Republic of the Philippines
OFFICE OF THE PRESIDENT
COMMISSION ON HIGHER EDUCATION

CHED MEMORANDUM ORDER (CMO)
No. 35
Series 2008

SUBJECT: POLICIES AND STANDARDS FOR BACHELOR OF SCIENCE IN GEOLOGY (BS GEOLOGY) PROGRAM

In accordance with the pertinent provisions of Republic Act (RA) No. 7722, otherwise known as the "Higher Education Act of 1994," by virtue of Resolution No. 275-2008 of the Commission en banc dated 02 June 2008 and for the purpose of rationalizing the undergraduate geology education in the country with the end view of keeping apace with the advances in science and the demands of globalization, the following Policies and Standards are hereby adopted and promulgated by the Commission.

ARTICLE I
INTRODUCTION

Section 1 Background and Rationale

Geology or "geolohiya (in Filipino)" is the science of the Earth, its processes, history, shapes and substances. It is a "unifying science" because it makes other sciences work towards understanding a single denominator - the Earth.

Geology seeks to answer questions about the Earth such as its origins, formation and changes. It also addresses problems on fuel and energy, pollution and waste disposal, conservation and use of natural resources, among others. The answers that geology intends to find help towards improving the quality of life and mitigate the effects of natural disasters particularly earthquakes, volcanic eruptions, landslides and floods – natural and man induced.

To address the diverse questions in its realm, geology consists of basic components such as mineralogy, petrology, stratigraphy and historical geology, paleontology, geochemistry, geophysics, field geology, and structural geology and tectonics among others. Examples of specialized fields of geology include volcanology, seismology, environmental geology, engineering geology, among others.

The interest in the geology discipline in the Philippines started as early as the 1920s; service courses in geology were already being offered in the University of the Philippines. The subsequent interest in the Philippine mining industry in the 1950s resulted in the offering of higher education programs in geology. The importance of geology to the country was recognized with the passage of the Geology Profession Law of the Philippines (RA 4209) in 1965.

The recent effort of the Commission on Higher Education (CHED) to revive the geology discipline and the renewed interest in mining may usher in interest in the field of geology as it did in the 1960s. This *Policies and Standards* serves as a follow up response by the CHED. This document provides the minimum academic requirements to offer a BS Geology program. It endeavors to standardize the quality of the program particularly in terms of faculty qualifications, equipment and library resources.

ARTICLE II
AUTHORITY TO OPERATE

Section 2 Authority to Operate

The BS Geology program shall be operated only by Higher Education Institutions (HEIs) with proper authority granted by the CHED or by the respective Boards in case of chartered State Universities and Colleges (SUCs), and Local Colleges and Universities (LCUs).

ARTICLE III
PROGRAM SPECIFICATIONS

Section 3 Degree Name

The degree program herein shall be called Bachelor of Science in Geology (BS Geology).

Section 4 Program Description

I. Nature of the Program

The Bachelor of Science in Geology program is designed to prepare students for careers as professional geologists or for admission to graduate school. The program is structured to provide an optimal curriculum that affords graduates with firm foundations on the concepts and theories in the geological sciences.

II. Objectives of the Program

A. General

The Bachelor of Science in Geology program shall:

a. Provide the students with the theoretical and practical background in the natural sciences and mathematics as a general preparation for their professional careers in geology.

b. Help the students, as future geoscientists, develop, not only their intellectual maturity, but equally important, their roles and responsibilities to society and to the local and international scientific community.

B. Specific

The Bachelor of Science in Geology program shall:

a. Prepare the students through the sufficient provision of pure and applied geoscientific backgrounds, both in theory and actual practice, specific to the needs of their perspective careers as academicians, researchers, or geoscientists in the local and international private and government institutions. This objective shall be attained through well-designed theoretical, laboratory, and field exercises.

b. Provide the students venues to develop their societal responsibilities in the form of short (several days) and long-term (several weeks) fieldworks and fieldtrips, membership in student and professional organizations, and/or involvement in applied geoscientific research activities or projects.

III. Specific professions/careers/occupations or trades that BS Geology graduates may go into.

Geology has varied career opportunities as determined by the diversity of its specialized fields. There are career opportunities in industry (e.g. energy, water and mineral resource exploration and development, and construction), environment, academe and government.

Aside from the careers that may be considered out of its specializations, BS Geology graduates also have the option of going into other fields such as education and teaching, science writing, and environmental law.

Government agencies and private consultancy firms for the mining and petroleum industries provide most of the local work and employment opportunities.

Section 5 Allied Programs

The Geology Program is allied to some professional fields that are duly recognized by the Professional Regulation Commission (PRC), of which specialists from these fields can teach some selected major and elective geology courses in the program.

a. Mining Engineering (Principles of Geology, Mineralogy, Petrology, Structural Geology and Tectonics, Metalliferous Ore Deposits, Mining Geology, Geology, Mining and Environmental Laws, Energy Policies and Ethics)
b. Metallurgical Engineering (Principles of Geology, Mineralogy)
c. Geodetic Engineering (Photogeology and Remote Sensing)
d. Civil Engineering (Geotechnical Engineering / Engineering Geology)

ARTICLE IV
COMPETENCY STANDARDS

Section 6 Competency Standards

The competencies of a graduate of a BS Geology program are:

a. Ability to observe and record important geological features, as well as the small, subtle and seemingly unimportant details.
b. Ability to visualize and draw geologic structures in multi dimensions.
c. Ability to analyze and interpret observations and solve related problems.
d. Ability to employ the Scientific Method.
e. Ability to write and communicate geological ideas to other scientists and the public.
f. Ability to quantify and analyze data and results.
g. Commitment to adhere to the Code of Ethics for geologists.

