Earth Science Honours Course Frameworks *(status 2020)*

The following module and submodule descriptions serve as a general guideline and are valid for 2020 only. Submodules content and lecturers can change from year to year to optimize the programme. Updated course frameworks will be posted on SUNLearn and will be available to students enrolled in the Programme of the specific year.

Compulsory modules

54895 - 795 Research Project
12240 – 771 Geology of Southern Africa
- Geology of South Africa (Kisters)
- Sedimentology (Tucker)
- Field tour (vdHeyden,)

12241 - 772 Research Methods in Earth Sciences
- Geostatistics (tba)
- GIS (Olivier, tba)
- Introduction to sampling, analytical methods and record keeping (tba , CAF staff)
- Writing Skills (Miller; not assessed)

12242 - 773 Special Topics in Earth Sciences: Two Special

Stream A – Applied Geology

12243 - 712 Concepts in Crustal Evolution
- Structural Geology (Kisters)
- Igneous Petrology (Stevens)
- Metamorphic Petrology (Mayne)
- Geochronology (Miller)

12247 - 742 Economic Geology
- Geological Modelling (Basson)
- Mineral Economics (von der Heyden)
- Ore Microscopy (von der Heyden)
- Geophysics (tba)

Stream B – Environmental Geochemistry

12244 - 714 Hazardous Waste Site Assessment
- Introduction to soil and rock mechanics (Roychoudhury)
- Hazardous Waste Assessment (Roychoudhury)
- Geohydrology (Roychoudhury)
- Analytical techniques (Roychoudhury)

12275 - 744 Environmental Systems
- Climate of the Past (Fietz)
- Climate change: present and future (Fietz)
- Marine Geochemistry (Fietz)
- Environmental Isotope Geochemistry (Miller)

Geology of South Africa (12240 771)

Prof. A. Kisters

The two-week module is taught daily. Lectures are 1-2 hours and involve a flipped class-room environment in which respective classes are taught and developed based on material that was handed out the previous day for self-study. Each day will be concluded by a short, ca. 10 minute test in which the students will be quizzed about aspects of the previous lecture and the studied material.

Topics that are prerequisites for this course – Structural and Economic Geology, Igneous and Metamorphic Petrology, Sedimentology and Tectonics

Specific topics

- Archean Geology - TTG-greenstone belts and crustal evolution
- Neo-Archaean basins - Wits, Pongola, Dominion, Ventersdorp, etc.
- Paleoproterozoic sedimentation and volcanism
- Mesoproterozoic events – Kheis, BIC, Vredefort, Waterberg/Soutpansberg
- Neoproterozoic evolution – Namaqua Natal Metamorphic Belt
- Pan-African belts – rifting to collision
- Phanerozoic basins – Cape, Karoo, Gondwana break up
- Recent uplift history

Sedimentology (12240 – 771) Earth's Rock Record

Dr Ryan T Tucker

This course is typically taught as a two weeks long module consisting of six lectures, student presentations and one fossils practical

Topics and concepts that Honours students are expected to be familiar with from 2nd and 3rd year undergraduate Applied Geology lectures, include:

- Tectonics and plate boundaries
- Sediment transport and deposition
- Facies and paleoenvironmental reconstruction
- Stratigraphy and correlation
- Chronostratigraphic chart

Topics and concepts covered during the Honours module

- Earth's tectonic cycles including super continental cycles
- Basin development in response to plate tectonism
- Patterns of basin sedimentation
- Tectono-sedimentary histories
- Paleo-archives and paleo-proxies used for paleoenvironmental reconstructions
- Broad-scale reconstructions for the Paleozoic, Mesozoic, and Cenozoic
- Biological records reflecting geological processes
- Climatic records reflecting geological processes
- Extinction events and patterns of post-recovery
- Key events in the fossil record

Field Tour (12240- 771)

