EARTH SCIENCES PART II – 2017-2018
LECTURE LIST

Skills Course - Dr Alex Copley

Thursday 5 Oct
2pm Introduction to part II [Dr Alex Copley, Harker Rm]
3pm Library sign-up [Sarah Humbert]

Monday 9 Oct
12-1pm Library, online resources, group 1 [Sarah Humbert]
3.15-4.15pm Mapping Project [Dr Alex Copley, Harker Rm]
4.15-5.30pm Mapping project display with Part III students [Dr Alex Copley, 1A Lab]

Tuesday 10 Oct
2-5pm Graphics software and map drafting, plus practical [Dr Owen Weller, Harker Room and Galson Lab]

Wednesday 11 Oct
12-1pm Library, online resources, group 2 [Sarah Humbert]
2-4pm Stereonet, Georient, SedLog, TSCreator [Dr Owen Weller, Harker Room and Galson Lab]

Thursday 12 Oct
3-4pm Reading, writing, and exam skills [Dr Alex Copley, Harker Room]

Monday 16 Oct
12-1pm Introduction to GIS [Simon Passey, Harker Room]
2-5pm GIS practical [Magda Biszczuk, Galson Lab]

Thursday 19 Oct
2-4pm Statistics lecture and practical [Dr David Al-Attar, Harker room]

Other sessions:

Late October/Early November
Photomicroscope training with Iris Buisman

Tuesday 23 January
1.30-5pm Petroleum Geology [Andy Bell – Shell]
Note: This session is a key part of your general geological education, and forms part of the Geolsoc accreditation of the degree, so attendance is compulsory.

C1: Geophysics and Tectonics

Lectures and practicals on Tuesday and Thursday mornings (9am-12pm), and one stand-alone lecture per week at 12 noon on Fridays. Lectures that are followed by a practical are labelled with [P].

Alex Copley, Nicky White, Nick Rawlinson, John Rudge, David Al-Attar.

Lectures 1-9: Dr Alex Copley

5 October

1. **Earthquake seismology [P]**

How to estimate earthquake locations, depths, and focal mechanisms.

6 October

2. **Faulting in large earthquakes: seismology, geomorphology, surface ruptures**
   What happens in big earthquakes? Combining seismology, field observations, aftershock, and geomorphology.

10 October

3. **Earthquake scaling laws and fault strength [P]**
   The rules controlling earthquakes and faulting. The controversy about the strength of faults.

12 October

4. **Space geodesy: InSAR and the earthquake cycle [P]**
   Mapping surface motions using satellites. How InSAR works, the earthquake cycle, inter-, co-, and post-seismic motion.

13 October

5. **Space geodesy: GPS and large-scale velocity fields**
   How GPS works, construction of velocity fields, tectonic applications.

17 October

6. **Large earthquake case studies – subduction zones and Nepal [P]**
   Combining geology and geophysics to understand subduction zone and continental megathrusts (in Sumatra, Japan, and Nepal).

19 October

7. **Mineral creep [P]**
   How minerals deform by diffusion and dislocation creep. Deformation maps, and theoretical and observational estimates of lower lithosphere viscosity.

20 October

8. **Plate driving forces**
   The forces that control the motion of the plates and the deformation on their edges.

24 October

9. Plate structure and rheology [P]

Thermal, seismological, flexural, and petrological insights into the rheology of the plates.

Lectures 10-14: Professor Nicky White

26 October

10. Gravity [P]

Gravitational field of the Earth. Free-air and Bouguer gravity corrections and anomalies. Isostatic calculations. Satellite gravity data. Gravity and mantle convection.

27 October

11. Topographic analysis

Topographic wavelength. Relationship with gravity. Flexural rigidity, flexural parameter and elastic thickness. Spatial and frequency domain methods for estimating elastic thickness. Oceanic and continental examples. How do foreland basins form?

31 October

12. Controlled source seismology: refraction [P]

Snell's law and ray tracing. First arrivals and travel-time diagrams. Layer-cake modelling. Forward and inverse models. What does continental crust look like?