ARTICLE V
CURRICULUM

Section 7 Curriculum Description

The BS Geology Curriculum shall be made up of a minimum number of 66 credit units of Geology courses divided into two categories, Required Geology courses (45 units) and Electives (21 units). In addition, at least 4 credit units of required non-geology and non-G.E. courses are integrated into the curriculum to provide the student the basic cartographic and geodetic skills. Optional to the curriculum would be a 3 (credit) unit undergraduate thesis or research work.

The total required minimum credit units for the degree Bachelor of Science in Geology shall be 139.

Courses that are offered by Visiting Professors or Scientists and by local Resource Persons invited as short-time (2-3 weeks) Lecturers may be offered as crash courses, can be taken by undergraduate students as elective courses, *provided* this is done in consultation with the adviser and the student has satisfied the required prerequisites of the course.

The Geology courses listed as Electives are considered specialized courses that could provide the student an array of possible fields of interest. These courses will guide the student on possible areas to specialize on as he or she enters the industry as professionals or pursue graduate studies.

Section 8 Curriculum Outline

SECTION		UNITS
General Education Courses		51
Science and Mathematics Courses		18
Geology Courses		66
Required	45	
Electives	21	
Other Required Non-geology Courses		4
Thesis (optional)		(3)
Total		**139 (142)**

Section 9 General Education (GE) Courses

The general education and legislated courses will follow the CHED Memorandum No. 04 series of 1997 (GEC-B; 51 units)

FIELDS OF STUDY	SPECIFIC COURSES	UNITS	
1. Language and Humanities	English	*6*	21
	Filipino	*6*	
	Humanities Subjects (e.g. Literature, Art, Philosophy) –	*9*	
2. Mathematics, Natural Sciences and Information Technology	Elective (e.g. Info. Technology, STS) –	*3*	15
	Mathematics –	*6*	
	Natural Sciences (courses should cover General Chemistry or Fundamentals in Biology) –	*6*	
3. Social Sciences	Consist of subjects such as Political Science, Psychology, Anthropology, Economics, History and the like, provided that the following topics are taken up in appropriate subjects: Taxation and Land Reform, Philippine Constitution, Family Planning and Population Education.	*12*	15
	Life and Works of Rizal (Mandated Subject)	*3*	
TOTAL			51

Section 10 Other Science and Mathematics Courses (18 Units)

The following courses must be covered in a BS Geology program.

I. Mathematics (Required minimum number of credit units: 6)

a. Analytical Geometry
b. Differential Calculus
c. Integral Calculus

II. Natural Sciences (Required minimum number of credit units: 12)

A. Physics

a. Mechanics and Dynamics
b. Electricity, Magnetism and Optics
c. Quantum Mechanics and Thermodynamics

B. Chemistry

a. Qualitative / Quantitative Inorganic Chemistry
b. Analytical Chemistry

C. Biology

This course could be covered as a Natural Science course (e.g. Fundamentals of Biology).

Section 11 Required Geology Courses (45 Units)

The following courses are prescribed in the BS Geology program. The courses are at least 3 units each. The topics covered in the required geology courses may be combined with topics in the elective geology courses depending on the strengths of the institution or the specializations that institution may choose.

a. Computer Applications in Geology
b. Field Geology
c. Geochemistry
d. Geology of the Philippines and Southeast Asia
e. Geology, Mining and Environmental Laws, Energy Policies and Ethics
f. Geomorphology
g. Geophysics
h. Mineralogy
i. Paleontology
j. Petrology
k. Principles of Geology
l. Resource Geology
m. Seminar in Geology
n. Stratigraphy and Historical Geology
o. Structural Geology and Tectonics

Section 12 Electives (21 Units)

The following courses are suggested as electives for the BS Geology program. No more than two courses (6 units) must be taken from the non-geology list. The choice of geology electives should be made in consultation with the adviser. The topics covered in certain elective courses may be combined with the topics in major courses depending on the strengths of the institution or the specializations that institution may choose.

I. Geology Electives

a. Applied Geochemistry
b. Applied Geophysics
c. Environmental Geology
d. Geodynamics and Tectonics
e. Geohazards
f. Geostatistics
g. Geotechnical Engineering/Engineering Geology
h. Geothermal Resources
i. Geothermy
j. Hydrogeology
k. Igneous and Metamorphic Petrology
l. Marine Geology
m. Metalliferous Ore Deposits
n. Micropaleontology
o. Mineral Economics
p. Mineral Resources of the Philippines
q. Mining Geology
r. Non-metalliferous ore Deposits

s. Optical Mineralogy
t. Ore Microscopy
u. Petrography
v. Petroleum Geology
w. Photogeology and Remote Sensing
x. Quaternary Geology
y. Sedimentary Petrology
z. Sedimentology
aa. Seismology
bb. Urban Geology
cc. Volcanology

II. Non-Geology Electives

a. Fluid Mechanics
b. Materials Science
c. Economics
d. Business Management
e. Statistics
f. Marine Science
g. Organic Chemistry
h. Physical Chemistry

Section 13 Required Non-Geology Courses (4 units)

The following courses are prescribed in the BS Geology Program. The courses are at least 2 units each. The topics covered are integral to the program as tools in performing geological work.

a. Engineering Drawing
b. Surveying Methods

Section 14 Optional Courses (3 units)

The optional courses may be offered as alternative to Field Geology. These courses may be offered independently or in combination. HEIs shall have the prerogative to choose a mode of implementing this component based on the available resources within the institution and opportunities for collaboration with suitable outside organizations. These courses should have a minimum of 3 units.