Dr Bjorn von der Heyden

The Honour's Field School forms an integral component of the broader GEO771 Geology of South Africa module. The field tour runs over a period of two weeks and has a strong focus on the geology and environmental geochemistry of the Southern African minerals extraction industry. During the tour, students will visit up to ten different mineral resources operations, including both underground and opencast mines, and minerals exploration sites. Students will have the opportunity to engage with industry-based professional geologists, and will be exposed to mining operations and minerals beneficiation plants. Additionally, emphasis will be placed on the environmental impacts of the mining sector, whereby tailings facilities will be visited and students will have the opportunity to engage with Environmental and Geohydrology personnel. Over-and-above the mine visits, the tour will incorporate field stops at various geological exposures and geochemical sites of interest, to provide students with experiential learning opportunities of the geology of South Africa.

Geostatistics (12241- 772)

Dr Bjorn von der Heyden

This course is typically taught as a one week long module consisting of 6 - 12 hours of formal lectures and substantial project-based and scientific literature-based self-study time.

The course aims to provide students with a basic overview of the quite extensive field of Geostatistics and covers the following broad themes.

1. Basic statistical theory and concepts
2. Importance of good data sampling and Quality Assurance Quality Control (QAQC)
3. Exploratory data analysis (univariate and bivariate statistics)
4. Methods of interpolation
5. Spatial continuity and the semivariogram
6. Measuring and applying anisotropy to semivariogram modelling and kriging
7. Use of SGeMS statistical software
8. Model validation and hand-over

GIS (12241- 772)

George Olivier, Room 1037, Chamber of Mines Building, Stellenbosch Campus

This course is typically taught as a 2 week module consisting of formal lectures and live demonstrations during the first week and self-work time to complete assignments during the second week.

The course makes use of ArcGIS. The aim of the GIS for Geologists short course is to provide you with a working knowledge of ArcGIS. In order to achieve this the course will take a practical hands-on approach, limiting theory work to the basics. After completion of the course you should be able to problem-solve basic problems and errors in ArcGIS, display, explore and analyse spatial data.

Themes covered during the course:

- Vector and Raster data types
- Projections
- Georeferencing
- Drone photography
- Problem-solving error messages when working in ArcGIS
- GPS
- MCE analyses
- DEM and hydrological analyses (basics)
- Data mining
- Sources of spatial data sets

Introduction to Minerals Processing for Geologists (12242 – 773)

Subject	Minerals Processing
Presenter	Prof Jodie Miller
Overview	This module consists of 4 contact classes of different types, as well as 4 assessments of different types. Two site visits are included, one to UCT and one to SU minerals processing laboratories. This module is an examination module.
Synosis	Introduction to minerals processing for geologists is an introductory module to help geologists understand what happens to ore once it leaves the mining environment and makes its way to the processing plant. The three main stages of processing are covered: (1) comminution; (2) separation; and (3) extractive metallurgy. The lecture material is supported by both practical calculation exercises as well as interactive site visits to the process mineralogy laboratories at both UCT and SU. The module is suitable for both applied earth science student and environmental geochemistry students as the environmental impacts of treating ores as well as the use and treatment of mine water is dealt with.
Course Structure	L1 Overview of Minerals Processing L2 Site visit to UCT Centre for Minerals Research L3 Site visit to SU Process Mineralogy L4 Practical exercises

Structural Geology (12243 - 712)

Prof Alex Kisters

The two-week module formally involves six set contact sessions (1-2 hours) over a period of two weeks (Mon, Wed, Fri), but the applied nature of the course requires a bit more flexibility and at least one day will be spent in the field, practising data collection and subsequent report writing. This will be discussed and coordinated with students at the very beginning of the module.

Topics that are prerequisties for this course – Structural Geology and Tectonics, Economic Geology, Igneous and Metamorphic Petrology, Sedimentology

Specific topics

- Cross-section construction and interpretation from selected regional and detailed maps
- Kinematic indicators, uses, pitfalls, sampling, exercises
- Stereographic projection – advanced techniques and applications
- Structural controls of fluid flow and applications
- Structural mapping and subsequent presentation of results and report
- Applications of the Mohr stress circle

Igneous Petrology (12243 712)

Metamorphic Petrology (12243 712)

Dr Matthew Mayne

This course is taught as a two week long module with 5x 2h long formal lecture sessions, online tests, a final practical task/test and a formal exam. This module will require substantial self-study time.