2 November

13. Controlled source seismology: reflection [P]

Sub-critical reflections. How are seismic reflection experiments carried out at sea and on land? The key steps of signal processing: stacking, deconvolution and migration. Two-, three-, and four-dimensional seismic imagery and what it means.

3 November

14. Geophysical analysis of the Icelandic plume

Measuring residual depth anomalies in the North Atlantic Ocean. Geophysical extent of Icelandic plume and its size. Transient thermal anomalies. Towards a fluid dynamical understanding of the Icelandic plume.

Lectures 15-18: Professor Nick Rawlinson

7 November

15. Seismic wave propagation [P]

On the generation and propagation of seismic waves in realistic media

9 November

16. The global seismic wavefield [P]

Global body wave phases, surface waves, normal modes, and what they look like on a seismogram

10 November

17. **Geophysical inverse problems**
    Basic concepts in geophysical inverse theory and case studies involving different types of data

14 November

18. **Earth imaging [P]**
    The structure and dynamics of the Earth's interior from large geophysical datasets

Lectures 19-22: Dr John Rudge

16 November

19. **The Fluid dynamics of convection [P]**
    Conservation laws. Scaling and the thermal time constant. Rayleigh number. Planform of convection. Laboratory and numerical experiments.

17 November

20. **Mapping mantle convection**
    Surface observations. Gravity anomalies and residual depth. Continental methods.

21 November

21. **Layered or whole mantle convection? [P]**
    Geochemical arguments for layering (e.g. argon). MORBs vs OIBs. Focal mechanisms in subducting slabs. Tomography.

23 November

22. **Other planets [P]**
    Magellan gravity and topography observations of Venus. Estimates of Te and planform of convection. Why plate tectonics?

Lectures 23-24: Dr David Al-Attar

24 November

23. **Post-glacial sea level change 1: Applications to Earth's viscosity structure**
    How sea level is defined, and why it varies in space and time. Viscoelastic materials and the Maxwell time. Observations and methods used to constrain mantle viscosity. Implications for mantle dynamics.

28 November

24. **Post-glacial sea level change 2: Applications to past and present climate change [P]**
    Spatial and temporal patterns of sea level change associated with deglaciation. Ice sheet reconstructions. Estimates of present day ice mass loss from Greenland and Antarctica. Sea level fingerprints and Melt Water Pulse 1A.

Seminars

13 Oct, 10 am

Camilla Penney, The active tectonics and earthquake hazard of the Makran subduction zone

27 Oct, 10 am

Jacky Austermann, Interactions of dynamic topography and paleo climate

10 November, 10 am

Marte Kloecking, Estimating mantle temperature and dynamic uplift from basalt geochemistry and shear wave velocity anomalies in western North America

24 November, 10 am

James Jackson, Earthquakes and Tsunamis in the Eastern Mediterranean

Field trip

1-9 December: 9-day field trip to study the active tectonics of central Greece, and its controls on sedimentation and volcanism.

C2: Ancient Life and Environments

Lectures and practicals [P] are scheduled for Monday and Wednesday mornings (9–12am), plus a stand-alone lecture on Fridays at 2pm (on occasion followed by a research seminar [S]).

Sasha Turchyn, Neil Davies, Nick Butterfield.

Lectures 1-11: Dr Sasha Turchyn

6 October

1. **Geochemistry and sedimentology in tidal environments**

9 October

2. **Tidal sedimentary environments 1 [P]**

11 October

3. **Tidal sedimentary environments 2 [P]**

13 October

4. **Tidal sedimentary environments 3 [S]**

16 October

5. **Sedimentary diagenesis 1 [P]**

18 October

6. **Sedimentary diagenesis 2 [P]**

20 October

7. **Biogeochemistry in modern environments (+ departure for Norfolk field trip)**

