University of Gondar

College of Natural and Computational Sciences

Department of Geology

Modular Curriculum

for a

Master's Program in Geological Sciences

November 22, 2017

Gondar, Ethiopia

Modular Curriculum for a Master's Program in Geological Sciences

Under the

Department of Geology

Submitted for approval to:

College of Natural and Computational Sciences

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1. INTRODUCTION

The University of Gondar took its initial foundation in 1954 GC in the historical town of Gondar as the then Public Health College & Training Center (PHC&TC). Through time, the PHC & TC had evolved to the College of Medical Sciences, and then to the Gondar University College. After passing through various levels of growth as a medical higher education institution, which took 49 years, it was officially inaugurated as a university in 2004, by expanding its programs and scope of activities.

The College of Natural and Computational Sciences (CNCS) is one of the academic units at the University and has received a college status in 2014. By now, after 13 years of its establishment, the college involves 6163 students and 140 staff members in 8 departments. The number of undergraduate programs increased from 4 to 5 and then to 12, currently came to down 8 and the number of postgraduate programs from zero to14.

Following the higher education expansion program of the Government of Ethiopia in early 2000s, a number of geology have been established or are being established in existing or new universities in the country.
At the University of Gondar, the Department of Geology has been established in 2011 and to date it produced 190 B.Sc. Degree graduates. The Department has been conducting training and research in the wide areas of geosciences in collaboration with local and international partners and institutions. Researchers and graduates from the Department have been contributing in sectors such as geological surveying, groundwater, construction, energy, mining, and environment.

With the principal aim of meeting the growing needs of public and private institutions for professionally qualified personnel in the Earth Sciences, a new modular MSc curriculum was drafted in 2017 and presented for revision to the relevant professionals and stakeholders. The current MSc Program has 3 specialization areas: Petrology, Paleontology and Paleoenvironment, and Environmental Geology and Geohazards. Additional specialization would be included in the future as the equipment and human resource requirements are appropriately fulfilled.

2. RATIONALE OF THE MSc PROGRAMS

Enhancing the capacity of developing and utilization of own natural resources is very crucial for the development of any country. This in turn depends on the presence of highly trained professionals with the necessary knowledge and skills to understand the genesis, localization, extraction and utilization of these natural resources. Ethiopia is endowed with diversified geological resources, including economic minerals, fossil fuel, water, geothermal energy, construction materials,

etc., which are currently poorly developed. Consequently, there is an incessantly growing demand for highly trained geologists in Ethiopia.

Moreover, the application of geoscience for practical problem solving purposes requires a strong foundation in basic and applied geosciences in order to understand how natural systems function and modify our earth. It is therefore compulsory for a teaching and research department like the Department of Geology at the University of Gondar to have a strong graduate program which can provide research and teaching staff in both basic and applied geosciences with a proper mix in diversification of specializations.

The strategic location of Ethiopia with respect to unique geologic features and events is the other realistic reasons to have a research based graduate program in earth sciences at the Department. Ethiopia is the only place on earth where we find a complete record from the onset of continental breakup and the initiation of sea-floor spreading to the final formation of a new ocean. Furthermore, other geologic features including the extensive Cenozoic flood basalt, the presence of the Arabian Nubian Shield and the Mozambique belt practically juxtaposed, the Mesozoic sedimentary rocks that serve as signatures of the breakup of Gondwana, and other geologic features make Ethiopia a natural and open-air laboratory for Earth Sciences.

In accordance with the above facts, and after a thorough need assessment from relevant professionals and stakeholders, the Department of Geology at the University of Gondar has been preparing to launch new postgraduate (MSc) programs in the coming academic year 2017/2018. The curriculum for these MSc programs underwent repeated revisions by the staff members of the department and by the postgraduate office of the university to incorporate new developments in Geology. The current postgraduate programs are called for because of the following major issues:

i. The need to line up the mission, vision and goals of the department with respect to the university's visions/missions/goals;

ii. The need to align the department with the mission and vision of the university to expand and focus on postgraduate program with solid research component;

iii. The need to meet the contemporary and ever-growing demand for highly trained geologists of the country;

iv. The need to emphasize the unique geologic setting of the country and the presence of hominid bearing sites, especially, its strong link with the science of human evolution.

3. OBJECTIVES OF THE MSc PROGRAMS

General Objectives

The MSc programs at the Department of Geology - University of Gondar is aimed at producing the skilled manpower required to meet the national demand in the sectors of mineral, energy, and groundwater exploration and also in the construction industry. The program is also envisaged to meet the requirement in scientific personnel that can contribute to the understanding of the unique geological environment of the country and thereby help in the alleviation of natural hazards, poverty and sustainable use of resources.

Specific Objectives

The new MSc Programs in Geology are expected to produce MSc graduates:

i. That can initiate and undertake major research projects in the various fields of the earth sciences;

ii. That can give the required service by way of leadership and/or research to the public, government and private sectors, etc.;

iii. That can fill the middle and upper level manpower needs of the country in the earth sciences fields.

4. PROFILE OF THE MSc PROGRAM

The current MSc Program has the following specializations:

- Petrology
- Paleontology and Paleoenvironment
- Environmental Geology and Geohazards

Additional specializations would be included in the future as deemed necessary and appropriate. The current curriculum emphasizes the need for all programs to have strong earth science basis in one hand and broad and flexible enough to accommodate candidates with diverse non-earth science backgrounds on the other hand. Following the university wide MSc program structure, a total of 90 - 92 ECTS are divided between modules (60 – 62 ECTS) and thesis (30 ECTS). Each program is underpinned by general area modules and tools needed to enter into specialization while the specialization area modules offer in depth transfer of knowledge and skills in the discipline.

For each of the MSc programs, the program profiles, program objectives, graduate profiles, admission requirements, module types, course content and sequencing, graduation requirements, as well as degree nomenclature is outlined below:

4.1. MSc Program in Petrology

4.1.1. Program Profile

The MSc program in petrology incorporates all the basic fields of geology including Mineralogy and Petrology, Geochemistry, Sedimentology and Stratigraphy, as well as Structural Geology. These fields of study are not only basic requirements to further studies in the applied fields of geology, but are also major tools in understanding practically all internal and external earth processes, and in the evaluation of all earth resources. The program will provide specialized knowledge on the modern geochemical, petrological, stratigraphic and structural tools employed in all fields of earth sciences.

The involved staff members have been actively contributing to the advancement of teaching and research on cross-cutting and multi-disciplinary geological issues. The Department has been building its capacity in all fields of geological facilities (both laboratory and field equipment) with considerable success. The Department has also a great potential of collaboration and networking with national and international universities and federal ministries for sharing facilities and capabilities. Moreover, the Department has the required credibility and experience in soliciting more resources to build more facilities.

4.1.2. Program Objectives

The program aims to provide concentrated modular training in petrology to enable graduates to lead the way in the advancement of geological sciences in the country, including working in the industry, teaching in higher learning institutions, and/or to be prepared to pursue a higher research (PhD) degree in Geological Sciences. The basic objectives of the program are to produce graduates with comprehensive geological knowledge and specialized knowledge in igneous, sedimentary, and metamorphic petrology. The Program will equip graduates with the required theoretical, analytical, and quantitative knowledge required to the study of earth processes and materials. Furthermore, the need for academic staff to be involved in both teaching and research activities in the new universities opened and to be opened calls for graduates having a deep understanding of the various geological sciences.

4.1.3. Graduate Profile

General: Upon successful completion of all the required modules/courses in the curriculum, the graduate of MSc in any of the programs will have an advanced

knowledge and skill in geoscience, acquire a thorough expertise in scientific research methods and applications, and be able to play a significant role in earth science related tasks and responsibilities, including:

- Teaching in institute of higher education in the undergraduate program
- Working in various public and private sectors and industries
- Designing and conducting independent geoscience research projects
- Carryout mainstream consultancy services as well as solving multifaceted contemporary geoscience problems
- Be able to perform key role in other societal issues related to professional values, environment, sustainable development and enhancement of science and technology.

Program Specific: In addition to the comprehensive graduate profile applicable to all programs in the Department of Geology outlined above, a graduate with MSc in Petrology will have additional specific graduate profiles as outlined below:

- Have the basic mineralogical, petrological, and geochemical knowledge;
- Have a comprehensive knowledge and in depth understanding of geological materials and processes
- Be able to conduct an in-depth analysis of natural geological processes;
- Have skills in identifing the petrography, petrological data and analysis.
- Be able to plan, develop, analyze and execute research works in the fields of mineralogy, petrology and geochemistry and provide basic data for applied fields of study.

4.2. MSc Program in Paleontology and Paleoenvironment

4.2.1. Program Profile

The MSc program in Paleontology and Paleoenvironment incorporates all the basic fields of Paleontology, such as Invertebrate Paleontology, Vertebrate Paleontology, Biostratigraphy, Micropaleontology, and paleobotany. The modules focus on the study of the major groups of fossils, with special reference to their evolutionary history and stratigraphic distribution, as well as fossils as paleoenvironmental indicators. These fields of study are basic requirements to further studies in the applied fields of Paleontology, including reconstruction of Paleoecology and Paleoenvironment, and understanding of ancient climate. The specialization will provide specialized knowledge on the modern paleontological, and biostratigraphic tools employed in the fields of paleobiology and the evolution of life on Earth. Moreover, Ethiopia is strongly endowed with immense paleontological resources, which includes a rich discovery of hominid fossils, like Lucy and others, from both the Afar and Omo basins. These discoveries qualified the country as “the origin of mankind”. Hence, this MSc program will provide an in-depth knowledge of the evolution of humans and their environment, and the evolutionary and functional morphology of their skeleton.

4.2.2. Program Objectives

The main objectives of the program include providing concentrated modular training in the history of life on Earth; the taphonomy and preservation of animal- and plant fossils and methods of studying them; the morphology and classification of the main groups of invertebrate animals with emphasis on those of geological importance; the science of palynology, paleobotany; the biostratigraphic importance of macrofossils and microfossils; comparison of living organisms with their fossil relatives, and the taxonomy and nomenclature of the main groups of fossil organisms.

4.2.3. Graduate Profile

General: The comprehensive graduate profile applicable to all programs in the Department of Geology is outlined above in section 4.1.3.

Program Specific: In addition to the comprehensive graduate profile applicable to all programs in the Department of Geology outlined above, a graduate with MSc in Paleontology and Paleoenvironment will have some additional specific graduate profiles as outlined below:

- Have a comprehensive knowledge and understanding of ancient environment: climate, tectonics, flora, fauna, etc.;
- Have the ability to apply the concepts of biostratigraphy in unraveling the geological history of the Earth at the local, regional and global scale;
- Have the role of active participation in the science of vertebrate paleontology and human evolution;
- Have the ability to undertake advanced research in the fields of invertebrate- and vertebrate paleontology, micropaleontology, human evolution, and reconstruction of paleoecology and paleoenvironment.

4.3. MSc Program in Environmental Geology and Geohazards

4.3.1. Program Profile

The MSc program in Environmental Geology incorporates all the broader issues of global environmental challenges facing the human society. After successful completion of the MSc program, the graduates will have an in depth understanding of the interactions between humans and the global environment; develop skills and insight into critical thinking and situational awareness of their surrounding environment; gain an understanding of the physical processes that operate in and on earth; will be equipped with the knowledge and aptitude that are useful in reducing risks for society caused by natural and human-induced hazards.

4.3.2. Program Objectives

The principal objective of this Program is to offer a comprehensive understanding of the environmental and hazardous earth activities. The program aims to produce graduates with sound knowledge and skills in environmental geology, who can work in collaboration with other geological and civil engineers, to critically evaluate, plan and execute environmental problem solving projects during large-scale construction activities, such as road construction, dam site selection and construction, etc.. The program also aims to train students that will be capable of integrating multi- disciplinary approaches to analyze, develop and manage geo-environmental resources in a sustainable manner, as well as in identification, analysis, assessment, prediction/forecasting and management of geological hazards (earthquakes, volcanism, landslides, flooding) and associated risks.

4.3.3. Graduate Profile

General: The comprehensive graduate profile applicable to all programs in the Department of Geology is outlined above in section 4.1.3.

Program Specific: In addition to the comprehensive graduate profile applicable to all programs in the Department of Geology outlined above, a graduate with MSc in Environmental Geology will have some additional specific graduate profiles as outlined below:

- Have a comprehensive knowledge and understanding of Environmental geological processes;
- Have both quantitative and qualitative skills in appraising geo-environmental processes;
- Have skills to model a geo-environmental system integrating all available information;

- Have skills in the acquisition and analysis of geo-environmental data for developing a sustainable resource use model, propose mitigation measures against geo-environmental problems;
- Be able to plan and design safe and quality environments for urban inhabitants;
- Be able to plan, develop, analyze and execute strategies to use geo-environmental resources, participate in community based activities and alleviate poverty through sustainable development;
- Have skills of characterizing and reasonably predicting geological hazards and developing mitigation measures;
- Be able to identify sites of geohazards, assess the risk and vulnerability of an area to geohazards, participate in designing and implementing a forecast, early warning, and management system of geohazards and involve in land use planning vis-à-vis geohazards.

5. ADMISSION REQUIREMENTS

5.1. General Admission Requirements

Applicants to the MSc Programs in the Department of Geology shall be admitted on condition that they have successfully completed Bachelor of Sciences Degree in any of the Geology/Earth Sciences fields or similar programs as per the university legislation. No work experience is required.

The admission of students from non-Geology background shall be given special consideration. The fundamental issue related to such candidates is their deficiency in Geology related courses, and hence the need to redress this deficiency so that they can fit to post graduate research in the fields of Geology. Although auditing of selected undergraduate courses as a mechanism to redress deficiencies has been in place for the past many years, it was found out to be inefficient, non-obligatory and not considered by the Registrar as a prerequisite neither for registration nor for status determination. Therefore, designing specific module(s) to each stream/ specialization depending on the background of the students and the requirement of the specialization to which the students are admitted is required. The module should incorporate selected topics of Geology relevant to the discipline and will be given by a number of instructors drawn from different fields of specializations in Earth Sciences. Each program area will determine the number of such modules and their ECTS.

Other general admission requirements are:

- General admission requirements of the University
- Acceptable performance in the entrance examination
- Preference to candidates with relevant work experience
- Other admission requirements to be set by each program

Applicants having institutional sponsor will have advantage to be considered for admission.

5.2. Program Specific Admission Requirements

5.2.1. Petrology

- General Admission requirements to the Gondar University Graduate Program;
- BSc degree in Geology/Earth Sciences only;

5.2.2. Paleontology and Paleoenvironment

- General Admission requirements to the Gondar University Graduate Program;
- BSc Degree in Earth Sciences/Geology only;
- Applicants with a BSc degree in Environmental and Biological Sciences might be admitted to the Paleontology and Paleoenvironment program. Such candidates are required to take the module "GEOL 5041: Earth Materials and Geologic Structures". If necessary the program may advise candidates to audit the following undergraduate courses: General Geology, Paleontology, Stratigraphy.

5.2.3. Environmental Geology and Geohazards

- General Admission requirements to the Gondar University Graduate Program;
- A BSc Degree in Earth Sciences/Geology;
- Applicants with a BSc degree other than geology streams might be admitted to the Environmental Geology and Geohazards program based on the evaluation of their credentials. However, such candidates are required to take the module "GEOL 5041: Earth Materials and Geologic Structures". If necessary the Program may advise candidates to audit the following undergraduate courses: General Geology, Environmental Geology.

6. REGISTRATION PROCEDURE

Registration is on semester basis. Students register for each module separately online after consultation of the Department Head. Registration procedures and timing shall be subject to change depending on the regulations and directions originating from the College Registrar Office or the Postgraduate Program Directorate.

7. PROGRAM STRUCTURE AND DURATION

The department has planned to give Environmental Geology and Geoinformatics programs in the following divisions; except Petrology and Paleontology and Paleoenvironment that will be provided only on regular basis.

- Regular program
- Summer program
- Extension program

The duration of these programs in normal condition will be in four semesters (two years) for regular students. However, this duration may vary depending up on the program divisions, which is two and half up to three years for extension and 4 summers for summer program and it is shown as follows:

Program Divisions	Minimum	Maximum
Regular	2 years	3 years
Extension	3 years	5 years
Summer	4 Summers	6 Summers

Extension of study period which is stated in the above table may be allowed, if the student would provide acceptable reason for an extension of this period and it should be approved by the department and by the Academic Unit Councils.

8. PROGRAM MANAGEMENT AND ACADEMIC GUIDANCE

The Department Graduate Committee shall be responsible for the implementation of the graduate program. The Department Graduate Committee is moreover responsible for monitoring the overall implementation of the program and monitoring and evaluation of the program. Module owner shall be assigned on semester basis by the Department Head. The Department Head, who will be assisted by a Graduate Program Coordinator will among others:

- Run day to day activities of the Graduate Program (module scheduling, class arrangements, etc.)
- Lead the administration of the entrance exams, final exams, thesis exams
- Guide students on academic matters and leading the student support system
- Serve as a chairperson of the DGC.

For academic guidance and arrangement of related matters, students shall consult the Graduate Program Coordinator or shall visit the University webpage.

9. EXAMINATION REGULATIONS, ASSESSMENT AND GRADING

Method of assessment

Students are assessed for a particular module continuously through examinations assignments, oral presentations, and reports (lab exercise, field reports). The assessment methods may vary from module to module. Grading of modules shall be based on the University or College wide Procedure. Final exams shall be assessed by an Examination and Standardization Committee under the Department Graduate Committee (DGC), and finally approved by the Department Unit Council (DUC). The overall module delivery and assessment is closely followed up by the Department Head, DGC and other committees to be established by the Department.

Evaluation/grading system

Examination or assessment points shall be marked out of 100% and later converted to letter grade. Each course shall have its own evaluation criteria and the grading system shall follow the rules and regulations of the University on such a matter.

Attendance

Students are expected to arrive on time and attend all classes, labs, tutorials, and fieldworks and for those who will not do these, the University policy shall be applied.

Plagiarism and cheating

Students must write their assignments in their own words. Whenever a student takes an idea, or a passage from another author, he/she must acknowledge the source. Plagiarism and cheating shall be considered as major academic offences. The Department shall use all appropriate mechanisms seriously to check and avoid plagiarism. For details see University's Legislation.

10. RESOURCES AND FACILITIES

10.1. Staff profile

S.N	Program	Staff	Specialization
1	Petrology	1 Associate professor (Dr. Dawit Lebenie) 1 Assistant Professor (Dr. Ilayaraja Kuman) 2 Lecturers	Sedimentologist & Paleontologist Sedimentologist and Remote Sensing

		(Mr. Tamrat Mekuria) (Mr. Wuletaw Mulualem)	Structural Geologist Metamorphic Petrologist
2	Paleontology & Paleoenvironment	1 Associate professor (Dr. Dawit Lebenie) 1 Assistant Professor (Dr. Ilayaraja Kuman)	Sedimentologist & Paleontologist Sedimentologist and Remote Sensing Specialist
3	Environmental Geology and Geohazards	1 Assistant Professor (Dr. Veera Narayana) 3 Lecturers (Mr. Wegene Talelign) (Mr. Alemu Mesele) (Mr. Desalegn Tiku)	Remote Sensing & GIS Engineering Geology Hydrogeology Geophysics
4	Technical Staff	Petrography Lab (1), Rock lab (1), Remote sensing & GIS Lab (1), Computer lab (1) and Crystallographic and Mineralogy lab (1)	

10.2. Facilities

S. N	Program	Facilities/teaching aids
1	Petrology	• *Rock laboratory* (hand specimens rocks) • *Crystallography and mineralogy Laboratory (*crystallography models) • *Petrographic laboratory (*Standard petrographic microscopes (1:1 ratio) and Standard thin sections of rocks and minerals) • Ore Microscopes (1:1) • Computer with Appropriate software (1:1) • LCD (1 per section), Computer (1 per section), internet connection (4 hr/week/student), • 2 Smart Class
2	Paleontology & Paleoenvironment	• Fossils, • Standard petrographic microscopes • Computer with Appropriate software (1:1) • LCD (1 per section), Computer (1 per section), internet connection (4 hr/week/student), • 2 Smart Class
3	Environmental Geology and Geohazards	• Dip meter (1:1), • Current meter (1:1), • pH meter (1:1), EC meter pack, • LCD (1 per section), Computer (1 per section), internet connection (4 hr/week/student),

11. GRADUATION REQUIREMENTS

Candidates for the MSc Degree in all the programs must:

- Satisfy the general graduation requirements of the of the University of Gondar;
- To complete courses in a program and graduate, a candidate need to take a minimum of 90 ECTS, a minimum CGPA of 3.00 and a maximum of one "C" grade in all courses as well as a minimum of "Satisfactory" grade in the MSc thesis work.

12. QUALITY ASSURANCE AND QUALITY INDICATORS

***12.1 Quality Assurance*:** To guarantee the quality and standard of the program the following must be considered:

- The presence of standard and updated text books and reading materials;
- The provision of adequate teaching aid per class (LCD, dedicated desktop, internet connection, and other aids as needed by the time and instructor);
- Adequate space and lab facilities for teaching and practical exercises;
- Courses be delivered by well qualified staff (Asst. Professor and above);
- Appropriate and enough number of personnel (academic staff and other necessary support staff), and field logistics (vehicles, tents, etc);
- Teaching load on the staff (not exceeding 12 credits hours) & a staff student ratio of about 1:10;
- Allocation of career counselor at a reasonable ratio and appropriate advisorship;
- Each course and the respective instructor will be properly evaluated by students and the feedback would be used to improve course delivery and examination;
- The department head will monitor the day to day activities and the postgraduate coordinator will follow the proper implementation of the curriculum;
- The curriculum will be reviewed every five years by considering feedbacks from staff members, students, alumni and stakeholders.

***12.2 Quality Indicators*:** When the above conditions are in place, the following will be considered as quality indicators:

- Attendance of at least 80 – 100 % (theory and practical/field) of the classes;
- Examination results of students;
- Competitiveness of graduates in the job market (through alumni track mechanisms);
- The result of student evaluation of instructors, courses, and Department according to the existing evaluation formats.

13. DEGREE NOMENCLATURE

Degree Nomenclature	
MSc Degree in Geological Science, specialized in Petrology	የማስተርስ ሳይንስ ዲግሪ በጂኦሎጂካል ሳይንስ (ፔትሮሎጂ)
MSc Degree in Geological Science, specialized in Paleontology & Paleoenvironment	የማስተርስ ሳይንስ ዲግሪ በጂኦሎጂካል ሳይንስ (ፓሊዮንቶሎጂ እና ፓሊዮኢንቫይሮሜንት)
MSc Degree in Geological Science, specialized in Environmental Geology and Geohazards	የማስተርስ ሳይንስ ዲግሪ በጂኦሎጂካል ሳይንስ (ኢንቫይሮሜንታል ጂኦሎጂ እና ጂኦሃዛርድ)

14. MODULE CODING AND MODULE LIST

The modules are coded with four-letter word followed by four numeric digits (e.g. GEOL 5041). "GEOL" in the Code represents "Geology" (i.e. Department of Geology). Module coding follows the following logic: in GEOL- Mwxyz, M represents Module; w represent the level of the module (level of the module increases from 5 to 6), w stands for level/year; xy is used for module number and z stands for geology modules when it is 1 and Supportive course when 2.

