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1 Welcome & Introduction

Scotland is known as the global home of geology because of its fascinating landscapes and immense geological diversity. This part of Earth’s crust is synonymous with internationally renowned geologists including Hutton, Barrow, Peach, Horne and Lyell and over the next five weeks you will literally walk in their food steps as you explore the temporal expanse of the Scottish Highlands. Geology has been taught at the University of St Andrews for over 120 years; today we are delighted to welcome you to our School.

ES4801 aims to expose students to the maximum amount of geological diversity as is possible in 5 weeks. Fortunately, the University of St Andrews (Fig. 1 a) is ideally located on the Fife coastline and has direct access to world class sedimentology and volcanology that starts from the doorstep of the School of Earth and Environmental Science (SEES). You will also spend one week working on classic metamorphic Buchan and Barrovian Sequences in the Grampian Highlands (Fig. 1 c, d & e), another week unravelling the complex structure of the Moine Thrust and the Caledonian Foreland (Fig. 1 f) and another on the Isle of Mull, Iona and Staffa (Fig. 1 g) building a synthesis on the geodynamic evolution of the Scottish Caledonides based on your own field data. Ultimately, this will allow you to visualise the anatomy of ancient mountain belts and develop a perspective on the geodynamic evolution of complex terranes over >3 Ga.

This document includes the course syllabus, information on the course logistics and information on what sort of equipment you will need to attend this course. Attending students will be provided with a course field guide and a course quick reference “Field Geology Methods” handbook. If you have any questions please see the module website (http://earthsci.st-andrews.ac.uk/study/earth-science-field-academy/), contact the Module Coordinator (Dr William McCarthy; geologyfieldcamp@st-andrews.ac.uk) or find us on Facebook (www.facebook.com/GeologyFieldCampScotland/).
2 Syllabus

2.1 Philosophy

Fieldwork and mapping are fundamental to the Earth and Environmental Sciences and form the foundation upon which the spatial and temporal frameworks of geological reconstructions are based. They are central to almost all geological and environmental studies and constitute an essential component of your training. You will, over the course of the next five weeks, develop skills in systematic observation and data collection, critical and independent testing of hypotheses, and accurate recording of that information.

We adopt the motto "the best geologists are the ones who have seen the most rocks" and so during this course students spend the maximum amount of time possible "on the rocks". This will allow you to learn how to independently interpret the geological history of a given terrane based on your own fundamental observations and field notes. As such, a brief series of lectures will introduce you to the geological history of Scotland and over the five week course you will to build a much more detailed understanding of this tectonic terrane through field work.

This module is appropriate for geoscience majors who have completed at least 24 US credits in geoscience. As an upper division course, each student is expected to supplement the prescribed reading & assignments with independent reading & research. Ask if you need direction. Interactive dialogue is the key to an interesting and successful course for everyone and will directly impact one’s ability to keep up with the high workload. There are no stupid questions, please ask challenging questions, express your ideas and share new insights.

2.2 Course Objectives

The benefits of gaining professional training in field geology extend well beyond Scotland. On completion of this course each student will have developed his or her own ability to:

- identify geological field relationships and interpret them in the context of complex geodynamic settings
- create, assess and test hypotheses using field based data sets to solve problems

Learning Outcomes

- develop skills in the systematic description & identification of minerals, rocks and geological structures
- learn how to systematically collect and compile data in a field notebook and geological log
- learn how to record and interpret data to construct a field map, office map and final map
- construct cross sections to visualise two-dimensional maps as an interpretation of 3-D relationships
- develop map reading, spatial awareness and compass/GPS skills
- enhance his/her ability to sketch, “picture speaks a thousand words” is a truism in geological training
- experience working in groups to refine communication, cooperation and organisational skills with and between group members in order to enhance and exchange ideas
- gain self-confidence and the ability to work independently (often the case in industry and academia)
- improve time management as you are required to complete each field area in an allotted time


## 2.3 Timetable

The summary timetable provided here is subject to change. Modifications will be made were adverse environmental conditions result in an unsafe work space. If a change needs to be made you will be notified by the Module Coordinator.