Topics and concepts that Honours students are expected to be familiar with from 3rd year undergraduate Metamorphic Petrology and Tectonics lectures, include:

- Metamorphic minerals and facies
- Phase equilibria and basic thermodynamics
- Garnet geothermobarometry

Topics and concepts covered during the Honours module

- Advanced graphical analysis of metamorphic rocks.
- Application of P-T, T-X pseudosections to understanding a range of metamorphic processes.
- Quantifying metamorphic fluid/rock interaction through reaction progress, resetting of stable isotope geochemistry or metasomatism.
- Garnet major and trace element geochemistry as an aid to understanding equilibrium and non-equilibrium metamorphic processes
- The major and trace element geochemistry of accessory minerals in metamorphic rocks.

Geochronology Framework (12243 - 712)

Module	Concepts in Crustal Evolution 712
Sub-Module	Geochronology
Presenter	Prof Jodie Miller
Overview	This module consists of 10 lectures and three assessments, which make up your class mark for this module and a test. There will also be an examination component for the geochronology sub-module.
Synosis	The geochronology honours module aims to give you a basic introduction to the dating of rocks and minerals in different environments. The introduction will focus on Rb-Sr to illustrate the isochron method of dating and then look at the Sm-Nd and U-Th-Pb methods of dating and the use of Concordia digrams. Analysis of error propagation and different sources of error are covered, as well as different analytical techniques. The age of the Earth and meteorites and the determination of model ages are discussed and assessed in context with the crustal evolution of the planet. Cosmogenic isotopes are introduced towards the end of the course and their application to different systems discussed. Students are expected to be able to assess datasets and to determine the right methodology for dating different rocks and minerals at the end of the module.
Course Structure	L1 History of geochronology L2 Revision of isotopes and radioactive decay L3 Rb-Sr system and isochrons L4 Sm-Nd isotopes and isochrons L5 Model ages and crustal evolution L6 U-Th-Pb dating L7 The age of meteorites and the Earth and common Pb evolution L8 Diffusion, closure temperatures, error propagation and measurement L9 Mineral reactions and their bearing on geochronology L10 Carbon 14 dating and cosmogenic isotopes Students are expected to attend all classes.

Geological Modelling (12247 – 742)

taught by external lecturer

Mineral Economics (12247 – 742)

Dr Bjorn von der Heyden

This course is typically taught as a two week long module consisting of 12 - 15 hours of formal lectures and substantial project-based and scientific literature-based self-study time (35 hours).

Topics and concepts that Honours students are expected to be familiar with from 3rd year undergraduate Economic Geology (GEO344), include:

- Metallogeny and the genesis of ore deposits
- Earth materials of economic value, and their associated commodity cycles

The course is designed to provide students with a comprehensive overview of the field of mineral economics, with specific focus on the factors to consider when developing a financial model for mineral asset evaluation. Additional topics include the role of the geologist in the mine value chain, the status of the global and the South African minerals sectors, and the legislative frameworks applicable to the mining industry and to resource and reserve reporting.

Ore Microscopy (12247 – 742)

Dr Bjorn von der Heyden, Room 2023, Chamber of Mines Building, Stellenbosch University

This course is typically taught as a two week long module consisting of six hours of formal lectures, additional six hours of lecturer contact time, and substantial practical based exposure to the optical microscopes.

Students are expected to have a working knowledge of the optical microscope as developed during their undergraduate course on transmitted light microscopy.

Through the duration of the course, students will develop a sufficient level of expertise to identify common ore minerals using colour, reflectance, hardness, texture, anisotropy, bireflectance and ore paragenesis as identifying properties. Students will be expected to identify and describe ore parageneses in polished blocks and will be expected to relate these to standard ore deposit types, as understood from their third year GEO344 curriculum.

