University of Toronto at Scarborough
Department of Physical and Environmental Sciences

EES A06: Introduction to Planet Earth

Winter 2021

Professor Nick Eyles

Teaching Assistants: Nicole Anasis, Andrew Zajch, Christine Palermo, Shane Sookhan,

Please read this document carefully especially the part on online modules. By answering the quiz which is worth 3 bonus marks you are agreeing to having read and accepted the conditions on submitting modules.

Structure of the course

This course consists of 12 weekly asynchronous lectures with a mid-term and final exam (each worth 30%) and 10 approximately weekly online modules involving self-assessment questions (10 x 4 = 40%).

Introduction

In this course, you will learn how our planet 'works' by virtual visits to countries in very different geologic settings and by meeting some of the people that live in dangerous areas affected by earthquakes, tsunamis and volcanic eruptions. We will examine how the planet formed and has evolved in the ancient past, how we determine the age of ancient rocks and events and the nature of changing paleoenvironments on the planet over its long 4.5-billion-year history. The course will conclude with a brief review of the geologic history of Canada, the importance of natural resources to our economy, and some of the current environmental problems facing our country and world.

For me life is a journey to see as much of the planet as possible; the idea behind this course is simply to share what I have learned, liked or disliked, with you all in the hope you will begin your own journey. Despite what it may appear at times in lectures, this is not a course about motorcycles. If you do like motorcycles so much the better. As a geologist I do a lot of fieldwork in various parts of the globe and I often use two wheels instead of four.

Geology rocks!

Geology (ge-ol’-o-gy): The study of planet Earth and its history (also referred to as Earth Science or Geoscience)
Physics: (‘fiziks’): The study of elemental matter and energy
Geophysics: (‘ge-o-fiziks’): The application of physics to geology

The scientific study of planet Earth is the subject of the scientific discipline called Geology. The science began in Ancient Egypt (many of today’s geologic terms are thousands of years old) but became globally important in the early 19th century primarily concerned with finding mineral resources such as coal and metal ores for the Industrial Revolution. It subsequently became a pillar of 19th century science by demonstrating the great age of the Earth (‘deep time’) which underpinned Darwin’s thesis that organisms have evolved through time.

Course summary

Planet Earth formed about 4.56 billion years ago (4.56 x 1, 000,000,000 which is abbreviated to Giga annum or 4.56 Ga) by condensation and accretion of dust and planetary debris. The Earth’s core, mantle and crust formed at this time by gravitational settling of heavier minerals in the planet’s interior. The oldest known rocks on Earth are dated at about 4.2 Ga suggesting that continents and oceans had already formed. The oldest bacterial life forms occur about 3.5 Ga and an oxygenated atmosphere developed somewhere around 2 Ga before present. Multicellular animal life forms became abundant about 600 million years ago (abbreviated to 600 Ma: mega annum: Ma) an event widely called the ‘Cambrian Explosion.’ The history of life since has been conditioned by episodic extinction events some possibly created by meteorite impacts.

Initially geologists thought that continents and oceans were immovable, fixed in position and had formed where they are now found. Continents grew in size through time by addition of crust around their margins; these views were propounded by *Permanentists* notably the American James Dwight Dana in the 1870s. Opponents called *Mobilists*, saw evidence that continents had previously been clustered together and had moved apart creating the modern oceans. The leading mobilist was the German Alfred Wegener a meteorologist by training and whose thesis (called Continental Drift) proposed in 1912 was rejected out of hand by Permanentists until the late 1960’s. How could continents move across solid rock below?

Better knowledge of the Earth’s interior and realization that the mantle is hot and is slowly moving by convection which when combined with improved knowledge of the ocean floors resulted in the development of Plate Tectonic theory in 1968 by the University of Toronto geologist, Jock Tuzo Wilson. The hard rocky outer skin of the planet (the crust) is thick (up to 100 km or more), brittle and broken into large pieces called ‘*lithospheric plates.*’ Continents are carried like passengers in the plates that move over the weak hot mantle rocks below at rates up to 25 cm a year. By sliding around the surface of the planet, plates move continents around, opening and closing ocean basins as continent collide or break apart and it has been in operation for at least 3.5 Ga.