MODULE LIST

Module code	Module Name	Course code	Course Name
GEOL M5011	Research Method in Geoscience	Geol 5011	Research Methods in Geosciences
GEOL-M5021	Petrology	Geol 5021	Crystallography, Mineralogy and Petrography
		Geol 5022	Advanced Sedimentary Petrology
		Geol 5023	Advanced Igneous Petrology
		Geol 5024	Advanced Metamorphic Petrology
		Geol 5025	Volcanology
GEOL-M5031	Geochemistry	Geol 5031	Geochemistry
		Geol 5032	Low-T Geochemistry
		Geol 5033	Isotope Geochemistry
		Geol 5034	Exploration Geochemistry
GEOL-M5041	Structural Geology and Tectonics	Geol 5041	Earth Materials and Geological Structures
		Geol 5042	Structural Geology
		Geol 5043	Tectonics and Geodynamics
		Geol 5044	Paleo-stress Analysis and Rift Evolution
		Geol 5045	Paleomagnetism
		Geol 5051	Invertebrate Paleontology
		Geol 5052	Vertebrate Paleontology

GEOL-M5051	Paleontology	Geol 5053	Human Evolution
		Geol 5054	Micropaleontology
		Geol 5055	Palynology and Paleobotany
		Geol 5056	Paleoenvironment and Paleoecology
GEOL-M5061	Stratigraphy	Geol 5061	Stratigraphy
		Geol 5062	Sedimentary Environments and Facies
GEOL M5071	Geologic Resource	Geol 5071	Petroleum and Coal Geology
		Geol 5072	Organic Geochemistry
		Geol 5073	Mineral Deposits
		Geol 5074	Geology and Economics of Nonmetallic Minerals
		Geol 5075	Resource Exploration and Evaluation
GEOL M5081	Geophysics	Geol 5081	Principles of Geophysics
		Geol 5082	Exploration Geophysics
GEOL M5091	Engineering Geology	Geol 5091	Engineering Geology for Civil Structures
		Geol 5092	Geotechnical Investigation
GEOL M5101	Hydrogeology	Geol 5101	Hydrogeology
		Geol 5102	Engineering Hydrology
		Geol 5103	Groundwater Flow and Contaminant Transport Modeling
		Geol 5104	Isotope hydrogeochemistry
GEOL M5111	Environmental Geology	Geol 5111	Geohazards
		Geol 5112	Integrated Geohazards Analysis and Disaster Management
		Geol 5113	Environmental Impact Assessment
		Geol 5114	Environmental Modeling
		Geol 5115	Urban Geology
GEOL M5121	Remote Sensing & Geoinformatics	Geol 5121	Fundamentals of Remote Sensing & GIS
		Geol 5126	Remote Sensing & GIS Applications
GEOL-M6131	Thesis	Geol 6131	Seminar
		Geol 6132	Thesis
GEOL M5142	Numerical Methods and Geostatistics Module	Geol 5141	Numerical Methods and Geostatistics
COMP M5152	Computer Programming Module	Comp5151	Computer Programming

15. MODULE SEQUENCING AND MODULE BREAKDOWN

15.1. Petrology

Semester	Course Code	Course Title	Credit Hours	ECTS
I	Geol 5011	Research Methods in Geosciences	3	6
	Geol 5031	Geochemistry	3	6
	Geol 5142	Numerical Methods and Geostatistics	3	6
	Geol 5042	Structural Geology	3	6
	Geol 5126	Remote Sensing & GIS Applications	3	6
II	Geol 5021	Crystallography, Mineralogy and Petrography	3	6
	Geol 5022	Advanced Sedimentary Petrology	3	6
	Geol 5023	Advanced Igneous Petrology	3	6
	Geol 5024	Advanced Metamorphic Petrology	3	6
III		Elective	3	6
	Geol 5131	Seminar	P/F	P/F
	Geol 5131	Thesis	6	30
Total			**36**	**90**

Electives

Geol 5081 Principle of Geophysics (6)
Geol 5073 Mineral Deposits (6)
Geol 5045 Paleomagnetism (6)
Geol 5075 Resource Exploration and Evaluation (6)
Geol 5071 Petroleum and Coal Geology (6)

15.2. Paleontology and Paleoenvironment

Semester	Course Code	Course Title	Credit Hours	ECTS
I	Geol 5011	Research Methods in Geosciences	3	6
	Geol 5061	Stratigraphy	3	6
	Geol 5022	Advanced Sedimentary Petrology	3	6
	Geol 5056	Paleoecology and Paleoenvironment	3	6
	Geol 5051	Invertebrate Paleontology	3	6
II	Geol 5052	Vertebrate Paleontology	3	6
	Geol 5054	Micropaleontology	3	6
	Geol 5055	Palynology and Paleobotany	3	6
	Geol 5053	Human Evolution	3	6
		Elective I	3	6
III		Elective II	3	6
	Geol 6132	Seminar	P/F	P/F
	Geol 6132	Thesis	6	30
Total			**36**	**90**

Electives

Geol 5041 Earth Materials and Geological Structures (6)
Geol 5033 Isotope Geochemistry (6)
Geol 5062 Sedimentary Environments and Facies (6)
Geol 5121 Fundamentals of Remote Sensing and GIS (6)

15.3. Environmental Geology and Geohazards

Semester	Course Code	Course Title	Credit Hours	ECTS
I	Geol 5011	Research Methods in Geosciences	3	6
	Geol 5142	Numerical Methods and Geostatistics	3	6
	Geol 5041	Earth Materials and Geological Structures	3	6
	Geol 5126	Remote Sensing & GIS Applications	3	6
II	Geol 5111	Geohazards	3	6
	Geol 5114	Environmental Modeling	3	6
	Geol 5103	Groundwater Flow and Contaminant Transport Modeling	3	6
	Geol 5113	Environmental Impact Assessment	3	6
	Geol 5112	Integrated Geohazard Analysis and Disaster Management	3	6
III		Elective	3	6
	Geol 5112	Seminar	P/F	P/F

	Geol 6132	Thesis	6	30
Total			**36**	**90**

Electives

Geol 5102 Engineering Hydrology (6)
Geol 5092 Geotechnical Investigation (6)
Geol 5115 Urban Geology (6)
Geol 5082 Exploration Geophysics (6)

15.5. Environmental Geology and Geohazards (Extension)

Semester	Module Code	Module Title	Credit	ECTS
I	Geol 5011	Research Methods in Geosciences	3	6
	Geol 5142	Numerical Methods and Geostatistics	3	6
	Geol 5041	Earth Materials and Geological Structures	3	6
II	Geol 5126	Remote Sensing & GIS Applications	3	6
	Geol 5111	Geohazards	3	6
III	Geol 5114	Environmental Modeling	3	6
	Geol 5103	Groundwater Flow and Contaminant Transport Modeling	3	6
IV	Geol 5113	Environmental Impact Assessment	3	6
	Geol 5112	Integrated Geohazard Analysis and Disaster Management	3	6
V		Elective	3	6
	Geol 6131	Seminar	P/F	P/F
VI	Geol 6132	Thesis	6	30
Total			**36**	**90**

Electives

Geol 5102 Engineering Hydrology (6)
Geol 5092 Geotechnical Investigation (6)
Geol 5115 Urban Geology (6)
Geol 5082 Exploration Geophysics (6)

15.6 Environmental Geology and Geohazards (Summer)

Summer	Module Code	Module Title	Credit	ECTS
I	Geol 5011	Research Methods in Geosciences	3	6
	Geol 5142	Numerical Methods and Geostatistics	3	6
	Geol 5041	Earth Materials and Geological Structures	3	6
	Geol 5126	Remote Sensing & GIS Applications	3	6
II	Geol 5111	Geohazards	3	6
	Geol 5114	Environmental Modeling	3	6
	Geol 5103	Groundwater Flow and Contaminant Transport Modeling	3	6
III	Geol 5113	Environmental Impact Assessment (6)	3	6
	Geol 5112	Integrated Geohazard Analysis and Disaster Management	3	6
		Elective	3	6
	Geol 6131	Seminar	P/F	P/F
IV	Geol 6132	Thesis	6	30
Total			**36**	**90**

Electives

Geol 5102 Engineering Hydrology (6)
Geol 5092 Geotechnical Investigation (6)
Geol 5115 Urban Geology (6)
Geol 5082 Exploration Geophysics (6)

16 . MODULE DESCRIPTIONS

16.1 General Study Modules

Module Name:	Research Methods in Geosciences
Module Code:	GEOL M5011
Course Title:	Research Methods in Geosciences
Course Code:	Geol 5011

Credit Hours:	3	**ECTS:**	6

Course Objectives: The module aims at introducing the students how to define a research or thesis project, library and internet searching techniques, completing a literature review, preparing a research or project plan, research methods, preparing the project or thesis proposal, preparing the final thesis or project document, and preparing a successful oral presentation.

Learning Outcomes: At the end of this course students are expected to have a broad knowledge of how to use library search engines and other tools to find appropriate references to support their research; write a literature review to support a research project; describe the components of a research plan; write a detailed draft outline proposal for their research; give an oral presentation of their research, thesis, or project proposal; and critically assess written and oral research reports.

Course Content: Theoretical foundation in geo-scientific research: philosophy of science and logic of argument; the method of multiple working hypothesis, definitions of knowledge and hierarchy of knowledge; steps of scientific method (ask a question –research the topic-formulate hypothesis- test the hypothesis-analyze the data); research proposals and steps: problem identification, research priority setting, research and policy linkages, proposal preparation, methodology and content, activity listing, critical path method and log-frame approach, research milestones, techniques for progress monitoring, evaluation and reporting and accounting; performance factors and research budgeting; Research design: data collection, analysis and interpretation; Ethical issues in geo-scientific research and writing: plagiarism, self-plagiarism, academic dishonesty, citing sources, using the internet; Geo-scientific writing: earth science journals, open source journals, publications, reports, bibliographic survey, references, abstracts, editing, self-archiving; Presentation: research result oral and poster presentations, visual aids in presentations.

Course Outline:

1. Introduction to Philosophy of Science and Logic of Argument
   - Occam's razor
   - Circular arguments
   - Inductive reasoning
   - Justifying conclusions
   - Hierarchy of knowledge (Data, information, knowledge)
   - Definition, analysis, synthesis
2. Geologic Thinking
   - The method of multiple working hypotheses
3. Research Problem Formulation and Hypothesis Setting
   - Asking a valid research question
   - Researching the topic
   - Formulating hypothesis
   - Testing hypothesis and analyzing data

4. Bibliography
    - Bibliographic archives and searching for bibliography
    - Catalogues
    - Indexes and Indexing, thesaurus, using Scopus
    - Writing annotated bibliography
5. Bibliography Assignment on Selected Topics
6. Components of a Complete Proposal
    - Problem identification, research priority setting, research and policy linkages
    - Proposal preparation, methodology and content, activity listing
    - Critical path method and log-frame approach, research milestones
    - Thesis proposal writing
7. Proposal Writing Assignment
    - Write a thesis proposal of your own
8. Geo-scientific Writing and Research Publications
    - Abstract writing
    - Writing technical and research papers
    - Open source journals, self-achieving
    - Earth science journals, impact factors
    - Reviewing, peer reviewing
    - Writing fact sheets, pamphlets
9. Abstract Writing Assignment
    - Write abstract to a thesis or technical report or scientific paper given these materials
10. Ethical issues in Geo-scientific Research and Writing
    - Plagiarism, self-plagiarism, academic dishonesty
    - Tools in detecting plagiarism
11. Preparing for a Presentation
    - Selecting presentable results
    - Keeping time & dressing properly
    - Responding to questions
12. Poster and Oral Presentation
    - Students present their proposal written in section 7 orally and using posters

Course Delivery: The course will be delivered with some formal lectures but emphasis is given to practical exercises, group discussions, assignments, internet browsing.

Course Assessment: Written final exam (40%), bibliographic survey assignment evaluation (15%), abstract assignment evaluation (15%), proposal assignment evaluation (15%), poster/presentation assignment evaluation (15%).

Textbooks and Reference Materials

- Bowden, J. (2008) Writing a Report: how to Prepare, Write and Present Really Effective Reports. ISBN-10: 1845282930, 223p.
- John S. (200). The Oxford to Writing and Speaking. Oxford. OUP

- Oshiman , A. and Hogue, A. (1991). College writing skill: McGraw Hill
- Rudolph, F and lass, A.H. (1996). The class guide to better writing. New York
- Solomon G/ giorgis. (b1991) writing for academic purpose. AAU printing press
- Axelrod, B. and Cooper, R. (2001). The St. Martin`s Guide to writing. 6th ed. Boston

Module Name:	Numerical Methods and Geostatistics		
Module Code:	GEOL M5142		
Course Title:	Numerical Methods and Geostatistics		
Course Code	Geol 5141		
Credit Hours:	3	**ECTS:**	6

Course Objectives: The course aims at introducing students to statistical methods appropriate for the analysis of geological data; to enable students apply the methods of statistics in scientific research, decision making and future career; to demonstrate the importance and practical usefulness of statistics and probability in geological problems; to show how probability is a necessary foundation for understanding statistics; to show how to present data informatively and clearly; to equip students to apply probability and statistical methods to solve standard problems from a wide range of disciplines; to give students an appreciation of the limitations of standard statistical methods; to enable students to communicate the results of their analyses in clear non-technical language.

Learning Outcomes: At the end of this course students are expected to: have a broad knowledge of the basic understanding of statistical techniques in geological problems demonstrated through principles of data collection, descriptive statistics, probability, probability and sampling distributions, statistical inference, design and analysis of experiments, regression and correlation; understand the methods of data collection, organization, presentation, analysis and interpretation in geological studies; know what is meant by sample space, event, relative frequency, probability, conditional probability, independence, random variable, probability distribution, probability density function, expected value and variance; be familiar with some standard discrete and continuous probability distributions used in geological problems.

Course Content: Review on matrix analysis and linear algebra: Linear equations, homogeneous and non-homogeneous systems, matrix algebra, vector spaces, norms, inner products and orthogonality, determinants, Eigenvalues and Eigenvectors; Review of calculus and Ordinary Differential Equations: derivatives, integrals, differential equations, basics on series (power series, Fourier series); Probabilities theory and Basic uni-variate statistics; Multivariate statistics; Geostatistics: linear geostatistics, non-stationary geostatistics, multivariate geostatistics, non-linear geostatistics, simulations; Review on other mathematical methods used in earth-sciences: fuzzy logic and artificial intelligence, support vector machine, fractals, review on geometry, review on graph theory and its applications in earth-sciences, deterministic methods for spatial estimation, finite

elements and finite differences, wavelet and Fourier transform Laboratory: Geostatistical software exercises. Vector and Tensor analysis. Differential equations. Boundary value problems in geophysics. Integral transforms. Contour integration and conformal transformation. Series integration. Residual theorem. Special functions. Legendre function. Matrix calculus. Calculus of variations. Integral equations. Dirac Delata function. Selected topics in numerical analysis applications.

Course Outline:

1. Review on matrix analysis and linear algebra
2. Review of calculus and Ordinary Differential Equations
3. Probabilities theory and Basic univariate statistics
4. Multivariate statistics
5. Geostatistics
6. Review on other mathematical methods used in geosciences

Course Delivery: Lectures, tutorials, discussions, demonstration, computer lab practical and assignments.

Course Assessment: Two or more tests and assignments (20%), Mid Semester Examination (30%), Final Examination (50%).

Textbooks and Reference Materials

- Davis, J. C. (2002) Statistics and Data Analysis in Geology, 3rd edition, Wiley, New York.
- Blaesid, P. and Granfeldt, J. (2002) Statistics with Applications in Biology and Geology. Chapman and Hall, CRC.
- Bluman, A.G., Elementary Statistics: A Step by Step Approach.
- Coolidge, F.L. (2006), Statistics: A Gentle Introduction, 2nd Edition.
- David, S.M., McCabe, P. and Craig, B. (2008) Introduction to the Practice of Statistics (6th edition). W.H. Freeman.
- Eshetu Wencheko (2000). Introduction to Statistics. Addis Ababa University Press.
- Snedecor, G.W and Cochran, W.G. (1980). Statistical Methods, 7th Edition.
- Spiegel, M.R. and Stephens, L.J. (2007) Schaum's Outline of Statistics, Schaum's Outline Series, 4th Edition, McGraw-Hill.
- Woodbury, G. (2001) Introduction to Statistics, Duxbury press.

16.2. Petrology Modules

Module Name:	Petrology
Module Code:	GEOL M5021
Course Title	Crystallography, Mineralogy, Petrography

Course Code	Geol 5021		
Credit Hours:	3	**ECTS:**	6

Course Objectives: Crystals are the basic components of the rocks. Knowledge of its internal structure is essential to understand the environment of formation and also their industrial and other applications. Proper understanding of their growth and internal structure is important to evaluate their advantages and utilities. The main objective of this course is to explain the students about the character of crystals in general; internal or atomic structure of crystals; various forms of crystals and their division into classes and systems; methods of studying crystals. The course exposes the students to basic concepts of minerals, crystals, lattice, symmetry elements, growth and geometry.

Learning Outcomes: At the end of this course the students will know the physical and optical properties of crystals, and the internal atomic structure of crystals; will have a clear understanding of the various forms of crystals and their respective classes and systems. From a theoretical perspective, students will understand how the properties of minerals are a product of their crystalline nature and how mineral structures can be understood systematically from crystal studies. Students will develop an understanding of the interconnections between crystalline nature, chemical composition, physical properties and optical properties.

Course Content: This course comprises five main chapters: I) Geometrical crystallography (Point symmetry - 7 crystal systems and 32 crystal classes - stereographic projection - crystal lattice). II) Crystal chemistry (Coordination polyhedra - Isotypism - Isomorphism). III) Descriptive mineralogy and mineral classification. IV) Optical properties (Indice indicatrix - optical symmetry - Principles of the polarizing microscope - Observations in transmitted polarized light - Observations in reflected light). V) Petrography of igneous, sedimentary and metamorphic rocks.

Course Outline:

1. Introduction
   - Definition of crystallography, crystal, a Mineral
   - Molecular structure
   - Crystalline and amorphous
   - External form, variation of form and surface
   - Constancy of the interfacial angles
2. Crystal symmetry, Systems and Classes
   - Crystal Symmetry: crystal morphology, mirror planes, rotation axes, diads
   - and comparing diads and mirror planes o Symmetry elements: revision and introduction to more symmetry elements:
   - rotation axes, centre of symmetry, non-translational symmetry, inversion
   - axes, and translational symmetry
   - Symmetry operations

- Possible classes of symmetry: crystal classes (point groups), crystal systems,
- Steno's and Haüy's laws, stereographic projections
- Systems of crystallization and symmetry classes

3. General Mathematical Relations of Crystals
   - Axial ratio, axial plane
   - Parameters, indices, symbol
   - The Law of rational indices
   - Form, zone of crystals
   - Stereographic projection
   - Zone Law, relationship between symbols of faces and edges
4. Habit and Features of Real Crystals
   - Forms of crystal growth: Real crystals
   - Crystal aggregates
   - Twins
5. Physical Properties of Crystals
   - Mechanical properties of crystals: Cleavage, hardness, deformation
   - Thermal properties of crystals: Heat conductivity
   - Electrical properties of crystals: Electrical conductivity, pyroelectric and
   - piezoelectric properties of crystals
   - Magnetic properties of crystals
6. Crystal Optics
   - Light and its properties
   - Examination of crystals in plane-polarized light
   - Opacity, color, refractive index and pleochroism
   - Examination of crystals under crossed polars
   - Isotropic and anisotropic crystals: uniaxial and biaxial minerals (cubic, tetragonal, hexagonal, orthorhombic, monoclinic, triclinic)
   - Interference colors
   - Birefringence
   - Examination of crystals in convergent light
7. Review Class

Course Delivery: Lectures, tutorials, discussions, demonstration, computer lab practical and assignments. Group discussion, library reading, audio video, assignments, and tutorials, and e-learning.

Course Assessment: Continuous assessment (50%) and Summative assessment (50%), through written examination.

Textbooks and Reference Materials

- Klein, C., Hurlbut, C.S. (1985) Manual of Mineralogy, John Wiley, ISBN: 0471805807, 696 pp.
- Hurlbut, C.S.,Edwin S.W. (1998) Dana's Minerals and How to Study Them, John Wiley & Sons, 328pp.

- Klein, C., Hurlbut, C.S. (2002) Manual of Mineral Science, 22nd Ed, John Wiley & Sons, ISBN: 0471251771.
- Klein, C. (1989) MINERALS AND ROCKS: Exercises in Crystallography, Mineralogy, and Hand Specimen Petrology, New York, 402p.
- Philips, Wm, R., Griffen, D.T. (1986) Optical mineralogy, CBS Edition.
- Perkins, D. and K.R. Henke (2004) Minerals in Thin Section, 2nd Ed., Prentice-Hall.
- Putnis A. (1992) Introduction to mineral Sciences, Cambridge University Press. ISBN-13: 9780521429474, 978-0521429474, 480 p.

Module Name:	Petrology	
Module Code:	GEOL M5021	
Course Title	Advanced Sedimentary Petrology	
Course Code	Geol 5022	
Credit Hours:	3	**ECTS: 6**

Course Objectives: The course aims to provide students with the specialist knowledge about the origin of Sedimentary, that make up the crust of the Earth are essential part of a geosciences training. Knowledge of sedimentary petrology is a key in understanding of the different types of sedimentary rocks, the way how they are formed and where they are formed. These enable to further understand the natural resources associated with sedimentary rocks. The course is to equip students with basic knowledge of sedimentary petrology and its application in the investigation of the different natural resources that are found associated with these types of rocks.

Learning Outcomes: On completing this course students will be able to classify, describe, identify and name the major types of sedimentary rocks, understand sedimentary processes and interpret them in rocks, and characterize the major sedimentary environments and identify equivalent facies in the geologic record.

Course Content: Texture, mineral content and classification of sandstones and other detrital rocks. Relationship of detrital textures and mineral content to provenance, environment of deposition, and diagenesis. Deposition and diagenesis of carbonate rocks, evaporates, phosphates, sedimentary ironstones, siliceous sedimentary rocks and carbonaceous sediments. Sedimentary structures and their significance.

Course Outline:

1. Introduction to Sedimentary rocks
   - Petrology and petrography of sedimentary rocks
   - Genesis of Sediments and controlling factors
   - Environments of transport and deposition
2. Petrology of Siliciclastic rocks

- Weathering and the origin of sediment
- Sedimentary textures and properties: grain size, grain parameters,
- composition of detrital components, grain types and controls on
- composition
- Petrography and diagenesis of siliciclastic rocks
- Sandstones: classification, cementation, color and mineral identification
- tips description format, conglomerates and breccias varieties
- o Mudrocks: classification, important properties: fissility, texture, color,
- mineralogy
- Depositional environments for siliciclastic Rocks

3. Petrology of Non-siliciclastic rocks
   - Introduction to transport and precipitation
   - Deposition, diagenesis, and petrology of major non-siliciclastic rock groups
   - Limestone
   - Dolomite
   - Evaporites
   - Cherts
   - Phosphates
   - Organic rocks
4. Fluid Mechanics and Sedimentary Structures
   - Basics of fluid mechanics and sediment transport
   - Sedimentary Structures
5. Depositional Environments and Tectonic Settings
   - Introduction to environmental deposition and interpretation
   - Continental environments
   - Marginal-marine environments
   - Marine environments
6. Facies and Stratigraphy
   - Facies concepts
   - Computer modeling of sedimentary facies
   - Lithostratigraphy
   - Seismic, sequence, and magnetic stratigraphy
   - Biostratigraphy
   - Chronostratigraphy
7. Additional Topics
   - Turbidity currents on continental margins
   - Glaciations
   - The Earth's climate system - present day and a geological perspective.

Course Delivery: Through lectures using overhead projector and beamer, group discussion, library reading, audio video, assignments, and tutorials, and e-learning.

Course Assessment: Continuous assessment (50% consisting of at least 4 short exams) and Summative assessment (50%), through written examination.

Textbooks and Reference Materials

- Boggs, S. Jr. (2001) Principles of Sedimentology and Stratigraphy, 3rd Edition, New York.
- Blatt, H., Middleton, G.V. & Murray, R.C. (1980) Origin of Sedimentary Rocks (2nd Edition, Prentice-Hall.
- Nichols, G. (1999) Sedimentology and Stratigraphy. Blackwell Scientific Publisher.
- Pettijohn, F.J., Potter, P.E. & Siever, R. (1987) Sand and Sandstone, 2nd Edition, Springer-Verlag.
- Summerfield, M.A. (1991) Global Geomorphology: An Introduction to the Study of Landforms. Longman.
- Tucker, M.E. (2001) Sedimentary Petrology: An Introduction to the Origin of Sedimentary Rocks, 3rd Edition, Blackwell Scientific publisher.
- Tucker, M.E. & Wright, V.P. (1990) Carbonate Sedimentology, Blackwell Scientific Publisher.

Module Name:	Petrology	
Module Code:	GEOL M5021	
Course Title	Advanced Igneous Petrology	
Course Code	Geol 5023	
Credit Hours:	3	**ECTS: 6**

Course Objectives: The objective of this course is to give students a broad understanding of igneous rocks petrology. It is also intended to give students knowledge on the classification of igneous rocks based on modal, texture and chemical composition, besides introducing them with magma evolution, genesis and petrotectonic environment of the different types of igneous rocks. Understanding of the genesis of magma, evolution and magma series and classification of igneous rocks based on texture and chemical composition are prerequisites in the understanding the varieties types of igneous rocks.

Learning Outcomes: On completing this course students will have the following skills/knowledge: understand nature and source of magmas, igneous processes such as fractional crystallization and partial melting, characterize and classify igneous rocks, interpret binary and ternary igneous phase diagrams, understand the relationship between plate tectonic processes and magma sources; gain skills for the synthesis and interpretation of compositional variations of igneous rocks; and gain an appreciation of the changes that occur within the deep parts of the Earth's mantle (the lithosphere and asthenosphere) and how deep processes affect the dynamic evolution of the Earth as a system.

Course Content: The course will cover magma genesis and differentiation, cooling and textures and magma emplacement, classification of igneous rocks and Igneous Rocks of Importance (e.g., granite, ophiolite and komatite). Topics covered include the plate tectonic setting of igneous activity; the various styles of, and physical controls on, emplacement of magmas within the crust; the modification of magmas by crustal contamination during ascent; the various styles of volcanic activity, including the physics of volcanic eruptions and the role of chemistry and volatiles in determining eruptive style; use of radiogenic and stable isotopes in identifying sources of magmas and their subsequent history within the crust. The general course content: Introduction, major, minor, and accessory minerals in igneous rocks; textures of igneous rocks; classification of igneous rocks; igneous structures and field relationships; and magmatic processes and chemical evolution of magmas; and tectonic-igneous rock associations.