<table>
<thead>
<tr>
<th>Day</th>
<th>Date</th>
<th>Academic Activity</th>
<th>Resident Town</th>
<th>Catering/Washing</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>05/06/2019</td>
<td>Edinburgh/Glasgow Airport pickup @ 1500 (i.e. start of course)</td>
<td>St Andrews</td>
<td>DO, W</td>
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<td>MYO B, L, DO, W</td>
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<tr>
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<td>St Andrews</td>
<td>MYO B, L, D, W</td>
</tr>
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<td>Ass. 1 - Stratigraphy</td>
<td>St Andrews</td>
<td>MYO B, L, D, W</td>
</tr>
<tr>
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<td>St Andrews</td>
<td>MYO B, L, D, W</td>
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<tr>
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<tr>
<td>8</td>
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<td>Ass. 2 – submit x-section + report</td>
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<td>Ass. 3 - Polyphase folding &amp; the Grampian Orogen</td>
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<td>Ass. 3 - Portsoy - Buchan Metamorphism</td>
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<td>Ass. 3 - Portsoy - Buchan Metamorphism</td>
<td>Cullen</td>
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<td>Neoproterozoic + Sauk Transgression stratigraphy</td>
<td>Durness</td>
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<tr>
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<td>Faraid Head + Knockan Craig (fold and thrust belts)</td>
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<td>Ass. 4 Fold &amp; Thrust Belt Mapping</td>
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<td>23/06/2019</td>
<td>Ass. 4 Fold &amp; Thrust Belt Mapping</td>
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<tr>
<td>22</td>
<td>26/06/2019</td>
<td>Archean and Proterozoic</td>
<td>Durness</td>
<td>MYO B, L, D, W</td>
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<tr>
<td>23</td>
<td>27/06/2019</td>
<td>Tour 3.2 Billion Years of Earth History in 8 hours</td>
<td>Inverness</td>
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<tr>
<td>24</td>
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<tr>
<td>25</td>
<td>29/06/2019</td>
<td>Ass. 5 - Ross of Mull &amp; Scotland's Geological History</td>
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<td>26</td>
<td>30/06/2019</td>
<td>Ass. 5 - Ross of Mull &amp; Scotland's Geological History</td>
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<td>MYO B, L, D, W</td>
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<tr>
<td>27</td>
<td>01/07/2019</td>
<td>Ass. 5 - Ross of Mill &amp; Scotland's Geological History</td>
<td>Mull</td>
<td>MYO B, L, D, W</td>
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<td>02/07/2019</td>
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<td>30</td>
<td>04/07/2019</td>
<td>Geological Tour of Mull, Geodynamic Synthesis</td>
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<td>31</td>
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<td>Glencoe Volcanics</td>
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<td>Tyndrum Gold Mine</td>
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<td>33</td>
<td>07/07/2019</td>
<td>Return to St Andrews</td>
<td>St Andrews</td>
<td>MYO B, L, DO</td>
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<td>34</td>
<td>08/07/2019</td>
<td>Edinburgh/Glasgow Airport Drop off at 0900 (i.e. end of course)</td>
<td>Halls of Res. B</td>
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</table>

**Notes:**
- **MYO B, L, D** = Make your own Breakfast, Lunch, Dinner out of food provided.
- **DO** = Dinner will be provided for you at a designated restaurant.
- **W** = Clothes washing facilities available (talk to Camp Logistics Officer).
2.4 Assessment

Continual assessment (Reports 1, 2, 3, 4 and 5) equates to 100% of your final mark for ES4801. 10% of the marks for each of the five assessments are awarded for participation and discussion. No extra credit will be granted. Students will receive feedback on submitted work within 7 days of submission.

You will receive a course hand book and a field guide at the start of the module. These guides will contain background information about the terrane you will work in and the exercise/s that you will submit at the end of each exercise. As a guide consider the details below.

Exercise 1 Midland Valley Stratigraphy
20% - Field Notebook, two stratigraphic logs, schematic diagram and accompanying report
Emphasis is on keeping a systematic notebook and recording detailed observations in your notebook and sedimentary log sections. Critical thinking skills are assessed based on your ability to construct a logical interpretation of the stratigraphic sequence in the context of the broader geodynamic system.