I. Apprenticeship, Internship, or On-the-Job Training (OJT)

The purpose of the apprenticeship, internship or OJT is exposure to geology related work. OJT is encouraged for industry and government. This course could be in lieu of the Field Geology course. The scope of the OJT should include tasks related to researches and fieldworks which should cover applications of concepts learned in at least four (4) of the required Geology courses. Students should be required to submit reports related to this course/activity. Examples of the courses that should be considered are Structural Geology and Tectonics, Petrology, Geophysics, Geochemistry and Resource Geology.

II. Undergraduate Thesis/Research

Like all science courses, Geology could provide students a choice in pursuing research as a field of interest. Thesis work can guide the student on the rigors of research from proposal making to data gathering and interpretation. The results of thesis work would be publishable papers. Geology however, aims to produce professionals capable of doing fieldwork thus the emphasis on Field Geology. It is in this context that requiring Thesis work would just be an option to institutions providing the Geology program.

Section 15 A Sample Program of Study: *(152 Units)*

Year	1st Semester				2nd Semester			
	Descriptive Title	Units			Descriptive Title	Units		
		Lec	Lab	Total		Lec	Lab	Total
I	GE Nat Sci I	3		3	Principles of Geology	3		3
	GE Math I	3		3	GE Nat Sci II	3		3
	GE course 1	3		3	GE Math II	3		3
	GE course 2	3		3	GE course 5	3		3
	GE course 3	3		3	GE course 6	3		3
	GE course 4	3		3	GE course 7	3		3
	PE 1		(2)	(2)	PE 2		(2)	(2)
	NSTP 1		(3)	(3)	NSTP 2		(3)	(3)
	Total	18		**18**	**Total**	18		**18**
II	Mineralogy	3	2	5	Petrology	3	2	5
	Differential Calculus	3		3	Engineering Drawing	2		2
	Inorganic Chemistry	3	2	5	Integral Calculus	3		3
	GE course 8	3		3	Mechanics & Dynamics	3	1	4
	GE course 9	3		3	GE course 10	3		3
	PE 3		(2)	(2)	PE 4		(2)	(2)
	NSTP 3		(3)	(3)	NSTP 4		(3)	(3)
	Total	15	4	**19**	**Total**	14	3	**17**
III	Stratigraphy & Historical Geology	3	1	4	Geophysics	3		3
	Computer Applications in Geology	3		3	Structural Geology & Tectonics	3		3
	Geochemistry	3		3	Geomorphology	3		3
	Plane Surveying	2		2	Paleontology	3		3
	Electricity & Magnetism	3	1	4	Elective I	3		3
	GE course 11	3		3	GE course 12	3		3
	Total	17	2	**19**	**Total**	18		**18**
Summer	Field Geology		6	6				
	Total		6	**6**				
IV	Resource Geology	3	2	5	Geology of the Phils & SE Asia	3		3
	Elective II	3		3	Seminar in Geology	2		2
	Elective III	3		3	Geology, Mining & Environmental Laws, Energy Policies & Ethics	3		3
	Elective IV	3		3	Elective V	3		3
	GE course 13	3		3	Elective VI	3		3
					Elective VII	3		3
					Thesis (optional)	(3)		(3)
	Total	15	2	**17**	Total	17		**17**
	Grand Total	132	17	**149** ***(152)***				

ARTICLE VI
COURSE SPECIFICATIONS

Section 16 COURSE SPECIFICATIONS OF REQUIRED GEOLOGY COURSES, ELECTIVE GEOLOGY COURSES, NON-GEOLOGY ELECTIVE COURSES, REQUIRED NON-GEOLOGY COURSES AND OPTIONAL COURSES.

The course specifications for the BS Geology program are contained in **ANNEX I** of this Memorandum

Section 17 SUGGESTED TEXTBOOKS AND REFERENCES

The suggested textbooks and references for the BS Geology program are contained in **ANNEX II** of this Memorandum.

ARTICLE VII
OTHER PROGRAM REQUIREMENTS

Section 18 Program Administration

The minimum qualifications of the head of the unit that implements the degree program are the following:

a. Dean of the college or its equivalent. The dean of a college must be at least a master's degree holder in any of the disciplines for which the unit/college offers a program; and a holder of a valid certificate of registration and professional license, where applicable.

b. Chair of the unit/department or its equivalent. The chair of the department must be master's degree holder in geology for which the unit/department offers a program or a master's degree holder in an allied program identified in Section 6 of this policies and standards; and a holder of a valid certificate of registration and professional license, where applicable.

Section 19 Faculty

I. Qualifications

a. As a rule, a master's degree in the discipline or its equivalent is required for teaching in the tertiary level.

b. A minimum of 50% of the geology courses in the curriculum must be handled by faculty with at least a Master's degree in the geology discipline or in any of the allied programs listed in Section 6.

c. All courses for the geology licensure examination shall be taught by persons who are holders of valid certificates of registration and valid professional license in geology or in any of the allied programs.

II. Full time faculty members

The institution shall maintain 50% of the faculty members teaching in the BS Geology program as full time in a given term.

III. Faculty Development

The institution must have a system of staff development. It shall encourage the faculty to:

a. Pursue graduate studies
b. Attend seminars, symposia and conferences for continuing education
c. Undertake research activities and to publish their research output
d. Give lectures and present papers in national/international conferences, symposia and seminars.

The institution must provide opportunities and incentives such as:

a. Tuition subsidy for graduate studies
b. Study leave with pay
c. Deloading to finish a thesis or carry out research activities
d. Travel grants for academic development activities such as special skills training and attendance in national/ international conferences, symposia and seminars.
e. Awards & recognition

Section 20 Instructional Quality

It is recommended that 50% of the total courses offered in a given term shall be handled by faculty with advanced degrees.