Course Outline:

1. Introduction
   - Major rock types
   - Earth's structure and composition
   - The mineral makeup of the Earth's mantle and crust
   - The origin of igneous rocks
2. Major, Minor, and Accessory Minerals in Igneous Rocks
   - A review (major rock-forming minerals are emphasized)
   - Introduction to igneous phase diagrams
   - Equilibrium, disequilibrium and metastable crystallization
3. Textures of Igneous Rocks
   - Major criteria used in the recognition of igneous rocks
   - Primary and secondary igneous textures, Zoning
   - How to use igneous textures for determination of rock's origin and crystallization history.
4. Classification of Igneous Rocks
   - Classification of various igneous rocks on the basis of their mineralogy,
   - texture and chemical composition
   - Root names and modifiers
5. Igneous Structures and Field Relationships
   - Extrusive and intrusive igneous bodies: forms and modes of occurrence
   - Types of igneous contacts
   - Emplacement of magmas in the crust and the "room problem".
6. Magmatic Processes and Chemical Evolution of Magmas
   - The chemical composition of igneous rocks as a tracer of magma
   - evolution
   - Parental, primitive, primary, evolved and derivative magmas
   - Major mechanisms and vehicles of magmatic differentiation
   - Magma evolution in graphs
7. Tectonic-igneous Rock Associations
   - Mid-oceanic ridge basalts and ophiolites

- Oceanic intraplate regionso Subduction zones and island arcs
- Continental arcs and subduction zones
- Hot spots continental rifts
- East African rift and associated igneous rocks (related to East African Rifts)

8. Granitoids/Rhyolites
9. Continental Flood Basalts and Other Rocks
    - Basalt/andesite
    - Layered mafic intrusions and large igneous provinces
    - Alkaline and associated rocks and anorthosites
10. Review Class

Course Delivery: The mode of instruction is mainly by lecturing, video, holding tutorial sessions; Formal lectures will provide an introduction to the theory underlying, igneous rock classification and the use of geochemistry in petrogenetic concepts.

Course Assessment: The course will be assessed through written examination. Continuous assessment (50%) and summative assessment of one final exam 50%.

Textbooks and References Materials

- Best, M. G. (2003) Igneous and Metamorphic Petrology, 2nd Edition, Blackwell.
- Cox, K. G., Bell, J. D. and Pankhurst, R. J. (1979) The Interpretation of Igneous Rocks. Unwin Hyman.
- Hall, A. (1996) Igneous Petrology, 2nd Edition, Longman Group Limited, Essex England, 551 p.
- Mackenzie W.S., Donaldson C.H., and Guilford C. (1982) Atlas of igneous rocks and their textures, Longman.
- McBirney, A.R. (2006) Igneous Petrology: Jones and Bartlett, Boston, 508 p.
- Middlemost, E. A. K. (1985) Magmas and Magmatic Rocks. Longman.
- Parfitt, E. and Wilson, L. (2008) Fundamentals of Physical Volcanology. Wiley-Blackwell.
- Thorpe R. and Brown G. (1985) The field description of igneous rocks, John Wiley and Sons.
- Wilson, M. (1989) Igneous Petrogenesis, Unwin Hyman, London.
- Winter, J. D. (2001) Introduction to Igneous and Metamorphic Petrology, Prentice-Hall.

Module Name:	Petrology	
Module Code:	GEOL M5021	
Course Title	Advanced Metamorphic Petrology	
Course Code	Geol 5024	
Credit Hours:	3	**ECTS: 6**

Course Objectives: The objective of this course is to equip students with the fundamental concepts on metamorphic processes and mineral reactions, metamorphic rocks, their textures and mineral assemblages; introduce students with the metamorphism of sedimentary and igneous rocks at different P-T conditions.

Learning Outcomes: After successful completion of the course, students will have an understanding of the metamorphic processes and mineral reactions, metamorphic rock textures and their mineral assemblages; will have gained the knowledge on the metamorphism of sedimentary and igneous rocks at various P-T conditions.

Course Content: The course will cover five major topics: (1) the physical and chemical metamorphic processes; (2) the description of metamorphic minerals and rocks; (3) the type of metamorphic facies and grades; (4) the relation between deformation and metamorphism; and (5) metamorphism of pelitic rocks, carbonate rocks, quartzo-feldspathic rocks, and mafic-ultramafic rocks.

Course Outline:

1. Metamorphic Processes
    - Environment of Metamorphism,
    - Metamorphism of Regional and Local Extents,
    - Overview of Metamorphism in Spreading, Subduction and Transform Plate Margins;
    - Physical and Chemical Processes;
    - Controlling Factors; Metamorphic Reactions;
    - Mineral and Phase Equilibria; Phase Rule of Metamorphism
2. Metamorphic Rocks and Minerals
    - Classification of Metamorphic Rocks;
    - Mineral assemblages and parageneses;
    - Graphic Representations; Triangular diagrams (AFM and ACF Projections)
3. Grades and Facies of Metamorphism
    - Index Minerals; Metamorphic Zones;
    - Metamorphic Facies;
    - Isograds and Reaction-isograds;
    - Prograde and Retrograde Metamorphism;
    - Geothermobarometry
4. Metamorphic Texture and Microstructures
    - Metamorphic Fabric and Texture,
    - Mineral Intergrowths, Overgrowths and Corona Structures,
    - Metamorphism and Deformation,
    - Porphyroblast-foliation Relationships
5. Metamorphism of Pelitic Rocks
    - Low-, Medium- and High-Pressure Metamorphism of Pelitic rocks;
    - Textural and mineralogical changes of pelites during metamorphism
6. Metamorphism of Carbonate and Quartzo-feldspathic Rocks

- Limestones, Dolomites, Marls and Quartzo-feldspathic Sediments in Low, Medium and High Pressure Regional metamorphism;
- Contact Metamorphism of Limestones and Dolomites

7. Metamorphism of Mafic and Ultramafic Rocks
    - Low-, medium- & High-grade Metamorphism of Basalts, Andesites & Gabbros;
    - Characteristic mineral assemblages of various facies;
    - Progressive Metamorphism of Lherzolites and Harzburgites (or Dunites)

Course Delivery: The mode of instruction is mainly by lecturing, video, holding tutorial sessions;

Course Assessment: The course will be assessed through written examination. Continuous assessment (50%) and summative assessment of one final exam 50%.

Textbooks and Reference Materials

- Barker, A.J. (1998) Introduction to Metamorphic Textures and Microstructures. Blackie, Glasgow, 162p.
- Best, M. G. (2003) Igneous and Metamorphic Petrology, 2nd Edition, Blackwell, 2003.
- Bucher, K. and Frey, M. (1994) Petrogenesis of Metamorphic Rocks. Springer-Verlag, Berlin, 318p.
- Fry, N. (1984) The Field Description of Metamorphic Rocks. John Wiley & Sons, New York, 110p.
- Passchier, C.W. and Trouw, R.A.J. (1996). Microtectonics. Springer-Verlag, Berlin.
- Winter, J. D., 2001. Introduction to Igneous and Metamorphic Petrology. Prentice-Hall.
- Yardley, B.M.D. (1989) An Introduction to Metamorphic Petrology. Longman, Edinburgh, 248p.
- Yardley, B.M.D., MacKenzie, W.S. and Guilford, C. (1998) Atlas of metamorphic rocks and their textures. Longman, England, 120p.

Module Name:	Petrology	
Module Code:	GEOL M5021	
Course Title	Volcanology	
Course Code	Geol 5025	
Credit Hours:	3	**ECTS: 6**

Course Content: This course is designed to provide students with adequate knowledge of the physical properties of magmas, eruptive mechanisms, volcanic products, and the relationship between volcanism and tectonics. The course is designed to introduce the student to the diversity in character of volcanism and its deposits within the geologic record. It also provides students to know the methods and instrumentation used to study volcanoes, the hazards of different types of eruptions, and the complex challenges of scientists being involved in the response to a crisis or eruption. The course has an equal emphasis on the physical processes governing volcanic eruptions, the products of eruptions and the effects of eruptions. Students will carry out an independent study that will take them through real cases at hand. Students will learn laboratory and field techniques; will acquire skills in modern methods of monitoring active volcanoes.

Course Outline:

Part I: Magmas and their Properties; Fluid dynamics
Part II: Global Volcanism
- Mid-ocean ridges, oceanic islands
- Continental Volcanoes and Island Arcs

Part III: Volcanic Eruptions and their Products
- Volcanic Edifices and Deposits
- Volatiles in Magma; Explosive Eruptions
- Pyroclastic Falls and Flow Deposits, Surges; Lahars
- Magma & Water

Part IV: Case Histories
- Iceland, Japan, Mid-ocean ridges
- Mt. St. Helens, Hawaii
- East African rift volcanoes: Niyragongo; Afar

Part V: Benefits and Hazards of Volcanoes; Extraterrestrial Volcanism
- Volcanic Hazard Assessment & Management
- Volcano Forecasting and Monitoring
- Benefits of Volcanoes
- Extraterrestrial Volcanism

Course Delivery: The mode of instruction is mainly by lecturing, video, holding tutorial sessions; Formal lectures will provide an introduction to the theory underlying, igneous rock classification and the use of geochemistry in petrogenetic concepts.

Course Assessment: The course will be assessed through written examination. Continuous assessment (50%) and summative assessment of one final exam 50%.

Textbooks and References Materials

- Best, M. G. (2003) Igneous and Metamorphic Petrology, 2nd Edition, Blackwell.
- Cox, K. G., Bell, J. D. and Pankhurst, R. J. (1979) The Interpretation of Igneous Rocks. Unwin Hyman.
- Hall, A. (1996) Igneous Petrology, 2nd Edition, Longman Group Limited, Essex England, 551 p.

- Mackenzie W.S., Donaldson C.H., and Guilford C. (1982) Atlas of igneous rocks and their textures, Longman.
- McBirney, A.R. (2006) Igneous Petrology: Jones and Bartlett, Boston, 508 p.
- Middlemost, E. A. K. (1985) Magmas and Magmatic Rocks. Longman.
- Parfitt, E. and Wilson, L. (2008) Fundamentals of Physical Volcanology. Wiley-Blackwell.
- Thorpe R. and Brown G. (1985) The field description of igneous rocks, John Wiley and Sons.
- Wilson, M. (1989) Igneous Petrogenesis, Unwin Hyman, London.
- Winter, J. D. (2001) Introduction to Igneous and Metamorphic Petrology, Prentice-Hall.

16.3. Geochemistry Modules

Module Name:	**Geochemistry**		
Module Code:	GEOL M5031		
Course Name:	**Geochemistry**		
Course Code:	Geol 5031		
Credit Hours:	3	**ECTS:**	6

***Course Objective*:** The course will cover advanced geochemistry theory with integrated applications in geochemistry for all streams as compulsory course. It will focus on the physical and chemical characteristic (including isotopic systems) of minerals, fluids and melts and how they influence the differentiation of Earth and contributed to its evolution over time.

***Learning Outcomes*:** On completion of this course the students will have the knowledge and skills to understand advanced concepts in geochemistry and explain the link between the physical and chemical properties of minerals.

***Course Content*:** This course will cover the following content: Introduction and fundamental thermodynamic concepts; Applications of thermodynamics to Earth Processes; Geochemistry of the solid Earth and introduction to the chemistry of the terrestrial planets; Geological processes and their geochemical signatures; Analytical methods in Geochemistry (XRF, INAA, ICP-ES/MS, AAS, EMPA, etc.). Geochemistry of Igneous, Sedimentary and metamorphic rocks; Aquatic and carbonate Geochemistry; Analyzing geochemical data (using major oxides, trace elements, REE, radiogenic isotopes, stable isotopes); Discrimination diagrams and interpretation of geochemical data; Isotope geochemistry and its application; Instrumentation and data generation of rock samples, analytical operation, calibration, standardization; source of error in geochemical analysis; Exploration geochemistry; Principles mineral exploration;

Sampling; analysis; Data generation and interpretation; Anomaly delineation and integration with geological; geophysical and structural data.

Course Outline:

Chapter 1 Introduction and fundamental thermodynamic concepts

Chapter 2 Applications of thermodynamics to Earth Processes

Chapter 3 Geochemistry of Igneous, Sedimentary and metamorphic rocks

Chapter 4 Geochemistry of the solid Earth (the crust, mantle and core)

Chapter 5 Geological processes and their geochemical signatures

Chapter 6 Aquatic and carbonate Geochemistry

Chapter 7 Analyzing geochemical data

7.1 Major oxides

7.2 Trace elements

7.3 Radiogenic isotopes and Stable isotopes

Chapter 8 Discrimination diagrams and interpretation of geochemical data

Chapter 9 Isotope geochemistry and its application

9.1 Concepts of radiogenic isotope geochemistry
9.2 Geochronological principles and applications
9.3 Stable isotopes in geological processes

Chapter 10 Instrumentation and data generation of rock samples

10.1 Analytical methods (XRF, INAA, ICP-ES/MS, AAS, EMPA, etc.)

Chapter 11 Exploration geochemistry

11.1 Principles mineral exploration

11.2 Sampling data generation, analysis and interpretation

11.3 Anomaly delineation and integration with geological; geophysical and structural data.

Course Delivery Method: Teaching is carried out as lectures and related examinations, laboratory exercises, literature survey and series of weekly and bimonthly seminars with compulsory attendance by each student in a course.

***Assessment Methods*:** The taught courses are assessed by a combination of written tests and continuous assessments including essays, seminars, presentations, practical reports and field reports. Grades are marked out of 100% and later converted to letter grade

Textbooks and Reference Materials

- ✓ Albarede, F. (1995) Introduction to Geochemical Modeling, 543 pp.
- ✓ Broecker, W.S. (1985) How to build a habitable planet.
- ✓ Faure, G. (1998) Principles and applications of geochemistry, Prentice Hall, 2nd Edition, ISBN 0023364505, 625 p.
- ✓ Krauskopf K.B., Bird, D.K. (1995) Introduction to geochemistry, McGraw Hill, 3rd Edition, ISBN 007113929X, 640 p.
- ✓ Li, Y.-H. (2000) A Compendium of Geochemistry, 475 p.
- ✓ Lunine, J.I. (1999) Earth, Evolution of a habitable planet.
- ✓ Manahan, S.E. (2000) Environmental Chemistry, 7th Edition, 898 p.
- ✓ Marshall, C.P., Fairbridge, R.W. (1999) Encyclopedia of geochemistry, 712 p.
- ✓ Rollinson, H. (1994) Using Geochemical Data: Evaluation, Presentation, Interpretation, 352 p.
- ✓ Morse J.W. and Mackenzie F.T. (1990) Geochemistry of Sedimentary Carbonates, 725p.
- ✓ Harry Y., Mcsween JR., Steven M., Richardson and Maria E. Uhle (2003) Geochemistry, Pathway and Processes, 381p.
- ✓ Ottonello G. (1997) Principles of Geochemistry, 938p.
- ✓ Zou H. (2007) Quantitative Geochemistry, 305p.
- ✓ Wilson M. (2007) Igneous Petrogenesis, 480p.

Module Name:	**Geochemistry**		
Module Code:	GEOL M5031		
Course Name:	**Low-T Geochemistry**		
Course Code:	Geol 5032		
Credit Hours:	3	**ECTS:**	6

***Course Objective*:** The course aims to provide students with detail knowledge of Low- and high-T geochemistry. It also introduces students the thermodynamic principals underlying modern geochemistry and it can be used to understand the distribution and migration of elements in various parts of the Earth (crust, mantle, core, atmosphere, oceans) and in minerals and rocks.

***Learning Outcome*:** It will provide in-depth understanding and quantitative-qualitative interpretations of chemical information and chemical reasoning to understand geological, hydrological and biological process.

***Course Content*:** The following topics will be covered in lectures and seminars and essay: Low-T Geochemistry includes Aquatic Geochemistry; Carbonate Geochemistry and diagenetic processes; Geochemistry of reactions at the Earth's surface: weathering, soils and streams; Oceans as a chemical system; Environmental Geochemistry (water, soil, air, etc.)

Course Outline

Chapter 1 Low-T Geochemistry

1.1 Aquatic Geochemistry

1.2 Carbonate Geochemistry and digenetic processes

1.3 Geochemistry of reactions at the Earth's surface (weathering, soils and streams)

1.4 Oceans as a chemical system

1.5 Environmental pollution (water, soil, air, etc.)

Course Delivery Method: Teaching is carried out as lectures and related examinations, literature survey and series of weekly and bimonthly seminars with compulsory attendance by each student in a course.

Assessment Method: The taught courses are assessed by a combination of written tests and continuous assessments including essays, seminars, and presentations. Grades are marked out of 100% and later converted to letter grade

Textbooks and References

- ✓ Albarede, F. (1995) Introduction to Geochemical Modeling, 543 pp.
- ✓ Broecker, W.S. (1985) How to build a habitable planet.
- ✓ Faure, G. (1998) Principles and applications of geochemistry, Prentice Hall, 2nd Edition, ISBN 0023364505, 625 p.
- ✓ Krauskopf K.B., Bird, D.K. (1995) Introduction to geochemistry, McGraw Hill, 3rd Edition, ISBN 007113929X, 640 p.
- ✓ Li, Y.-H. (2000) A Compendium of Geochemistry, 475 p.
- ✓ Lunine, J.I. (1999) Earth, Evolution of a habitable planet.
- ✓ Manahan, S.E. (2000) Environmental Chemistry, 7th Edition, 898 p.
- ✓ Marshall, C.P., Fairbridge, R.W. (1999) Encyclopedia of geochemistry, 712 p.

- ✓ Rollinson, H. (1994) Using Geochemical Data: Evaluation, Presentation, Interpretation, 352 p.
- ✓ Morse J.W. and Mackenzie F.T. (1990) Geochemistry of Sedimentary Carbonates, 725p.
- ✓ Harry Y., Mcsween JR., Steven M., Richardson and Maria E. Uhle (2003) Geochemistry, Pathway and Processes, 381p.
- ✓ Ottonello G. (1997) Principles of Geochemistry, 938p.
- ✓ Zou H. (2007) Quantitative Geochemistry, 305p.
- ✓ Wilson M. (2007) Igneous Petrogenesis, 480p.

Module Name:	Geochemistry		
Module Code:	GEOL M5031		
Course Name:	Isotope Geochemistry		
Course Code:	Geol 5033		
Credit Hours:	3	**ECTS:**	6

Course Objective: The course aims to provide students with detail knowledge in isotope geochemistry. For a geochemist, isotope geochemistry used to determine the age of the rocks and it is tracers to understand any geological processes as a basis for mineral exploration. It is also integrated with geology interdisciplinary areas such as economic and petroleum geology, petrology (igneous, metamorphic and sedimentary), structure and tectonics, hydrogeology, etc.

***Learning Outcomes*:** On completion of this course the students will have the knowledge and skills to understand and be able to use the various techniques of radiometric dating to determine the age of geologic materials and events, (2) be able to explain how radiogenic isotopes are used as tracers of geological processes, including evolution of the continental crust and mantle, and ocean circulation, (3) be able to explain how slight differences in mass lead to slight differences in chemical behavior of isotopes of an element.

Course Description: The course will cover details of Nucleosynthesis and Nuclear decay; The Principles of Radioactive Dating and Radiometric Dating Methods; Radiogenic Isotope Geochemistry; Stable Isotope applying Geochemistry; Isotope and Dynamic Systems Analysis; Instrumentation and Technique.

Course Outline

1. Nucleosynthesis and Nuclear decay

1.1 The chart of the nuclides

1.2 Nucleosynthesis

1.3 Radioactive decay

1.4 The low of Radioactive decay
2. The Principles of Radioactive Dating and Radiometric Dating Methods
2.1 K-Ar-Ca, Rb-Sr, Nd-Sm, U-Th-Pb, Lu-Hf, and RE-Os systems
2.2 Zircon and monazite dating
2.3 U-Decay Series dating.
2.4 C-14, Be, Al, Cl and other cosmogenic nuclides
2.5 Noble gases
3. Radiogenic Isotope geochemistry
3.1 Radiogenic Isotope geochemistry of the Mantle
3.2 Radiogenic Isotope geochemistry of the crust and crustal evolution
4. Stable Isotope Geochemistry
4.1 Equilibrium and kinetic fractionations in the hydrologic system and in the biosphere
4.2 Stable isotope systems: H, O, C, N, S, etc.
5. High-temperature applications of stable isotopes
5.1 Oxygen-isotope geothermometry and in assimilation and subduction systems
5.2 O- and S-isotopes in metamorphism, hydrothermal systems and ore deposits
6. Low-temperature applications of stable isotopes
6.1 Applications in Hydrology
6.2 Applications in Climate and Palaeoclimate
6.3 Applications in Palaeontology and Archaeology
7. Instrumentation and Technique
7.1 Analytical operation
7.2 Calibration and standardization
7.3 Source of error in geochemical analysis

Course Delivery Methods: Teaching is carried out as lectures and related examinations, laboratory exercises, literature survey and series of weekly and bimonthly seminars with compulsory attendance by each student in a course.

***Assessment Methods*:** The taught courses are assessed by a combination of written tests and continuous assessments including essays, seminars, presentations. Grades are marked out of 100% and later converted to letter grade.

Textbooks and References

- ✓ Allegre C.J. (2008) Isotope Geology, 534p.
- ✓ Stille p. and Shields G. (1997) Radiogenic isotope Geochemistry of Sedimentary and Aquatic Systems, 225p.
- ✓ Hoefs J. (2009) Stable isotope Geochemistry, 293p.
- ✓ Manoru O. and Podosek F.A. (2004) Nobel Gas Geochemistry, 302p.
- ✓

Module Name:	Geochemistry		
Module Code:	GEOL M5031		
Course Name:	Exploration Geochemistry		
Course Code:	Geol 5033		
Credit Hours:	3	**ECTS:**	6

***Course Objectives*:** The course aims to provide an overview of geochemical surveys and basic geochemical processes in the surficial environment and enable the student how to collect geochemical information in the field, organize sample materials and ensure appropriate quality control in the process in any exploration projects.

***Learning Outcome*:** On completion of this course the students will have the knowledge knowledge of using and interpreting any geochemical data for exploration purpose 2) to understand and design various geochemical methods in any exploration projects 3) helps to undertake proper planning in any exploration projects.

***Course Content*:** The following topics will be covered in lectures and seminars and essay: -the basic analytical methods and equipment; Geochemical sampling for chemical analysis and dating; Weathering; Soil Formation and Geochemical Characteristics; Surficial Environments (chemical equilibria, mechanical and biological dispersion, dispersion patterns); Natures of Geochemical Anomalies (element associations, dispersion mechanism, host material); Type of Geochemical Anomalies (residual anomalies, transported anomalies (syngenetic and epigenetic), natural water, drainage sediment anomalies); Geochemical exploration techniques (Exploration methods: sequence of exploration, orientation surveys, sampling design and methods, sample processing and analysis, data processing and interpretation).

Course Outline

Chapter 1 Geochemistry in mineral exploration
Chapter 2 Weathering
- 2.1 Nature of weathering
- 2.2 Weathering process
- 2.3 Factor Affecting weathering process
- 2.4 Weathering Products

Chapter 3 Soil Formation and Geochemical Characteristics
- 3.1 factors affecting soil formation
- 3.2 Classification of soils
- 3.3 Geochemical soil survey

Chapter 4 Chemical equilibria in surficial Environments
- 4.1 Eh-pH relationships

4.2 Mechanical and biological dispersion in the surficial Environments
4.3 Surficial dispersion patterns

Chapter 5 Natures of Geochemical Anomalies
5.1 Element associations and geochemical mobility
5.2 Geochemical dispersion mechanism
5.3 Geochemical reaction

Chapter 6 Type of Geochemical Anomalies
6.1 Residual anomalies
6.2 Transported anomalies (syngenetic and epigenetic)
6.3 Anomalies in natural water and drainage sediment
6.4 Geochemical drainage survey

Chapter 7 The basic analytical methods and equipment

Chapter 8 Geochemical sampling for chemical analysis and dating

Chapter 9 Geochemical exploration techniques
9.1 Choice of exploration method
9.2 Orientation surveys and Sampling media
9.3 Geochemical sampling design and methods
9.4 Sample processing and analysis
9.5 Data processing and interpretation.

Course Delivery Methods: Teaching is carried out as lectures and related examinations, laboratory exercises, field work and literature survey and series of weekly and bimonthly seminars with compulsory attendance by each student in a course.

Assessment Methods: The taught courses are assessed by a combination of written tests and continuous assessments including essays, seminars, presentations, practical reports and field reports. Grades are marked out of 100% and later converted to letter grade.