Geophysics (12247 – 742)

tba, Chamber of Mines Building, Stellenbosch Campus

taught by external lecturer

Hazardous Waste Site Assessment (12244 -714) (for 2020)

Analytical techniques - Waste Site Assessment - Introduction to Soil and Rock Mechanics

Prof A Roychoudhury

This course comprises of three two weeks long submodules: **Analytical techniques**, **Waste Site Assessment** and **Introduction to Soil and Rock Mechanics**. Each submodule consisting of 12h of formal lectures, substantial self-study time and maybe 1-2x3h-long seminars/practical sessions as required.

Honours students are expected to be familiar with concepts from their undergraduate Environmental Geochemistry, Chemistry and Geology modules, which include:

- Fundamentals of physical chemistry, acid-base and redox reactions
- Evolution of water chemistry
- Thermodynamics and kinetics of biogeochemical processes affecting speciation of ions
- Working knowledge of wet chemistry laboratory and safety protocols
- Knowledge of geochemistry of minerals and rocks

Topics and concepts covered in **Analytical Chemistry submodule**

- Basic statistical methods and data analyses including data quality
- Environmental analytical process and method development
- Equipment and techniques for safe collection of contaminated water and sediment samples
- Advanced methods for environmental sample analyses – ion chromatography, flow-injection analyses and synchrotron based techniques for particle chemistry analysis

Topics and concepts covered in **Waste site analysis submodule**

- Methods and method selection to assess waste sites
- Manual and automatic equipment used for collection of environmental samples
- Procedures for collecting water and sediment samples for contaminant assessment
- Advanced methods for environmental sample analyses – ion chromatography, flow-injection analyses and synchrotron based techniques for particle chemistry analysis
- Integrated site characterization, monitoring and remediation
- Above and below ground site reconnaissance and detailed characterization
    - Flow system characterization
    - Geological aspects of site characterization including lithology, structure and geohydrology
- Non-invasive Geophysical techniques for subsurface site characterization
    - Resistivity survey
    - Seismic survey
    - EM survey

Topics and concepts covered in **Introduction to Soil and Rock Mechanics submodule**

- Physical and chemical weathering and formation of different soils
- Index parameters for cohesive and non-cohesive soils
- Engineering characterization/classification of soils
- In-situ and laboratory tests for testing strength of material
    - Mohr-Coulomb theory of rock failure
- Engineering classification of intact rocks
- Drilling and excavation techniques
    - Drilling for collection of intact or disturbed core samples
    - Various Percussion and Rotary drilling techniques
    - Borehole logging
- Blasting design and blasting for safe removal of material
- Excavation
    - Scraping, ripping and digging and equipment used
- Slope Stability analysis
    - Typical soil and rock slope failures (Rotational and planer failures)
    - Force field analysis - coefficient of friction, Stress and strength
    - Factor of safety analysis
    - Slope failure in mine pits and waste sites

Marine Geochemistry Framework (12244 -714)

Dr Susanne Fietz

This course is typically taught as a two weeks long module consisting of 12h of formal lectures, 1-2x3h-long seminars/practical sessions, and substantial self-study time.

Topics and concepts that Honours students are expected to be familiar from 2nd year undergraduate Environmental Geochemistry lectures, include:

- Basics of physical oceanography
- Sources of chemical species in the open ocean: air-sea interface, riverine, hydrothermal inflow
- The ocean reservoir: water column parameters, chemical composition
- Chemical and biological controls
- Residence times

