GEOL 20150: Earth Structure and Surface Processes

MODULE COORDINATOR: Dr Eoghan Holohan

ADDITIONAL LECTURERS: Dr Aggeliki Georgiopoulou

CREDITS: 5	**MODULE LEVEL**: 2	**SEMESTER**: I

PRE-REQUISITES/PRIOR LEARNING:

An introductory level module in Geology would be advantageous but is not essential.

OVERVIEW OF MODULE:

Plate tectonic motions define the internal structure, surface morphology, and sedimentological response of the Earth. We consider plate tectonic theory, its history and how it helps (or not!) to explain the structure and morphology of our planet. Moving from deep to shallow levels through the Earth, we explore how rocks deform and what geological structures are observed as a consequence. We examine how plate tectonic motions contribute to changes in sea level, topography and climate. Lastly, we analyse how rocks degrade and what evidence they provide as to the agents of degradation and transportation on the Earth's surface. Teaching formats include lectures, practical classes and a day field trip to a locality showing the effects of plate tectonics and related surface processes in the greater Dublin area.

LEARNING OUTCOMES:

On completion of this module students should be able to:

1. Describe the principles of and evidence for plate tectonics;
2. Outline the main theoretical and experimental constraints on rock deformation;
3. Understand the fundamental concepts of stress, strain and the rheology of rocks;
4. Differentiate brittle, brittle-ductile and ductile deformations and related structures;
5. Understand the main mechanisms of folding and the geometries of resulting folds;
6. Explain the origin and nature of foliations, lineations and shear zones in rocks;
7. Describe the nature and origin of rock fractures, such as faults, joints and hydraulic fractures;
8. Outline the strains associated with transpressional deformation;
9. Establish the geological structure of an area from map data;
10. Comprehend the links between plate tectonic motions, changes in sea/base level, and the sediment budget. Understand the fundamental concepts of sediment entrainment and transportation;
11. Recognise sedimentary structures and explain how they form;
12. Link sedimentary structures to the surface processes that produced them (flowing water, wind, gravity, waves);
13. Interpret and justify the original environment of deposition of sedimentary material;
14. Record, represent and analyse 3D structural and sedimentological data on a stereonet projection

ASSESSMENT:

Mid Term Test 1: 10%
(MCQ test covering material from lectures and practicals in weeks 1-3)

Mid Term Test 2: 10%
(MCQ test covering material from lectures and practicals in weeks 4-8)

Continuous Assessment: 30%
(Continuous assessment of laboratory notebooks, assignments and field notebooks)

Practical Examination: 20%
(2-hour end of semester practical examination covering practical work from entire course)

Examination: 30%
(2-hour end of semester written examination covering entire course)

LECTURES:

Lecture 1: Plate Tectonics: Origins and Evidence. *(Dr E.P. Holohan)*
Planet-scale structure of the Earth and the origins of plate tectonics. Evidence from geology, geodesy, seismology, magnetic and gravity data. Earth's principal tectonic features. Plate motions past and present.

Lecture 2: Tectonic Plates: Dividing and Sliding. *(Dr E.P. Holohan)*
Plate break up ('rifting') and divergent plate boundaries. 'Passive' continental margins. Transform/strike-slip plate boundaries.

Lecture 3: Tectonic Plates: Colliding. *(Dr E.P. Holohan)*
Convergent plate margins and 'active' continental margins. Continental collisions and the anatomy of orogenic belts. Neo-tectonics. Limits and uncertainties of Plate Tectonic Theory.

Lecture 4: Under Pressure: Stress, Strain and the Deformation of Rocks. *(Dr E.P. Holohan)*
Fundamentals of rock mechanics. Concepts of stress-tractions-forces, hydrostatic and deviatoric stress. Strain ellipse & lab-derived stress-strain relationships. Elastic, viscous, visco-elastic & plastic deformation.

Lecture 5: Rocks: Break or Bend? *(Dr E.P. Holohan)*
Introduction to brittle vs ductile deformation. Laboratory-derived constraints on factors controlling brittle-ductile behaviour of rocks. Implications for distribution of brittle and ductile deformation in the Earth.