23 October

8. **Suffolk field trip [P]**

25 October

9. **Sediments to sedimentary rocks [P]**

27 October

10. **Geochemistry in ancient Environments 1 [S]**

30 October

11. **Geochemistry in ancient Environments 2 [P]**

Lectures 12-23: Professor Nick Butterfield

1 November
12. Early records of life on Earth [P]

3 November
13. The evolving Proterozoic Earth system 1

6 November
14. The evolving Proterozoic Earth system 2 [P]

8 November
15. Early evolution of eukaryotes [P]

10 November
16. Cryogenian to Ediacaran Earth and evolutionary history

13 November
17. Ediacaran palaeobiology [P]

15 November
16. The Cambrian Explosion [P]

17 November
19. The Burgess Shale and other taphonomic windows [S]

20 November
20. The Great Ordovician Biodiversification Event [P]

22 November
21. Reefs and reef-building organisms [P]

24 November
22. Coevolution, ecosystem engineering & the modern marine biosphere [S]

27 November
23. Astrobiology

Lecture 24: Dr Neil Davies

29 November
24. Terrestrialization [P]

Seminars
13 October, to be confirmed
27 October, to be confirmed
17 November, to be confirmed
24 November, to be confirmed

Field Trips
20–22 Oct, Norfolk field trip
23 Oct, Suffolk field trip

C3: Petrology

This 24-lecture course is designed to introduce you to a range of fundamental ideas and concepts that will provide you with a sound basis for petrological Part III projects and courses. It includes 6 lectures on topics in metamorphic and igneous petrology, reinforcing and expanding pre-existing skills. It includes Schreinemakers analysis, pelite bulk composition diagrams, siliceous dolomites and CO_2-H_2O fluids, granulites, melting, and oxidation-reduction. The next 3 lectures will develop your petrographic skills and teach you how to decode the record of rock history preserved in thin sections of both metamorphic and igneous rocks. Magma chambers are covered in 5 lectures, with a discussion of fluid dynamical processes occurring during solidification of basaltic and andesitic magma (including the effects of convection, liquid immiscibility, progressive fractionation, degassing, ore formation, and the triggering, dynamics and effects of explosive eruptions). A basic geochemical toolbox will be delivered over 5 lectures, building on the whole-Earth geochemistry you have already covered in 1B and demonstrating the range of geochemical techniques used in a wide range of exciting topics such as core formation, mantle reservoirs of noble bases, non-traditional stable isotope geochemistry and U-series dating. The final 4 lectures will show how synthesizing fluid dynamics, geophysics and geochemistry can be used to answer some of the big questions of mantle convection and Earth history.

Lectures will be held on Monday, Wednesday, and Friday mornings (9am). Where stated, practical sessions and seminars follow the lecture.

Tim Holland, Marian Holness, Marie Edmonds, Ed Tipper, John Maclennan.

Professor Tim Holland
This part of the course will reinforce and expand their understanding of thermodynamics, with application to metamorphic and igneous petrology.

19 January

1. **Pelitic rocks 1**
   Schreinemakers constructions. (Lecture only)

22 January

2. **Pelites 2**
   AFM projections, univariant & divariant equilibria, grids, pseudosections.
   Practical

24 January

3. **Siliceous dolomites**
   T–$X(CO_2)$ and mixed volatile equilibria. Fluid-rock interaction. Swiss Alps.
   Practical

26 January

4. **Granulites 1**
   Granulites and water activity. Tectonic settings and implications.
   Isotope Coffee

29 January

5. **Granulites 2**
   Granulites and melting in the crust and mantle. Dry and wet melting, major element partitioning among minerals and melts.
   Practical

31 January

6. **Oxygen fugacity**
   Graphite and sulphide controlled equilibria and fluids. Mantle fO_2 and carbonates/diamond etc.
   Practical

Professor Marian Holness

This set of lectures will teach them how to interrogate and interpret thin sections, giving them the background knowledge to obtain microstructural information on rock history with application to metamorphic and igneous petrology. The last two lectures introduce the physics and chemistry of mafic layered intrusions, using microstructure as the key to understand mass transport and solidification in magma chambers.

