GEOS343

Magmas, Ores and Geochemistry

S2 Day 2018

Dept of Earth and Planetary Sciences

Contents

General Information

Unit convenor and teaching staff
Bruce Schaefer
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Credit points
3

Prerequisites
GEOS207 and GEOS272

Corequisites

Co-badged status

Unit description
This unit explores the behaviour and evolution of silicate magmas and aqueous fluids in both the crust and mantle. We use examples of mafic/ultramafic and intermediate-silicic magmatic rock associations, and their associated fluids and ore deposits to investigate the geochemistry and petrology of magmatic systems. Such associations are investigated from a deposit to mantle domain scale. Physical attributes of magma-fluid systems and isotopes are considered as exploration and petrogenetic tools. Important ore deposits in sedimentary basins are also considered. Practical work involves integrating geochemical databases with microscopic investigation of key magmatic suites.

Important Academic Dates

Information about important academic dates including deadlines for withdrawing from units are available at https://www.mq.edu.au/study/calendar-of-dates

Learning Outcomes

On successful completion of this unit, you will be able to:

an understanding of the genesis and geochemistry of the major igneous rock suites

a process oriented understanding of the genesis and exploration criteria of the major ore deposit types

an ability to identify the major rock-forming and ore minerals using a petrographic microscope

an ability to recognize and interpret igneous and ore micro-textures

experience in interpreting and modelling geochemical data

understanding scientific methodology and an ability to access, research and assess appropriate scientific information

a capacity to communicate the findings of research through scientific writing

General Assessment Information

If you receive special consideration for the final exam, a supplementary exam will be scheduled in the interval between the regular exam period and the start of the next session. By making a special consideration application for the final exam you are declaring yourself available for a resit during the supplementary examination period and will not be eligible for a second special consideration approval based on pre-existing commitments. Please ensure you are familiar with the policy prior to submitting an application. You can check the supplementary exam information page on FSE101 in iLearn (bit.ly/FSESupp) for dates, and approved applicants will receive an individual notification one week prior to the exam with the exact date and time of their supplementary examination.

Assessment Tasks

Name	Weighting	Hurdle	Due
Practical classes	10%	No	ongoing
Exam: Theory	40%	No	TBA
Practical exam	20%	No	Week 11
Bushveld Complex	15%	No	Week 4
Ore Deposits and Geodynamics	15%	No	Week 10

Practical classes

Due: **ongoing**
Weighting: **10%**

Practical work to be handed in during the semester, a maximum of 4 will be assessed.

On successful completion you will be able to:

- an understanding of the genesis and geochemistry of the major igneous rock suites
- a process oriented understanding of the genesis and exploration criteria of the major ore deposit types
- an ability to identify the major rock-forming and ore minerals using a petrographic

microscope
- an ability to recognize and interpret igneous and ore micro-textures
- experience in interpreting and modelling geochemical data

Exam: Theory

Due: **TBA**
Weighting: **40%**

End of semester written theory exam

On successful completion you will be able to:
- an understanding of the genesis and geochemistry of the major igneous rock suites
- a process oriented understanding of the genesis and exploration criteria of the major ore deposit types
- experience in interpreting and modelling geochemical data

Practical exam

Due: **Week 11**
Weighting: **20%**

Optical microscopy practical exam

On successful completion you will be able to:
- an understanding of the genesis and geochemistry of the major igneous rock suites
- an ability to identify the major rock-forming and ore minerals using a petrographic microscope
- an ability to recognize and interpret igneous and ore micro-textures

Bushveld Complex

Due: **Week 4**
Weighting: **15%**

A number of specific sub-topics are available for each of the broad assignment topics. Included below is the list of topics and recommended starting reading/references. Your assigned topic can be found in the table in the unit guide on iLearn.

Much of your reading for this unit will be from articles in academic journals and chapters of specialist books. These sources will be critical for your individual research projects. While the vast majority of these are available online through the university library (although logging on externally can sometimes be slow and/or problematic), ***some are available in hard copy only***. Therefore plan your access to these resources carefully and obtain photocopies etc for your assignments early. This is particularly the case for ore deposit geology, where some of the

journals are:

Economic Geology (QE1.E15)

Mineralium Deposita (QE351.M27)

Ore Geology Reviews (QE390.O74)

Transactions of the Institution of Mining and Metallurgy (TN1.I67).