Exercise 2 Fife Coastal Mapping
15% - Fife coast field map, office map, final map and notebook
5% - Geological history (~2 pages of your field notebook) and schematic cross section
Emphasis is on the systematic collection and representation of data on field maps & in field notebooks, the correct translation of this information onto the office map and the production of a professional final map. Credit is awarded for the accuracy of the compiled data and where this data is used to test rolling hypotheses. Evidence of critical thinking in 4D should be present in the end of day summary. The Cross section must be justified in the context of your field data and the geological history should be supported with references to field notes.

Exercise 3 - Grampian Terrane & Metamorphic Isograds
10% - Skatie Shore field maps, final map and notebook.
Credit is awarded for the identification of key index minerals and mapping out metamorphic isograds and regional scale geological structures in this field area. Detailed, annotated sketches should be a focal point of your efforts. A summary report should be included in the final end of day report.
10% - Portsoy field maps, final map, schematic sketch and notebook
Emphasis is placed on critical thinking in metamorphic P-T space. Your final interpretation will be presented in the schematic sketch and summary report. Your report must be supported by referring to key sketches and notes on your final map.

Exercise 4 Scotland’s Geodynamic History
20% - Geodynamic Synthesis of the evolution of Scotland report
The aim of this report is to incorporate multiple observations to independently develop a coherent geological interpretation of each field area i.e. go beyond the technical task of data collection. Credit is awarded where fundamental key pieces of field evidence are used to construct logical geological interpretations from multiple mapping areas. First Class marks are awarded for the successful comparisons drawn between geodynamic processes observed in the Scottish Caledonides to those observed in North America.

Exercise 5 Caledonian Foreland Exercise
20% - Durness field maps, office map, final map & cross section
The ultimate objective of this course is to recognise and become confident in interpreting the geodynamic nature of orogenesis. Emphasis is on your ability to utilise stratigraphy to understand the structural geology of the Moine Thrust Zone in three dimensions. Credit will be awarded where evidence for critical thinking and logic is presented and supported with data compiled on the field map and notebook. The cross section must be to scale and make sense in the context of your geological map and the known stratigraphy.
2.5 Grading & Mark Translation

Grades are assigned in line with the University of St Andrews Honours BSc Grade Point Criteria. These results can be converted to either US or Canadian equivalent scores using the University of St Andrews Guidelines for Credit and Grade Transfer criteria which can be found at this website: https://www.st-andrews.ac.uk/studyabroad/outgoingstudents/academicinformation/creditandgradeconversion/. As a guide only, the table below reflects the approximate scale at which grades have been converted in the past. Actual translation will depend on your home institutions policies and procedures.

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<th>% Mark</th>
<th>20 Point Scale</th>
<th>Degree Class</th>
<th>ECTS</th>
<th>% Mark</th>
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<th>Group 2</th>
<th>Group 3</th>
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<td>A+</td>
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<td>1</td>
<td>A</td>
<td>90-100</td>
<td>A+</td>
<td>A</td>
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<td>18</td>
<td>1</td>
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<td>80-84</td>
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<td>2i+</td>
<td>B</td>
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<td>B+</td>
<td>B+</td>
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<td>E</td>
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<tr>
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<td>≤ 4</td>
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<td>X</td>
<td>F</td>
<td>F</td>
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</table>

2.6 Standard of behaviour

Once accepted as a course participant you are a student at the University of St Andrews and represent the School of Earth and Environmental Science at all times. You are expected to conduct your business in a matter that upholds the reputation of the University and our School. Please note that you are bound by the rules and regulations of the University (see https://www.st-andrews.ac.uk/students/rules/). Any deviation from this standard will result in swift disciplinary action which may well result in your expulsion.

Every year thousands of geoscientists visit the world famous outcrops that you will be working. Your conduct can influence how geologists are regarded in an area for years to come. Be polite, respect landowner’s property and rights, take your rubbish home, close gates, don’t damage fences or harass livestock. For more information see the Field Geology Code that will be issued to each student.
The School of Earth and Environmental Science Staff

Geology has been taught at St Andrews since 1850 however the Earth and Environmental Sciences was recognised as an independent School 2017. The University has played host to several famous geologists over the last 150 years, including Charles Lapworth, Alleyne Nicholson and Harald Drever, and continues to produce exceptional graduates today, such as Dr Andrew Mackenzie, the current CEO of BHP Billiton and Professor Gordon Osinski, NSERC/MDA/CSA/CEMI Industrial Research Chair in Earth and Space Exploration at the University of Western Ontario.