Topics covered during the Honours module

- Distribution of chemical species in the ocean, including links between geochemistry and biology as well as internal cycling
- Use of international data repositories and Ocean Data View
- Marine carbon cycle: processes driving CO_2 dissolution, alkalinity, Revelle factor, and ocean acidification
- Particle sinking: downward flux, scavenging, and processes at the benthic boundary layer
- Natural processes at the water sediment interface, porewater chemistry
- Role of estuaries in the marine ecosystem
- Marine sediments: Distribution, components, diagenesis
- Anthropogenic impacts, e.g.
    - Seabed mining
    - Radioactivity in the marine environment
    - Marine plastic pollution, from surface to sediment
    - Toxic metals, from surface to sediment
    - Oil spills in South Africa and current status of remediation

Global Climate Change (12275 – 744)

Dr Susanne Fietz

This course is taught in two submodules, both in 2nd semester

1) **Climate of the Past**

A two weeks-long submodule consisting typically of 12 core lectures, 1 seminar/practical session and substantial self-study time.

Topics and concepts covered during the Honours **Climate of the Past** submodule

- How do we know about past, i.e. natural climate changes?
    - Archives and proxies used for paleo-climate reconstructions
    - International core repositories, data repositories, and working with large data sets
- What was the extent and rate of past (natural) climate change?
    - Long-term changes up to ca. 100 000 years ago, focus on climate of the past as modern analogues, e.g. PETM, Glacial/Interglacial changes
    - Changes since the last Interglacial: LGM and DO, H events
    - Holocene, focus on the last 1000 years (e.g. Little Ice Age)
- Do these past, natural changes correspond to observed changes in the Anthropocene?
    - Recent climate changes since industrial revolution
    - Review of driving factors, feedback processes, and paleo-sensitivity

2) **Climate Change: present and future**

A two weeks-long submodule consisting typically of 12 core lectures, 1 seminar/practical session and substantial self-study time.

Topics and concepts covered during the Honours **Climate Change: present and future** submodule

- Overview of extent and rate of past, natural climate changes
    - Review of driving factors, feedback processes
    - Making sense of paleo-sensitivity
- Current changes and impacts:
    - Changes of the last 100 years
    - Impacts of climate change: global and local examples
- The future looks ..
    - Role of IPCC; scenarios and lessons for the future
    - Concept of tipping points
- Why do we need geochemists in the climate debate?
    - Global biogeochemical cycles in a changing world, focus on C, N, and S
    - Geoengineering tools for climate mitigation

For both submodules:
Topics and concepts that Honours students are expected to be familiar with from 2nd year undergraduate Environmental Geochemistry lectures, include:

- Concepts of weather vs. climate
- Atmospheric gases, incl. molecular structures of greenhouse gases
- Earth energy budget, incl. calculations
- Isotopes, especially Rayleigh Effect

Geohydrology (12275 – 744)

To be developed by new lecturer in 2020

Environmental Isotope Geochemistry (12275 – 744)

Module	Environmental Systems 744
Subject	Environmental Isotopes
Presenter	Prof Jodie Miller
Overview	This module consists of 6 lectures of varying length, one assignment with an oral presentation and several ad hoc in class assessments to test understanding of concepts. Your class mark for this module will be made up of the assignment, the oral presentation, as well as small in class exercises. There will also be an examination component for the isotope geochemistry sub-module during the end-of-year exams
Synosis	The isotope geochemistry honours module aims to give you a basic introduction to the application of isotopes to the environmental sciences. There will be a focus on revision and reinforcement of basic concepts to help you in understanding how both stable and radiogenic isotopes work and the application of isotopes to solving environment problems. There is a strong emphasis on isotope hydrology but other areas are also examined. The lectures will cover a limited number of isotope systems but you are encouraged to investigate others and to understand the advantages and disadvantages of each. The topics covered in this course are outlined below. They are by no means an exhaustive list of isotopes and applications but are designed instead to highlight the great utility of isotopes for a myriad of problems.
Course Structure	L1 Isotope geochemistry revision L2 The meteoric system – O and H isotopes L3 Radioactive dating of groundwater systems L4 Mass dependent vs mass independent fractionation L5 The carbon and nitrogen isotope cycles L6 Sr isotopes as tracers of terrestrial and marine processes