Textbooks and Reference Materials

- Moon C.J., Michael K.G., Whateley and Evan A.M. (2006) Introduction to mineral Exploration, 499p.
- Marjoribanks R. (2010) Geological methods in mineral Exploration and mining, 248p.
- Rose A.W., Hawakes H.E. and Webb J.S. (1979) Geochemistry in Mineral Exploration, 656p.

16.4. Structural Geology Modules

Module Name:	Structural Geology and Tectonics		
Module Code:	GEOL- M5041		
Course Name:	Earth Materials and Geologic Structures		
Course Code:	Geol 5041		
Credit Hours:	3	**ECTS:**	6

Course Objectives: The course aims to provide students with a general introduction to the geological science, the planet Earth, the Earth materials, as well as the physical and historical processes of the Earth. It also introduces students with basic concept of structural geology and petrology with varieties of representative mineral, rock and fossil specimens. The module will serve as a basis for many of the geology modules.

Learning Outcomes: On completing this module students will have the basic understanding of geology and its branches, the Earth and its materials, and various geological processes; and will be familiar with the main features of mechanical behavior of different minerals and rocks.

Course Content: The course will include seven chapters: Introduction to the earth where students are briefly introduced to and composition of the earth and its internal and external processes of our dynamic planet, the materials of the earth including the types of rocks and processes of their formations and alterations, Mechanical Behavior of rocks, Modes of Fracturing, Extensional Fault Systems, Rift Zones, Fault Geometry in Rifts, Deformation Mechanisms, Fold Geometry, Modes of Folding the various resources of the earth, and finally the geology of Ethiopia, major rocks types and their outcrop.

Course Outline:

1: Introducing the Earth

1.1 Specific methods of studying earth processes, materials and events:
1.2 The Earth in Space:
1.3 Structure and composition of the Earth:
1.4 The plate tectonic concept:

2: Materials of the Earth

2.1 Crystals and Minerals:
2.2 Petrology of Igneous rocks:
2.3 Petrology of metamorphic rocks:
2.4 Petrology of Sedimentary rocks:
2.5 Petrography: microscopic identification of minerals and rocks

3: Internal Earth Processes

3.1 Geological structures: brittle structures: faulting and jointing; ductile
3.2 structures: folds and foliations
3.3 Volcanism and volcanic hazards
3.4 Earthquakes and earthquake hazards

4: External Earth Processes and geomorphology
4.1 Weathering and Soil formation
4.2 Mass movements: causes of mass movements; types of mass movements: land sliding, subsidence
4.3 Landforms: major water, wind, glacial and coastal landforms

5: The Concept of time in Geology (Geological time)
5.1 How we count time in Geology
5.2 Methods of dating of rocks and events:
5.3 concepts of paleontology and geochronology
5.4 The Geological time scale

6: Mechanical Behavior of Rocks during Deformation:
6.1 Elastic and Plastic Behavior of Materials,
6.2 Behavior of Crustal Rocks,
6.3 Controlling factors of Rock Behavior

7: Recognition and Description of Fractures and Faults:
7.1 Rock Fractures and Joints, Fault Geometry, Description and Classification of Faults,
7.2 Modes of Fracturing, Shear Stress and Brittle Failure,
7.3 Extensional Fault Systems

8: Recognition and Description of Folds:
8.1 Fold Geometry, Classification of Folds,
8.2 Poly- phase Folding and Fold Interferences,
8.3 Modes of Folding,
8.4 Controlling Factors of Folding

9: Earth Resources
9.1 Concepts of resources and reserves
9.2 Classification of earth resources

10: Geology of Ethiopia

10.1General geological and geomorphologic makeup of Ethiopia
10.2Evolution of the major rock formations in Ethiopia

Module Delivery: Lectures, tutorials, discussions, demonstration, computer lab practical and assignments, group discussion, questioning and answering,

Module Assessment: Written tests, assessment of the practical exercises, related assignments and practical exam (50%) and one written final examination (from the lecture material) (50%).

Textbooks and Reference Materials

- Busch, R.M., (2000) Laboratory Manual in Physical Geology, Prentice Hall, New Jersey, 276p.
- Chernicoff, S. (1999) Geology, Houghton Mifflin Co., New York, 596p.
- Hamblin, W.K. and Christiansen, E.H. (2001) Earth's Dynamic Systems. Prentice-Hall, New Jersey, 735p.
- Lutgens, F.K. and Tarbuck, E.J. (2000) Essentials of Geology, Prentice Hall, New Jersey, 449p.
- Press, F. and Siever, R. (1997) Earth, Freeman, 672p.
- Davis, G.H. and Reynolds, S.J. (1996) *Structural Geology of Rocks and Regions* (2nd Edn). John Wiley and Sons, Inc., New York, 776p.
- Hatcher, R.D. (1995) Structural Geology: Principles, Concepts and Problems (2nd Edition). Prentice Hall, 525p.

Module Name:	Structural Geology and Tectonics		
Module Code:	GEOL- M5041		
Course Name:	Structural Geology		
Course Code:	Geol 5042		
Credit Hours:	3	**ECTS:**	6

Course Objectives: The course aims to provide students with the basic concepts of deformation of rocks and regions, and of the mechanisms and causes of deformation; to familiarize students with how to appreciate, describe and record geological structures in the field; to enable students how to evaluate, analyze and interpret structural data and incorporate it into regional synthesis of an area.

Learning Outcomes: On completing the course students will have the basic knowledge on rock deformation and rock mechanics, have the necessary skill to recognize, describe and analyze rock structures, and be familiar with the main concept of plate tectonics.

Course Content: The course covers the following topics: Primary and secondary structures; Environment of deformation; Forces and stresses; Stress Equations;

Deformation of rocks and the Concept of Strain; Stress-strain relationships; Mechanical behavior of rocks; Deformation mechanisms. Brittle structures: fractures and faults. Ductile structures: folds, classification of folds, mechanism of folding. Foliations, poly-deformation structures. Lineation's, boudins, mullions, rods. Shear zones, shear-criteria.

Course Outline:

Part 1

1. Stress Components and Stress Fields:
   Normal and Shear Stresses, Stress Equation in Two-Dimension, Mohr Stress Diagram, Laboratory Compression Tests
2. Strain Analysis and Strain Ellipsoid: Non-rigid Body Deformations, Strain Measurements, Strain Equations, Pure Shear and Simple Shear, Determination of Strain in Rocks
3. Mechanical Behavior of Rocks during Deformation: Elastic and Plastic Behaviorof Materials, Behavior of Crustal Rocks, Controlling factors of Rock Behavior
4. Recognition and Description of Fractures and Faults: Rock Fractures and Joints, Fault Geometry, Description and Classification of Faults, Modes of Fracturing, Shear Stress and Brittle Failure, Extensional Fault Systems
5. Rift Zones: Mechanism, Tectonic and Magmatic Evolution, Fault Geometry in Rifts, Kinematics and Dynamics of Rifting, Oceanic Rifts, Cenozoic Rifting in Ethiopia

Part 2

6. Deformation Mechanisms and Microstructures Micro-fracturing, Mechanical winning and Kinking, Dissolution Creep, Diffusion Creep, Dislocation Creep
7. Recognition and Description of Folds: Fold Geometry, Classification of Folds, Poly-phase Folding and Fold Interferences, Modes of Folding, Controlling Factors of Folding
8. Foliation, Lineation and Fabric Development in Rocks:Types of Cleavages and Lineations, Mechanisms of Fabric development in Rocks
9. Structural Analysis of Shear Zones: Shear Zone Development and Geometry, Characteristic features of shear zones, Kinematic Indicators of Sense of Shearing
10. Deformation and Recrystallization: Metamorphic Textures and Microstructures, Deformation and Metamorphism, Structural Analysisof Multiphase Deformation, Basement terrain in Ethiopia

Module Delivery: Lectures and reading assignments, and possibly discussions and e-learning practices.

Module Assessment: Reading assignment(s) and /or a series of written tests (40%) and a written final examination (60%).

Textbooks and Reference Materials

- Davis, G.H. and Reynolds, S.J. (1996) Structural Geology of Rocks and Regions, 2nd Edition, John Wiley and Sons, Inc., New York, 776p.
- Hatcher, R.D. (1995) Structural Geology: Principles, Concepts and Problems, 2nd Edition, Prentice Hall, 525p.
- Park, R.G. (1989) Foundation of structural Geology. Blackie and Son Ltd., London, 135p.
- Passchier, C.W. and Trouw, R.A.J. (1996). Microtectonics. Springer-Verlag, Berlin.
- Price, N.J. and Cosgrove, J.W. (1990) Analysis of Geological Structures. Cambridge University Press, Cambridge, England, 502p.
- Suppe J. (1985) Principles of Structural Geology. Prentice- Hall, Englewood Cliffs, New Jersey, 537p.
- Twiss, R.J. and Moores, E.M. (1992) Structural Geology. W.H. Freeman and Company, New York, 532p.

Module Name:	Structural Geology and Tectonics		
Module Code:	GEOL- M5041		
Course Name:	Tectonics and Geodynamics		
Course Code:	Geol 5043		
Credit Hours:	3	**ECTS:**	6

Course Objectives: The crust of the earth is the product of the ongoing plate tectonic process. Sedimentary basin development volcanic activities, mountain building process and associated structures and metamorphism are the result of the interplay between the interior and exterior of the earth. The distribution of economic mineral deposits, strtigraphic disposition, zone of hazards and driving forces require the knowledge of plate tectonics. Therefore Tectonics and geodynamics course is an essential core course for structural geologist and is an essential elective course for other branches of geology.

Learning Outcomes: The course will provide an overview of the Earth´s tectonic evolution in the context of plate tectonics. This intern will provide students with the knowledge to link local geological set-up (structural, stratigraphic, metamorphic, mineral deposit, and etc) with regional and global tectonic process.

Course Content: The course consists of lectures giving a systematic description of geological processes and the Wilson cycle, which includes formation of continental rifts and margins, oceanic spreading, transform faults, subduction and island arcs, as well as continental collision and formation of mountain belts. The tectonic processes typical of the various stages of the Wilson cycle, and their significance for basin formation, deformation, metamorphism and generation of magma. The course will also deal with

large-scale plate motions, paleogeography and the link between plate tectonics and the Earth´s interior.

Course Outline

1. Introduction: Definitions of tectonics and geodynamics,
   1.1 the interior of the earth and terrestrial planets,
   1.2 the lithosphere, characteristics of the Earth's crust,
   1.3 the dynamics and tectonics of lithospheric plates.
   1.4 Plate tectonic theories.

2. Plate boundaries and their characteristics,
   a. Structures, magmatism, metamorphism and mineralizations
   b. divergent margins and continental rifting,
   c. transform fault boundaries and related fracture zones,
   d. convergent margins and the Circum-Pacific tectonic System, Collisions and deformational models.

3. Principal tectonic features of the earth,
   a. ocean basins, structure of continental crust, tectonics in the past, Precambrian shields, Phanerozoic regions.

4. Introduction, Direct measurements of tectonic movements,
   4.1 geologic – geomorphic features, neotectonic behaviour of faults and folds, the Afar depression and east African rift system

5. Geophysical techniques in tectonics and geodynamics,
   a. gravity studies, gravitational studies, heat, temperature and the Earth.
   b. Acceleration external to the rotationally distorted Earth; centrifugal acceleration and the acceleration of gravity; the gravitational potential and Geoid;
   c. Paleomagnetism and the relative and absolute motion of plates, paleogeographic reconstruction. Triple junctions and their stability.

6. Heat transfer; introduction,
   a. surface heat flow, heat production; thermal effects of erosion and sedimentation, surface heat flux, chemical geodynamics, radioactivity and geochronology.

7. Elasticity and flexure: Introduction,
   a. stress state of solids, two dimensional bending, flexure of plates, bending of plates under applied loads at various tectonic environments, flexure and the structure of sedimentary basins.

8. Fluid mechanics: Introduction,
   a. one dimensional channel flows, asthenospheric counter flow, pipe flow, flow through volcanic pipes, conservation of fluid in two dimensions, the

stream function, postglacial rebound, angle of subduction, diapirism, folding, stokes flow, plume head and tails, thermal convection, the forces that derive plate tectonics.

9. Rock Rheology;
   a. Introduction, Elasticity, diffusion creep, dislocation creep, shear flows of fluids with temperature and stress dependent rheologies, mantle rheology, rheology effects on mantle convection and the cooling of the Earth, crustal rheology, visco-elasticity, elastic-perfectly plastic behaviors.

10. Faulting:
   a. Introduction, Anderson theory of faulting, Anderson classification of faults,
   b. friction on faults, strength envelope,
   c. thrust sheets and gravity sliding,

Module Delivery: The course will be delivered through lectures, students seminars and term paper (essay by students).

Module Assessment: Reading assignment(s) and /or a series of written tests (40%) and a written final examination (60%).

Textbooks and Reference Materials

Text books and references

- ✓ Poblet, J. & Leslie R. J. (2011.) Kinematic evolution and structural styles of fold-and-thrust belts. Special Publication, Geological Society of London,London, 263p.
- ✓ Kearay P., Keith A., Frederick J. and Vine P (2009). Global Tectonics (3rd Edition). Johan Wiley & Sons LTD, 495p.
- ✓ Ben A. van der Pluijm and Stephen Marshak (2004) Earth Structure : An Introduction to Structural Geology and Tectonics. (2nd Edition); W. W. Norton & Company, Inc; 673p.
- ✓ Storti, F. Holdsworth, R.E and Salvini F. (2003); Intraplate Strike slip Deformation Belts. Geological Society of London Special Publication No. 210; 243p.
- ✓ John J.W. Rogers and Santosh.M. (2004). Continents and Supercontinents. Oxford University Press
- ✓ Haakon, F.(2010). Structural Geology. Cambridge University Publication, 298p

Module Name:	Structural Geology and Tectonics
Module Code:	GEOL- M5041
Course Name:	Paleo-Stress Analysis and Rift Evolution

Course Code:	Geol 5044		
Credit Hours:	3	**ECTS:**	6

Course Aim/Rationale: The course aims to provide students with the basic concepts of Faulting, earthquakes, elastic solutions for strike slip faulting, continental rifts and rifted margins, tectonics of the oceanic crust, geophysical surveys, neo-tectonics, rifting and sedimentary basins.

Learning Outcomes: On completing the course students will have the basic knowledge on Continental rifts and Associated geological structures, have the necessary skill to recognize, describe and analyze stress field and interpret statical data, and be familiar with the main concept of MER, red sea, gulf of Aden, associated magmatism and rifting.

Course Content: The course covers the following topics: Morphotectonics of the East African Rift System (EARS): Kenyan Rift, MER and Afar Stress fields and stress trajectories, geometry and timing of fault populations, shear criteria in fault zones, kinematic analysis, extension and the stress field, statistical analyses of structural data, relationship of the EARS with the Red Sea and Gulf of Aden rifts, faulting and magmatism, timing of uplift, volcanism and rifting (Passive and active rifting) seismicity of the EARS

Course Outline

- Morphotectonics of the East African Rift System (EARS): Kenyan Rift, MER and Afar Stress fields and stress trajectories
- Geometry and timing of fault populations
- Shear criteria in fault zones
- Kinematic analysis, extension and the stress field
- Statistical analyses of structural data
- Relationship of the EARS with the Red Sea and Gulf of Aden rifts
- Faulting and magmatism: Timing of uplift, volcanism and rifting (Passive and active rifting)
- Seismicity of the EARS
- Sedimentation and paleomagnetism of the EARS

Module Delivery: The course will be delivered through lectures, students seminars and term paper (essay by students).

Module Assessment: Reading assignment(s) and /or a series of written tests (40%) and a written final examination (60%).

Textbooks and Reference Materials

- Poblet, J. & Leslie R. J. (2011.) Kinematic evolution and structural styles of fold-and-thrust belts. Special Publication, Geological Society of London,London, 263p.
- Kearay P., Keith A., Frederick J. and Vine P (2009). Global Tectonics (3rd Edition). Johan Wiley & Sons LTD, 495p.
- Ben A. van der Pluijm and Stephen Marshak (2004) Earth Structure : An Introduction to Structural Geology and Tectonics. (2nd Edition); W. W. Norton & Company, Inc; 673p.
- Storti, F. Holdsworth, R.E and Salvini F. (2003); Intraplate Strike slip Deformation Belts. Geological Society of London Special Publication No. 210; 243p.

Module Name:	Structural Geology and Tectonics		
Module Code:	GEOL- M5041		
Course Name:	Paleomagnetism		
Course Code:	Geol 5045		
Credit Hours:	3	**ECTS:**	6

Course Objectives: The course aims to provide students with the basic concepts of Magnetic property of solids and the origin of the Natural Remnant Magnetism, and of the mechanisms and causes of Earth magnetic property; to familiarize students with how to study, describe, collect and record paleomagnetic data in the field; to enable students how to evaluate, analyze and interpret those data and incorporate it into regional synthesis of an area.

Learning Outcomes: On completing the course, students will have the basic knowledge on Ferromagnetic minerals: Magnetic property of solids and the Origin of the Natural Remanent Magnetism, have the necessary skill to study field sampling of paleomagnetic data, describe and analyze Statistics of Paleomagnetism data, and be familiar with the main concept of Geological Applications of Paleomagnetism.

Course Content: The course covers the following topics: Introduction to geomagnetism, ferromagnetic minerals, origin of the Natural Remanent Magnetism, paleomagnetic field sampling, stability of paleomagnetic data, statistics of paleomagnetic data, paleomagnetic poles, geological applications of Paleomagnetism.

Course Outline

1: Introduction to Geomagnetism
- 1.1 Basic definitions and Geocentric Axial Dipole
- 1.2 Model and Origin of the Geomagnetic Field.

2: Ferromagnetic minerals: Magnetic property of solids
- 2.1 Diamagnetism, Paramagnetism,

2.2 Ferromagnetism,
2.3 Mineralogy of Ferromagnetic minerals,
2.4 Titano magnetite and Titano hematite,
2.5 Iron Oxyhydroxides and sulphides

3: The Origin of the Natural Remanent Magnetism
3.1 Ferromagnetism of Fine particles,
3.2 Magnetic Domains, Domain Walls and their interaction energies;
3.3 Hysteresis in the various Ferromagnetic Minerals;
3.4 Magnetic Relaxation and Superparamagnetism;
3.5 NRM, Thermoremanent Magnetism (TRM),
3.6 Chemical Remanent Magnetism (CRM),
3.7 Detrital Remannet Magnetism (DRM),
3.8 Viscous Remanent Magnetism (VRM), Thermoviscous Remanent Magnetism (TVRM),
3.9 Isothermal Remanent Magnetism (IRM)

4: Paleomagnetic Filed Sampling,
4.1 Directional measurement in the Laboratory,
4.2 Display of Paleomagnetic Data.
4.3 Scheme of Oriented Paleomagnetic samples collection,
4.4 Measurements and Display of NRM directions,
4.5 Structural corrections for bedding attitudes,
4.6 Recognition and Identification of Primary and Secondary NRM,
4.7 Identification of Ferromagnetic Minerals Carrying the Magnetization.

5: Stability of Paleomagnetic Data
5.1 Partial Demagnetization techniques,
5.2 Theories of Alternating Field,
5.3 Thermal and Chemical Demagnetization techniques;
5.4 Progressive Demagnetization techniques,
5.5 Display of Paleomagnetic Data and Identification of Magnetization Components;
5.6 Principal Component Analysis; Field Test of Paleomagnetic Stability,
5.7 The Fold test, Conglomerate Test, Reversal Test, and Baked Contact and Consistency tests.

6: Statistics of Paleomagnetic data
6.1 The Normal, Fisher and Non-Fisherian Distributions,
6.2 Computing a mean Direction,
6.3 Dispersion estimates, Confidence Limits,
6.4 Site-Mean Directions and Significance Tests.

7: Paleomagnetic Poles, Geomagnetic Pole
7.1 Virtual Geomagnetic Pole,
7.2 Paleomagnetic Pole,
7.3 Averaging out of the Geomagnetic Secular Variation,

7.4 Paleosecular Variation.

8: Geological Applications of Paleomagnetism
- 8.1 Geochronological Applications;
- 8.2 Development of the Geomagnetic Polarity Time Scale,
- 8.3 Magnetic Polarity Stratigraphy;
- 8.4 Paleogeographic Applications,
- 8.5 Paleomagnetic Poles and Paleogeographic Maps,
- 8.6 Apparent Polar Wander Paths,
- 8.7 Paleogeographic Reconstruction of Continents;
- 8.8 Application to Regional Tectonics.

Module Delivery: Lectures and reading assignments, and possibly discussions and e-learning practices.

Module Assessment: Reading assignment(s) and /or a series of written tests (40%) and a written final examination (60%).

Textbooks and Reference Materials

- Davis, G.H. and Reynolds, S.J. (1996) Structural Geology of Rocks and Regions, 2nd Edition, John Wiley and Sons, Inc., New York, 776p.
- M. W. McElhinny, Palaeomagnetism and Plate Tectonics, Cambridge, London, 356 pp., 1973. Chapter 1 presents an introduction to the geomagnetic field.
- R. T. Merrill and M. W. McElhinny, The Earth's Magnetic Field, Academic Press, London, 401 pp., 1983. An excellent text on geomagnetism.
- P. N. Shive, Suggestions for the use of SI units in magnetism, Eos Trans. AGU, v. 67, 25, 1986. Summarizes the problems with units in magnetism.
- R. B. Bates, M. E. Beck, Jr., and R. F. Burmester, Tectonic rotations in the Cascade range of southern Washington, Geology, v. 9, 1984–189, 1981.
- M. E. Beck, Jr., Discordant paleomagnetic pole position as evidence of regional shear in the western Cordillera of North America, Am. J. Sci., v. 276, 694–712, 1976.
- M. E. Beck, Jr., Paleomagnetic record of plate-margin tectonic processes along the western edge of North America, J. Geophys. Res., v. 85, 7115–7131, 1980.
- M. E. Beck, Jr., Has the Washington–Oregon Coast Range moved northward?, Geology, v. 12, 737–740, 1984.
- M. E. Beck, Jr., and C. D. Burr, Paleomagnetism and tectonic significance of the Goble Volcanic Series, southwestern Washington, Geology, v. 7, 175–179, 1979.

16.5. Paleontology Modules

Module Name:	Paleontology
Module Code:	GEOL M5051
Course Title:	Invertebrate Paleontology

Course Code:	Geol 5051		
Credit Hours:	3	**ECTS:**	6

Course Objectives: To introduce the history of life on Earth; the preservation of animals and plants as fossils and methods of studying them; the morphology and classification of the main groups of invertebrate animals with emphasis on those of geological importance; the science of palaeobotany; the stratigraphical importance of fossils including microfossils; comparison of living organisms with their fossil relatives.

Learning Outcomes: Up on completion of this course, the students will have a good working knowledge of the taxonomy and evolutionary history of invertebrate animals and plants throughout the Phanerozoic; have developed accurate observational skills, which will aid generic identification; and, have developed an understanding of the use of fossils in a variety of contexts.

Course Content: Definition and use of fossils; occurrence and mode of preservation of fossils; taxonomy and nomenclature in paleontology; evolution and extinction; earliest fossils and the evolution of organisms through time; principles of paleoecology; systematic paleontology (morphology, classification and identification of fossils, especially invertebrates); their living habitats and their use in biostratigraphy.

Course Outline

1. The Origin of Life and theory of evolution
    - Scope of paleontology and Organic evolution
    - Origin, extinction, migration of life
    - Species concepts, evolutionary mechanisms and processes
    - Systematic and characters of organisms
2. Fossils and fossilization
    - Modes of fossilization (molds, casts, minerals)
    - Mega fossils, microfossils, nanofossils, ichnofossils identification and illustration
    - Taphonomy; preserving soft tissues; trace fossils
3. Concepts of taxonomy and nomenclature
    - Species concepts
    - Taxon and taxa
    - A recipe for a species description
4. Phylum Arthropoda
    - The geologic history of the important groups, their ranges of habitat,
    - functional morphology,
    - paleoecological and paleoenvironmental significance,
    - basic patterns of diversification and extinction
5. Phylum Mollusca
    - Bivalves, Gastropods and Cephalopods:
    - The geologic history of the important groups, their ranges of habitat,
    - functional morphology,
    - paleoecological and paleoenvironmental significance

- basic patterns of diversification and extinction

6. Phylum Brachiopoda
    - The geologic history of the important groups, their ranges of habitat, functional morphology, paleoecological and paleoenvironmental significance, and basic patterns of diversification and extinction
7. Phylum Cindaria
    - The geologic history of the important groups, their ranges of habitat, functional morphology, paleoecological and paleoenvironmental significance, and basic patterns of diversification and extinction
8. Bryozoans and Sponges
    - The geologic history of the important groups, their ranges of habitat, functional morphology, paleoecological and paleoenvironmental significance, and basic patterns of diversification and extinction
9. Phylum Echinodermata: Echinoderms
    - The geologic history of the important groups, their ranges of habitat, functional morphology, paleoecological and paleoenvironmental significance, and basic patterns of diversification and extinction
10. Phylum Hemichordata: Graptolites
    - The geologic history of each group, its range of habitats, functional morphology, paleoecological and paleoenvironmental significance, and basic patterns of diversification and extinction with special focus on graptolites
11. Micropalaeontology
    - The geologic history of the important groups, their ranges of habitat, functional morphology, paleoecological and paleoenvironmental significance, and basic patterns of diversification and extinction with special focus on foraminifera, radiolarians, conodonts, pollen and spores
12. Trace fossils
    - Naming trace fossils
    - Record of activity and behaviour of past life
    - Main types of trace fossils
13. Paleoecology
    - Concepts of paleoecology
    - Facies and facies fossils
    - Marine environments (patterns of life, feeding relationships, modern and ancient reefs)

Course Delivery: Lectures, tutorials, discussions, demonstration, computer lab practical and assignments.