I also have .pdf's for most of the recommended journal articles for the research assignments which are *not* available electronically through the library. I will endeavour to put these on iLearn upon request.

Assignment 1. The Bushveld Complex.

Topic 1: Geodynamic setting of the Bushveld Complex

Richardson SH, Shirey SB, 2008. Continental mantle signature of Bushveld magmas and coeval diamonds. **NATURE 453**: 910-913

Gregoire M, Tinguely C, Bell DR, et al., 2005. Spinel lherzolite xenoliths from the Premier kimberlite (Kaapvaal craton, South Africa): Nature and evolution of the shallow upper mantle beneath the Bushveld complex. **LITHOS, 84 (3-4)**: 185-205

Topic 2: Geochemical evolution of the Bushveld Complex

Cawthorn RG, 2007. Cr and Sr: Keys to parental magmas and processes in the Bushveld Complex, South Africa. **LITHOS, 95 v3-4**: 381-398.

Lundgaard KL, Tegner C, Cawthorn RG, et al. 2006. Trapped intercumulus liquid in the Main Zone of the eastern Bushveld Complex, South Africa **CONTRIBUTIONS TO MINERALOGY AND PETROLOGY, 151:** 352-369.

Arndt N, Jenner G, Ohnenstetter M, et al., 2005. Trace elements in the Merensky Reef and adjacent norites Bushveld Complex South Africa, Author(s): **MINERALIUM DEPOSITA, 40 (5):** 550-575.

Topic 3: Mineralisation within the Bushveld Complex

Naldrett AJ, Wilson A, Kinnaird J, et al., 2009. PGE Tenor and Metal Ratios within and below the Merensky Reef, Bushveld Complex: Implications for its Genesis **JOURNAL OF PETROLOGY, 50 (4):** 625-659.

Wilson A, Chunnett G, 2006. Trace element and platinum group element distributions and the genesis of the Merensky Reef, western Bushveld Complex, South Africa. **JOURNAL OF PETROLOGY, 47 (12):** 2369-2403

Topic 4: Magmatic layering in the Bushveld Complex: origin and significance

Tegner C, Cawthorn RG, Kruger FJ, 2006. Cyclicity in the main and upper zones of the Bushveld Complex, South Africa: Crystallization from a zoned magma sheet **JOURNAL OF PETROLOGY, 47 (11):** 2257-2279

Smith DS, Basson IJ, 2006. Shape and distribution analysis of Merensky Reef potholing, Northam Platinum Mine, western Bushveld Complex: implications for pothole formation and growth **MINERALIUM DEPOSITA, 41(3):** 281-295

Topic 5: Thermal and structural effects and controls on the emplacement of the Bushveld Complex

Clarke BM, Uken R, Watkeys MK, et al., 2005. Folding of the Rustenburg Layered Suite adjacent to the Steelpoort pericline: implications for syn-Bushveld tectonism in the eastern Bushveld Complex, **SOUTH AFRICAN JOURNAL OF GEOLOGY 108 (3):** 397-412

Clarke B, Uken R, Reinhardt J, 2009. Structural and compositional constraints on the emplacement of the Bushveld Complex, South Africa, **LITHOS 111 (1-2):** 21-36.

*Note that these assignments differ from conventional essays in that they are **true research review style articles**. As such it is anticipated that your primary reference sources will be peer reviewed scientific literature that is appropriately cited and referenced. Some articles of this nature are included under each topic to get you started. Note that you will be expected to supplement these with at least four **extra** research articles that you find through your own research. You must use figures to illustrate key concepts.*

These are assignments of at least 1000 words and a ***maximum of 1500 words***, and are designed to give you some grounding in the material to be covered in the week they are due to be handed in.

On successful completion you will be able to:

- an understanding of the genesis and geochemistry of the major igneous rock suites
- a process oriented understanding of the genesis and exploration criteria of the major ore deposit types
- understanding scientific methodology and an ability to access, research and assess appropriate scientific information
- a capacity to communicate the findings of research through scientific writing

Ore Deposits and Geodynamics

Due: **Week 10**
Weighting: **15%**

A number of specific sub-topics are available for each of the broad assignment topics. Included below is the list of topics and recommended starting reading/references. Your assigned topic can

be found in the table in the study guide in iLearn.