The School of Earth and Environmental Sciences is recognized internationally as a leader in geological field training. The Guardian University Guide has judged St Andrews the best university is Scotland and the best place to study geology in the UK (2017 Complete University Guide). Scotland’s geological diversity is a key factor in our School’s field training. Situated in the Midland Valley Terrane, and just 1 hour from the Highlands, travel time is minimised allowing our students to spend more time “on the rocks”.

Note that you will have several tutors for this course, which reflects a standard practice in UK higher education. The exposure to a variety of different teaching styles is intentional, and ultimately is a positive learning experience for you, the student. Below you can find information on some of the lecturers you will work with over the course of ES4801 Geology Field Camp in Scotland.

William McCarthy  
Field Academy Director
Will conducts research on the architecture and structural controls on magma transport and storage in the crust of rocky planets. He employs a combination of traditional field geology, quantitative strain analysis, rock magnetic analysis and geochronology to investigate the formation of granitoid plutons and porphyry deposits.

Tony Prave  
Head of School
Tony obtained his PhD at Penn State University in 1986. His area of expertise is stratigraphy and the interpretation of key events in Earth history. His methods are dictated largely by a diligence to field geology and geochemical analyses.

Catherine Rose  
Sub-honours Advisor
Catherine is interested in pairing sedimentary stratigraphic data with a range of geochemical proxies to explore key Earth history events, such as large perturbations to the global carbon cycle and changes in climate. This work relies on making original field observations at a range of scales from rock outcrops to thin sections. She is currently investigating the impact sedimentology has on isotopic signatures preserved in modern and ancient settings.
Richard White
Chair of Geology
Richard is a world-leading metamorphic geologist with a broad spectrum of field, tectonic, petrological, mineralogical and thermodynamic research and teaching experience. Uniting the theory of novel thermodynamic models with the reality of field and petrographic relationships to understand the evolution of Earth’s crust formulate the core of his research.

Paul Savage
MSc Geochemistry Coordinator
Paul took his PhD at Oxford and now focusses on the application of non-traditional stable isotope techniques to planetary sciences. Combining his training as a field geologist with cutting-edge advances in geochemistry Paul investigates the early evolution of terrestrial planets.

Sebastian Fischer
Field Academy Co-Leader
Sebastian studies high-grade metamorphic process such as partial melting and melt segregation through a combination of zircon geochronology and geochemical data that is grounded in geological field observations. His current research focus centres on the mineral zircon and how high-grade metamorphic processes like partial melting affect the its isotropic composition and consequently the tectonothermal information stored in it.

Eva Stueeken
Field Academy Co-Leader
I am interested in the co-evolution of Earth and the biosphere, in particular in the environmental conditions that led to the origin of life, the invention of particular metabolisms and the rise of complex organisms. I use geochemical tools, including nitrogen, carbon, selenium and sulfur isotopes, combined with sedimentological observations, to characterize biogeochemical cycles in ancient environments and to establish linkages between environmental conditions and biospheric diversity.
4 Logistics
All transport, accommodation and sustenance expenses are included in your course fee. In order to ensure all participants in the module are comfortable and catered for it is important that everyone takes note of the instructions below.

4.1 Accommodation
While residing in St Andrews, each student will be assigned to a bedroom in the halls of residence. During field excursions dormitory hostel accommodation is provided. You will be asked to divide yourselves into groups of between 4 - 8 people to match the number of beds in each dormitory room. Please consider the fact that some students may wish to reside in single sex dorms, requests such as this will take first priority where possible. Laundry facilities are available at least every 4 days, many of our field bases have laundry facilities on site.

4.2 Transport
Transport for all excursions is via mini bus. It is imperative that seat belts are fastened and all baggage is stored in the designated area of each vehicle before the vehicle engine is turned on. When packing please be aware that space is limited.