Course Assessment: A one to two hour long essay exam after covering section 7 (40 %), a two hours long essay type exams on week 14 (60%),

Textbooks and Reference Materials

- Black, R.M.,1988. The elements of palaeontology. 2nd Edition. Cambridge University Press
- Benton, M.J. and Harper, D.A.T., 1997. Basic Palaeontology. Longman.

- Boardman, R.S., Cheetham, A.H., and Rowell, A.J., eds., 1987. Fossil Invertebrates. Blackwell.
- Clarkson, E.N.K., 1986. Invertebrate Paleontology and Evolution, 2nd ed. Allen & Unwin.
- Cowen, R., 2005. History of Life, 3rd ed. Blackwell. Breezy, informal, and terrible limericks.
- Levin, H. J., 1999. Ancient Invertebrates and Their Living Relatives. Prentice Hall. Low level.
- McKerrow, W.S., ed., 1978. The Ecology of Fossils.
- Milsom, C. and Rigby, S., 2004. Fossils at a Glance. Blackwell.
- Prothero, D.R., 2004. Bringing Fossils to Life. An Introduction to Paleontology. WCB McGraw-Hill.
- Sheldon, P., Palmer, D. and Spicer, R.A. 2001. Fossils and the History of Life.
- Skelton, P.W., Spicer, R.A. & Rees, P.M., 1997. Evolving Life and the Earth. Open University Press.

Module Name:	Paleontology		
Module Code:	GEOL M5051		
Course Title:	Vertebrate Paleontology		
Course Code:	Geol 5052		
Credit Hours:	3	**ECTS:**	6

Course Objectives: The objective of this course is to equip students with in depth understanding of vertebrate life through ages, evolution of reptiles and mammals, as well as introductory paleoanthropology (with emphasis on primate fossils found in Ethiopia).

Learning Outcomes: After successful completion of the course, students will have an understanding of the fossilized remains, the behavior, reproduction and appearance of extinct animals with vertebrae or a notochord.

Course Content: Vertebrate paleontology is the subfield of paleontology that seeks to discover, through the study of fossilized remains, the behavior, reproduction and appearance of extinct animals with vertebrae or a notochord. It also tries to connect, by using the evolutionary timeline, the animals of the past and their modern-day relatives.The fossil record shows aspects of the meandering evolutionary path from early aquatic vertebrates to mammals, with a host of transitional fossils, though there are still large blank areas. The earliest known fossil vertebrates were heavily armored fish discovered in rocks from the Ordovician Period about 500 to 430 Ma (megaannum, million years ago). The Devonian Period (395 to 345 Ma) brought in the changes that allowed primitive air-breathing fish to remain on land as long as they wished, thus

becoming the first terrestrial vertebrates, the amphibians. Amphibians developed forms of reproduction and locomotion and a metabolism better suited for life exclusively on land, becoming more reptilian. Full-fledged reptiles appeared in the Carboniferous Period (345 to 280 Ma). The reptilian changes and adaptations to diet and geography are chronicled in the fossil record of the varying forms of therapsida. True mammals showed up in the Triassic Period (225 to 190 Ma) around the same time as the dinosaurs, which also sprouted from the reptilian line. Birds first diverged from dinosaurs between 100 Ma and 60 Ma.

Course Outline:

1. Phylum Chordata (vertebrates)
    - Class Agnatha (jawless fish)
    - Subclass Cyclostomata (hagfish and lampreys)
    - Subclass Ostracodermi (armoured jawless fish)
    - Class Chondrichthyes (cartilaginous fish)
    - Subclass Elasmobranchii (sharks and rayes)
    - Subclass Holocephali (chimaeras and extinct relatives)
    - Class Placodermi (armoured fish)
    - Class Acanthodii ("spiny sharks", sometimes classified under bony fishes)
    - Class Osteichthyes (bony fish)
2. Subclass Actinopterygii
    - Subclass Sarcopterygii
    - Class Amphibia
    - Subclass Labyrinthodontia
    - Subclass Lepospondyli †
    - Subclass Lissamphibia
    - Class Reptilia
3. Subclass Anapsida
    - Order Cotylosauria †
    - Order Testudines
    - Subclass Synapsida
    - Order Pelycosauria †
    - Order Therapsida †
    - Subclass Euryapsida
    - Order Sauropterygia †
    - Order Ichthyosauria †
4. Subclass Diapsida (lizards & snakes too)
    - Order Crocodilia (crocodiles, alligators etc.)
    - Order Sphenodontia (Tuatara and relatives)
    - Order Squamata (Lizards and snakes)
    - Order Thecodonts †
    - Order Pterosauria †
    - Order Saurischia (dinosaurs) †
    - Order Ornithischia (dinosaurs) †

Course delivery method: The course will be delivered by lecture seminars, journal reviews, field and laboratory techniques. Field excursions will also be undertaken.

Assessment method: The assessment will be based on seminar journal reviews, reports (40%), field work, laboratory analysis and report (30%), and exams 30%.

Textbooks and References

- Hackett, S.J., Kimball, R.T., (2008) A phylogenomic study of birds reveals their evolutionary history. Science.
- Rudwick, Martin. Georges Cuvier, Fossil Bones, and Geological Catastrophes, (Chicago: Chicago University Press), 1997.
- Jefferson, Thomas, "A Memoir on the Discovery of Certain Bones of a Quadruped of the Clawed Kind in the Western Parts of Virginia", Read before the American Philosophical Society, March 10, 1797. Jefferson, Thomas (1799), "A Memoir on the Discovery of Certain Bones of a Quadruped of the Clawed Kind in the Western Parts of Virginia", Transactions of the American Philosophical Society, Vol. 4.

Module Name:	Paleontology		
Module Code:	GEOL M5051		
Course Title:	Human Evolution		
Course Code:	Geol 5053		
Credit Hours:	3	**ECTS:**	6

Course Objectives: The objective of this course is to equip students with the study of human evolution that includes many scientific disciplines, including physical anthropology, primatology, archaeology, paleontology, neurobiology, ethology, linguistics, evolutionary psychology, embryology and genetics. Genetic studies show that primates diverged from other mammals about 85 million years ago,

Learning Outcomes: After successful completion of the course, students will have an understanding of human evolution with its many scientific disciplines, including physical anthropology, primatology, archaeology, paleontology, neurobiology, ethology, linguistics, evolutionary psychology, embryology and genetics.

Course Content: Human evolution is the evolutionary process that led to the emergence of anatomically modern humans, beginning with the evolutionary history of primates – in particular genus Homo – and leading to the emergence of Homo sapiens as a distinct species of the hominid family, the great apes. The study of human evolution involves many scientific disciplines, including physical anthropology, primatology, archaeology, paleontology, neurobiology, ethology, linguistics, evolutionary psychology, embryology and genetics. Genetic studies show that primates diverged from other mammals about 85 million years ago, in the Late Cretaceous period, and the earliest fossils appear in the

Paleocene, around 55 million years ago. Within the Hominoidea (apes) superfamily, the Hominidae family diverged from the Hylobatidae (gibbon) family some 15–20 million years ago; African great apes (subfamily Homininae) diverged from orangutans (Ponginae) about 14 million years ago; the Hominini tribe (humans, Australopithecines and other extinct biped genera, and chimpanzee) parted from the Gorillini tribe (gorillas) between 9 million years ago and 8 million years ago; and, in turn, the subtribes Hominina (humans and biped ancestors) and Panina (chimps) separated about 7.5 million years ago to 5.6 million years ago.

Course Outline

1. Anatomical changes
1.1 Bipedalism
1.2 Encephalization
1.3 Sexual dimorphism
1.4 Other changes
2 History of study
2.1 Before Darwin
2.2 Darwin
2.3 First fossils
2.4 The East African fossils—and Homo naledi in South Africa
2.5 The genetic revolution
2.6 The quest for the earliest hominin
2.7 Human dispersal
2.7.1 Dispersal of modern homo sapiens
3 Evidence
3.1 Evidence from molecular biology
3.1.1 Genetics
3.2 Evidence from the fossil record
4 Before Homo
4.1 Early evolution of primates
4.2 Divergence of the human clade from other great apes
4.3 Genus Australopithecus
5 Evolution of genus Homo
5.1 H. habilis and H. gautengensis
5.2 H. rudolfensis and H. georgicus
5.3 H. ergaster and H. erectus
5.4 H. cepranensis and H. antecessor
5.5 H. heidelbergensis
5.6 H. rhodesiensis, and the Gawis cranium
5.7 Neanderthal and Denisovan
5.8 H. floresiensis
5.9 H. sapiens
6 Use of tools
6.1 Stone tools
7 Transition to behavioral modernity

Module Name:	Paleontology
Module Code:	GEOL M5051

Course Title:	Micropalaeontology		
Course Code:	Geol 5054		
Credit Hours:	3	**ECTS:**	6

Course Objectives: The objective of this course is to equip students with the use of microfossils that are especially noteworthy for their importance in biostratigraphy. Since microfossils are often extremely abundant, widespread, and quick to appear and disappear from the stratigraphic record, they constitute ideal index fossils from a biostratigraphic perspective. Also, the planktonic and nektonic habits.

Learning Outcomes: After successful completion of the course, students will have an understanding of the use of microfossils that are useful for biostratigraphy; extraction by a variety of physical and chemical laboratory techniques.

Course Content:

Survey of the major microfossil groupings, with reference to their classification, stratigraphic history and evolution. Significance in applied Geology. Application of microfossils on petroleum exploration: importance in biostratigraphic and paleoenvironmental interpretation.

Course Outline:

1. Calcareous Microfossils
   - Introduction to subgroups of calcareous microfossils
   - Taxonomic affinity, morphology and classification
   - Ecology and paleoecology
   - Stratigraphic applications
2. Siliceous Microfossils
   - Introduction to subgroups of calcareous microfossils
   - Taxonomic affinity, morphology and classification
   - Ecology and paleoecology
   - Stratigraphic applications
3. Phosphatic Microfossils
   - Introduction to subgroups of calcareous microfossils
   - Taxonomic affinity, morphology and classification
   - Ecology and paleoecology
   - Stratigraphic applications
4. Organic walled microfossils or Playnomorphs
   - Introduction to subgroups of calcareous microfossils
   - Taxonomic affinity, morphology and classification
   - Ecology and paleoecology
   - Stratigraphic applications
5. Applied Micropaleontology
   - Commercial applications of micropaleontology

Course delivery method: The course will be delivered by lecture seminars, journal reviews, field and laboratory techniques. Field excursions will also be undertaken.

Assessment method: The assessment will be based on seminar journal reviews, reports (40%), field work, laboratory analysis and report (30%), and exams 30%.

Textbooks and References

- Stringer, Chris (June 12, 2003). "Human evolution: Out of Ethiopia". Nature. London: Nature Publishing Group. 423 (6941): 692–695. ISSN 0028-0836.
- Johanson, Donald (May 2001). "Origins of Modern Humans: Multiregional or Out of Africa?". actionbioscience. Washington, D.C.: American Institute of Biological Sciences.
- Mixon, Bobbie; Ehardt, Carolyn; Hammer, Michael (September 6, 2011). "Evolution's Past Is Modern Human's Present" (Press release). National Science Foundation. Press Release 11-181.
- O'Neil, Dennis. "Early Modern Homo sapiens". Evolution of Modern Humans: A Survey of the Biological and Cultural Evolution of Archaic and Modern Homo sapiens (Tutorial). San Marcos, CA: Palomar College.

Module Name:	Paleontology		
Module Code:	GEOL M5051		
Course Title:	Palynology and Paleobotany		
Course Code:	Geol 5055		
Credit Hours:	3	**ECTS:**	6

Course Objectives: The objective of this course is to equip students with the use of palynology for a diverse range of applications, related to many scientific disciplines: Biostratigraphy and geochronology. Geologists use palynological studies in biostratigraphy to correlate strata and determine the relative age of a given bed, horizon, formation or stratigraphical sequence. Palaeoecology and climate change. Palynology can be used to reconstruct past vegetation (land plants) and marine and freshwater phytoplankton communities, and so infer past environmental (palaeoenvironmental) and palaeoclimatic conditions.

Learning Outcomes: After successful completion of the course, students will have an understanding of palynological studies in biostratigraphy to correlate strata and determine the relative age of a given bed, horizon, formation or stratigraphical sequence.

Course Content:

1. What Paleopalynology Is and Is Not

2. Why One “Does” Paleopalynology and Why It Works
3. The Natural History of Palynomorphs
4. Spores/Pollen Basic Biology
5. Spores/Pollen Morphology
6. Stratigraphic Palynology–Precambrian, Cambrian, Ordovician
7. Cambrian to Silurian Non-Marine Palynology
8. Devonian Palynology
9. Carboniferous/Permian Palynology to the End of the “Paleophytic” Permo- Triassic Palynofloras
10. Triassic-Jurassic Palynologyi
11. Triassic-Jurassic Megaspores, Dinoflagellates, Other Microplankton
12. Jurassic-Cretaceous Palynology: End of the “Mesophytic.” Advent and Diversification of Angiosperms. Dynamic Evolution of Dinoflagellate
13. Paleogene Palynology
14. Neogene Palynology
15. Holocene Palynology
16. Production, Dispersal, Sedimentation and Taphonomy of Spores/Pollen in Relation to the Interpretation of Palynofloras
17. Differential Sorting of Palynomorphs into Sediments: Palynofacies, Palynodebris
18. Discordant Palynomorphs
19. Some Factors Affecting Practical Applications of Paleopalynology

Course delivery method: The course will be delivered by lecture seminars, journal reviews, field and laboratory techniques. Field excursions will also be undertaken.

Assessment method: The assessment will be based on seminar journal reviews, reports (40%), field work, laboratory analysis and report (30%), and exams 30%.

Textbooks and References

- Al-Hajri, S., and Owens, B., eds., 2000, Stratigraphic Palynology of the Palaeozoic of Saudi Arabia, Gulf PetroLink, Spec. GeoArabia Publ. 1.
- Berglund, B. E., ed., 1986, Handbook of Holocene Palaeoecology and Palaeohydrology, Wiley, Chichester.
- Aaby and Digerfeldt (coring and other sampling techniques), Berglund and Ralska-Jasiewiczowa (pollen analysis and pollen diagrams), Prentice
- Birks, H. J. B., and Birks, H. H., 1980, Quaternary Palaeoecology, Edward Arnold, London.
- Brooks, J., ed., 1981, Organic Maturation Studies and Fossil Fuel Exploration, Academic Press, London.

Module Name:	Paleontology
Module Code:	GEOL M5051
Course Title:	Paleoenvironment and Paleoecology
Course Code:	Geol 5056

Credit Hours:	3	**ECTS:**	6

Course Objectives: The objective of this course is to equip students with the study of interactions between organisms and/or interactions between organisms and their environments across geologic timescales. The aim of paleoecology is therefore to build the most detailed model possible of the life environment of previously living organisms found today as fossils. Such reconstruction takes into consideration complex interactions among environmental factors such as temperatures, food supplies, and degree of solar illumination. Often much of this information is lost or distorted by the fossilization process or diagenesis of the enclosing sediments, making interpretation difficult.

Learning Outcomes: After successful completion of the course, students will have an understanding of how to build the most detailed model possible of the life environment of previously living organisms found today as fossils.

Course Content: Paleoecology (also spelt palaeoecology) is the study of interactions between organisms and/or interactions between organisms and their environments across geologic timescales. As a discipline, paleoecology interacts with, depends on and informs a variety of fields including paleontology, ecology, climatology and biology. Paleoecology emerged out of the field of paleontoloy in the 1950's, though paleontologists have conducted paleoecological studies since the creation of paleontology in the 1700s and 1800s. Combining the investigative approach of searching for fossils with the theoretical approach of Charles Darwin and Alexander von Humboldt, paleoecology began as paleontologists began examining both the ancient organisms they discovered and their environments. Visual depictions of past marine and terrestrial communities has been considered an early form of paleoecology.

Course Outline:

Chapter 1. Overview of Paleoecological Approaches
Chapter 2. Major Principles
Chapter 3. Paleoecological Methods
Chapter 4. Quaternary
Chapter 5. Applications of Paleoecology

Course delivery method: The course will be delivered by lecture seminars, journal reviews, field and laboratory techniques. Field excursions will also be undertaken.

Assessment method: The assessment will be based on seminar journal reviews, reports (40%), field work, laboratory analysis and report (30%), and exams 30%.

Textbooks and References

- Sahney, S., Benton, M.J. and Ferry, P.A. (2010). "Links between global taxonomic diversity, ecological diversity and the expansion of vertebrates on land" PMID 20106856. doi:10.1098/rsbl.2009.1024.
- Charles D.F.; Whitehead D. R.; Engstrom D. R.; et al. (1987) Paleoliminological evidence for recent acidification of Big Moose Lake, Adirondack Mountains, New-York (USA).

16.6. Stratigraphy Modules

Module Name:	Stratigraphy		
Module Code:	GEOL M5061		
Course Title:	Stratigraphy		
Course Code:	Geol 5061		
Credit Hours:	3	**ECTS:**	6

Course Objectives: The main objective of this course is to let the student learn new concepts in startigraphy and sedimentology that help to understand how a certain sedimentary basin has evolved throughout geological time. Factors affecting evolution of sediments in 3D (vertically and laterally) will be assessed in this course. The course is also very important for petroleum and mineral explorations as well as for understanding the tectonic evolution and history of the earth.

Course Content This course consists of two parts, sequence stratigraphy and basin analysis. The first part covers historical perspectives and introduction, concepts and principles of sequence stratigraphy, sequence stratigraphy of fluvial, paralic and deep marine clastic sediments, carbonate sequence stratigraphy, ryhthms and events, autocycles, orbital rhythms, long oscillations in the ocean – atmosphere system, biotic evolution, the T- factory, the C- and M- factories, and case studies. The second part (Basin Analysis) deals with sedimentary basins and their formation, basins and their plate tectonic environment, the physical state of the lithosphere, mechanisms of basin formation (stretching, flexure) mantle dynamics, strike slip deformation, the sedimentary basin fill, the sedimentary routing system, basin stratigraphy, subsidence and thermal history, sedimentary basins of Ethiopia (case study), subsurface stratigraphy and sedimentology, seismic reflection data, borehole stratigraphy, geophysical logging, subsurface facies and basin analysis.

Course Outline

Chapter 1 Concepts and Principles of Sequence Stratigraphy
Chapter 2 Sequence Stratigraphic Tools, Seismic, outcrop and well data, chronostratigraphic charts, biostratigraphy
Chapter 3 Application of sequence stratigraphy to clastic systems
Chapter 4 Carbonate systems, carbonate accumulation, carbonate facies models, rhythms and events in carbonate stratigraphy, fundamentals of carbonate sequence stratigraphy, T- factory, Sequence stratigraphy of C and M factories

Chapter 5 Sedimentary basins
Chapter 6 Basins and their plate tectonic environment
Chapter 7 Mechanisms of basin formation and basin fill
Chapter 8 Basin stratigraphy, subsidence and thermal history
Chapter 9 Sedimentary basins of Ethiopia

Course delivery method: The course will be delivered by lecture seminars, journal reviews, field and laboratory techniques. Field excursions will also be undertaken.

Assessment method: The assessment will be based on seminar journal reviews, reports (40%), field work, laboratory analysis and report (30%), and exams 30%.

Textbooks and References

- Emery, D., and Myers, K. J. (1996) Sequence Stratigraphy, Blackwell Science, Oxford.
- Loucks, R. G., and Sarg, F. eds. (1993) Carbonate Sequence Stratigraphy, Recent Developments and Applications, AAPG Memoir 57,
- Schlager, W. (2005) Carbonate Sedimentology and Sequence Stratigraphy, SEPM Concepts in Sedimentology and Paleontology #8, Tulsa, Okhlahoma, 200pp
- Wilgus, C. K., Hastings, B. S., Kendall, C. G. St.C., Posamentier, H. W., Ross, C. A., and Van Wagoner, J. C.(eds) (1988) Sea Level Changes: An Integrated Approach, Special Publication Society of Economic Paleontologists and Mineralogfists, Tulsa, Okhlahoma, 42

Module Name:	GEOL M5061		
Module Code:	Stratigraphy		
Course Title:	Sedimentary Environments and Facies		
Course Code:	Geol 5062		
Credit Hours:	3	**ECTS:**	6

Course Objectives: The objective of this course helps the student to understand modern and ancient depositional systems, facies models, mineralogy and diagenesis of sediments. Up on completion of this course a student will be able to reconstruct paleoenvironments and processes of deposition from any sediment record with high resolution age control.

Learning Outcomes: After successful completion of this course, students will have an understanding of modern and ancient depositional systems, facies models,

mineralogy and diagenesis of sediments. Students will be able to reconstruct paleoenvironments and processes of deposition from any sediment record with high resolution age control.
Course rationale:

Course Content: This course consists of development of sedimentology and sedimentary geology as an introductory part, siliciclastic sedimentology (sandstones, conglomerates, breccias, shales and mudrocks), carbonate sedimentology which includes constituents of carbonate sediments and limestones, geological background to carbonate sedimentation, modern carbonate environments, lacustrine carbonates, shallow water carbonates, deep-water, pelagic and resedimented limestones, carbonate mineralogy and chemistry, diagenetic processes, products and environments, dolomites and dolomitization models, the geological record of carbonate rocks, evaporite sedimentology, silceous sediments, iron and phosphate deposits, volcanoclastic sediments, as well as applications of sedimentology.

Course Outline:

Chapter 1 Introduction
Chapter 2 Controls on the sedimentary rock
Chapter 3 Alluvial Sediments
Chapter 4 Lacustrine Sediemnts
Chapter 5 Desert Aeolian sediments
Chapter 6 Sediments in Shallow clastic seas
Chapter 7 Evaporites
Chapter 8 Carbonates,
Chapter 9 Deep sea sediments, siliciclastic
Chapter 10 Glacial sediments
Chapter 11 Volcanic Environment

Course Delivery Method: The course will be delivered by lectures, seminars (at least three seminars) journal reviews, and field and laboratory techniques on diagenesis, mineralogy, geochemistry and depositional patterns of sedimentary rocks. Field excursions will include area where carbonate, siliciclastic and other types of rocks like evaporates, coal etc. crop out.

Assessment Method: The assessment will be based on seminar and journal reviews and reports (40%), field work, lab analysis and report (30%) and examination (30%).

Textbooks and References

- Boggs, S. (2007) Principles of Sedimentology and Stratigraphy, Prentice Hall
- Flugel, E. (1982) Microfacies Analysis of Limestones, Berlin, Springer, 633p
- Flugel, E. (2004) Microfacies of Carbonate Rocks, Springer, 976 p.
- Leeder, M. (1999) Sedimentology and Sedimentary Basins: Oxford, Blackwell 608p.
- Reading, H. G. (1996) Sedimentary Environments: Processes, Facies and Stratigraphy, Blackwell Scientific Publications, Oxford, 688pp

- Schlager, W. (2005) Carbonate Sedimentology and Sequence Stratigraphy, SEPM Concepts in Sedimentology and Paleontology #8, Tulsa, Okhlahoma, 200pp.
- Scholle, P. A., Bebout, D. G., and Moore, C. H (1983) Carbonate Depositional Environments: American association of Petroleum Geologists Memoir 708p.
- Tucker, M., Wright, V. P., (1990) Carbonate Sedimentology, Blackwell publishers, Oxford 700p.

16.7. Geologic Resources Module

Module Name:	Geologic Resources		
Module Code:	GEOL M5061		
Course Title:	Petroleum and Coal Geology		
Course Code:	Geol 5071		
Credit Hours:	3	**ECTS:**	6

Course Objectives: This course aims at developing ability to use all sedimentological, structural, and petrological knowledge to explore coal and petroleum occurrences in sedimentary basins

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Course Content: The majority of the world's energy comes from fossil fuels. In Ethiopia oil and gas are imported even though there is gas occurrence in the Ogaden Basin and there are some coal deposits in certain parts of the country. The country has a hydrocarbon potential in its sedimentary basins, which must be thoroughly explored. Therefore, any exploration of oil and gas must be well founded in a basic understanding of coal and petroleum geology. In this course, students learn about the origin, evolution and occurrence of coal and petroleum as well as exploration and exploitation techniques.