Much of your reading for this unit will be from articles in academic journals and chapters of specialist books. These sources will be critical for your individual research projects. While the vast majority of these are available online through the university library (although logging on externally can sometimes be slow and/or problematic), ***some are available in hard copy only***. Therefore plan your access to these resources carefully and obtain photocopies etc for your assignments early. This is particularly the case for ore deposit geology, where some of the journals are:

Economic Geology	(QE1.E15)
Mineralium Deposita	(QE351.M27)
Ore Geology Reviews	(QE390.O74)
Transactions of the Institution of Mining and Metallurgy	(TN1.I67).

I also have .pdf's for most of the recommended journal articles for the research assignments which are *not* available electronically through the library. I will endeavour to put these on iLearn upon request.

Assignment 2: Geodynamics and ore deposits:

Topic 1: Setting and characteristics of Volcanic Hosted Massive Sulphide (VHMS) deposits

Huston, DL; Stevens, B; Southgate, PN, et al. 2006. Australian Zn-Pb-Ag ore-forming systems: A review and analysis. **ECONOMIC GEOLOGY 101** v**6**: **1117-1157**

Saez, R; Pascual, E; Toscano, M, et al., 1999. The Iberian type of volcano-sedimentary massive sulphide deposits. **MINERALIUM DEPOSITA 34** v **5-6: 549-570**

Galley, AG, 2003. Composite synvolcanic intrusions associated with Precambrian VMS-related hydrothermal systems. **MINERALIUM DEPOSITA** Volume: **38** v**4**: **443-473**

Topic 2: Setting and characteristics of Sedex (including MVT) deposits

Sangster D F, 1990. Mississippi valley-type and sedex lead-zinc deposits: a comparative examination. **Trans. Inst. Mining Metallurgy, B99,** 21-42

Tornos, F; Heinrich, CA 2008. Shale basins, sulfur-deficient ore brines and the formation of exhalative base metal deposits **CHEMICAL GEOLOGY**, **247** (**1-2): 195-207**

Large, RR; Bull, SW; Cooke, DR, et al., 1998. A genetic model for the HYC deposit, Australia: Based on regional sedimentology, geochemistry, and sulfide-sediment relationships. **ECONOMIC GEOLOGY AND THE BULLETIN OF THE SOCIETY OF ECONOMIC GEOLOGISTS**, **93** (**8):** 1345-1368.

Topic 3: Porphyry Cu (±Mo) mineralization: Characteristics and geodynamic controls

Titley, S.R., and Beane, R.E., 1981, Porphyry copper deposits. Part I. Geologic settings, petrology and tectogenesis: **Econ. Geol. 75th Anniversary Vol.**, p. 214-235.

Beane, R.E., and Titley, S.R., 1981, Porphyry copper deposits. Part II. Hydrothermal alteration and mineralization: **Econ. Geol. 75th Anniversary Vol**., p. 235-269.

Seedorff, E; Barton, MD; Stavast, WJA, et al., 2008. Root Zones of Porphyry Systems: Extending the Porphyry Model to Depth **ECONOMIC GEOLOGY**, **103** (**5):** 939-956

Proffett, JM., 2009 High Cu grades in porphyry Cu deposits and their relationship to emplacement depth of magmatic sources **GEOLOGY**, **37** (**8):** 675-678

Topic 4: Hydrothermal (including Epi- and Mesothermal) ore deposits

Phillips, GN; Powell, R ., 2009. Formation of gold deposits: Review and evaluation of the continuum model. **EARTH-SCIENCE REVIEWS**, **94** (**1-4):** 1-21

Mikucki, EJ., 1998. Hydrothermal transport and depositional processes in Archean lode-gold systems: A review **ORE GEOLOGY REVIEWS 13**(**1-5):** 307-321

Kisters, AFM; Meyer, FM; Seravkin, IB, et al., 1999. The geological setting of lode-gold deposits in the central southern Urals: a review. **GEOLOGISCHE RUNDSCHAU**, **87**(**4):** 603-616

Goldfarb, R.J.; Groves, D.I.; Gardoll, S. Orogenic gold and geologic time: a global synthesis **Ore Geology Reviews**

Topic 5: Iron Oxide Copper Gold deposits: Features, temporal and spatial controls