4.3 Food & Allergies
When residing in St Andrews
Breakfast and dinner will always be provided (at no additional cost) in the halls of residence and a packed lunch will most often be handed out to each student in the minibus each day before departure to the field locality. However, on occasion (e.g. arrival weekend & departure day) lunch will be provided from the halls of residence. Please see the timetable for details.

When working in the Highlands
Materials from which you will make your own continental breakfast, packed lunch and dinner will be provided (at no additional cost). Students will be separated into "cooking groups" of approximately 5 people for the purpose of cooking dinner while in the highlands. Once we establish cooking groups please discuss what you would like to cook for dinner and relay this information to the Module Coordinator at the scheduled time (at least 24 hrs ahead of time).

- You are responsible for feeding yourself out of the materials provided while in the Highlands
- Eat breakfast and pack a big lunch; you will burn a lot of energy each field day
- Work as a team, organise cooking group & get your food order in at least 24hrs before you need it

Allergies
Students with any allergies should identify themselves to the Module Coordinator upon arrival to discuss any preventative measures that need to be put in place.

4.4 Safety in the Field
Safety is the number one concern and at all times. Every student is required to return a signed Field Geology Code declaration form. In addition, students are required to read, acknowledge and sign a risk assessment for each field excursion that will outline the risks that you will be exposed to and the safety measures put in place to avoid or guard against these risks.

Staff must be made aware of existing or potential medical issues at the start of the module and before any fieldwork is undertaken. Please be aware that we cannot provide any medication in the case of an emergency and so the onus is on each individual to carry appropriate medication at all times. This may include an inhaler, epi pens, antihistamine, diabetic medications etc.
If you do not wear your safety equipment* as and when instructed you will be reprimanded immediately, consider the following rules;

- *Full safety equipment* means hard hat, high visibility vest, goggles when hammering, warm clothing, waterproof pants and coat and suitable foot wear.

**Leader Responsibilities**
A leader of a field excursion will be appointed by the School and will be in charge of all participating staff and students. They will ensure that:

- a safety lecture is given and in time for students to obtain necessary field equipment
- staff have a list of the names, addresses and phone numbers of next of kin of all participants (a copy will be left with the School secretary)
- students acknowledge receipt of spoken and/or written advice by signature and that a witness is available to confirm any additional advice
- staff inspect students field equipment

**Student Responsibilities**
Students must:

- take safety advice seriously
- not endanger themselves or others by indiscipline or abuse of drugs and/or alcohol
- obey the instructions of the staff including the rigorous keeping of appointments
- inform the leader prior to the trip of any injuries, illnesses or disabilities that may present a risk
- report any injury, illness or harassment immediately
- provide up to date details about next of kin in case of accidents
- obtain suitable field clothing and footwear as advised
- sign a document stating that they agree to abide by all instructions given by staff
- receive and sign for a Health and Safety document

**General Hazards**

- lack of adequate equipment (maps, compass, clothing, etc.)
- isolation; stay with your partner(s)/group
- helmets must be worn on steep slopes and under rock overhangs
- hammering without goggles and using chisels is forbidden
- animals (wild or domesticated)---do not disturb them
- severe changeable weather (‘four seasons in-a-day’); everyone must have appropriate clothing

**Site-Specific Hazards**

- Do not expose yourself to hazards inherent in caving, rock climbing, or steep and exposed slopes.
- Do not work in active quarries; ask quarry owners for permission to enter disused properties.
- Road sections require lookouts wearing high-visibility clothing and to warn of approaching traffic.
- Streams and rivers can flood quickly; if the water level is above your knees then you should not cross.
- Upland areas can have steep, unstable surfaces (rock faces, cliffs and screes), changes in weather can be extreme and high winds and sudden drops in temperature can induce hypothermia.
- Watch out for boggy areas, sink holes and concealed rock crevices; beware of rock falls, avalanches and landslides; lakes can have unstable sides and slippery shores.
- Coastal areas have all the hazards of upland areas plus changing and variable tides, currents and abnormal waves; headlands and coves can become cut off at high tide; coasts can have slippery rocks and boulders and are particularly exposed to bad weather; **don’t go swimming.**

**CONCLUSION:** If you feel frightened, then you should not be there.
4.5 Contact Information

If you need general assistance you should call the numbers below. In the vast majority of cases, your first port of call should be the module coordinator or other members of staff who you know are nearby. This may be the head office in your halls of residence, the SEES office or most likely other members of staff in the field.

