(Assoc. Prof. T. Manzocchi)*
Type and origin of sedimentary basins. Geothermal gradients. Deposition and mechanical compaction of sediment. Formation water, pore pressure. Under-compaction and over-pressure. The carbon cycle. Coal formation. Kerogen formation and types. Oil and gas chemistry. Hydrocarbon-associated gasses.

Lecture 6: Conventional Petroleum 1. *(Assoc. Prof. T. Manzocchi)*
The conventional Petroleum system. Source rocks. Preservation of high TOC. Measures of maturation. 1D Basin modelling. Primary and Secondary migration. Capillary pressure and capillary entry pressure.

Lecture 7: Conventional Petroleum 2. *(Assoc. Prof. T. Manzocchi)*
Seismic reflection data acquisition and interpretation. Structural and stratigraphic traps. Seals. Reservoir rocks. Porosity and Permeability. Diagenetic effects: cementation, authigenic clays. The Petroleum System chart.

Lecture 8: Unconventional Petroleum. *(Assoc. Prof. T. Manzocchi)*
Definitions and types. Production trends. Shale Gas and Shale Oil. Heavy Oil and Bitumen; Oil Shale; Gas hydrates. Clean Coal; Coal-bed methane.

Lecture 9: Selected Petroleum provinces of NW Europe. *(Assoc. Prof. T. Manzocchi)*
Tectonic and stratigraphic evolution of the North Sea. Rotliegend reservoirs. Brent reservoirs. Tertiary deep-water reservoirs. Production histories and forecasts: UK, Norway. Irish Petroleum Geology. The Corrib field. Exploration in the Irish Atlantic Margin. Conjugate margins.

Lecture 10: The future of Fossil Fuels. *(Assoc. Prof. T. Manzocchi)*
Long-term oil, gas and coal supply-cost curves. Carbon Capture and Storage (CCS). Enhanced Oil Recovery. The transition to clean energy: peak oil or stranded assets?

Lecture 11: Renewable energy 1. *(Dr L. Comas Bru)*
What is renewable energy? H2020 targets. Where does the wind come from? (incident solar radiation, geostrophic winds, local winds and surface winds). Wind energy potential in Ireland. Harvesting wind energy onshore and offshore. Wind power capacity and production in Ireland. Predictability of wind power. Critical metals for wind energy. Energy storage. Pumped storage plants (Turlough Hill) and dammed power stations (Ardnacrusha power plant).

Lecture 12: Renewable energy 2. *(Dr L. Comas Bru)*
Ocean energy potential. Technologies to harness waves' energy (WEC). Wave energy potential and test sites in Ireland (Carnegie Wave Energy Project). Technologies to harness tidal energy. Technological barriers to overcome. Ocean energy in Ireland. Global insolation patterns (potential of solar energy). Thermal energy. Electricity production (photovoltaics and concentrated solar power). Energy storage. Environmental impacts (production of panels, critical metals). Emerging technologies. Solar resource in Ireland. Integrated energy systems.

Lecture 13: Nuclear and geothermal energy. *(Prof. F. McDermott)*
Distinction between shallow and deep geothermal energy sources. Low- and high-enthalpy geothermal sources. Distribution of heat producing elements in the Earth's crust. Exploitation of geothermal energy in high- and low-enthalpy settings. Potential geohazards associated with geothermal energy exploitation. Advantages of geothermal in an integrated energy system that have high levels of intermittent renewables. Fundamentals of nuclear fission and nuclear power plants. Nuclear waste, inventories and storage options. Update on nuclear fusion research.

Lecture 14: Introduction to ore deposits; hydrothermal fluids. *(Assoc. Prof. J.F. Menuge)*
Ore deposits – ore and industrial minerals; geological processes concentrating metals; reserves and resources; factors affecting economic viability; evidence for the existence of hydrothermal fluids; chemical and physical properties of hydrothermal fluids in the upper crust; fluid inclusion analysis; causes of metal solubility and deposition; hydrothermal alteration; isotopic evidence for the origin of hydrothermal fluid components.