HITZMAN, MW; ORESKES, N; EINAUDI, MT., 1992 Geological characteristics and tectonic setting of Proterozoic Iron-Oxide (Cu-U-Au-REE) deposits. **PRECAMBRIAN RESEARCH 58** v**1-4**: **241-287**

Bastrakov, EN; Skirrow, RG; Didson, GJ., 2007. Fluid evolution and origins of iron oxide Cu-Au prospects in the Olympic Dam district, Gawler Craton, South Australia, **ECONOMIC GEOLOGY**, **102** (**8)**: 1415-1440

Skirrow, RG; Bastrakov, EN; Baroncii, K, et al., 2007. Timing of iron oxide Cu-Au-(U) hydrothermal activity and Nd isotope constraints on metal sources in the Gawler craton, South Australia, **ECONOMIC GEOLOGY**, **102** (**8)**: 1441-1470.

Belperio, A; Flint, R; Freeman, H., 2007. Prominent Hill: A hematite-dominated, iron oxide copper-gold system **ECONOMIC GEOLOGY**, **102** (**8):** 1499-1510

*Note that these assignments differ from conventional essays in that they are **true research review style articles**. As such it is anticipated that your primary reference sources will be peer reviewed scientific literature that is appropriately cited and referenced. Some articles of this nature are included under each topic to get you started. Note that you will be expected to supplement these with at least four **extra** research articles that you find through your own research. You must use figures to illustrate key concepts.*

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Delivery and Resources

You are required to attend 2 lectures and 1 practical session per week. Both sessions will be held in E5A 210. Scheduled times are:

Lectures: Monday 9 am-11 am

Practicals: Monday 11am –2 pm

However we may be able to shift things around on this day to make more convenient times for everybody.

The iLearn site is the main source of resources for this unit.

Unit Schedule

Provisional unit timetable for GEOS343, Semester 2, 2018; All classes in E5A210

Week	Lectures	Practical	Presenter
1 30/7	Nomenclature, tectonic associations; chemistry and mineralogy refresher	Petrology refresher, volcanic rocks	JC
2 6/8	i) Phase equilibria, melting processes; ii) Binary and Ternary systems	Bushveld I: Mineralogy, textures, macroscopic layering	SPT

3 13/8	Geochemistry: i) Major elements ii) Trace elements	Bushveld II: Textural relationships; petrogenetic sequences, liquid line of descent and binary phase diagrams	SPT
4 20/8	i) Origin of basaltic magma ii) Diversification of magmas *1st assignment due (Bushveld)*	Modelling partial melting	SPT computing prac
5 25/3	Magmatism in ocean basins i) MORB ii) OIB	Modelling crystal fractionation	SPT computing prac
6 3/9	Island Arc Magmatism	Bulk mixing, discriminating between mixing vs AFC, isochron	JC computing prac
7 10/9	Volcanology	Volcanic rocks	CF
8 1/10	Labour day holiday		
9 8/10	Granites, I, S, A, crustal growth and evolution, skarns; sedimentary provenance, detrital systems	Granites	BFS
10 15/10	Mineralising processes: BIF's, hydrothermal systems, placers,redox, regolith *2nd assignment due (Geodynamics of ore deposits)*	Sedex ore deposits	BFS
11 22/10	Principles of ore petrogenesis; S saturation, differentiation, accumulation, redox	PRAC EXAM	BFS
12 29/10	The isotopic tool kit: mixing and isochrons	Using radiogenic isotopes	BFS

13 5/11	Solar system and planet formation, atmospheric formation and evolution, meteorites		BFS/guest lecturers from ANU

BFS: Bruce Schaefer, SPT: Simon Turner; JC: John Creech, CF: Chris Firth

Policies and Procedures

Macquarie University policies and procedures are accessible from Policy Central (https://staff.mq.edu.au/work/strategy-planning-and-governance/university-policies-and-procedures/policy-central). Students should be aware of the following policies in particular with regard to Learning and Teaching:

- Academic Appeals Policy
- Academic Integrity Policy
- Academic Progression Policy
- Assessment Policy
- Fitness to Practice Procedure
- Grade Appeal Policy
- Complaint Management Procedure for Students and Members of the Public
- Special Consideration Policy *(**Note:** The Special Consideration Policy is effective from 4 December 2017 and replaces the Disruption to Studies Policy.)*

Undergraduate students seeking more policy resources can visit the Student Policy Gateway (https://students.mq.edu.au/support/study/student-policy-gateway). It is your one-stop-shop for the key policies you need to know about throughout your undergraduate student journey.

