# Earth Science Honours Course Frameworks *(status Jan 2021)*

**The following module and submodule frameworks are valid for 2021 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 (credits = 80)**

54895 - 795 (35 credits) Research Project
12240 - 771 (20 credits) Geology of Southern Africa
Both streams: Sedimentology (Tucker) 5 credits
Both streams: Field tour (vd Heyden) 5 credits
Applied Geo: Geology of South Africa (Kisters) 10 credits
Env. Geochem: Hydrogeology (Chow) 10 credits
12241 - 772 (15 credits) Research Methods in Earth Sciences
Geostatistics (vd Heyden & external) 5 credits
GIS (Olivier) 5 credits
Introduction to sampling, analytical methods and record keeping (Fietz & CAF staff; not assessed) 2.5 credits
Writing Skills (not assessed) 2.5 credits
12242 - 773 (10 credits) Special Topics in Earth Sciences: Two Special topics, each worth 5 credits
**plus**
Earth Science seminars

**Choice of one stream (credits = 40)**

**Stream A – Applied Geology (credits = 40)**

12243 - 712 (20 credits) Concepts in Crustal Evolution
Structural Geology (Kisters) 5 credits
Igneous Petrology (Stevens) 5 credits
Metamorphic Petrology (Mayne) 5 credits
Geochronology (Tucker) 5 credits
12247 - 742 (20 credits) Economic Geology
Geological Modelling (external) 5 credits
Mineral Economics (von der Heyden) 5 credits
Ore Microscopy (von der Heyden) 5 credits
Geophysics (external) 5 credits

**Stream B – Environmental Geochemistry (credits = 40)**

12244 - 714 (20 credits) Hazardous Waste Site Assessment
Analytical techniques (Roychoudhury) 5 credits
Intro. to soil and rock mechanics (Roychoudhury) 5 credits
Hazardous Waste Assessment (Roychoudhury) 5 credits
Env. Isotopes (Fietz/Chow/Roychoudhury) 5 credits

12275 - 744 (20 credits) Environmental Systems
Climate of the Past (Fietz) 5 credits
Climate Change: Present and Future (Fietz) 5 credits
Marine Geochemistry (Fietz) 10 credits

## Geology of South Africa (12240 771)

Alex Kisters, 10 credit module

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 prerequisties 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

## Geohydrology (12240 - 771)

Dr. Reynold Chow, 10 credit module

This course takes place over two weeks consisting of about 16 hours of lecture over eight days (2 hours of lecture per day). Two days will be dedicated to student presentations where students will choose a specific hydrogeological contaminant transport case study to present. Online quizzes, a practical assignment, and a final exam will also be part of the evaluation.

Concepts students should be familiar from 3$^{rd}$ year undergraduate Hydrogeology lectures include:

- Hydraulic head and gradients
- Hydrogeologic properties (e.g., hydraulic conductivity, specific storage, porosity, etc.)
- Darcy's Law
- Hydrostratigraphy and aquifer types (e.g., confined, unconfined, perched, aquitards)
- Drilling and well installation methods
- Methods to obtain hydrogeologic properties (e.g., permeameter, slug tests, pumping tests)

Topics and concepts to be covered in this Honours module:

- Groundwater resource management – the paradox of safe yield
- Common and emerging groundwater contaminants
- Solute transport – advection, mechanical dispersion, and molecular diffusion
- Transport of reactive solutes
- Groundwater remediation

## Sedimentology (12240 – 771) Earth's Rock Record

Dr Ryan T Tucker, Chamber of Mines Building, Stellenbosch Campus

5 credits

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, Room 2023, Chamber of Mines Building, Stellenbosch University

5 credits

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, Room 2023, Chamber of Mines Building, Stellenbosch University

5 credits

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

5 credits

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

## Structural Geology (12243 - 712)

Alex Kisters

5 credit module

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)

Prof Gary Stevens, Room 2008, Chamber of Mines Building, Stellenbosch Campus

5 credits

This course is typically taught as a two week long module consisting of approximately 14 hours of formal lectures, substantial self-study time and a written assignment.