Tectonics literally means ‘*to build*.’ Lithospheric plates are growing today at so-called ‘mid-ocean ridges’ (also called ‘spreading centers’) where new volcanic magma rises to the surface from the underlying mantle and cools to add to the edge of the plate. Addition of new magma and its cooling, results in continuous movement of the plate away from the spreading centre (hence its name). This is referred to as a ‘divergent plate margin’ and is most clearly seen in Iceland today where the mid-Atlantic Ridge is exposed on land and which separates the North American plate from the European plate which are moving in opposite directions away from the spreading centre. The North American continent is embedded in the North American plate and is moving to the west; Toronto is moving 3.7 cm every year. *In the 50 years that UTSC has been in existing it has moved almost 2 m westward from its original position.* Your home is not where it was last night and will be in a different place tomorrow. Don’t get lost.

The movement of plates leads to collisions between adjoining plates (called *orogeny*) and destruction of some plates by a process called *subduction* where one plate (usually the oldest) is driven down below the other. This is happening along the west coast of the Americas and around the margins of the Pacific Ocean and gives rise to large damaging earthquakes and volcanic eruptions. These are called ‘*convergent plate margins*.’

The entire plate tectonic process can be likened to a conveyor belt where new crust is created at spreading centres and eventually destroyed by subduction. In this way, the Earth is neither expanding nor shrinking in size. In some cases, orogenic events result in the fusing together of plates (a process called ‘obduction’) and the creation of even larger plates (called *supercontinents*). Geologists recognize a cycle of supercontinent formation and breakup (*the Wilson cycle* named after Tuzo Wilson) which is the basic rhythm of Earth history and divides the history of the planet into distinct chapters.

Four Wilson Cycles are currently recognized starting with a supercontinent called *Superia* or *Sclavia* (also known as *Kenorland* among some geologists) at roughly 2.6 billion years, *Nuna* at 1.8 billion, *Rodinia* at 1.0 billion and *Pangea* at 600-350 million years before present. There are probably even older ones too given that the original continental crust on Earth is just over 4 billion years old. On a hotter earlier planet before 3 billion years ago, plates may have been thinner and moved much faster and our understanding of how the Earth has worked for the last billion years may not apply to the very remote past. As we shall see in this course, Canada’s and Ontario’s geology reflects events during the formation and breakup of these supercontinents.

Planet Earth is currently in a phase of continent dispersal following the breakup of *Pangea* when the modern oceans first formed some 200 million years ago. The formation of the next supercontinent (*Pangea II*) will occur in another 250 million years’ time. This basic process is driven by convection of hot rock in the deep mantle (fueled by the heat of radioactive decay) and has been modeled to continue for another 4 billion years.

Ancient conditions on the surface of the planet are preserved in the form of rocks and by study of the ‘rock record’ we can reconstruct ancient (paleo)environments based on understanding how the modern Earth works. This simple concept (‘the present is the key to the past’) is called *uniformitarianism*. Apart from catastrophic events like large meteorite impacts that result in widespread extinctions, the concept has served geologists well.

The course concludes by looking at the 4 billion years long geological history of Canada and Ontario including reference to modern environmental problems facing Canadians. We will look at the complex causes and impacts of climate change, mineral exploration and mining, the impact of urban development, disposal of a wide variety of wastes, the clean-up of contaminated sites and waters, and the key role that environmental geoscientists play in our society. Some have argued that the influence of mankind on our environment is now so profound that we are now living in a different geological era referred to as the *Anthropocene*.

Learning outcomes

At the end of this course, you will know how planet Earth 'works' regardless of your course of study. This knowledge is the key to protecting our complex human world from risks and natural disasters, the need to protect the environment and to find ever scarcer resources, especially the minerals needed for a green economy and water, and extract them in an environmentally-sustainable fashion. This is a field called 'Environmental Geoscience' which is the focus of a Specialist Undergraduate Program within the Department of Physical and Environmental Sciences (DPES) and a 12-month all-course professional Master of Environmental Science (M. Env.Sc) program.

There is a shortage of suitably qualified environmental geoscientists in Canada and abroad. The profession requires well-trained individuals and offers many diverse opportunities for a career. If you are interested in a career in geoscience see the web site of the Association of Professional Geoscientists of Ontario (pgo.ca) and how to become a P.Geo.

Hopefully after this course you will want to do more courses in geoscience and environmental science. If you need advice join us online during office hours or email the instructor.

Other notes

1) The course textbook is *Canada Rocks – The Geologic Journey*. It frames the geological history of Canada against what is known of modern global plate tectonics. Relevant chapters for each lecture are shown on the attached weekly schedule. I don't e4xpect you to know or be examined on every detail and term in the textbook it is designed to provide background for what we do in lectures.

2) The course is organized around the *Wilson Cycle* and a useful resource is the 5-part *Geologic Journey- World* TV documentary series which aired on Canadian Broadcasting Corporation's 'The Nature of Things' in late 2010 with David Suzuki and myself and *which is available online*. It is based on the geology of various parts of the world and you will need to watch these to supplement lectures.