Lecture 15: Granite-related tin-tungsten and volcanogenic massive sulphide deposits. *(Assoc. Prof. J.F. Menuge)*
Distribution of tin-tungsten granite deposits; the Cornish polymetallic vein deposits as an example: mining history, spatial and temporal variations in vein type, geochronology of granite intrusion, cooling and mineralization. Kuroko-type VMS deposit characteristics: the Avoca deposits as an ancient example; black smokers and Cyprus-type VMS deposits; Abitibi-type VMS deposits; fluid origin and mineral precipitation in VMS deposits.

Lecture 16: Irish gold and orogenic gold deposits *(Assoc. Prof. J.F. Menuge)*
Gold deposits in the Dalradian of Co. Tyrone and the Lower Palaeozoic of south Co. Mayo – geological setting, paragenesis, age, origin of mineralizing fluids and gold; orogenic gold deposits worldwide – isotopic evidence for fluid sources; amphibolite facies metamorphism and gold sources.

Lecture 17: Carbonate-hosted ore deposits. *(Assoc. Prof. J.F. Menuge)*
The Irish midlands orefield and the distribution of Irish-type zinc-lead deposits; the Navan and Lisheen deposits as examples – geological history, hydrothermal mineralogy, fluid inclusion constraints; models for Irish-type deposit formation. Comparison of Mississippi Valley-type and SEDEX deposits with Irish-type deposits.

Lecture 18: Rare metal ore deposits. *(Assoc. Prof. J.F. Menuge)*
The industrial needs for rare metals; the markets for rare metals; rare metal concentration processes and rare metal-rich rocks – pegmatites, carbonatites, laterites, sulphide liquids, brines; examples of rare metal ore deposit types; rare metal supply and demand; the critical metals concept.

Lecture 19: Industrial Mineral Deposits 1. *(Assoc. Prof. J.F. Menuge)*
Definition of industrial minerals; dimension stone; sedimentary processes that weather, erode, sort, concentrate and deposit minerals; sand and gravel deposits and their uses; mineral sands as sources of heavy minerals; laterites including clays, bauxite and supergene metal deposits.

Lecture 20: Industrial Mineral Deposits 2. *(Assoc. Prof. J.F. Menuge)*
Chemical and biochemical precipitation processes; limestones, lime, cement and concrete; gypsum deposits and plaster; phosphate, nitrate and halite deposits; industrial minerals in igneous rocks – quartz, feldspar, mica, chromite; metamorphic talc and graphite; the scale of industrial mineral use.

PRACTICAL CLASSES:

Practical 1: Hydrogeology I. *(Dr C.J. Childs)*
Construct a contour map of a potentiometric surface from borehole data and evaluate how a producing well will perturb groundwater flow.

Practical 2: Hydrogeology II. *(Dr C.J. Childs)*
A range of standard hydrogeological formulae are used to calculate groundwater storage, flow and well production in 6 questions based on different input hydrogeological parameters.

Practicals 3 - 6: The Oil Game. *(Assoc. Prof. T. Manzocchi)*
Form teams of oil companies, bid for exploration licenses. Weekly updates of drilling results lead to improved understanding of the prospects. Two plays: reef deposits forming structural traps, and a sub-unconformity stratigraphic trap.

Practical 7: Estimating the energy output of a wind turbine. *(Dr L. Comas Bru)*
Use of wind data to estimate energy production of a wind turbine. Evaluate wind turbine power curves. Assess the relationship between wind speed and capacity factor as well as their uncertainties and limitations. Evaluate advantages and disadvantages of wind and solar energy.

Practical 8: Cornish tin-tungsten ores. *(Assoc. Prof. J.F. Menuge)*
Description of Cornish granite-hosted Sn-W veins in hand specimen, and analysis of a virtual microscope thin section, to determine mineralization processes.

Practical 9: Abbeytown zinc-lead ores. *(Assoc. Prof. J.F. Menuge)*
Description of sphalerite-galena-iron sulphide from the Abbeytown base metal deposit, Co. Sligo, in hand specimen, and analysis of a virtual microscope thin section, to determine mineralization processes.

Practical 10: Rare metal ores in pegmatites. *(Assoc. Prof. J.F. Menuge)*
Description and analysis of spodumene pegmatite hand samples, thin sections and chemical maps, to interpret sequence of crystallization and rare metal enrichment processes.