2 February

7. **Crystal nucleation and growth**
   Classical nucleation theory (revision), heterogeneous vs homogeneous nucleation. Crystal size distributions, Ostwald ripening, nucleation inhibition in small pores, eutectic crystallization.
   Seminar: Helen Williams

5 February

8. **Crystal shape**
   Diffusion vs interface limited growth, dendrites, spherulites, sector zoning.
   Practical: Thin sections (igneous and metamorphic)

7 February

9. **Textural equilibrium**
   Equilibrated microstructures (both solid and fluid-bearing), effect of anisotropy, effect of surface chemistry, implications for mass transport in the mantle (Fe-rich vs silicate melts)
   Practical: Thin sections (igneous and metamorphic)

9 February

10. **Microstructural evolution in cumulates**
    Revision of cumulus concept, in situ growth vs crystal settling, permeability of mush layer, compaction and the limitations of the “trapped liquid” concept. How to create an adcumulate.
    Isotope Coffee

12 February

11. **Mafic Layered Intrusions**
    Skaergaard, background and general introduction. Discussion of the controversies, including effects of liquid immiscibility, compaction, comparison of the behavior of crystal mushy layers on the roof, walls and floor. Could include comparison with Rum (open system chamber feeding an active volcano).
    Practical: Skaergaard thin sections, illustrating all the points covered in the previous 4 lectures.

Dr Marie Edmonds

This set of lectures follows on from the last two of MBH's course. It develops ideas of the physical and chemical behavior of magma in the crust, incorporating fluid dynamics and geochemistry.

14 February

12. **Storage and transport of magma in the crust**
    Architecture and longevity of crustal magma reservoirs; intrusive/extrusive magma budgets. Link to Marian's lectures wrt compaction processes, entrainment of mushes into erupting magmas, fluid dynamics of magma reservoirs. Magma mixing and recharge and generation of andesites.
    Practical: Andesites (thin sections): magma mixing, mafic recharge

16 February

13. **Crustal fluids**
    Magma degassing and implications of volatiles for magma differentiation, phase equilibria. Dynamics of bubbles in magma reservoirs. Partitioning of elements into fluids. Transport of metals to ore deposits.
    Seminar: Jerome Neufeld

19 February

14. **Volcanic eruptions**
    Fluid dynamics of eruptions; impacts. Role of volcanoes in global geochemical cycling.
    Practical: Pinatubo, 1991 – eruption triggering and timescales, outgassing, impacts, hazards.

Dr Ed Tipper

Here the students will be given a basic geochemical toolbox, building on the whole-Earth geochemistry they did in 1B and demonstrating the range of geochemical techniques using a wide range of exciting topics.

21 February

15. **Geochronology and planetary differentiation**
    Practical: Model ages and U-Pb Concordia. Age of the crust.

23 February

16. **Short-live isotopes and planetary differentiation**
    Seminar: Speaker tbc

26 February

17. **Fundamentals of stable isotopes: why do they fractionate?**
    Practical: Dating crustal formation using 142Nd

28 February

18. **Stable isotopes and planetary differentiation: Novel isotope systems**
    Practical: Si in the Earth's core

2 March

19. **The noble gases: He, Ne and Xe**
    Group supervision revising practical techniques

Dr John MacLennan

Showing how synthesizing fluid dynamics, physics and geochemistry can be used to unravel the Big Picture of mantle spatial variability and the extent and processes involved in melting it.

5 March

20. **Mantle melting** - Physical basis - solid flow field, energy balance during melting, prediction of melt fractions and volumes, thermal consequences of presence of heterogeneities.
    Practical

7 March

21. **Mantle melting** - Geochemical predictions - Quantitative relationship between Tp, lithospheric thickness, mantle flow and bulk melt composition. Influence of short-lengthscale heterogeneity on aggregated melt composition. Relationship between isotopic and trace element composition of basalt and underlying mantle.
    Practical

9 March

22. **Volatiles in the mantle** - Storage capability of deep mantle minerals. Observational constraints on mantle volatile contents. Influence of volatiles on phase diagrams and melting behaviour. Redox melting.
    Seminar: John Rudge (tbc)

12 March

23. **Melt transport** - Rates and observational constraints. Mechanisms - Porous flow, solitary waves, channelisation, reaction, rheological feedback.
    Practical

14 March

24. **Mixing in mafic and ultramafic systems** - Understanding the record melt mixing during transport and storage. Again, consequences for understanding mantle heterogeneity. Mixing of chemical heterogeneities by mantle convection.
    Practical: possibly to which everyone contributes…a revision/exam practice session?