ES4801 Coordinator;
William McCarthy email; geologyfieldcamp@st-andrews.ac.uk

School of Earth and Environmental Sciences office;
Phone; +44 (0)1334 463940 email; earthsci@st-andrews.ac.uk

David Russell Apartments (Halls of Residence);
Phone +44 (0)1334 467100 email; drareception@st-andrews.ac.uk

In the event of an emergency please do not hesitate to contact the emergency services

Emergency Numbers
999 or 112
You can call or text these numbers (where signal is poor a text may still send)

Ask for mountain rescue if you are in an isolated area, especially if there is no roadside access. Be ready to give a CHALET report;

Casualties
Number of casualties, their names and, if possible, their age. List the type of injuries sustained (e.g. lower leg, head injury, collapse) etc.

Hazards
Hazards to the rescuers; for example, strong winds, avalanche, rock fall, dangerous animals.

Access
Name of the area and description of the terrain. Describe the approach and any distinguishing features such as an orange survival bag. Information on the weather conditions at the incident site is useful, particularly if you are in cloud or mist.

Location
What is your location? Use your field map or GPS to provide a grid reference and a description of your position. Don’t forget to give the map sheet number and please say if the grid reference is from a GPS device.

Equipment
What equipment is at the scene; torches, other mobile phones, group shelters, medical personnel?

Type of incident
What caused the accident? What is the nature of the environment (mountain, aircraft, train, etc.)?
5 Field Equipment

Always be prepared for changing climate conditions; this means carrying extra layers, wearing appropriate footwear and carrying extra food and water. If you are unsure what to pack please ask sooner rather than later and refer to the Field Geology Code for advice on equipment.

The type of field equipment needed on a daily basis may vary. As a guide, your basic back pack kit should always include:

<table>
<thead>
<tr>
<th>Item</th>
<th>Keep / Return at end of course</th>
<th>Received?</th>
<th>Returned?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard hat</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High visibility vest</td>
<td>R</td>
<td></td>
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</tr>
<tr>
<td>Goggles</td>
<td>R</td>
<td></td>
<td></td>
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<tr>
<td>Headlamp</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water bottle (lots)</td>
<td>R</td>
<td></td>
<td></td>
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<tr>
<td>Extra food (lots)</td>
<td>R</td>
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<td></td>
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<tr>
<td>Mobile phone</td>
<td>R</td>
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<td>Medical items</td>
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<td>Towel</td>
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<tr>
<td>Sun cream</td>
<td>R</td>
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<tr>
<td>Field hat</td>
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<tr>
<td>Swimsuit</td>
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<tr>
<td>Music for the van!</td>
<td>R</td>
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<tr>
<td>Hard hat</td>
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<tr>
<td>High Visibility Vest</td>
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<tr>
<td>Goggles</td>
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<tr>
<td>Compass Clinometer</td>
<td>R</td>
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<tr>
<td>Field Clipboard / mapping board</td>
<td>R</td>
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<tr>
<td>A group first aid kit</td>
<td>R</td>
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<tr>
<td>Field Guide</td>
<td>K</td>
<td></td>
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<tr>
<td>Hand lens + Lace</td>
<td>K</td>
<td></td>
<td></td>
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<tr>
<td>Field Notebook</td>
<td>K</td>
<td></td>
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<tr>
<td>Acid Bottle</td>
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<tr>
<td>Geological Map of the UK</td>
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<tr>
<td>Geological Time Scale</td>
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<tr>
<td>Grain size card</td>
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</tbody>
</table>

* Non-essential
* Bedding is provided – no sleeping bag needed

**You will be provided with the following items in your starting pack**

(R = must return, K = yours to keep)
6 Suggested Reading

A reading list with will be distributed to successful applicants after they have been formally enrolled in this course. This list will direct students to specific literature that is essential to ES4801. Below is a list of reference for general background reading.