The first part of the course focuses on the geology of coal. It deals with definition origin and occurrence of coal, sedimentology of coal bearing strata (coal seams), chemical analysis of coal, coal petrology (techniques and methods of coal microscopy), lithotypes, maceral and microlithotypes, classification of coal in terms of rank, grade, type lithotypes, coal preparation, carbonization, gasification, hydrogenation, combustion and production of fertilizer from coal, coal as source rock in petroleum generation, Ethiopian coal occurrence (case study) detail, and reserve calculation. The second part concerns with petroleum geology. It includes definition, origin, occurrence and composition of petroleum, migration of petroleum (primary, secondary), hydrocarbon reservoir, seal, trap; basic ideas of drilling, sampling; recovery of petroleum (primary, secondary, ERM), kerogen and oil shales, and Ethiopian petroleum occurrence (case history) detail.

Course Outline

Chapter 1 Fundamental concepts of organic and inorganic theories of hydrocarbon.

Chapter 2 Sedimentary processes and accumulation of organic matter.
Chapter 3 Occurrence and distribution of hydrocarbons in sedimentary basins
Chapter 4 Types of coal - mode of occurrence
Chapter 5 Physical and chemical characteristics of coal
Chapter 6 Coal occurrence in Ethiopia
Chapter 7 Theories of origin of petroleum
Chapter 8 Transformation of organic matter into petroleum.
Chapter 9 Limiting conditions of petroleum occurrence.
Chapter 10 Definition and types of reservoir and source rocks.
Chapter 11 Reservoir traps and classification.
Chapter 12 Migration and accumulation of petroleum.
Chapter 13 Petroleum potential and occurrence in sedimentary basins of Ethiopia

Course delivery method: The course will be delivered by lecture seminars, journal reviews, field and laboratory techniques. Field excursions will also be undertaken.

Assessment method: The assessment will be based on seminar journal reviews, reports (40%), field work, laboratory analysis and report (30%), and exams 30%.

Textbooks and References

- Larry Thomas (2012) Coal Geology, Wiley-Blackwell.
- James G. Speight (2012) The Chemistry and Technology of Coal: Chemical Industries, CRC Press.
- Richard C. Selley and Sonnnenberg, S., (2015) Elements of Petroleum Geology, Elsevier Academic Press.

Module Name:	Geologic Resources		
Module Code:	GEOL M5061		
Course Title:	Organic Geochemistry		
Course Code:	Geol 5072		
Credit Hours:	3	**ECTS:**	6

Course Objectives: The course aims to provide students with a organic geochemistry studies biochemical compounds such as carbohydrates, proteins, and lignin, which are the raw materials for the production of organic matter, and the products of transformation of such compounds in the outer geospheres

Learning Outcomes: On completing this course students will have the basic understanding of geology and its branches, the Earth and its materials, and various geological processes; and will be familiar with the main features of mechanical behavior of different minerals and rocks.

Course Content: The course will include a division of geochemistry that studies organic matter in the various geospheres of the earth. The task of organic geochemistry includes examination of the evolution of organic compounds (hydrocarbons and their derivatives) from the moment of their formation and a study of the subsequent change in their composition and distribution. Organic geochemistry studies biochemical compounds such as carbohydrates, proteins, and lignin, which are the raw materials for the production of organic matter, and the products of transformation of such compounds in the outer geospheres under the action of bacteria, temperature, pressure, and other geological factors. Among such products are humus, sapropel, coal, combustible shale, and petroleum.

Course delivery method: The course will be delivered by lecture seminars, journal reviews, field and laboratory techniques. Field excursions will also be undertaken.

Assessment method: The assessment will be based on seminar journal reviews, reports (40%), field work, laboratory analysis and report (30%), and exams 30%.

Textbooks and References

- Larry Thomas (2012) Coal Geology, Wiley-Blackwell.
- James G. Speight (2012) The Chemistry and Technology of Coal: Chemical Industries, CRC Press.
- Richard C. Selley and Sonnnenberg, S., (2015) Elements of Petroleum Geology, Elsevier Academic Press.

Module Name:	Geologic Resource		
Module Code:	GEOL- M5071		
Course Name:	Mineral Deposits		
Course Code:	Geol 5073		
Credit Hours:	3	**ECTS:**	6

Course Objectives: the objective of this course is to summarize the major types of metallic deposits, their genesis and occurrences, and metallogenic provinces**.** After successful completion of this course, students will be in position to know the origins of earth's major geological resources and awareness of uses of the resources; basic knowledge of contrasting mineral deposit types which display a range of characteristics and modes of formation; developed an understanding of the methods used to derive information about the formation of mineral deposits by using case studies. The course

Learning Outcomes: At the end of this course students will be able to apply the basic principles of economic geology and origin of mineral deposits; mode of formation of the deposits and mineral and country rock association. It briefly discusses the different ore deposits models, it highlights the comparison between similar deposits globally and plate tectonics and associated mineral deposits.

Course Content: This course is basically designed to focus in mineral deposits versus orebody, ore forming process, paragenesis, tectonic setting, characteristics age and proposed genetic model of local and world class mineral deposits. Major topics are: Genesis and classification of metallic deposits, Magmatic, Hydrothermal and Sedimentary processes in the formation of metallic ore deposits, ore deposit models, morphology, grade and tonnages of ore bodies, interpretation of Mineral deposits, Chromite Deposits, Nickel (Copper) sulfide deposits, Platinum-Group Element (PGE) Deposits, Porphyry Deposits, Skarn Deposits, Volcanic-Associated Massive Sulfide (VMS) Deposits, Mississippi Valley-Type (MVT) Zink-Lead Deposits, Uranium Deposits, Precambrian Iron Formation.

Course Outline

1: Introduction
- 1.3 Mineral Deposits versus Orebody
- 1.4 Styles of Mineralization and Morphology of Mineral Deposits
- 1.5 Distribution of Mineral Deposits
- 1.6 Understanding Mineral Deposits

2: Formation of Mineral Deposits
- 2.6 Ore forming Process
- 2.7 Orthomagmatic Process,
- 2.8 Sedimentary Process
- 2.9 Metamorphic Process
- 2.10 Hydrothermal Process

3: Interpretation of Mineral deposits
- 3.10 Introduction
- 3.11 Geologic Setting
- 3.12 Ore Minerals
- 3.13 Ore-Gangue Texture
- 3.14 Stability Relations of Ore Minerals and Assembleges),
- 3.15 Hydrothermal Alteration
- 3.16 Zoning
- 3.17 Fluid Inclusion
- 3.18 Trace Element distribution

4: Chromite Deposits
- 4.8 Type of Deposits
- 4.9 Distribution
- 4.10 Stratiform Deposits

4.11 Podiform Deposits
4.12 Chromite cpmposition,
4.13 Origin
4.14 Metallogenesis

5: Nickel (Copper) sulfide deposits
5.8 Type of Deposits
5.9 Distribution
5.10 Ore Composition
5.11 Hydrothermal Alteration and Metamorphism
5.12 Origin of Kambalde-Type Deposits
5.13 Metallogenesis

6: Platinum-Group Element (PGE) Deposits
6.5 Types of Deposits
6.6 Ore composition
6.7 Origin of Merensky-type PGE Deposits
6.8 Origin of PGE-enriched Chromities in Layered Intrusions
6.9 Metallogenesis

7: Porphyry Deposits
7.5 Porphyry Copper Deposits
7.6 Porphyry Molybdenum Deposits
7.7 Porphyry Tin Deposits

8: Skarn Deposits
8.9 Skarns and Skarns Deposits
8.10 Types of Skarn and Skarns Deposits
8.11 Origin
8.12 Metallogenesis

9. Volcanic-Associated Massive Sulfide (VMS) Deposits
9.1 Types of Deposits
9.2 Distribution
9.3 Ore composition
9.4 Hydrothermal Alteration
9.5 Metamorphism And Deformation
9.6 Origin
9.7 Metallogenesis

10. Sediment-hosted Massive Zink-Lead Sulfide (SMS) deposits

10.1 Types of Deposits

10.2 Distribution
10.3 Ore composition
10.4 Hydrothermal Alteration
10.5 Origin
10.6 Metallogenesis

Mississippi Valley-Type (MVT) Zink-Lead Deposits

11.1 Types of Deposits
11.2 Distribution
11.3 Ore composition
11.4 Alteration
11.5 Brecciation
11.6 Origin
11.7 Metallogenesis

12. Uranium Deposits
    12.1 Types of Deposits and Distribution
    12.2 Mineralogy and Texture
    12.3 Origin
    12.4 Metallogenesis

13. Precambrian Iron Formation
    13.1 Iron Formation
    13.2 Distribution
    13.3 Iron formation facies
    13.4 Ore composition
    13.5 Metamorphism
    13.6 Time bounded distribution of Iron formation

Module Delivery: Lectures and reading assignments, and possibly discussions and e-learning practices.

Module Assessment: Reading assignment(s) and /or a series of written tests (40%) and a written final examination (60%).

Textbooks and Reference Materials

- Evans A.M. 1993. Ore geology and industry minerals. Blackwell Science. 346 p.
- Evans, A M. 1997. An introduction to economic geology and its environmental impact, Blackwell
- Evans, A.M. 1993. An Introduction to Mineral Exploration, Blackwell.
- Franco P. Hydrothermal Mineral Deposits.

- Guilbert, J. M. and Park, C.F., 1986 The Geology of Ore Deposits, Waveland Press, reissued in 2008.
- Mookherjee, A. (2000) Ore genesis – A Holistic Approach. Allied Publisher
- Rob L., 2005. Introduction to ore forming processes. Blackwell publishing, 373p.
- Torling, D.H. (1981) Economic Geology and Geotectonics, Blackwel Sci Publ.

Module Name:	Geologic Resource		
Module Code:	GEOL- M5071		
Course Name:	Resource Exploration and Evaluation		
Course Code:	Geol 5074		
Credit Hours:	3	**ECTS:**	6

Course objective: The course aims to provide the students with basic knowledge and skills on the prospecting and exploration of mineral resources; and with the basic understanding of the occurrence of mineral deposits in space and time.

Learning Outcomes: At the end of the course, student will be in conditions to make the right decisions and to determine the technical methods of mineral explorations. By the end of the course the student should be familiar with the fundamentals of mineral/ore resources evaluation, and exploration. Students will have enough knowledge on how to plan and design a given mineral deposit.

Course description: This course will make the students to be familiar with the geologic and economic parameters which are used to assess the size and the economic value of an ore body. Topics are: Resource Estimation: calculation of grade and tonnage, reserves and resources, measured indicated and inferred resources, calculation of resources and reserves, grade control, application of computing systems in reserve estimation. Mineral Economics and Economic Evaluations of mineral projects: supply and demand of minerals, commodity prices, land ownership and taxation, Ethiopian mining law, time, place and unit value of a mineralization, mine life and production rate, calculation of cut-off grade and net smelter return (NSR), pre-feasibility study or order-of-magnitude evaluation of a mineral property, calculation of costs for development, mining, processing, transportation and marketing of a mineral project, feasibility study and mining project design, assessment of investment and return, cash flow, net present value and rates of return, risk analysis, financing of mining projects.

Course outline

1 Resource estimation (average grade, tonnage calculation) using different methods

2. Mineral Economics and Economic Evaluations of mineral projects

    2.1 Supply and demand of minerals,

2.2 Commodity prices,
2.3 Land ownership and taxation,
2.4 Time, place and unit value of a mineralization,
2.5 Mine life and production rate.
2.6 Calculation of cut-off grade and net smelter return (NSR),

3. Pre-feasibility study or order-of-magnitude evaluation of a mineral property
3.1. Calculation of costs for development,
3.2 mining, processing, transportation and
3.3 marketing of a mineral project.

4 Feasibility study and mining project design
4.1 Assessment of investment and return,
4.2 cash flow, net present value and rates of return,
4.3 risk analysis, financing of mining projects.

Course delivery method: Teaching is carried out as lectures and related examinations, laboratory exercises, field work and literature survey and series of weekly and bimonthly seminars with compulsory attendance by each student in a course.

Assessment method: The taught courses are assessed by a combination of written tests and continuous assessments including essays, seminars, presentations, practical reports and field reports. Grades are marked out of 100% and later converted to letter grade.

Text books and references

- ✓ Evans, A.M. (Ed.) (1995) Introduction to Mineral Exploration, 396 p.
- ✓ Kessler, S.E. (1994) Mineral Resources, Economics and the Environment, 391 p.
- ✓ Reedman J.H. (1990) Technique in Mineral Exploration Applied Sciences Publishers LTD. Essex, England.

16.8. Geophysics Modules

Module Name:	Geophysics		
Module Code:	GEOL M5081		
Course Name:	Fundamentals of Geophysics		
Course Code:	Geol 5081		
Credit Hours:	3	**ECTS:**	6

Course Objectives: The purpose of the course is to provide the students with the fundamental principles of geophysics and their use to unravel the hidden structure of the solid Earth and natural geological processes that occur within the Earth.

Learning Outcomes: Upon successful completion of the course, students will understand the basic principles of geophysics (gravity, seismic waves, magnetism, and heat) as applied to unraveling the hidden structure and composition of the earth.

Course content: This module is designed to introduce the students with the main physical properties of the Earth, their characteristics and measurement. It is to be a survey of the various sub disciplines of geophysics (gravity; geodesy, geomagnetism, seismology, and geothermic) and their relevance to the study of the Earth. The course is to be delivered in the form of a combination of lectures, discussion of a recent journal article on a topic covered in the lectures, and a combination of resuscitation and literature discussion.

Course Outline

1. The Earth in the Solar System
1.1. Solar system formation, accretion, early thermal state of the Earth
1.2. Rotation and angular momentum
1.3. One-dimensional Earth's structure
2. The Earth's Gravity
2.1. Basics of gravity
2.2. Gravity field and gravity potential of the Earth
2.3. The figure (shape and size) of the Earth
2.4. The geoid and the ellipsoid
2.5. The Normal (theoretical) and observed gravity
2.6. Gravity measurement
2.7. The reduction of gravity data and global gravity anomalies
2.8. Isostasy
2.8.1. The basics of Isostasy
2.8.2. Isostasy and the oceanic and continental lithosphere
2.8.3. Correlation between gravity anomalies and topography
2.8.4. Gravity anomalies of continents and ocean basins.
3. The Magnetic Field of the Earth
3.1. Theories of the sources of the internal field
3.2. The geocentric dipole field
3.3. The Geodynamo theory and problems of core-mantle coupling
3.4. The main, internal and external fields and their variations;
3.5. Magnetic induction due to a magnetic dipole
3.6. Crustal field and rock magnetism
3.7. Spectrum of the geomagnetic field,
3.8. Field reversals and paleomagnetism
3.9. Magnetic anomalies of continental and oceanic basins
3.10. Magnetism and plate tectonics
3.11. Applied geomagnetism
4. Seismology
4.1. Historical perspective of Seismology
4.2. Theory of elasticity and nature of seismic waves
4.3. Types of waves and their mode of propagation
4.4. Nomenclature of Body Waves in Earth's Interior
4.5. Ray Geometries of the Wave Field

4.6. Travel time Curves and radial Earth structure
4.7. Earthquake seismology
4.8. Seismic tomography and global seismicity distribution
5. The Earth's Heat: heat flow
5.1. Internal and external heat
5.2. Heat transfer; geothermal gradient
5.3. Worldwide heat flow and total heat loss from the Earth
5.4. Diffusion, radioactivity as Earth's heat source
5.5. Thermal structure of the continental and oceanic lithosphere

Course delivery: The course delivery will be in the form of gapped lecture, interactive lecture, group discussion, presentation, reading assignment, independent study, with special emphasis on review article and presentation on topics.

Course assessment: Written mid exam (30%), review of articles and presentation (20%) and final written exam (50%).

References

- Lowrie, W., 1997, Fundamentals of Geophysics: New York, Cambridge University press, 392p.
- Fowler, C. M. R., 2004, The Solid Earth: An Introduction to Global Geophysics, 2nd Edition, Cambridge University Press, McGraw-Hill, 686p.
- Turcotte, D. Schubert, G., 1982, Geodynamics. 2nd Edition, Cambridge University Press.

Module Name:	Geophysics		
Module Code:	GEOL M5081		
Course Name:	Exploration Geophysics		
Course Code:	Geol 5082		
Credit Hours:	3	**ECTS:**	6

Course objectives: The course provides students with the basic knowledge in the application of geophysical methods; with the knowledge and skills in survey design, field procedures, and presentation of results, interpretation of anomalies.

Learning Outcomes: After successful completion of this course, students will have skill of operating the different instruments of geophysics, data collection and interpretation; and be able to prospect the deep-seated resources of the earth.

Course Content: The course covers the basics of geophysical methods used for determining the composition and structure of the shallow Earth with the aim of introducing students to the geological application of geophysics. Topics include seismic, gravity, magnetic, electrical, electromagnetic and radioactive methods. Generally, emphasis is placed on the applications and relative merits of the various geophysical methods for particular aspects of exploration: mineral, groundwater, geothermal and hydrocarbon resources, engineering site characterization and environmental studies.

Course Outline

1. A general introduction to geophysical prospecting methods.
1.1. Basic principles and application of geophysical exploration
1.2. Overview of the different geophysical methods
2. Seismic refraction and reflection techniques
2.1. Seismic refraction
2.1.1. Two layer earth model (horizontal & inclined refractors)
2.1.2. More than two layer earth model
2.1.3. Travel time curves
2.1.4. Data acquisition & analysis
2.2. Reflection techniques
2.2.1. Basics of Reflection techniques
2.2.2. Travel time curves
2.2.3. Data acquisition & analysis
3. Electrical and Electromagnetic methods
3.1. Types of Electrical Methods (General overview)
3.2. Electrical Resistivity method
3.2.1. Basics of Electrical Resistivity method
3.2.2. Apparent resistivity and electrode configuration (Array)
3.3. Electrical Resistivity data processing and interpretation
3.4. Induced polarization
3.5. Spontaneous potential
3.2. Electromagnetic methods
4. Gravity and Magnetic methods
4.1. Gravity method
4.1.1. Overview of the basics
4.1.2. Instrumentation and data acquisition
4.1.3. Data reduction and analysis
4.1.4. Gravity anomalies
4.1.5. Separation of anomalies (regional, residual)
4.1.6. Qualitative and Quantitative interpretation
4.1.7. Application of gravity exploration
4.2. Magnetic method
4.2.1. Overview of the basics
4.2.2. Instrumentation and data acquisition
4.2.3. Data reduction and analysis
4.2.4. Magnetic anomalies
4.2.5. Separation of anomalies (regional, residual)
4.2.6. Qualitative and Quantitative interpretation

4.2.7. Application of magnetic exploration
5. Gamma ray spectrometric methods
5.1. General introduction to spectrometry
5.2. Fundamentals of gamma-ray spectrometry
5.3. Introduction to ground and airborne surveying
5.4. Calibration and data processing
5.5. Spectral methods for reducing noise
5.6. Data reduction methods
5.7. Gamma-ray fundamentals for effective interpretation
5.8. Presentation and interpretation
6. Interpretation of geophysical survey data

Course delivery: The course delivery will be in the form of gapped lecture, interactive lecture, group discussion, presentation, reading assignment, independent study, with special emphasis on review article and presentation on topics.

Course assessment: Written mid exam (30%), review of articles and presentation (20%) and final written exam (50%)

References

- Sheehan, A.F. and Jones, C.H., Burger, H.R.,(2006) Introduction to Applied Geophysics: Exploring the Shallow Subsurface, Norton publisher.
- Keary ,P., Brooks ,M., Hill, I.,(2002) An introduction to geophysical exploration, 3rd Edition, Blackwell publisher.
- Burger, H.R. (1992) Exploration Geophysics of Shallow Subsurface, Prentice Hall, TN26 B86.
- Keller, G.V. and Frischknecht F. C. (1996) Electrical Methods of Geophysical Prospecting. Pergamon Press, New York.
- Telford, W.M, Geldart, L.P and Sheriff, R.E. (1990) Applied Geophysics. Cambridge University Press, Cambridge.

16.9. Engineering Geology Modules

Module Name:	Engineering Geology		
Module Code:	GEOL M 5091		
Course Title:	Engineering Geology for Civil Structures		
Course Code:	Geol 5091		
Credit Hours:	3	**ECTS:**	6

Course Objective: The construction and design of tunnels, highways, dams, reservoirs and building foundations require a comprehensive site investigation and analysis based on surface and subsurface mapping and sampling in order to have a safe and

economically viable infrastructure. Hence studying engineering geology will equip students with a higher caliber for selecting the best site which is free from geological problems and contribute his/her part for the safe design of any infrastructure.

Learning Outcome: Upon successful completion of this course, the students will be able to

- acquire a basic understanding of different engineering structures (dam, road, bridge, building and others) and evaluate their suitable site and foundation condition.

- aware and evaluate different geological problems on different engineering structures and recommend their engineering solution,

- Acquire a basic understanding to identify the suitable potential source of geological construction material and characterize the geological construction material for different engineering structures.

Course Content:
Engineering Geology for civil structures is an applied discipline of geology that relies heavily on knowledge of geologic principles and processes. It is the means by which the engineering geologist applies geologic skills to solve an engineering problem. It requires that engineering geologist must be a competent geologist, able to translate geologic findings into forms applicable to engineering needs capable of providing sound judgment and finally he must be competent enough to take independent decisions. Thus, keeping the above fact in mind the present course is designed in such a way so that it provides all necessary knowledge of geological principles and processes that relates to the design of engineering civil structures.This course deals in depth about engineering geological field methods and site investigation for dams and tunnels; slope stability and foundation conditions for dams, buildings, roads and highways and the construction materials that will be used in the construction process. In this course students will learn to: Dams and dam sites, types of dams, investigation of dam sites; reservoirs, types of reservoirs, investigation of reservoir sites; embankment dams, types, their zoning and selection, stability analysis, embankment details, design specification and construction of filter, specification and quality control of earthworks, construction materials etc.; underground structures, investigation of tunnels and underground caverns, geological conditions and tunneling; tunneling in soft and hard ground, methods of tunneling, stability and tunnel support analysis, supporting mechanisms and ground settlement; road alignment, types and various part and their function, design and cause of pavement failure: type of bridges ,structural elements, design criteria and investigation; railway, alignment selection and root way ,geotechnical study; assessment on construction materials, nature ,source, type and standards and test

Course Outline:

1. Engineering geological considerations of surface excavations
    - 6.1 Basics of surface excavation and work
    - 6.2 methods of excavation
    - 6.3 stability of slopes treatment of slopes and groundwater
    - 6.4 Geotechnical study for building foundations
2. Site engineering geological evaluations of reservoirs, dams and dam sites
    - 6.1 Introduction, type and zones of reservoir
    - 6.2 Topographical and hydrological investigation
    - 6.3 Engineering Geological Investigation of Reservoir Sites
    - 6.4 Geological Problems (including Reservoir slope stability, Seismic actions and induced seismicity) and their solution for reservoir sites
    - 6.5 Introduction and Classification of dams (gravity, buttress, arch), spillways, outlet and penstock
    - 6.6 Engineering geological study for dam site and selection criteria
    - 6.7 Sliding problems in dams site
    - 6.8 critical compaction, seepage and uplift pressures vs hydraulic structures in dams
    - 6.9 Abutment Problems and Channel section problems

3. Engineering geology of embankment dams
    - 6.1 Introduction to embankment dams, types, zoning, basic requirement and selection criteria
    - 6.2 General nature of field investigation (foundations, abutment, spilways and outlet channel locations, borrow area and excavation areas, test quarries and test pits
    - 6.3 General design considerations
    - 6.4 Foundation and abutment preparation
    - 6.5 Design of embankment (Location of Core in Dam Section and Type of Core and design of transition filters) and appratnous structures
    - 6.6 Drainage of Embankment and Control of Seepage Through Embankment Dams
    - 6.7 Quality Control in Construction of Embankment Dams,
4. Engineering geology of tunnels
    - 6.1 Introduction and classification of tunnels
    - 6.2 Influence of geological conditions
    - 6.3 Geomechanical design parameters
    - 6.4 Rock mass classifications for tunneling
    - 6.5 Tunnel support design using rock mass classifications
    - 6.6 Excavability
    - 6.7 Tunnel excavation and support methods in soil
5. Engineering geology of roads and bridges

5.1 Introduction, classification and various parts of bridge (abutment, piers)
5.2 Types of bridge foundation and their design consideration
5.3 Site Investigation for Bridge site
5.4 Introduction on type and components of road/pavement
5.5 Basic requirement of pavement, route corrider and alignment selection
5.6 Functions of different components of pavement Change in Strength of Sub-grade
5.7 Factors affecting pavement design, Methods of Pavement Design,
5.8 Drainage design criteria
5.9 Causes of Failure of Pavement

6. Engineering geology of railways
   6.1 Introduction
   6.2 Route way and alignment selection
   6.3 geotechnical study
7. Assessments of construction material
   7.1 Identifying the suitable potential sources of geological construction materials
   7.2 Factors controlling the suitability of sources of geological construction materials (distance, overburden material, accessibility, workability, land cover and etc)
   7.3 Types of geological construction material (Road aggregates, Masonry stone, Embankment dam construction material, roofing stone and etc)
   7.4 Important tests and standards of geological construction material

Course Delivery: Lecture, video supported lectures, group discussion, case studies and team teaching.