Evaluation and marks

The course will be evaluated by:

a) **Mid-term exam** (multiple-choice):	30 marks
b) **Completion of 10 online modules***:	40 marks
c) **Final exam** (*non-cumulative* multiple-choice):	30 marks

*Note that we will drop the lowest 2 module marks for everyone at the end of the course.

Exams will be based primarily on lectures and the textbook and will be online: if you miss them for medical reasons all relevant UTSC paperwork must be completed and submitted. *I will give you sample exam questions and specify that material I need you to revise.*

Things to make your life easier (and ours)

1. Please check Quercus regularly for updates and commonly asked Questions and Answers. I and the TAs will be available during regularly-scheduled office hours which will be announced asap.

2. We don't bell curve exam marks- ever!

3. We don't know the dates of the mid-term and final exams until we are informed of them by the Registrar's Office: we have no control over when they are *so don't ask.* Their dates will be announced as soon as we know.

4. AccessAbility Services: Students with diverse learning styles and needs are welcome in this course. In particular, if you have a disability/health consideration that may require accommodations, please feel free to approach the AccessAbility Services Office as soon as possible. They will work with you to ensure you can achieve your learning goals in this course. All enquiries are confidential. The UTSC AccessAbility Services staff members are available by appointment to assess specific needs, provide referrals and arrange appropriate accommodations (416-287-7560) or ability@utsc.utoronto.ca.

5. There are over 1000 students in this course and we have a well-tried system in place that works to ensure your time with us is worry-free. It works well *so you have no reason to email me* unless *there is a pressing personal matter that is not allowing you to fulfill the needs of this cours*e.

We do welcome feedback, and we will post online office hours so come join us and introduce yourself.

Enjoy the course and learn something you didn't know about this wondrous planet

Nick Eyles: December 2020

Module topics and dates and times of availability (Eastern Standard Time)

Each module will be posted on-line on the Monday of the relevant lecture (see lecture schedule) and you will have two *weeks* to review and complete each one with *no extensions*. Note that the last four modules (7 and 8, 9 and 10) are only available for one week only. Once you have completed the module, the material will still be available thereafter for exam revision purposes *but you will no longer have access to the questions/answers.*

1. The Plate Tectonic paradigm (available January 18th at 10 am to 5 pm January 31st)
2. How Earth works (available 10 am January 25th to 5 pm February 7th)
3. Divergent plate boundaries (available 10 am February 1st to 5 pm February 14th)
4. Convergent plate boundaries (available 10 am March 1st to 5pm March 14th)
5. Earth Materials (available 10 am March 8th to 5pm March 21st)
6. Natural Resources (available 10 am March 8th to 5 pm March 21st)
7. Canadian Shield (available 10 am March 22nd to 5 pm April 4th
8. The Paleozoic (available 10 am March 22nd to 5 pm April 4th)
9. Pleistocene glaciations (available 10 am March 29th to 5 pm April 4th): *one week only*
10. The Anthropocene (available 10 am March 29th to 5 pm April 4th): *one week only*

It is your responsibility to check the module schedule carefully for due dates. Also dates are subject to change based on unforeseen circumstances, it is your responsibility to check announcements regularly to ensure due dates have not changed.

The most common reasons for not completing the modules are illnesses, family emergencies, technical issues, and simply forgetting the deadline. Most issues can easily be avoided if you start early. The discussion board is the place to ask general academic questions but if you have any personal concerns (illness etc.,) or issues with the modules and your marks you must email **Andrew Zajch** (see below).

Technical issues may arise when completing questions online and prevent you from completing the module. These issues can be reduced by completing the modules on desktop or laptop computers rather than on mobile devices or tablets, using computers with Ethernet connection rather than Wi-Fi, using Chrome or Firefox browsers, and not leaving the module open and idle for more than 5-10 minutes. In the event of a **technical issue** with completing the module you must email Andrew Zajch at least 24 hours before the module deadline otherwise it will not be considered.

Sometimes Quercus will not post a mark for a module when completed. **ALWAYS TAKE AND KEEP A SCREENSHOT OF THE FINAL MARK SCREEN after finishing the module**. *It is up to you to check your marks that they are up-to-date, however please be patient as they may take up to 24 hours to update*. In this eventuality of a mark issue, email Andrew Zajch (andrew.zajch@utoronto.ca) *within a week of the deadline for that* *particular module. Submissions of screen shot documentation for multiple modules at the end of the semester will not be accepted.*