Section 21 Library

a. Policy

Libraries service the instructional and research needs of the staff and students making it one of the most important service units within an HEI. It is for this reason that libraries should be given special attention by HEI administrators by maintaining it with a wide and up-to-date collection, qualified staff, and communications and connectivity portals.

b. Library Staff

The Head Librarian should: 1) have an appropriate professional training; 2) be a registered librarian; and 3) have a Master's degree. The library should be: 1) staff with one full time professional librarian for every 1,000 students and 2) a ratio of 1 librarian to 2 staff / clerks should be observed.

c. Library Holdings

Library holdings should conform to existing requirements for libraries. For the BS Geology program, the libraries must provide 5 non-duplicating book titles per professional course found in the curriculum at a ratio of 1 volume per 15 students enrolled in the program. The latest editions of the books in the suggested list of references (Annex II) under each of the course descriptions should be made available.

The HEI is likewise encouraged to maintain periodicals and other non-print materials relevant to geology to aid the faculty and students in their academic

work. CD-ROMs could complement a library's book collection but should otherwise not be considered as replacement for the same.

d. Internet Access

Internet access is encouraged but should not be made a substitute for book holdings.

e. Space Requirements

At least 126 m^2 or approximately 2 classrooms shall be required for the library. It should include space for collections, shelving areas, stockroom, office space for staff and reading area.

The library must be able to accommodate 5% of the total enrollment at any one time.

f. Finance.

All library fees should be used exclusively for library operations and development for collections, furniture and fixtures, equipment and facilities, maintenance and staff development.

g. Networking

Libraries shall participate in inter-institutional activities and cooperative programs whereby resource sharing is encouraged.

h. Accessibility

The library shall be readily accessible to all.

i. Office Hours

The library shall be open to serve the needs of the users.

Section 22 Facilities and Equipment

I. Laboratory requirements

Laboratories should conform to existing requirements as specified by law (RA 6541, "The National Building Code of the Philippines" and Presidential Decree 856, "Code of Sanitation of the Philippines"). List of required and recommended equipment are listed in the course specifications above.

II. Classroom requirements (Class Size)

a. For lecture classes, ideal size is 35 students per class, maximum is 50.
b. For laboratory and research classes, class size shall be specific to the discipline to be stated in the policies and standards.
c. Special lectures with class size more than 50 may be allowed as long as the attendant facilities are provided.

III. Educational Technology /Audio Visual Centers

The institution shall provide facilities to allow preparation, presentation and viewing of audio-visual materials to support instruction.

Section 23 Research and Development

Universities and Colleges offering a BS Geology program shall promote and undertake researches in Geology in order:

a. To contribute to the acquisition of baseline and advanced knowledge on local and regional Geology,
b. To aid in the solutions of local and national geoscientific problems, and
c. To provide proper hands-on exposures to students in the conduct of researches by giving them sufficient participation, especially in simple research activities. The conduct of researches in Geology should uphold internationally accepted standards, and the data therefrom should ultimately be published in local or international geoscientific journals.

Universities and Colleges offering a BS Geology program shall be encouraged to also initiate institutional twinnings or cooperative links with other academic and non-academic institutions undertaking researches in Geology in order to enhance their research capabilities and the mutual exchange of ideas among Geologists and Geology-related researchers.

Section 24 Extension Services

Universities and Colleges offering a Bachelor of Science in Geology program should be encouraged to provide extension services in any form, especially in:

a. The introduction of Geology as a science basic to the understanding of the Philippine geologic environment and the attendant natural consequences to relevant groups, such as communities situated in geologically active areas,
b. The upgrading of knowledge in Geology of elementary, high school, and tertiary science teachers,
c. The solution of local and national geoscientific problems.

Section 25 Admission and Retention

The basic requirement for eligibility for admission of a student to any tertiary level degree program shall be graduation from the secondary level recognized by the Department of Education. Higher education institutions must specify admission, retention and residency requirements. They should ensure that all students are aware of these policies.

ARTICLE VIII
TRANSITORY, REPEALING AND EFFECTIVITY PROVISIONS

Section 26 Transitory Provision

HEIs that have been granted permit or recognition for Bachelor of Science in Geology program are required to fully comply with all the requirements in this CMO, within a non-extendable period of three (3) years after the date of its effectivity. State Universities and Colleges (SUCs) and Local Colleges and Universities (LCUs) shall also comply with the requirements herein set forth.

Section 27 Repealing Clause

All CHED issuances, rules and regulations or parts thereof, which are inconsistent with the provisions of this CMO are hereby repealed.

Section 28 Effectivity Clause

This CMO shall take effect fifteen (15) days after its publication in the Official Gazette, or in two (2) newspaper of national circulation. This CMO shall be implemented beginning Academic Year 2008-2009.

Pasig City, Philippines July 18, 2008

FOR THE COMMISSION

ROMULO L. NERI
Chairman

ANNEX I

COURSE SPECIFICATIONS

Higher education institutions have the option to offer the following courses as purely lecture or as a combination of lecture and laboratory, unless otherwise specified in the course. The number of hours indicated is the average contact hours per week based on a 3-unit lecture class; this will vary when the HEI implements the alternative option of a lecture and laboratory combination.

I. COURSE SPECIFICATIONS OF REQUIRED GEOLOGY COURSES

1. COMPUTER APPLICATIONS IN GEOLOGY

COURSE DESCRIPTION

The course reviews the application of computer methods to the various fields of Geology. The course introduces the use of computers in data management, analysis, and presentation application in the geosciences. It covers a wide range of topics, such that, it also serves as a platform to introduce basic computations and programming in geology, geostatistics, and image processing. All topics are presented through problem solving exercises. The course incorporates the survey of computer-based techniques in the storage, retrieval, analysis, and representation of spatially distributed data. Emphasis is on application of GIS technology to problems such as geologic hazard mapping, surface runoff and erosion, contaminant transport, population density, and environmental impact assessment.