Lecture 6: Folds in rocks: Geometry, Classification and Importance. *(Dr E.P. Holohan)*
Fold geometry and nomenclature. Quantitative classification using orthogonal thickness and dip isogons. Fold orientation, facing, symmetry and vergence. Importance of folds in Earth structure and morphology.

Lecture 7: How to Fold Rock. *(Dr E.P. Holohan)*
Folding mechanisms – buckle, flexural slip, flexural flow. The influence of viscosity contrast on fold geometry. Introduction to superimposed folding, interference patterns, polyphase deformation.

Lecture 8: Fold-related structures: A tale of Foliations, Lineations and Sausages. *(Dr E.P. Holohan)*
Cleavage, schistosity and relationship to folds. Crenulation cleavage. Strain and foliation development. Geometry and formation of lineations. Classification and origin of L-S fabrics, boudinage, rods & mullions.

Lecture 9: Shearing Rocks: From Streaky to Squeaky. *(Dr E.P. Holohan)*
Definitions of shear zones and brittle/ductile types. Ductile shear zone geometries and growth. Structures within ductile shear zones. Consideration of brittle shear zone movement indicators and fault rocks.

Lecture 10: Breaking Point: The Fracturing of Rocks. *(Dr E.P. Holohan)*
Brittle failure in theory and experiment. Principal, normal and shear stresses. Failure envelopes and the Mohr diagram. Conjugate fault sets and stress orientations. Fault geometry and nomenclature.

Lecture 11: Normal and Strike-slip fault systems. *(Dr E.P. Holohan)*
Normal (extensional) fault systems, their geometry and growth. Strike-slip (transcurrent) faults and associated features, such as pull-apart basins and negative flower structures.

Lecture 12: Thrust and Strike-slip fault systems. *(Dr E.P. Holohan)*
Thrust (compressional) fault systems. Geometry and nomenclature. Principles of section balancing and the geometries of thrusts in subduction zones and accretionary prisms. Pop-ups and positive flower structures.

Lecture 13: Joints, Veins and 'Fracking'. *(Dr E.P. Holohan)*
The formation of joints, veins and their relationships to folding and regional uplift. Controls of joints on water flow, landscape, and weathering. Principals of natural or man-made hydraulic fracturing.

Lecture 14: Plate Tectonics, Magmatism, and Volcanism. *(Dr E.P. Holohan)*
How plate tectonics is linked with the generation, transportation and eruption of magma. Structural forms of igneous intrusions. Controls of host rock strength vs magma viscosity. Impacts of volcanism on landscape.

Lecture 15: The Interplay of Tectonics, Morphology and Sedimentology. *(Dr A. Georgiopoulou)*
The planet's surface morphology is a direct consequence of plate tectonics. How sedimentary processes respond to morphological changes such as orogenesis and basin creation. The role of base level.

Lecture 16: Sea Level Changes and Sedimentary Responses. *(Dr A. Georgiopoulou)*
Sea level changes and sedimentation. Modern carbonate sediments: shallow and deep water. Contrasts between siliciclastic and carbonate sediments. Carbonate platforms and Ramps. Slope, lagoon, sabkhas and reef environments.

Lecture 17: Riddle of the Sands: Where from and how far? *(Dr A. Georgiopoulou)*
Sediment texture; grain size, sorting and skewness. Udden-Wentworth and phi grain size scales. Stokes Law. Typical sandstone components. Composition and sandstone classification. QFL-diagrams. Main controls on sandstone composition. Sand provenance.

Lecture 18: Fluids on the Move. *(Dr A. Georgiopoulou)*
Fluid properties and flow behaviour. Laminar vs. turbulent flows - geological examples. Subcritical and supercritical flow. Hydraulic jumps. Flow boundaries and flow separation. Bedform stability diagram. Hjulstrom diagram.

Lecture 19: Rivers of Water and Ice: Erosion and Deposition. *(Dr A. Georgiopoulou)*
Ripples and dunes. Cross-lamination and cross-stratification. Parallel lamination and antidunes. Structureless sands. Post-depositional structure: flame structures, water escape, liquefaction and fluidisation. Moraines and ice rafted debris.