If you would like to see all the policies relevant to Learning and Teaching visit Policy Central (https://staff.mq.edu.au/work/strategy-planning-and-governance/university-policies-and-procedures/policy-central).

Student Code of Conduct

Macquarie University students have a responsibility to be familiar with the Student Code of Conduct: https://students.mq.edu.au/study/getting-started/student-conduct

Results

Results shown in *iLearn*, or released directly by your Unit Convenor, are not confirmed as they are subject to final approval by the University. Once approved, final results will be sent to your student email address and will be made available in eStudent. For more information visit ask.mq.edu.au.

Student Support

Macquarie University provides a range of support services for students. For details, visit http://students.mq.edu.au/support/

Learning Skills

Learning Skills (mq.edu.au/learningskills) provides academic writing resources and study strategies to improve your marks and take control of your study.

- Workshops
- StudyWise
- Academic Integrity Module for Students
- Ask a Learning Adviser

Student Services and Support

Students with a disability are encouraged to contact the Disability Service who can provide appropriate help with any issues that arise during their studies.

Student Enquiries

For all student enquiries, visit Student Connect at ask.mq.edu.au

IT Help

For help with University computer systems and technology, visit http://www.mq.edu.au/about_us/offices_and_units/information_technology/help/.

When using the University's IT, you must adhere to the Acceptable Use of IT Resources Policy. The policy applies to all who connect to the MQ network including students.

Graduate Capabilities

Creative and Innovative

Our graduates will also be capable of creative thinking and of creating knowledge. They will be imaginative and open to experience and capable of innovation at work and in the community. We want them to be engaged in applying their critical, creative thinking.

This graduate capability is supported by:

Learning outcomes

- an understanding of the genesis and geochemistry of the major igneous rock suites
- a process oriented understanding of the genesis and exploration criteria of the major ore deposit types
- an ability to recognize and interpret igneous and ore micro-textures

Assessment task

- Practical classes

Capable of Professional and Personal Judgement and Initiative

We want our graduates to have emotional intelligence and sound interpersonal skills and to demonstrate discernment and common sense in their professional and personal judgement. They will exercise initiative as needed. They will be capable of risk assessment, and be able to handle ambiguity and complexity, enabling them to be adaptable in diverse and changing environments.

This graduate capability is supported by:

Learning outcomes

- an understanding of the genesis and geochemistry of the major igneous rock suites
- a process oriented understanding of the genesis and exploration criteria of the major ore deposit types
- an ability to identify the major rock-forming and ore minerals using a petrographic microscope
- an ability to recognize and interpret igneous and ore micro-textures
- understanding scientific methodology and an ability to access, research and assess appropriate scientific information
- a capacity to communicate the findings of research through scientific writing

Assessment tasks

- Bushveld Complex
- Ore Deposits and Geodynamics

Commitment to Continuous Learning

Our graduates will have enquiring minds and a literate curiosity which will lead them to pursue knowledge for its own sake. They will continue to pursue learning in their careers and as they participate in the world. They will be capable of reflecting on their experiences and relationships with others and the environment, learning from them, and growing - personally, professionally and socially.

This graduate capability is supported by:

Learning outcomes

- an understanding of the genesis and geochemistry of the major igneous rock suites
- a process oriented understanding of the genesis and exploration criteria of the major ore deposit types
- an ability to recognize and interpret igneous and ore micro-textures
- understanding scientific methodology and an ability to access, research and assess appropriate scientific information

- a capacity to communicate the findings of research through scientific writing

Assessment tasks

- Practical classes
- Bushveld Complex
- Ore Deposits and Geodynamics

Discipline Specific Knowledge and Skills

Our graduates will take with them the intellectual development, depth and breadth of knowledge, scholarly understanding, and specific subject content in their chosen fields to make them competent and confident in their subject or profession. They will be able to demonstrate, where relevant, professional technical competence and meet professional standards. They will be able to articulate the structure of knowledge of their discipline, be able to adapt discipline-specific knowledge to novel situations, and be able to contribute from their discipline to inter-disciplinary solutions to problems.