COURSE / LEARNING OBJECTIVES

The course aims to teach students how computers may be used to aid in geologic interpretations and introduce to them geostatistics, GIS and remote sensing.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITES

a. 3rd year standing

COURSE CONTENT/ OUTLINE

a. Overview of computer systems and component
   - Overview
     - Spreadsheet data format
     - Use of built-in equations
     - Data presentation using graphs

- Basic Programming
  - Visual Basic in Excel
  - MATLAB

b. Computations and Programming using spreadsheets (MS Excel, MATLAB)
- Probability and Testing
  - Populations
  - T-test
  - Variance, Standard deviation
- Correlation
  - Interpretation
  - Regression
- Geostatistical Models

c. Geostatistics (Statistica, MATLAB)
- Computer-aided design (AutoCAD)
- Image processing (ENVI, ERMapper,GlobalMapper, etc)
- Geographic Information Systems (Arcview, ArcGIS)

d. Introduction to GIS and Remote Sensing

EQUIPMENT AND FACILITIES

a. Computers
b. LCD projectors
c. Internet access
d. Computational software with geological applications

2. FIELD GEOLOGY

COURSE DESCRIPTION

Field Geology involves the use of the basic principles of stratigraphy, structural geology and geological history on observations and data collected from the field. The final product is a geologic map and a report. The course is offered only during the summer term.

COURSE / LEARNING OBJECTIVES

The students should be able to acquire the basic skills necessary for conducting a field mapping project. The students will concentrate on specific skills such as the use of the Brunton compass, reading topographic maps and geologic maps, constructing topographic profiles and geologic cross-sections and writing geologic history based on map and field observations. Included are the production of related figures such as location maps and stratigraphic column. The course trains the students the various geological field methods and instrumentations. The students should be able to describe, compile and interpret maps of rock formations and structures from outcrops, subsurface and remotely-sensed data. It is expected of the students to be able to a) study in the field a wide variety of rocks, structures, and field relations among geologic structures, b) comprehend the analysis of samples, interpretation of geological data and

where possible, geophysical and geochemical data, and c) write a formal geologic report.

CREDITS: 3 units

NUMBER OF HOURS: 27 hours per week

PREREQUISITES

a. Principles of Geology
b. Petrology
c. Structural Geology & Tectonics
d. Geomorphology
e. Stratigraphy and Historical Geology

COURSE CONTENT/ OUTLINE

a. Identification of field / study area
b. Identification of problem and purpose
c. Review of climate, vegetation, topography and geomorphology
d. Review of field and laboratory methodologies
e. Regional geologic and tectonic setting of study area
f. Geology of the study area

EQUIPMENT AND FACILITIES

a. Computers
b. LCD projectors
c. Internet access
d. Field equipments
e. Brunton compass
f. Sample picks
g. Field notebooks

3. GEOCHEMISTRY

COURSE DESCRIPTION

The course introduces the students to the fundamentals of chemistry applied to different geological processes. Included are topics on the origin, distribution and geochemical behavior of elements, the chemical evolution of the earth, geochemistry of natural waters, isotope geochemistry, crystal chemistry, trace element geochemistry and organic geochemistry. Also included are studies on chemical thermodynamics, phase rule chemistry, equilibrium reactions and reaction kinetics as applied to geology.

In further detail, the course puts emphasis on the study of elements, their classification and distribution in different rocks and their cosmic abundances. Chemical weathering and alteration, colloids and solutions, Eh-pH in natural environments are also presented. The geochemistry of the hydrosphere, atmosphere and biosphere are given emphasis.

Radioactive decay, nuclear devices and techniques, geochemistry and distribution of U and Th in rocks, minerals and sediments and isotopic geochronometers are additional topics worth discussing.

COURSE / LEARNING OBJECTIVES

The course objective is to expose students to the various chemical techniques and methods in solving geological problems as well as interpreting geological situations. These techniques incorporate qualitative and quantitative studies of geologically important elements and their distribution in solar system as well as in the earth's crustal environments. The course will provide the student a better understanding of the importance of thermodynamics and kinetics in geological processes. Further enhanced will be their understanding of chemical bonding, solution equilibria, chemical weathering, pH-Eh diagrams and their relevance to base metal deposits.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITES

a. Principles of Geology
b. Mineralogy
c. Petrology
d. Chemistry

COURSE CONTENT/ OUTLINE

a. The earth as a chemical system
b. Chemical behavior of the elements
c. Acids, Bases and Salts
d. Thermodynamics and Kinetics
e. Oxidation –reduction reaction
f. Radioactive and Stable isotopes
g. Chemical weathering
h. Geothermometry and Geobarometry
i. Global geothemical cycles

EQUIPMENT AND FACILITIES

a. Computers
b. LCD projectors
c. Internet access
d. Laboratory equipment (AAS, XRD, XRF)
e. Exposure trips
f. Field and sampling equipment

4. GEOLOGY OF THE PHILIPPINES AND SOUTHEAST ASIA

COURSE DESCRIPTION

This course introduces the students to the geology and tectonics of the Philippines and the Southeast Asia. General discussions on the regions' stratigraphy, structures and tectonic setting in relation to geodynamic processes are incorporated. Included are presentations of models of the geodynamic evolution of the region and updates on developments from recent research.