Topics and concepts that Honours students are expected to be familiar with from their undergraduate Earth Science course:

- Chemical classification of igneous rocks
- Igneous rock nomenclature
- Mineral chemistry and the trace element affinity of different mineral groups
- Tectonic environments on Earth associated with igneous activity

Topics and concepts covered during the Honours module

- Incongruent melting of rocks and the behaviour of incompatible and compatible elements during melt-residuum segregation
- Tectonic environments on Earth associated with igneous activity
- Fundamentals of anataxis in the mantle and in the crust
- Flux of matter between crustal and mantle reservoirs during partial melting of crustal and mantle sources
- Processes that shape the chemistry of igneous rocks
- Igneous processes in the formation of high-temperature mineral deposits

## Metamorphic Petrology (12243 – 712)

Dr Matthew Mayne, Room 2015, Chamber of Mines Building, Stellenbosch Campus

5 credits

This course is taught as an online two week long module with 5x 2 hour blended learning sessions, a module long marked assignment and online assessment. 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

- Interpreting the field context of metamorphic rocks
- Metamorphic applications of analytical techniques
- Data handling
- Advanced graphical analysis of metamorphic rocks.
- Application of P-T, T-X pseudosections to understanding a range of metamorphic processes.
- 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 (12243 - 712)

Dr Ryan Tucker, Room 2014a, Chamber of Mines Building, Stellenbosch Campus

5 credits

This two-week intensive subject addresses the utility of geochronology in tectonic and sedimentary systems with a hands-on approach to applying geochronological theory and data within real-world scenarios. In particular, this course takes a theoretical (week one) and practical approach (week two) to better understand the typical minerals for age dating (Ar/Ar or U/Pb), the varied methods of data recovery (SHRIMP, TIMS, LA-ICPMS), and the application of said data once processed, including the pitfalls for each. During the later phases for this class, it will critically assess zircon's ($ZrSiO_4$) utility and versatility in geological studies. While working with zircon data, students will be expected to: process raw U/Pb data, assess recovered grain ages via ISOPOLT and Age Pick and formulate meaningful linkages between grains age and source terrain via the KS-Test. Over the two week course, students will particularly address questions concerning: 1) development of new strategies for improving the age constraint of clastic stratigraphic successions and tectonic events through the application of mineral geochronology, and 2) coupling these results to address the timing and pattern of basin development and other major events preserved in earth's rock record.

## Mineral Economics (12247 – 742)

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

5 credits

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

5 credits

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.

**Hazardous Waste Site Assessment (12244 -714)**

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

Prof A Roychoudhury, Room 2009, Chamber of Mines Building, Stellenbosch Campus

15 credits

This course comprises of three two weeks long submodules: **Analytical techniques** (5 Credits), **Waste Site Assessment** (5 Credits) and **Introduction to Soil and Rock Mechanics** (5 Credits). 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 -744)**

Dr Susanne Fietz, Room 2010, Chamber of Mines Building, Stellenbosch Campus

10 credits

This course is typically taught as a two weeks long module consisting of formal lectures, seminars/practical sessions, substantial self-study time and if possible a field day.

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

These topics will be reviewed again at Honours level, esp. for the benefit of external Honours students.

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, Room 2010, Chamber of Mines Building, Stellenbosch Campus

10 credits (5+5 for each sub-module)

This course is taught in two submodules, i.e. 2x two weeks-long submodules consisting typically of core lectures, seminar/practical session and substantial self-study time.

1) **Climate of the Past** (5 credits)

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** (5 credits)

A two weeks-long submodule consisting typically of core lectures, 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 Climate Change submodules:**
Topics and concepts that Honours students are expected to be familiar with from 2$^{nd}$ 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