Lecture 20: Tides and Waves. *(Dr A. Georgiopoulou)*
Wave induced ripples and hummocks. Hummocky and swaley cross-bedding. A traverse across a storm-influenced shelf. Origin and nature of tidal currents. Mud drapes, tidal couplets and heterolithic bedding.

Lecture 21: Blown by the Wind. *(Dr A. Georgiopoulou)*
Main differences between sediment transport by water and air. Wind vs. water ripples. Growth of aeolian sand dunes. Stratification types. Structures in wind-blown damp sand.

Lecture 22: Slumps and Instability of Slopes. *(Dr A. Georgiopoulou)*
Why slopes fail under gravity. Submarine slumps, slides, debris flows, turbidity currents, and their deposits. Tsunamis. The Bouma sequence. Deep sea fan concept.

PRACTICAL CLASSES:

Practical 1: Geological outcrop patterns on maps and their relationship to topography.
(Dr E.P. Holohan)
The geological map of Cheddar and how to break it down. Topographic contours and profiles. Structural contours and how they relate to topography and geological map patterns. Complete Maps 1, 4 & 5 in class.

Practical 2: Unconformities on geological maps. *(Dr E.P. Holohan)*
Unconformities. Complete Maps 9 & 10 in class - Bonus marks for cross-section of Map 10. Can you trace any unconformity on geological map of Cheddar?

Practical 3: Folded rocks and related map patterns. *(Dr E.P. Holohan)*
Folding. Complete Maps 11 & 12 in class – Bonus marks for cross-section of Map 12. Any evidence of folding on geological map of Cheddar?

Practical 4: Faults, folds and unconformities on geological maps and cross-sections.
(Dr E.P. Holohan)
Unconformity, faults and folds. Complete Maps 17 and 18. Give brief consideration to the structure of a map with non-plunging folds beneath an unconformity fault (Map 25). Can you make a sketch cross-section of the geological map of Cheddar?

Practical 5: Plunging folds and igneous rocks on geological maps. *(Dr E.P. Holohan)*
Plunging folds (Map 37) and Igneous rocks (Map 26), including flows and intrusions. Bonus marks for cross-sections in both cases. Any plunging folds on the geological map of Cheddar?

Practical 6: A real geological map – working out the geological structure and history.
(Dr E.P. Holohan)
Tackle the tasks and questions on the handout regarding the Cheddar Map.

Practical 7: Representing 3D structural data on a 2D image. *(Dr E.P. Holohan)*
Structure of a stereonet and how 3-D geological planes and lines are plotted on it. Use of stereonet to determine apparent dips from dip and strike readings, and to plot folded beds.

Practical 8: Calculating fold geometry from bedding data. *(Dr E.P. Holohan)*
Using pi diagrams (plotting poles to planes) to analyse 3-D data from folds. Determination of fold axis, axial plane and inter-limb angle of folds. Determination of stress orientations for a conjugate pair of faults.

Practical 9: Plotting and analysing your own field data from Loughshinny. *(Dr E.P. Holohan)*
Stereonet analysis of bedding and cleavage data from Loughshinny fieldtrip. Estimation of fold axis, axial plane and inter-limb angle for a selection of Loughshinny folds.

Practical 10: Graphical representations of grain size data. *(Dr A. Georgiopoulou)*
Measuring and plotting grain size distribution. Fundamentals of statistics and their use in grain size characterisation. Calculating permeability. Characterisation of texture and provenance interpretation.

Practical 11: Plotting and analysing palaeocurrent data. *(Dr A. Georgiopoulou)*
Construction of rose diagrams and interpretation. Plotting palaeocurrent data on stereonets.

Practical 12: Deducing depositional environments. *(Dr A. Georgiopoulou)*
Deducing depositional environments by using a lithological log and hand specimens with sedimentary structures in them.

FIELD CLASSES:

Loughshinny. *(Dr E.P. Holohan)*
Loughshinny holds evidence of a plate tectonic collision that happened some 300 Million years ago. Here we can examine a variety of resulting structures, including folds, faults, cleavage, fanning, fold-cleavage relationship, shear zones and pressure solution. Also visible are effects of long-term climate change, erosion and glaciation on the landscape. You will receive instruction in the use of compass-clinometer and the collection of structural data.