Course Assessment: case study discussion based on scientific journal (15%), long term assignment with presentation (20 %), seminars (15%) and essay type final examination (50%).

Textbooks and Reference Materials

- Johnson R.B and DeGraff J.V., 1988. Principles of Engineering Geology, Wiley, New York, London 497pp.
- Franklin J.A. and Dusseault M., 1991. Rock Engineering Applications 431pp (B) 1991, McGraw Hill, New York.
- Krynine, D, Judd W., 2005. Principles of Engineering geology and geotechniques, CBS Publishers and Distributors.
- Richard E.Goodman, 1989. Introduction to Rock Mechanics, 2nd Edition, John Wiley & sons.

Module Name:	Engineering Geology		
Module Code:	GEOL M 5091		
Course Name:	Geotechnical Investigation		
Course Code:	Geol 5092		
Credit Hours:	3	**ECTS:**	6

Course Objective: the course aims to provide the foundations of geotechnical field investigation principles and techniques which allow students to plan and carryout site investigation.

Learning Outcome: Upon successful completion of this course, the student will have a basic and compressive knowledge of geotechnical site investigation and able to conduct geotechnical site investigation, understanding the role of geo materials on engineering work, a knowledge on the range of instruments and field testing for evaluation and characterization purpose and a skill to prepare engineering geological map.

Course Content: It provides principles and skills to the design and philosophy of geotechnical site investigations. It discusses the range of exploration and testing techniques available to geotechnical engineers, and will also learn how investigations are planned and how the results of investigations relate to the design processFundamentals of Engineering Geological site investigations: elements and phases of investigations, site exploration methods, common problems; project type ,design , project evaluation and supervision of site investigation ,presentation formats ; engineering role of geological materials , significance and challenge of rock and soil ; Impact of subsurface water on engineering woks and controlling methods; sampling and drilling techniques, instrumentation and in-situ tests; Geological factors during the planning and construction of structures like buildings, dams, reservoirs, roads, bridges and underground excavations; guidelines, types and presentation of site investigation results by report and engineering geological mapping

Course Outline

1. Geotechnical Investigation Principles
    - 1.1 Introduction, objective and stage/phase of site investigation
    - 1.2 Site exploration techniques
    - 1.3 Common problem, practice and trends
2. Project Initiation, Design and Organization of Site Investigations
    - 2.1 Project type, planning and scope of investigation
    - 2.2 Design of Site Investigations (Building the Geotechnical Model and Guidelines for Design of an SI)
    - 2.3 Progress evaluation of site investigation data and supervision of investigation
    - 2.4 Data presentation format of investigation work
3. Engineering Significance of Soil, Rock and Sub-surface water;

3.1 Brief introduction on soil
3.2 Significance of soil as an engineering material
3.3 Challenges of soil engineering and their solution
3.4 Rock as an engineering material and their significance
3.5 problem related with rock engineering
3.6 Definitions, terminologies, zones, occurrences of groundwater
3.7 Properties of sub surface rocks (storage and transmissivity of rocks)
3.8 Dewatering excavation for foundations, drainage by electroosmosis, engineering sub drainage

4. Drilling and Sampling of Soil and Rock
   4.1 soil drilling (types of soil samples and sampler)
   4.2 sampling interval, sample recovery and identification
   4.3 rock drilling and sampling (types of core drilling)
   4.4 data collection during core drilling core handling and labeling
   4.5 care and preservation of undisturbed soil sample and rock sample
   4.6 general comment how to prepare log and boring log preparation
5. In-situ Testing and Monitoring
   5.1 Introduction to in situ testing
   5.2 Penetration Testing
   5.3 Strength and Compressibility Testing
   5.4 Permeability Testing
   5.5 Introduction to field monitoring
   5.6 Use of instrumentation
   5.7 Requirements for instrumentation
   5.8 Common instrumentation practices
6. Engineering geology and construction
   6.1 Typical geotechnical Investigation related to Building Foundation,
   6.2 Typical geotechnical Investigation related to Roads/ Bridge/railway
   6.3 Typical geotechnical Investigation related to Dams / Reservoir,
   6.4 Typical geotechnical Investigation related Tunnels
   6.5 Typical geotechnical Investigation related Landfills and Waste Disposal Sites
7. Reporting of Site Investigations
   7.1 General geotechnical report preparation guidelines
   7.2 Types of geotechnical reports
   7.3 Data presentation
   7.4 Limitations
8. Engineering Geological Mapping
   8.1 Principles of engineering geological mapping
   8.2 Requirements of engineering geological map
   8.3 Types and scales of engineering geological maps
   8.4 Geological information on engineering geological maps
   8.5 Land Classification and Land Evaluation

8.6 Three dimensional mapping, cross section and graphical data presentation

Course Delivery: Lecture, video supported lectures, group discussion, case studies and field visit on any nearby construction sites.

Course Assessment: field visit report writing (15 %), long term assignment with presentation (20 %), seminars (15 %) and essay type final examination (50%).

Textbook and Reference

1. De Vallejo L.IG. and Ferrer M. 2011, Geological Engineering, CRC press.
2. Bell F.G. (2007) Engineering Geology, 2nd edition.
3. Bell F.G. (2004) Engineering Geology and Construction, Spon press, London.
4. Walthan T (2000) Foundations of Engineering Geology, 3rd edition.
5. Hunt H.E. (2007) Geotechnical Investigation Methods: A field Guide for Geotechnical Engineers, CRC Press.
6. Federal Highway Administration (FHWA). (2001) geotechnical investigation standards *Circular No. FHWA: TS-89-045*, Washington, D.C.

16.10. Hydrogeology Modules

Module Name:	Hydrogeology		
Module Code:	GEOL M5101		
Course Title:	Hydrogeology		
Course Code:	Geol 5101		
Credit Hours:	3	**ECTS:**	6

Course Rationale: This course will upgrade students' knowledge on the hydrologic cycle, water budget and basic hydrologic processes; aquifer characterization; Groundwater dynamics; techniques of groundwater resources assessment, development and evaluation.

Course Objectives: This course will enable students to enhance their theoretical knowledge on the overall dynamics of water in the atmosphere, the land surface and in the underground. They will develop their practical experience on the data collection, analysis and interpretation in physical hydrogeology.

Course Description: This course deals with the hydrologic cycle, water budgets and basic hydrologic processes; Physical properties of porous media and groundwater flow principles (Steady-state groundwater flow and transient groundwater flow) and flow through fractures and fracture networks, well hydraulics and groundwater resource evaluation and regional groundwater flow.

Course Content: This course is designed to provide the basic background knowledge on hydrogeological principles and applications for the different pertinent streams in the Department at advanced level. The course includes: Basic concept of the water balance,

assessment of the components of the hydrological cycle from the point of view of groundwater recharge estimation and groundwater and surface water interactions, Aquifer parameters, Darcy's law, groundwater flow equations and well hydraulics, flownet, surface water and groundwater interaction, well hydraulics and groundwater resource evaluation and regional groundwater flow, Hydrogeological maps.

Course Outline:

1. The Drainage Basin Concepts
   - 1.1 Introduction
   - 1.2 Watershed
   - 1.3 Hydrology and Hydrologic cycle
   - 1.4 World's Water Resource
   - 1.5 Concepts of water balance
   - 1.6 Introducing concepts of groundwater and groundwater hydrology

Precipitation Processes and Measurements

2.1 Introduction
- 2.2 Formation of precipitation
- 2.3 Forms of precipitation
- 2.4 Factors affecting the amount and distribution of precipitation
- 2.5 Types of precipitation
- 2.6 Measurement of precipitation
- 2.7 Rain gauge density
- 2.8 Graphical representation of rainfall data
- 2.9 Rainfall data processing
  - 2.9.1 Determination of aerial depth of precipitation
  - 2.9.2 Supplementing or estimating missing data

Evapo-transpiration Processes & Measurements

3.1 Interception
- 3.1.1 Factors Affecting Interception Loss from Vegetation
- 3.1.2 Measurement of Interception

3.2 Evaporation
- 3.2.1 Factors Affecting Evaporation
- 3.2.2 The atmospheric conditions above evaporating surface or evaporating capacity of the atmosphere
- 3.2.3 Type of evaporating surface

3.3. Transpiration

3.3.1. Factors Affecting Transpiration

3.3.2. Determination of Transpiration

3.4. Measurement of Evaporation and Evapotranspiration

3.4.1. Atmometers

3.4.2. Evaporation Pans

3.4.3. Water Balance
3.4.4. Lysimeters and Field Plots
3.5. Physical Theories and Formulae on Evaporation and Evapotranspiration
3.5.1. Penman's Formula
3.5.2. Energy Emission by Radiation
3.5.3. Empirical Formulae on Evapotranspiration

Stream flow characterizations & measurements

4.1 Surface flow types and zones, runoff generation and unit hydrograph
4.2 Stream flow measurements and gauging
4.3 Basin morphometry (stream ordering, stream length, basin area, shape of basin, basin relief and slope)
4.4 Factors affecting runoff, timing of runoff

Recharge and Discharge

5.1 Methodologies in estimating groundwater recharge
  5.1.1 Direct and indirect methods
  5.1.2 Water balance method
  5.1.3 Base flow separation method
  5.1.4 Soil water balance parameterizations
  5.1.5 Geochemical method in arid zone hydrology
5.2 Recharge mechanism
  5.2.1 Direct and indirect recharge processes
  5.2.2 Groundwater recharge in arid zones
5.3 Climate change impact on recharge

Basics of groundwater and groundwater flow, groundwater flow equations

6.1 Groundwater Flow
6.2 Water flow in aquifers – the Darcy Law
6.3 Pumping test and pumping test analysis techniques
6.4 Physical properties of porous media and groundwater flow principles (Steady-state groundwater flow and transient groundwater flow)
6.5 Groundwater flow in fractured hard rock aquifers
6.6 Flow Nets, modeling fluid flow, numerical methods.

Groundwater flow to wells

7.1 Derivation of equations for groundwater flow to wells

Learning Outcomes: After successful completion of the module students shall:

- Demonstrate an understanding of groundwater flow and its relation to topography, hydrology, geology
- Identify the significant components of catchment and aquifer water balances
- Calculate water balances and their components
- Interpret hydrogeological field data, including resolving inconsistencies and dealing with uncertainty

- Understand groundwater flow processes, mathematical representation groundwater flows, fundamental physical laws of groundwater flows

Delivery Method: Lecture, hands on training, group discussion and exercises, Practical laboratory training

Recommended Reading:

- C.W. Fetter, (1994) Applied hydrogeology (3rd ed.), (or 4th Ed, 2000). MacMillan
- A M. Price, (0000) Introducing groundwater (2nd ed.), Chapman and Hall.
- A P.L. Younger (2006) Groundwater in the environment. Blackwell. ISBN: 978-1-4051-2143-9
- A F.W. Schwartz & H Zhang, (2003) Fundamentals of groundwater. Wiley. ISBN: 0471429058.
- Heath, R. C. (1998) Basic Ground-Water Hydrology: U.S. Geological Survey Water-Supply Paper 2220.
- Keith, David (1980) Ground water Hydrology, 2nd Edition.
- Price, M. (1995). Introducing Groundwater, Chapman and Hall, London, 195p.
- Raghunath, H.M. (1987) Groundwater Hydrology, 2nd Edition.
- Schwartz F. W. and Zhang, H. (2003) Fundamentals of Ground Water

Assessment Criteria: Comprehensive exam (50 %), Practical exercises (20%), Group assignment (30 %).

Module Name:	Hydrogeology	
Module Code:	GEOL M5101	
Course Title:	Engineering Hydrology	
Course Code:	Geol 5102	
Credit Hours:	3	**ECTS:** 6

Course Objectives: This course will give students a quantitative understanding of the hydraulics of subsurface fluid flow and engineering applications and design.

Course Description: This course covers groundwater concepts; hydrologic cycle and water balance; Principles of groundwater flow; Well hydraulics; Engineering applications of groundwater hydraulics; Hydraulic structures ; Hydrograph separation will be discussed.

Course Outcome: Upon successful completion of this course, the students will be able to:

- Acquire a basic understanding in groundwater concepts, hydrologic cycle and water balance
- Acquire a basic understanding in groundwater flow and well hydraulics
- Acquire a basic understanding in engineering applications of groundwater hydraulics and hydraulic structures
- Acquire a basic understanding in hydrograph separation.
- Acquire a quantitative understanding of the hydraulics of subsurface fluid flow and engineering applications and design.

Course Outline

1. Groundwater Concepts and Hydrologic cycle
   - 1.1 Characteristics of porous media
   - 1.2 Hydrologic cycle; Precipitation, Evaporation, Infiltration, Evapotranspiration
   - 1.3 The localized water balance
   - 1.4 Characteristics of water in the Vadose zone; unsaturated flow
2. Principles of groundwater flow
   - 2.1 Darcy's law of fluid flow in porous media
   - 2.2 Flow lines and flow nets
   - 2.3 Continuity principles
3. Well hydraulics
   - 3.1 The response of ideal aquifer to pumping
   - 3.2 Computing drawdown caused by a pumping well
   - 3.3 Determining aquifer parameters from time drawdown data
   - 3.4 Slug test
   - 3.5 Estimating aquifer parameters from specific capacity data
   - 3.6 Intersecting pumping cones and well interference
   - 3.7 Effects of hydrogeologic boundaries
   - 3.8 Collection and analysis of pumping test data
   - 3.9 Engineering applications of groundwater hydraulics
4. Hydraulics structures
   - 4.1 Dam
   - 4.2 Reservoir
5. Hydrograph separation
   - 5.1 Equilibrium hydrograph analysis
   - 5.2 Unit hydrographs, hydrograph synthesis, routing
   - 5.3 Frequency Analysis, runoff generation

Mode of delivery: The course will be delivered mainly in a lecture format, but group discussion, computer analysis and laboratory measurements are also thought to be incorporated. The course will be delivered mainly in a lecture format, but group discussion, computer analysis and laboratory measurements are also thought to be incorporated. Teaching is carried out as lectures and related examinations, laboratory

exercises, literature survey and series of weekly and bimonthly seminars with compulsory attendance by each student in a course.

Mode of Assessment: The course is assessed by a combination of written tests and continuous assessments including essays, seminars, presentations, practical reports and field reports. Grades are marked out of 100% and later converted to letter grade.

Textbooks and Reference Materials

- Applied Hydrogeology, C.W Fetter, 200.
- Groundwater, Freeze and Cherry, 1979.
- Applied Hydrogeology, Zekai Sen.
- Groundwater and wells, Driscoll, 1986.
- Introduction to hydrogeology, David Deming.
- Water in Environmental planning, Thomas Dunne and Luna B. Leopold.

Module Name:	Hydrogeology		
Module Code:	GEOL M5101		
Course Title:	Isotope Hydrogeochemistry		
Course Code:	Geol 5104		
Credit Hours:	3	**ECTS:**	6

Course Objectives: This course aims to understand aqueous inorganic chemistry and to interpret groundwater chemistry data sets in the context of water-rock interactions to solve problems of regional flow, pollution and well designIn this course, the major hydrochemical processes of importance in groundwater such as Theory of dissolution/precipitation, acid-base, redox, and sorption reactions isotopes as tracers and their application to water resources and contaminant hydrogeology are introduced. It will provide students with the basic concepts of chemical analysis relevant to the water in the hydrologic cycle; establish outline knowledge of a range of common analytical techniques and issues surrounding sample collection and handling. Interpretation techniques for combining data and defining hydrochemical types are also discussed as part of an integrated approach to understanding groundwater flow mechanisms. The basis for the application of environmental isotopes in groundwater investigations are discussed with emphasis given to groundwater source identification, origin of groundwater recharge and age dating using stable and radioactive isotopes of water.

Course Content: This course examines the chemical composition of meteoric waters, emphasizing how the chemistry of groundwater is controlled by the interaction with rocks. In most hydrogeologic investigations, chemical analyses of water play a key role, whether a pristine situation such as chemical evolution of ground water or one involving contamination by inorganic or organic compounds as a result of human activity. The relationships between chemistry, geology, human activity, and natural processes are explored. Approaches to determine reliability of analytical data are applied to real data. Methods of data interpretation that will be covered include ionic ratios, graphical techniques, statistical techniques and equilibrium modeling. Topics of organic compound nomenclature and properties are followed by consideration of partitioning of organic compounds in water, soil, and air. Field and Laboratory Methods in Geochemistry involving the practical side of geochemistry: how to collect various types of water samples and field and laboratory analytical techniques will be introduced in this course. The field methods will focus on accepted standards and documentation of water sample collection. Field analytical techniques will include measurement of conductivity, temperature, pH, and alkalinity. Laboratory analytical techniques will focus on the operation and standardization instruments including specific ion electrodes, atomic absorption spectroscopy, ion chromatography, ICP spectrometry, fluoremetry, gas chromatography, and gas chromatography-mass spectrometry. This course also introduces a variety of isotope systems and their applications to solving geologic problems. Isotopes are powerful tools with a range of applications, from environmental tracers to sources of magmatic contamination. Both radiogenic and stable isotopes are presented along with case studies of both high and low temperature systems. The use and limitations of many isotope systems are discussed throughout the semester. This part is organized in a seminar format with a balance between supervisors and students presenting material.

Course Outline

1 Introduction
- 1.1 Nomenclature and units
- 1.2 Major and trace ions representation
- 1.3 Diagrams and ionic relations
- 1.4 Stable and radioactive isotopes
- 1.5 Fieldwork and analysis (Quality control)

2 Origin of chemical constituents in groundwater
- 2.1 Properties of water
- 2.2 Chemical composition of Earth Materials
- 2.3 Principles and processes controlling composition of natural waters

2.4 Evolution of groundwater chemistry (Chebotarev facies concept)
2.5 Anthropogenic sources

3 Techniques of presentation and interpretation of hydrochemical data
3.1 Graphical techniques
3.2 Statistical techniques
3.3 Ionic ratio
3.4 Equilibrium modeling

4 Isotope hydrology
4.1 Environmental isotopes (natural tracers) and Injected (artifitial tracers)
4.2 Lab analysis for stable isotopes (Mass Spectrometer)
4.3 Principles in isotope hydrology (Isotopic ratios, concentrations and notation; Isotope fractionation, radioactivity, reactions)
4.4 Isotope effects and hydrology (Temporal and spatial distribution of water isotopes and their causes; Stable isotopes in the water cycle)
4.5 Dating of groundwater
4.6 Isotope hydrology and hydrogeochemistry combined
4.7 Applications in hydrology and hydrogeology with case studies

Course Delivery: Lectures, tutorials and practical exercises and field excursion.

Course Assessment: Written exam (40%), exercise during tutorial sessions (30 %), and seminars (30 %).

Textbooks and Reference Materials

- Appelo, C.A.J. &Postma, D. (1993) Geochemistry, groundwater and pollution. Balkema, Rotterdam, 536p.
- Bethke, Geochemical and Biogeochemical Reaction Modeling, Cambridge, 2nd edition.
- Freeze R. A. and Cherry, J.A. (2004) Groundwater.
- Hem, (1989) Study and Interpretation of the chemical characteristics of Natural water, USGS.
- Environmental Isotopes in Hydrogeology. I.D. Clark and P. Fritz, 1997, CRC Press, 328 p.
- Groundwater. Robert Bowen, 1986, Elsevier Applied Science Publications, New York, 427p.
- Groundwater Geochemistry- Fundamentals and applications to contamination. W.J. Deutsch, 1997, Lewis Publications, New York, 221p.
- Handbook of Environmental Isotope Geochemistry. P. Frits and J. Ch. Fontes (Eds.), 1980, Volume I, The Terrestrial Environment, Elsevier Scientific Publishing Company, New York, 545p.
- Isotope Tracers in Catchment Hydrology. C. Kendall and J. J. McDonnell (Eds.), 1998, Elsevier Science B.V., Amsterdam.

- Principles of Isotope Geology. G. Faure, 1986, John Wiley and Sons, New York, 589 p.
- Radioactivity in Geology, Principles and Applications. E.M. Durrance, 1986, John Wiley and sons, New York, 441p.
- Strontium isotope geology. G. Faure and J.L. Powell, 1972, Springer-Verlag, New York, 188 p.
- The Geochemistry of Natural Waters. James I. Drever, 1988, Prentice Hall, Eaglewood Cliffs, New Jersey, 437p.

Module Name:	Hydrogeology		
Module Code:	GEOL M5101		
Course Title::	**Groundwater Flow and Contaminant Transport Modeling**		
Course Code:	Geol 5103		
Credit Hours:	3	**ECTS:**	6

Course Objectives: This course is intended to provide the background and skills necessary to maintain proficiency with the rapidly-evolving groundwater modeling technology. Such models are essential decision support tools for decision makers in groundwater management. Contaminant Transport Modeling main emphasis is to explore how dissolved and suspended materials are transported in groundwater and how that transport can differ from average groundwater flow. The mathematical equations governing solute transport are developed. The aim of this course is to introduce students with the theoretical and practical know how of the mathematical and computer modeling of groundwater flow and nonreactive solute transport through geological formations; conceptual flow-models for geologic systems; formulation of governing mass and energy conservation equations; application of analytical, numerical and stochastic models to real-world problems, the fundamental principles and factors that govern the fate of pollutants in the groundwater. Students will learn about the range of possible contaminants and the mechanisms by which they are transported in groundwater systems. They will also get an understanding of how human activities can modify the quality of groundwater, and how such modifications can be detected and distinguished from natural processes, as well as the means by which the results can be simulated.

Course Content: The course is designed in such a way that to prepare students to develop ability to apply the fundamental principles of groundwater flow and solute transport to hydrogeological problems, and apply of analytical solutions, to develop an understanding of the principles of numerical groundwater flow models, to develop and understanding of the principles of numerical solute transport models. To be able to solve hydrogeological problems use numerical techniques and be familiar with industry standard modelling software. This groundwater flow and transport modelling; Groundwater flow processes; Numerical methods for groundwater modelling; Conceptual model development; modelling protocol; Introduction to groundwater

modelling software; Model calibration; Model result presentation; Contaminant transport, transport processes, contaminant sinks and rises, sources of contaminants, classification of contaminants, the advective-diffusive transport equation, Particle tracking, MODPATH, MT3D, modelling contaminant transport, Contaminant transport in unsaturated zones, Case Study and practical exercises

Course Outline

1. The background to analytical models:
   a. The continuity equation, Laplace and Poisson equations.
   b. Assessment of 1-D flow in confined, unconfined and leaky aquifer systems.
   c. Assessment of 2-D flow in regional systems.
   d. Derivation of equations in radial coordinates under steady state and transient conditions.
2. Modeling protocol
   a. Conceptual model development
   b. Mathematical model
   c. Numerical formulation
   d. Computer program
   e. Code verification
   f. Model redesign
   g. Model calibration and sensitivity analysis
   h. Model validation and prediction
   i. Presentation and postaudit
   j. Groundwater models and performance monitoring
3. Modeling Contaminant Transport using the advection-dispersion equation (advection, dispersion, diffusion, retardation).
   a. Conservative and reactive transport principles
   b. Diffusion in porous media
   c. Hydrodynamic dispersion (Convection and Advection processes)
   d. Equations of solute transport
   e. Mass transport with chemical reactions
   f. Equilibrium sorption reactions
   g. Conceptual models of contaminant migration
4. Numerical modeling the finite difference and finite element methods.
5. Modeling Groundwater Flow The MODFLOW package: principles and methods of application Particle tracking: the use of (MODPATH) to determine flow directions.
6. Modeling Contaminant Transport: the three-dimensional (MT3D) modeling program.
7. Groundwater Modeling Practice

Course Delivery: Lectures, tutorials and practical exercises and field excursion.

Course Assessment: Practical modeling exercise (30 %), and Assignment (20 %) and Written exam (50%).

Textbooks and Reference Materials

- Anderson and Woessner (1992). Present an overview of applied groundwater flow and advective transport modeling.
- Appelo, C.A.J. &Postma, D. (1993) Geochemistry, groundwater and pollution. Balkema, Rotterdam, 536p.
- Bethke, Geochemical and Biogeochemical Reaction Modeling, Cambridge, 2nd edition.
- Fetter, C. W. (1994) Applied Hydrogeology, 3rd Edition.
- Freeze R. A. and Cherry, J.A. (2004) Groundwater.
- Hem, (1989) Study and Interpretation of the chemical characteristics of Natural water, USGS.
- Zheng and Bennett (1995). Present an overview of the theory and practice of contaminant transport.