C4: Earth's Climate System

Lectures will be held on Monday, Wednesday and Thursday afternoons (2 pm). Practical sessions are as indicated in the course synopsis below. There will also be four invited seminars, times and dates to be confirmed.

David Hodell, Luke Skinner, Eric Wolff.

18 January
David Hodell Course introduction: Marine sediments as paleoclimate archives - what makes a good record?
Practical 1: Smear Slide Description and Pelagic Sediment Classification (IA Lab)

22 January
David Hodell Palaeotemperature proxies
Practical 2: Sediment Coarse Fraction Description– Foraminifera and Ice rafted detritus (IA Lab)

24 January
David Hodell Oxygen isotopes, ice volume, and temperature
Practical 3: Oxygen isotope Age Models and Sediment Physical Properties (Galson Lab)

25 January
David Hodell Intensification of Northern Hemisphere Glaciation at the base of the Quaternary

29 January
David Hodell Orbital forcing and the Milankovitch theory of glacial-interglacial climate change
Practical 4: Orbital Forcing and Introduction to Spectral analysis (Galson Lab)

31 January
David Hodell Problems with the Milankovitch theory
Practical 5: Spectral analysis of U1308 data (Galson Lab)

1 February
David Hodell Origin of the 41-kyr cycle and The Middle Pleistocene Transition

5 February
David Hodell Cyclostratigraphy and the Geologic Time Scale
Practical 6: Cyclostrat Practical (Galson Lab)

7 February
David Hodell Paleotracers of Deep-water Circulation, Nutrient and Water Mass Chemistry Proxies ($\delta^{13}C$, Cd/Ca, Nd…)
Practical 7: TBD

8 February
David Hodell Dynamic Paleocirculation Proxies (Pa/Th and ^{14}C and sortable silt)
Practical 8: Interpreting Ocean Circulation Records from the Atlantic and Pacific

12 February
David Hodell Case study: Quaternary history of Deepwater Circulation
Practical 9: TBD

14 February Seminar
TBD

15 February
Eric Wolff Ice sheets and ice cores
Practical 10: visit to the BAS ice core labs

19 February
Eric Wolff Orbital and millennial events in ice cores, and links to other archives
Practical 11: Dating ice cores and synchronising them to other archives

12 February
Eric Wolff The cryosphere and ice dynamics

22 February
Luke Skinner Trends, rhythms and 'surprises' in Earth's climate history (timescales and patterns of change over time)
Practical 12: Dynamical systems (I) (Galson lab)

26 February
Luke Skinner Millennial climate change: the atmosphere, ocean and hydrological cycles
Practical 13: Dynamical systems (II) (Galson lab)

28 February
Luke Skinner Millennial climate change: the cryosphere (polar temperatures, sea-level, sea ice)

1 March
Luke Skinner Mechanisms of rapid change: freshwater forcing, ocean heat transport and the bipolar seesaw
Practical 14: The Stommel model and hysteresis (Galson lab)

5 March
Luke Skinner Mechanisms of rapid change: wind, sea-ice, without 'hosing'
Seminar: TBD

7 March

Luke Skinner Biogeochemical impacts: Nitrogen cycle and methane
Seminar: TBD

8 March

Luke Skinner Biogeochemical impacts: carbon cycle (I)
Practical 15: biogeochemical box model solutions

12 March

Luke Skinner Biogeochemical impacts: carbon cycle II
Practical 16: biogeochemical GCM solutions

14 March

Luke Skinner The bigger picture: the role of abrupt climate change in longer-term climate evolution

Seminar Speakers (times/dates tbc):
TBC

C5: Mineralogy

Lectures will be held on Tuesday and Thursday mornings (9 am) and Friday afternoons (2 pm). Most lectures are accompanied by a practical session. There will also be four invited seminars.

Richard Harrison, Emilie Ringe, Simon Redfern, Michael Carpenter.