This graduate capability is supported by:

Learning outcomes

- an understanding of the genesis and geochemistry of the major igneous rock suites
- a process oriented understanding of the genesis and exploration criteria of the major ore deposit types
- an ability to identify the major rock-forming and ore minerals using a petrographic microscope
- an ability to recognize and interpret igneous and ore micro-textures
- experience in interpreting and modelling geochemical data

Assessment tasks

- Practical classes
- Exam: Theory
- Practical exam
- Bushveld Complex
- Ore Deposits and Geodynamics

Critical, Analytical and Integrative Thinking

We want our graduates to be capable of reasoning, questioning and analysing, and to integrate and synthesise learning and knowledge from a range of sources and environments; to be able to critique constraints, assumptions and limitations; to be able to think independently and systemically in relation to scholarly activity, in the workplace, and in the world. We want them to have a level of scientific and information technology literacy.

This graduate capability is supported by:

Learning outcomes

- an understanding of the genesis and geochemistry of the major igneous rock suites
- a process oriented understanding of the genesis and exploration criteria of the major ore deposit types
- an ability to identify the major rock-forming and ore minerals using a petrographic microscope
- an ability to recognize and interpret igneous and ore micro-textures
- experience in interpreting and modelling geochemical data

Assessment tasks

- Practical classes
- Exam: Theory
- Practical exam
- Bushveld Complex
- Ore Deposits and Geodynamics

Problem Solving and Research Capability

Our graduates should be capable of researching; of analysing, and interpreting and assessing data and information in various forms; of drawing connections across fields of knowledge; and they should be able to relate their knowledge to complex situations at work or in the world, in order to diagnose and solve problems. We want them to have the confidence to take the initiative in doing so, within an awareness of their own limitations.

This graduate capability is supported by:

Learning outcomes

- an understanding of the genesis and geochemistry of the major igneous rock suites
- a process oriented understanding of the genesis and exploration criteria of the major ore deposit types
- an ability to identify the major rock-forming and ore minerals using a petrographic microscope
- an ability to recognize and interpret igneous and ore micro-textures
- experience in interpreting and modelling geochemical data

Assessment tasks

- Practical classes
- Practical exam
- Bushveld Complex
- Ore Deposits and Geodynamics

Effective Communication

We want to develop in our students the ability to communicate and convey their views in forms effective with different audiences. We want our graduates to take with them the capability to read, listen, question, gather and evaluate information resources in a variety of formats, assess, write clearly, speak effectively, and to use visual communication and communication technologies as appropriate.

This graduate capability is supported by:

Learning outcomes

- a process oriented understanding of the genesis and exploration criteria of the major ore deposit types
- an ability to identify the major rock-forming and ore minerals using a petrographic microscope
- an ability to recognize and interpret igneous and ore micro-textures
- understanding scientific methodology and an ability to access, research and assess appropriate scientific information
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Assessment tasks

- Practical classes
- Exam: Theory
- Practical exam
- Bushveld Complex
- Ore Deposits and Geodynamics

Engaged and Ethical Local and Global citizens

As local citizens our graduates will be aware of indigenous perspectives and of the nation's historical context. They will be engaged with the challenges of contemporary society and with knowledge and ideas. We want our graduates to have respect for diversity, to be open-minded, sensitive to others and inclusive, and to be open to other cultures and perspectives: they should have a level of cultural literacy. Our graduates should be aware of disadvantage and social justice, and be willing to participate to help create a wiser and better society.

This graduate capability is supported by:

Learning outcomes

- a process oriented understanding of the genesis and exploration criteria of the major ore deposit types
- understanding scientific methodology and an ability to access, research and assess

appropriate scientific information
- a capacity to communicate the findings of research through scientific writing

Socially and Environmentally Active and Responsible

We want our graduates to be aware of and have respect for self and others; to be able to work with others as a leader and a team player; to have a sense of connectedness with others and country; and to have a sense of mutual obligation. Our graduates should be informed and active participants in moving society towards sustainability.

This graduate capability is supported by:

Learning outcomes

- a process oriented understanding of the genesis and exploration criteria of the major ore deposit types
- understanding scientific methodology and an ability to access, research and assess appropriate scientific information
- a capacity to communicate the findings of research through scientific writing

Assessment task

- Ore Deposits and Geodynamics