16.11. Environmental Geology & Geohazards Modules

Module Name:	Environmental Geology		
Module Code:	GEOL M5111		
Course Name:	Environmental Impact Assessment		
Course Code:	Geol 5114		
Credit Hours:	3	**ECTS:**	6

Course Objectives: The purpose of EIA is to: provide information for decision making on the environmental consequences of proposed actions and to promote environmentally sound and sustainable development through the identification of appropriate enhancement and mitigation measures. Environmental Impact Assessment promotes environmental and economic benefits in which cost and time of project implementation and design are reduced, treatment/clean-up costs are avoided and impacts of laws and regulations are evaluated prior to implementation. The course introduces basic foundation of EIA and its importance for project planning and design, find ways and means to reduce adverse impacts, shape projects to suit the local environment and present the predictions and options to decision-makers

Learning Outcomes: Upon successful completion of the course students will be able to discuss the methods and procedures needed in EIA; Demonstrate an introductory understanding of EIA and why it is necessary; conduct an environmental Impact Assessment project (review or original); appreciate the advantages of conducting EIA prior to implementing a

project; appreciate the worldwide influence of EIA practice; promote sustainable development

Course Content: The EIA course includes the specific topics; the history and process of EIA, the Implementation of EIA, Screening and scoping, Alternatives in EIA, Impact prediction, Review of EIA reports, Consultation and participation, Mitigation measures, EIA and decision-making, Monitoring and auditing

Course Outline

1. Introduction to EIA: process and systems
1.1. Back ground
1.2. Importance and role of EIA
1.3. EIA as a planning tool
1.4. Cost and benefits of EIA
2. Law, policy and institutional arrangements for EIA systems
2.1. About EIA systems
2.2. EIA Policy and legislation
2.3. EIA requirements of International Organizations
2.4. Principles for a functional EIA systems
3. Public involvement in EIA
3.1. Stakeholder involvement
3.1.1. Importance of stake holder involvement
3.2. Stakeholder involvement in the EIA process
3.2.1. Stakeholder analysis
3.2.2. Power and access to information
3.2.3. Timing of stakeholder involvement
3.3. Public involvement approaches

4. Preliminary environmental assessment
4.1. Registration
4.2. Screening
4.2.1. Objectives of screening
4.2.2. Approaches to screening
4.2.3. Responsibilities
4.2.4. Screening categories
4.2.5. Information for screening
4.3. Project alternatives
4.3.1. Project planning and alternatives
4.3.2. Assessment of alternatives
4.4. Scoping
4.4.1. Objectives of scoping
4.4.2. Responsibilities for scoping
4.4.3. Timing of scoping
4.4.4. Scoping steps
4.4.5. Boundaries for the EIA study
4.4.6. Result of scoping
5. Impact analysis and management

5.1. Impact identification
5.1.1. Check list
5.1.2. Matrices
5.1.3. Network diagrams
5.1.4. Map overlays
5.1.5. Geographic information system (GIS)
5.2. Impact prediction
5.2.1. Impact magnitude
5.2.2. Extent of impact
5.2.3. Impact duration
5.2.4. Prediction methods, Mathematical modeling
5.3. Impact evaluation
5.3.1. Importance of impact significance
5.3.2. Consideration in evaluating significance
5.3.3. Using environmental standards
5.3.4. Matrices
5.4. Impact mitigation, Mitigation, Enhancement
5.4.1. Types of mitigation measures
5.4.2. Identification of mitigation measures
5.5. Impact mitigation planning
5.5.1. Role of impact mitigation plan
5.5.2. Implementation of impact mitigation plans
5.5.3. Institutional involvement
5.5.4. Scheduling of mitigation activities
5.5.5. Public involvement
5.5.6. Integration of mitigation in to the project planning process
5.6. Monitoring
5.6.1. Purpose
5.6.2. The role of monitoring in EIA process
5.6.3. Types of monitoring
6. EIA reporting (EIS) and review of EIA quality
6.1. Preparation of environmental impact statements (EIS)
6.1.1. Aims and objectives
6.1.2. Decision making
6.1.3. Responsibilities
6.2. Contents of an environmental impact statement
6.2.1. Outline
6.2.2. Overview of different reports
6.3. EIS presentation
6.3.1. Submission
6.3.2. Media of presentation
6.4. EIA review
6.4.1. Objectives of reviewing
6.4.2. Types of review
6.4.3. Managing the EIA review process
6.4.4. Timing of the EIA review and quality control in EIA process
6.4.5. Approaches to EIA review
6.4.6. Steps and tools of EIA review
6.4.7. Determining remedial options

7. EIA decision-making and auditing
7.1. Decision-Making
7.2. EIA performance assessment
7.3. Environmental Auditing

Course delivery: The course delivery will be in the form of gapped lecture, interactive lecture, group discussion, presentation, reading assignment, independent study, with special emphasis on review article and presentation on topics.

Course assessment: Written mid exam (30%), review of articles and presentation (30%) and final written exam (40%)

Text Books and References

- Environmental Engineers' handbook (1999), CRC Press LLC.
- Eccleston, H.C. (2000) Environmental Impact Statements. John Wiley & Sons, Inc. Canada. 346 pp.
- Wathern P. (1995) Environmental Impact Assessment: Theory and Practice, Biddles Ltd, Guildford and King's Lynn, Great Britain, 332p.

Module Name:	Environmental Geology	
Module Code:	GEOL M5111	
Course Title:	Integrated Geohazard Analysis and Disaster Management	
Course Code:	Geol 5112	
Credit Hours:	3	**ECTS:** 6

Course Objective: The course is aimed to increase students' knowledge of integrated geohazard analysis and disaster management.

Course Content: This course covers the collection, analysis, interpretation of geological, social (settlement, population, etc.), economical, technical and organizational data for hazard identification, risk assessment, forecasting, early warning, monitoring, and management (first, rehabilitation, reconstruction etc.) of geohazards. Techniques (remote sensing, geotechnical investigations, geomorphological analysis etc) involved in the whole process of disaster forecast and management will be discussed.

Learning Outcomes: Upon successful completion of this course, the students will be able to:

- Characterize hazards and disasters from landslide, earthquake, flood, volcano and other geohazards.
- Perform risk assessment for different disaster types using different risk assessment methodologies

- Acquire a basic understanding to hazard identification, risk assessment, forecasting, early warning, monitoring, and management.

Course Content

1. Characteristics of particular hazards and disasters
    - 1.1 Landslide
    - 1.2 Earthquake
    - 1.3 Volcano
    - 1.4 Flood and other geohazards
2. Risk assessment for different disaster types using different risk assessment methodologies
    - 2.1 Remote Sensing
    - 2.2 Geotechnical investigations
    - 2.3 Geomorphological studies
    - 2.4 Meteorological studies
3. Disaster Monitoring
    - 3.1 Design
    - 3.2 Operational Mitigation
4. Geohazard Management Planning Process
5. Nature of responses to geohazards
    - 5.1 Problems of financing and insurance
    - 5.2 Trends in natural hazard activity, training of emergency management personnel
6. Policy issues for disaster prevention, preparedness, reduction and management
    - 6.1 Disaster preparedness and its components
    - 6.2 Disaster reduction and prevention
    - 6.3 Disaster management
    - 6.4 Disaster profile, national policies, government structure for warning and emergency response
7. Preparation of base-line data and mapping on each disaster-prone area
8. Case histories of major natural hazards
    - 8.1 Prediction
    - 8.2 Forecasting, and
    - 8.3 Prevention of natural disasters

Mode of delivery: The course will be delivered mainly in a lecture format, but group discussion, computer analysis and laboratory measurements are also thought to be incorporated. Teaching is carried out as lectures and related examinations, laboratory exercises, literature survey and series of weekly and bimonthly seminars with compulsory attendance by each student in a course.

Mode of Assessment: The course is assessed by a combination of written tests and continuous assessments including essays, seminars, presentations, practical reports and field reports. Grades are marked out of 100% and later converted to letter grade.

Textbooks and Reference Materials

- Environmental Geology Facing the challenges of our changing earth by Jon Erickson, 2002.

- Environmental Geology by James S. Reichard, 2011.
- Foundations of Environmental Geology Fourth Edition, by Edward A, 2008.
- Introduction to Environmental Geology, Forth Edition by Edward A, 2008.
- Environmental Geology, Ninth Edition by Carla W. Montgomery, 2011

Module Name:	Environmental Geology	
Module Code:	GEOL M5111	
Course Title:	Environmental Modeling	
Course Code:	Geol 5114	
Credit Hours:	3	ECTS: 6

Course Objective: This course is designed to familiarize and acquaint students with the techniques of environmental system analysis and modeling.

Course Description: This course introduces *the concepts on* Natural Environments and causes of changes (climate, etc.): understanding the nature, timing and rate of changes of natural systems: ecosystems dynamics, land surface/land cover changes and geomorphic processes (mass wasting, fluvial and wind processes and human impact); water resources variability; atmospheric oceanic and cryospheric changes. Past human experiences in coping with natural variability. Human impact (timing, nature and rate): land use and land cover changes and impacts on soils, water and air - environmental degradation and natural resources depletion. Land reclamation, erosion, sediment transport and deposition. The second part of the course will introduce concepts of mathematical and computational modelling which is an ever more important tool in environmental science. The course will take two approaches: the focus will be on understanding the concepts of what modelling is and how it can be used to better understand the complexities in environmental systems; and on the other hand will introduce very basic modelling techniques that underlie the more complex models such as large scale climate change models. The emphasis will be on understanding concepts rather mathematical techniques – although there will be a basic introduction to simple functions and computer simulations as well as hands-on training on some simple environmental computer models.

Course outcome: Upon successful completion of this course, the students will be able to:

- ✓ Acquire a basic understanding in the concepts on natural Environments and causes of changes (climate, etc.)
- ✓ Acquire a basic understanding in the nature, timing and rate of changes of natural systems.
- ✓ Acquire a basic understanding in Human impact in environment
- ✓ Acquire a basic understanding in very basic environmental modelling techniques

Course Outline

1. Concepts on natural environmental systems and causes of changes
    - 1.1 Changes in natural environmental systems causes, rates, parameters
    - 1.2 Ecosystems dynamics, geomorphic processes
    - 1.3 Water resources variability
    - 1.4 Climate change
    - 1.5 Atmospheric oceanic and cryospheric changes.
2. Humans and natural environments: impacts and experiences
    - 1.6 Past human experiences in coping with natural variability.
    - 1.7 Land use and land cover changes
    - 1.8 Impacts on soils, water and air
    - 1.9 Environmental degradation and natural resources depletion
    - 1.10 Land reclamation, erosion, sediment transport and deposition
3. Concepts of Environmental modeling
    - 1.11 Introduction to very basic modeling techniques
    - 1.12 Conceptual modeling
    - 1.13 Mathematical modeling
    - 1.14 Computational modeling

Mode of delivery: The course will be delivered mainly in a lecture format, but group discussion, computer analysis and laboratory measurements are also thought to be incorporated. The course will be delivered mainly in a lecture format, but group discussion, computer analysis and laboratory measurements are also thought to be incorporated. Teaching is carried out as lectures and related examinations, laboratory exercises, literature survey and series of weekly and bimonthly seminars with compulsory attendance by each student in a course.

Mode of Assessment: The course is assessed by a combination of written tests and continuous assessments including essays, seminars, presentations, practical reports and field reports. Grades are marked out of 100% and later converted to letter grade.

Textbooks and Reference Materials

- Environmental Geology Facing the challenges of our changing earth by Jon Erickson, 2002.
- Environmental Geology by James S. Reichard, 2011.
- Foundations of Environmental Geology Fourth Edition, by Edward A, 2008.
- Introduction to Environmental Geology, Forth Edition by Edward A, 2008.
- Environmental Geology, Ninth Edition by Carla W. Montgomery, 2011

Module Name:	Environmental Geology

Module Code:	GEOL M5111	
Course Title:	Urban Geology	
Course Code:	Geol 5115	
Credit Hours:	3	**ECTS:** 6

Course objective: This aim of this course is giving an introduction to the role and scope of geological processes in the light of contemporary urban society.

Course Content: This course describes a Land-Air-Water systems and interaction which include topics such as air and water pollution, earth movements, waste disposal, mineral, energy and water resources, construction engineering, and effects caused by human activities. It also describes geology and hydrologic factors controlling the occurrence, movement, quality, recovery and development of water supply and distribution in an urban context. This course covers the problems relating to water pollution and urbanization of flood plains. It introduces site selection for construction materials, methods of excavation, safety measures, land degradation as a result of quarry activities, quarry rehabilitation. It introduces sources of surface and groundwater contamination, issues of radioactive wastes and toxic substances in natural waters. It describes waste disposal, waste management and groundwater; hydrochemical behavior of contaminants; aspects of flushing and aquifer cleanup; eutrophication process; nature, sources and characterization of hazardous waste; collection, transportation and disposal of hazardous wastes; fundamentals of toxicology and risk assessment; application of geologic principles and methods in the assessments and remediation of abandoned hazardous waste sites and contaminated aquifers and finally review of selected case histories.

Learning outcome: Upon successful completion of this course, the students will be able to:

- Acquire a basic understanding in natural environmental systems which includes Land-Air-Water systems and interaction
- Acquire a basic understanding in human induced environmental effects.
- Acquire a basic understanding in Human impact in environment and urbanization of flood plains
- Acquire a basic understanding in urban water supply and associated geological and hydrological problems
- Acquire a basic understanding in quarry sites in urban settings and sources of construction materials
- Acquire a basic understanding in application of geologic principles and methods in the assessments and remediation of abandoned hazardous waste sites and contaminated aquifers

Course Outline

1. Natural Environmental systems
    - 1.1 Land-Air-Water systems and interaction
    - 1.2 Air and water pollution
2. Human Induced environmental effects
    - 2.1 Physical and chemical Pollution
    - 2.2 Waste disposal
    - 2.3 Waste management and groundwater
    - 2.4 Hydrochemical behavior of contaminants
    - 2.5 Aspects of flushing and aquifer cleanup
    - 2.6 Earth movements
    - 2.7 Mineral, energy and water resources
    - 2.8 Construction engineering
3. Urban water supply and associated geological and hydrological problems
    - 3.1 Geology and hydrologic factors controlling the occurrence, movement, quality
    - 3.2 Recovery and development of water supply and distribution in an urban context
4. Urbanization of flood plains
    - 4.1 Problems relating to water pollution
    - 4.2 Sources of surface and groundwater contamination
    - 4.3 Issues of radioactive wastes and toxic substances in natural waters
    - 4.4 Urbanization of flood plains
    - 4.5 Nature, sources and characterization of hazardous waste
    - 4.6 Collection, transportation and disposal of hazardous wastes
    - 4.7 Fundamentals of toxicology and risk assessment
    - 4.8 Application of geologic principles and methods in the assessments
    - 4.9 Remediation of abandoned hazardous waste sites and contaminated aquifers
5. Quarry sites in urban settings and sources of construction materials
    - 1.1 Selection for construction materials
    - 1.2 Methods of excavation and safety measures
    - 1.3 Land degradation as a result of quarry activities
    - 1.4 Quarry rehabilitation
6. Review of selected case histories

Mode of delivery: The course will be delivered mainly in a lecture format, but group discussion, computer analysis and laboratory measurements are also thought to be incorporated. The course will be delivered mainly in a lecture format, but group discussion, computer analysis and laboratory measurements are also thought to be incorporated. Teaching is carried out as lectures and related examinations, laboratory

exercises, literature survey and series of weekly and bimonthly seminars with compulsory attendance by each student in a course.

Mode of Assessment: The course is assessed by a combination of written tests and continuous assessments including essays, seminars, presentations, practical reports and field reports. Grades are marked out of 100% and later converted to letter grade.

Textbooks and Reference Materials

- Environmental Geology Facing the challenges of our changing earth by Jon Erickson, 2002.
- Environmental Geology by James S. Reichard, 2011.
- Foundations of Environmental Geology Fourth Edition, by Edward A, 2008.
- Introduction to Environmental Geology, Forth Edition by Edward A, 2008.
- Environmental Geology, Ninth Edition by Carla W. Montgomery, 2011

Module Name:	Remote Sensing & Geoinformatics		
Module Code:	GEOL M5121		
Course Name:	Fundamentals of Remote Sensing and GIS		
Course Code:	Geol 5124		
Credit Hours:	3	**ECTS:**	6

Course objectives: This course introduces the student to the principles of Remote Sensing and GIS as a tool for mapping. Study about the data products, their properties and methods of preparing thematic information. To provide exposure to data models and data structures in GIS and to introduce various Raster and Vector Analysis capabilities. To expose the concept of quality and design of cartographic outputs in open GIS environment.

Learning outcome: On completing the course students will have the better understanding of remote sensing and GIS concepts and advanced techniques. Upon completion of this course students can demonstrate a working knowledge of GIS and remote sensing software.

Course Contents: Remote Sensing is a science of studying natural and manmade earth features and analyzing the digital satellite data which are used in applications in water resources, land use/land cover, forest resources, environmental monitoring etc. In this module first we study electromagnetic radiation of sun, and its interaction

with the atmosphere and main earth surface features like vegetation, soil, and water and their spectral reflectance characteristics. We also study different satellites, platforms, sensors and orbital characteristics and their role in getting the remote sensing data. In the second part we will learn about Geographical Information Systems (GIS), a powerful tool in which we can model the behavior of certain aspects of the earth surface. This part includes an overview and general principles of GIS, data types, data handling and projections. Basic spatial data analysis will be covered. In the third part we will learn about the practical component that involves the use of desktop software for image processing and analysis using ERDAS Imagine, ENVI, and GIS software ArcGIS. Both theoretical and practical components are important.

Course Outline:

1. Basics of remote sensing
1.1 Concepts of Remote Sensing,
1.2 Remote Sensing Definition, Wave Theory Electromagnetic Spectrum (UV, Visible, MIR, ThIR).
2. Energy Interactions with Atmosphere
2.1 Scattering & Absorption.
2.2 Energy interactions with Earth Surface Features, Incident Energy, Reflectance, Absorbance, Transmittance.
2.3 Interaction with Vegetation, Soil and Water.
3. Data Acquisition and Interpretation)
3.1 Platforms: Airborne, Space borne,
3.2 Remote Sensing Satellite Terminology Geo-stationery, Sun-synchronous
3.3 Orbits Sensors, Resolutions: Spatial, Spectral, Temporal,
3.4 Earth Resources Satellites: An overview, Landsat, SPOT, IRS, IKONOS (orbit and Sensor Characteristics).
4 (Geographic Information System)
4.1 What is GIS? Examples of GIS applications, Components of GIS.
4.2 Data acquisition and Entry.
4.3 Data Sources, Data Entry.
4.4 Data and their integration in GIS.
4.5 Entering existing data (maps, tables), data from GPS.
4.6 Coordinate Systems and Geo-referencing.
4.7 Organizing/Mapping of Spatial Data.
5 (Data Models & Structures)
5.1 Database Concepts and Management Data Analysis and Errors.
5.2 Organizing geographic data for analysis, Data Layers, Partitioning the coverage area.
5.3 Maintenance and analysis of non-spatial attribute data.
5.4 Integrated analysis of spatial and attribute data, Output and Formatting.
5.5 Map annotation, text labels, texture patterns and line ,styles, graphic symbols.

6 (Practicals)
6.1 Introduction to Scanning, Toposheet Reading.
6.2 Importing raw satellite digital data.
6.3 Geo-referencing toposheets, Image to Map.
6.4 Image to Image Registration, Mosaicing.
6.5 Changing Projections, Sub setting the area of Interest (AOI).
6.6 Simple Image Processing Operations, Enhancement Techniques.
6.7 ArcGIS: Introduction to ArcGIS (ArcCatalog, ArcMap, ArcToolbox).
6.8 Exploring Maps and Displaying, Vector Layer Creation: Line, polygon, Point.
6.9 Onscreen Digitization, Attribute Tables and Data Entry.
6.10 Projection and Transformation. Map Generation, File Transformations, Map Generation, Labels, Text, Annotation.

Course Delivery methods: On campus regular mode. Classroom lectures will be supplemented with audio-visual materials and group discussions. Laboratory sessions will be conducted immediately following the lecture.

Assessment methods: 20% presentation & 30% practical and its exam; 50% final exam

List of Text Books & References:

- C.P. Lo, Albert K.W.Yeung, Concepts and Techniques of Geographic Information Systems, 2nd Edition, Prentice Hall, 2006, ISBN-13: 9780131495029.
- Kang-tsung Chang, Introduction to Geographic Information Systems with Data Set CD-ROM, 6th Edition, Mc Graw Hill, 2011, ISBN-10: 0077465431, ISBN-13: 978-0077465438.
- John Jensen, Ryan Jensen, Introductory Geographic Information Systems, International Edition, Pearson Publishers, 2012, ISBN-10: 0136147763, ISBN-13: 9780136147763.
- Menno-Jan Kraak, Ferjan Ormeling, Cartography: Visualization of Spatial Data, 2009, 3rd Edition, Pearson Publishers.
- Curran, Paul J; 1985, Principles of Remote Sensing, Longman, London.

Module Name:	Remote Sensing & Geoinformatics		
Module Code:	GEOL M5111		
Course Name:	Remote Sensing and GIS Applications		
Course Code:	Geol 5126		
Credit Hours:	3	**ECTS:**	6

Course Objectives: The objectives of the course is to impart knowledge about the various field applications of remote sensing and GIS includes (Land use/ Land Cover Mapping, Urban plan Mapping, Geomorphic Mapping, Agricultural Crop Inventory and Mapping, Water Resource Applications and Environmental applications).

Learning outcome: On completion of this course, the student shall be able to understand the various application areas of remote sensing and GIS.

Course Contents: GIS and Remote Sensing are rapidly evolving towards becoming standard tools and influencing everyday decision-making particularly among professionals. there are numerous applications of GIS in various disciplines such as Earth Sciences, Land use planning, Disaster Management, Natural resources Management, Agriculture, Forestry, Wild life, Transportation and supply network, Transmission and Telecommunication network will be included. The course is designed for the students to use computers throughout the course, enabling them to use the latest software available in the fields of GIS and Remote Sensing.

Course Outline:

Chapter-1 (Land use/ Land Cover Mapping)
1.1 Land use/Land cover classification system; Multi – level classification.
1.2 Land use/land cover mapping using vertical aerial photographs and satellite imageries.
Chapter-2 Urban plan Mapping
2.1 Urban land use classification system; Urban land use mapping and change detection.
2.2 Interpretation of residential land use and the measurement of net residential areas.
2.3 Urban population estimation.
Chapter-3 Geomorphic Mapping
3.1 Physiographic analysis; Photo/image sample study for understanding basic elements of interpretation in terrain evaluation.
3.2 Remote sensing data in identification, delineation and mapping of various landforms and their significance.
3.3 Identification and delineation of different rock types and geologic structures.
Chapter-4 Agricultural Crop Inventory and Mapping
4.1 Spectral characteristics of crops using Spectro radiometer.
4.2 Land use/land cover mapping using visual interpretation methods.
4.3 Agricultural land use mapping using digital techniques.
4.4 Crop identification and crop acreage estimation.
4.5 Creation of spatial and non – spatial data for land use change detection and crop inventory analysis.
Chapter-5 Water Resource Applications
5.1 Mapping, monitoring of surface water bodies, tanks, lakes / reservoirs,

5.2Quantification, hydro geomorphic mapping, ground water zoning from unconsolidated, semi consolidated and hard rocks, groundwater quantification.
Chapter-6 Environmental applications
6.1 Mapping and monitoring of Natural hazards, floods, Droughts, Landslides, Volcanoes, Earthquakes,
6.2 Analysis of human-induced hazards, Pollution, Deforestation, Erosion, Siltation, Degradation of water bodies and wetlands.
Chapter-7 (Practicals)
7.1 Analysis of aerial photographs and satellite images for drainage morphometry and water shed demarcation.
7.2 Geomorphic mapping using aerial photographs and satellite images.
7.3 Crop inventory mapping
7.4 Ground and surface water potential mapping.
7.5 Natural and manmade disaster mapping.

Course Delivery methods: On campus regular mode. Classroom lectures will be supplemented with audio-visual materials and group discussions. Laboratory sessions will be conducted immediately following the lecture.

Assessment methods:
20% presentation & 30% practical and its exam.
50% final exam.

List of Text Books & References:

- Drury, S.A. image interpretation in Geology, Chapman and Hall London 1993 6. Michael N.Demers Fundamentals of GIS, John Wiley & sons, inc 1999.
- Remote Sensing and image interpretation by Thomas M.Lilles and Ralph E.Kiefer John Wiley & Sons, inc 2004.
- Remote Sensing for the earth sciences Vol.3 edited by Andrew Rencz American Society of Photogrammetry and Remote Sensing John Wiley & sons inc 2004 10.
- Nancy Hoalst-Pullen, Mark W. Patterson; Geospatial Technologies in Environmental Management (Geo technologies and the Environment), 2010, Springer.