COURSE / LEARNING OBJECTIVES

This course is intended to provide the student a better understanding and appreciation of the geology of the Philippines and Southeast Asia with the reconstruction of the geodynamic evolution of the region.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITES

a. 4th year standing

COURSE CONTENT/ OUTLINE

a. Review of Tectonic principles
b. Regional Geodynamic Setting
c. Geology of the Philippines
   - General Geology
   - Stratigraphy (per Tectono-stratigraphicTerrane approach)
     - Basements Rocks
     - Ophiolites
     - Metamorphic Belts
     - Igneous Belts
     - Volcanic Belts
   - Tectonic Structures
     - Trenches
     - Faults
     - Fold Belts / Collision Zones
   - Sedimentary Basins
d. Geology of other Southeast Asian Countries / Regions
   - General Geology
   - Tectonic Structures
e. Geodynamic Evolution of Southeast Asia
   - Regional Tectonic History
   - Palinspathic Reconstructions

EQUIPMENT AND FACILITIES

a. Computers
b. LCD projectors

c. Internet access
d. Structural models

5. GEOLOGY, MINING AND ENVIRONMENTAL LAWS, ENERGY POLICIES AND ETHICS

COURSE DESCRIPTION

The student is introduced through this course the legal and ethical issues affecting the conduct of mineral exploration and mining specifically contracts and obligations. The underlying policies, consequent legal regimes, regulatory practices and current practical issues concerning the practice of the geological profession are studied. Emphasis is given on the discovery, development and utilization of earth resources. Particular attention is given to the implications of contemporary environmental issues, indigenous people's rights, and social acceptability in natural resources development. The course also introduces the student to various issues pertaining to the use of earth materials and the environment with a focus on pollution and prevention. The legal processes are considered and recognized in shaping environmental policies. The course also introduces the student to the concepts, principles and constraints relevant to the formulation, implementation, monitoring, and evaluation of energy and mineral development policies. The course is designed to make it relevant to those working in the mining, natural resources, energy and international business and financial transaction industries.

COURSE / LEARNING OBJECTIVES

On completion of this subject, the student should be aware of the political, economic, and social policy considerations that shape legal regimes and regulatory practice in the practice of the geology profession. The course would provide the students an opportunity for applying environmental law concepts and principles through a service project. The course will also develop student's analytical skills and a solid doctrinal footing in environmental law. It will also give students the opportunity to discuss environmental law topics and gain experience in forming legal arguments. The students are also given the chance to examine different statutory models that define environmental standards and examine different strategies to apply environmental standards. The course is in collaboration with major companies in the resource industry and it is expected that students be equipped with skills needed to respond to the pressures affecting the industry sector. The students should be able to develop knowledge of the legal and policy framework of the industry as well upgrading their skills.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITES

a. 4th year standing

COURSE CONTENT/ OUTLINE

The course will be delivered using a combination of lectures, class presentations and reporting, and possible resource speakers:

a. The principal topics to be covered under Mining Laws and Ethics:
   - Policy considerations – sustainable development in resource extractive industries, foreign ownership of natural resources, state ownership of natural resources and indigenous people's rights, renewable energy.
   - Discussion of relevant Philippine laws on minerals and petroleum, coal, geothermal energy exploration and development
   - Petroleum service contracts and mining agreements
   - The planning and implementation of environmental systems
   - Financing of energy and mineral projects: nature of project financing; risks allocation and assessment; contractual arrangements
   - Case study on human rights and other social concerns in relation to resource development projects
   - Securities and Exchange Commission and Philippine Stock Exchange reportorial requirements: Role of geologists engaged by publicly listed companies in the disclosure of resources and reserves calculations
   - Discussion of the "Geology Profession Law of the Philippines" and professional ethics of resource-based professionals

b. The principal topics to be covered under Environmental Laws:
   - Role of Risk Assessment in Federal Environmental Law
   - Common Law
   - Administrative Law
   - Enforcement Issues
   - National Environmental Policy Act
   - Constitutional Issues; abstract of service proposal due
   - Water Allocation
   - Clean Water Act
   - Non-point Source Water Pollution Control
   - Wetlands Protection
   - Local Environmental Control
   - Clean Air Act
   - Management of Solid and Hazardous Wastes
   - Endangered Species Act
   - Habitat Conservation Plans
   - The Choice of Regulatory Tools

c. The principal topics to be covered under Energy (and Mineral) Policies:
   - Mineral Law and Policy
   - Mineral and Petroleum Taxation
   - Mineral Resource Policy and Economics

- Investment Decision Making in the Energy and Mining Industries

EQUIPMENT AND FACILITIES

a. Computer
b. LCD projector
c. Internet access

6. GEOMORPHOLOGY

COURSE DESCRIPTION

Geomorphology is the study of landforms and the processes that produce and modify them. It puts emphasis on the dynamics of surface geology specifically on the changes in the landscape. It focuses on the various controls of landform development such as lithology, erosion, deposition and past geological events. The development of landforms takes into consideration interrelationships of earth materials and the natural forces (e.g. gravity, wind, water etc) applied to them. The study of the different geomorphic systems also looks into the influence of tectonics as well as their influence to the atmosphere, hydrosphere and biosphere which affects humans. Geomorphologic approaches to the environment and natural hazards management will also be studied.