Lectures 1-6: Professor Richard Harrison. Mineral Magnetism

This course describes the theory and applications of fine-particle magnetism in natural systems. We explore how a knowledge of small magnetic particles helps to answer a diverse range of questions, including how meteorites retain information about the magnetic field strength of the early solar system, how magnetic proxies are used as tracers of environmental processes, and how magnetic minerals are exploited by biological systems for navigation. The lectures are accompanied by practicals that reinforce the core concepts covered (including a 'field trip' to the Granta pub to collect magnetotactic bacteria!) and a seminar that puts the methods learned into the context of current research. The course provides the necessary core material to take the Part III option "Magnetism of Earth and Planetary Materials".

18 January

1. **How to Build a Magnetic Mineral Part 1**

19 January

2. **How to Build a Magnetic Mineral Part 2**

23 January

3. **To Saturation and Back Again: Magnetic Hysteresis**

25 January

4. **Nature's Hard Disk: Recording Natural Magnetic Remanence**

26 January

5. **Using magnetic minerals to trace Earth's changing climate**

30 January

6. **A Bug's Life: Magnetic Minerals in Biological Systems**

26 January
Seminar: Dr James Bryson
Title to be confirmed

Lectures 7-12: Dr Emilie Ringe. Diffraction

This course describes how diffraction techniques, including X-ray, neutron, and electron diffraction, can reveal the atomic and grain structure of minerals. Building on symmetry concepts, we first explore the rules governing diffraction and learn how to think in reciprocal space. We then examine how diffraction data is used to understand not only crystal structure, but also orientation, grain size, strain, etc. The lectures are accompanied by practicals on X-ray and electron diffraction with a special emphasis on data interpretation and applications, as well as a seminar that explores current research topics.

1 February
7. Diffraction and scattering

2 February
8. Bragg's law and reciprocal space

6 February
9. Structure factors and systematic absences

8 February
10. X-ray diffraction

9 February
11. Electron diffraction

13 February
12 Interpreting diffraction patters

9 February
Seminar. Prof. Richard Harrison.
X-ray holography: diffractive imaging of nanoscale magnetism in meteorites

Lectures 13-18: Professor Simon Redfern. Lattice Dynamics

We pick up from the Diffraction course. Now we know how we know "where the atoms are" in a mineral – but many of the properties of rocks and minerals are down to how the atoms move – the dynamics of the lattice. In this course we learn how to calculate the forces between atoms, and how those forces are responsible for the way that atoms move, when considered in terms of classical Newtonian mechanics. Finally, we will learn how to use computational methods to calculate the physical properties of minerals at the extreme conditions of the Earth's deep interior, and how such calculations provide insights into planetary processes.

15 February
13. Introduction to Lattice Dynamics

16 February
14. Lattice Dynamic Models

20 February
15. Lattice Dynamics of Silicates

22 February
16. Lattice Dynamics of Monatomic Crystals Part 1

23 February
17. Lattice Dynamics of Monatomic Crystals Part 2

27 February
18. Lattice Dynamics of Multi-atom Crystals

23 February
Seminar. Dr. Xiaolei Feng.
Predicting the structure properties of solids from first principles.

Lectures 19-24: Michael Carpenter. Phase transitions

Any change in atomic, magnetic or electronic structure that occurs in crystalline materials is almost invariably accompanied by lattice distortions (strain). This has implications for the thermodynamics of phase transitions and can result in very substantial (10's of %) changes in elastic properties. In this course, the fundamentals of elastic properties of minerals will be introduced using tensors and their relationship to symmetry. These will be illustrated using specific examples of phase transitions in minerals and functional oxides.

1 March
19. Physical properties of crystals I: tensors, strain and thermal expansion

2 March
20. Physical properties of crystals II: the piezoelectric effect

6 March
21. Introduction to Landau theory of phase transitions

8 March
22. Octahedral tilting transitions in perovskites and introduction to elasticity measurements

9 March
23. Elastic properties of perovskites

13 March
24. Ferroelasticity

9 March
Seminar, Seb Haines
Title to be confirmed

Seminars
Seminars on current research topics in Mineral Sciences will be provided fortnightly on Fridays at 2/4pm, interspersed on alternate weeks with practical material.

Supervisions
Supervisions are arranged in groups of 2-4 and given towards the end of each set of lectures.