COURSE / LEARNING OBJECTIVES

The objective of the course is to provide students the basic foundations in understanding better how landforms evolve through geological time. The course is designed to challenge students on the use of basic science such as physics, chemistry and calculus, in exploring the behavior of the earth's surface systems. The course will expose students to the study of topographic maps, geologic maps, aerial photographs and satellite image where most of the geomorphic features and systems are best presented.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITES / *COREQUISITES*

a. Principles of Geology
b. Mineralogy
c. Petrology
d. Stratigraphy and Historical Geology
e. Structural Geology and Tectonics

COURSE CONTENT/ OUTLINE

a. Introduction to the basic concepts of Geomorphology
b. Physical properties of rocks, soil and water
c. Structural landforms and Geomorphic systems
d. Weathering processes and sediment properties

e. Slopes and Mass wasting
f. Fluvial systems (processes and landforms)
g. Aeolian systems (processes and landforms)
h. Coastal systems (processes and landforms)
i. Glacial systems (processes and landforms)

EQUIPMENT AND FACILITIES

a. Computers
b. LCD projectors
c. Internet access
d. Topographic Maps
e. Geological maps
f. Aerial Photographs
g. Satellite Images
h. Stereoscopes
i. Exposure trips
j. Field equipments

7. GEOPHYSICS

COURSE DESCRIPTION

As an introductory course, the subject covers two aspects: a) description of the physical attributes of the Planet Earth—provides an overview of the Earth's crustal and internal structure, shape and rotation, its elastic, magnetic, gravitational, thermal, and electrical properties, and b) application of physics to geology—discusses theories and applications of physics on the study of the Earth and rocks, including seismology, potential fields (gravity, magnetic, and electrical properties), and heat flow.

COURSE / LEARNING OBJECTIVES

The course introduces the student to the physical properties of the Planet Earth and its materials and to the quantitative methods of observation and inference on the physical properties of the Planet Earth and its materials. The course aims to develop the student's ability to understand and assess certain problems and determine the appropriate quantitative geophysical method to be applied to solve the problem and to provide the students with knowledge on the basic principles of geophysics, geophysical methods, instrumentation and field procedures.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITES / *COREQUISITES*

a. Principles of Geology
b. Mineralogy
c. Petrology

d. Physics
e. Math
f. Stratigraphy and Historical Geology
g. Structural Geology and Tectonics
h. Geomorphology

COURSE CONTENT/ OUTLINE

a. Introduction to geophysics
b. The Earth as a planet
c. The Earth and its internal structure
d. Elastic theory: Stress and Strain
e. Seismic waves and wave propagation
f. Earthquake seismology
g. Exploration seismology
h. Earth's rotation, size and shape
i. Gravitational attraction and Earth's gravity field
j. Gravity measurements and gravity anomalies
k. Interpretation of gravity anomalies
l. Magnetic field theory and Earth's magnetism
m. Rock magnetism and paleomagnetism
n. Magnetic surveying
o. Interpretation of magnetic anomalies
p. Thermal structure of the Earth and heat flow
q. Earth's electrical features and electrical surveys
r. Contributions of geophysics to the plate tectonics theory

EQUIPMENT AND FACILITIES

a. Computers
b. LCD projectors
c. Internet access
d. Calculators
e. Drawing instruments
f. Protractor
g. Stereo net
h. Maps
i. Globe with latitude and longitude markings
j. Computers with data analysis and geophysical data interpretation programs
k. Table-mounted magnetic coils (varied lengths/diameters) and magnetic measurement wand
l. Field Magnetometer
m. Field Gravity meter
n. Seismographs for earthquake observation
o. Reflection/refraction seismic survey instrument
p. Field Resistivity meter
q. Exposure trips

8. MINERALOGY

COURSE DESCRIPTION

The course introduces a systematic approach in identifying and understanding the different rock and ore forming silicates as well as non-silicate minerals. It is also an introduction to mineral crystallography (symmetry, face indices, zones, forms, irregularities), to the physical and chemical properties, occurrences and uses of minerals. Emphasis is given to the study of the crystal structures, chemistry and diagnostic properties of the different minerals for megascopic identification and description. An introduction to X-ray crystallography is provided.

Also introduced in the course are studies on the optical properties of minerals. This is one of the systematic approaches in the identification and understanding of minerals (silicates) that make up different rocks, ores and non-silicates. The skills developed in the use of the microscope would be essential. Studies on light properties, polarization, pleochroism and extinction angles among others are included in the course.

COURSE / LEARNING OBJECTIVES

The main objective of the course is to provide the student the basic understanding of what minerals are and the information they have to offer. The student is also provided knowledge on the various resources that can be used to obtain information on minerals, as well as experiences and skills in gathering and interpreting the information. At the end, the student should be able to identify common minerals, understand the relationships between crystal structures, and determine the chemical composition and physical properties of minerals. The student should be able to appreciate the role of minerals and their socio-economic values.

The student should also be familiar to the various equipments and techniques used in the identification of minerals. The course provides the student a basic tool (to use) in the study (identification and analysis) of minerals which is the petrographic microscope. The student would eventually get familiar with the various skills and techniques in the use of the microscope and in the identification of minerals.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITE

a. Principles of Geology

COURSE CONTENT/ OUTLINE

a. Crystallography / crystal symmetry
b. Physical properties of minerals
c. Mineral composition / crystal chemistry
d. Mineral identification and classification
e. Phase equilibrium

f. Environment of formation and association
g. Mineral growth and stability
h. Economics of minerals
i. Optical properties of minerals
j. Basic light behavior
k. Optical principles behind the use of the microscope
l. The petrographic microscope

EQUIPMENT AND FACILITIES

a. Computers
b. LCD Projectors
c. Internet Access
d. Crystal models
e. Mineral specimen
f. Sample preparation laboratory
g. Grain mounts and mineral thin sections
h. Petrographic microscope
i. Chemical analysis
j. X-ray

9. PALEONTOLOGY

COURSE DESCRIPTION

The course deals with the major groups of fossil-forming animals and plants, their classification, nomenclature, morphology, ecology and stratigraphic distribution. It also introduces the mechanism of organic evolution and extinction and how fossils are used to recreate past environments and to determine the history of life on earth. The lecture is supplemented with field and laboratory exercises. In the laboratory, emphasis is given on invertebrate groups with an extensive fossil record.

The course also looks into further detail the structural variations and diversity in fossils, the evolution of life, principles of taxonomic nomenclature and classification, species concepts, biometrics, biostratigraphic principles, palaeoenvironmental reconstruction, paleo-biogeography, and isotopic palaeontology. Brief discussions will be on functional morphology and evolution of major invertebrate groups. Included would be the classification and environmental significance of trace fossils. The collection and preparation techniques of microfossils, morphology and classification of foraminifera and some common benthic and planktonic foraminifera will be included in the course. Preparation techniques and analysis would include the use of the scanning electron microscope for some microfossils.

COURSE / LEARNING OBJECTIVES

At the end of the course, the students are expected to know the characteristics of the major groups of fossil organisms and understand the evolutionary and ecological principles that shaped ancient life. The

students should also have a better understanding of the geological significance of fossils, be able to know the Index Fossils of Philippine Rocks and be able to identify any well-preserved invertebrate fossil to class level without references

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITE / *COREQUISITES*

a. Principles of Geology
b. Mineralogy
c. Petrology
d. Stratigraphy and Historical Geology
e. Structural Geology and Tectonics
f. Geomorphology

COURSE CONTENT/ OUTLINE

a. Fossils: their preservation, uses and significance
b. Taxonomy: classification and nomenclature
   - Ichnology
   - Theory of Evolution
   - Paleobiology
   - Protista/Monera
   - Invertebrates
     - Porifera and allies
     - Coelenterata/Cnidaria
     - Bryozoa
     - Brachiopoda
     - Mollusca
     - Echinodermata
     - Arthropoda
     - Graptolites and Conodonts
   - Vertebrates
     - Fishes
     - Amphibians
     - Reptiles
     - Birds
     - Mammals
     - Man
   - Paleobotany
   - Plants
     - Non-vascular
     - Vascular
   - Index fossils of Philippine Rocks

EQUIPMENT AND FACILITIES

a. Computers

b. LCD projectors
c. Internet access
d. Stereozoom microscopes with accessories (e.g. camera)
e. Fossil specimen models

10. PETROLOGY

COURSE DESCRIPTION

The course looks into the distribution, mineral associations and chemical composition of rocks that compose the crust and upper mantle, and relating them to various tectonic environments. The course also looks into the genesis, classification, textures of constituent minerals, structures and modes of occurrence of igneous, sedimentary and metamorphic rocks. The concepts of chemical equilibria and reactions, the Phase Rule, binary and ternary systems will be the foundation of the course. Suggested additional topics would included the dynamics of crustal and mantle melting as preserved in the chemical composition of minerals of igneous rocks, the long-term record of global climate change as preserved in the minerals of sedimentary rocks, and the time-temperature-depth record preserved in minerals of metamorphosed crustal rocks.

The course also introduces the student in the study of igneous, sedimentary and metamorphic rocks with the use of the petrographic microscope. The appreciation of the student to the basic microscopic methodologies in the analysis of rocks will be one of the expected outputs of the course. Petrogenesis of the different rocks would be well understood in the study and analysis of rocks both in hand specimens and in thin sections.

COURSE / LEARNING OBJECTIVES

The skills gained in the interpretation of the physical and chemical properties of minerals would be aligned to studies of petrogenic or rock forming processes. At the end of the course, the student should be familiar with the use of phase diagrams in explaining how equilibrium or stable mineral assemblages change under different conditions. The students should be able to relate their interpretations generated from petrogenesis to plate tectonics and to the present geological setup of an area.

An expected output of the course would be the ability of the student to identify rocks not only from hand specimen but also form thin sections under the microscope.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITES

a. Mineralogy
b. Principles of Geology

COURSE CONTENT/ OUTLINE

a. Igneous petrology
   - Magmatic processes, tectonic environments and igneous rocks
b. Metamorphic petrology
   - Metamorphism and metamorphic rocks
c. Sedimentary petrology
   - Sedimentation (textures and structures) and sedimentary rocks
d. Phase diagrams and the Phase Rule

EQUIPMENT AND FACILITIES

a. Computers, LCD projectors, internet access
b. Rock (and mineral) specimen
c. Rocks (and minerals) in Thin Sections
d. Petrographic microscope
e. X-ray
f. Chemical analysis
g. Sample preparation laboratory

11. PRINCIPLES OF GEOLOGY

COURSE DESCRIPTION

The course introduces the students to earth phenomena and processes. This would include crustal processes and evolution in terms of global plate tectonics, internal structure and composition of the earth, igneous, sedimentary and metamorphic processes, rock formation processes, structures, seismology and earthquakes, geologic time, landscape evolution, and the formation of natural resources.

COURSE / LEARNING OBJECTIVES

The student should be able to describe and discuss how certain important geologic processes work and the features left by these processes. The student must be able to apply his or her knowledge of these features and processes to solve and analyze certain practical problems. The student must be able to discuss contemporary theories on the evolution of the earth's features such as continents or ocean basins. By the end of the course, the student should have developed skills in understanding how rocks and minerals form and what they tell about processes and geological environments. The student should also have acquired basic skills in geological mapping.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITES: None

COURSE CONTENT/ OUTLINE

a. The Planet Earth
b. Plate Tectonics
c. Minerals
d. Igneous Rocks
e. Volcanism
f. Sedimentary Rocks
g. Sedimentary Environments
h. Historical Geology
i. Metamorphic Rocks
j. Rock Deformation
k. Earthquakes
l. Mass Wasting
m. Mineral resources
n. Groundwater

EQUIPMENT AND FACILITIES

a. Computers
b. LCD projector
c. Internet access
d. Geological maps
e. Satellite images
f. Rock and Mineral specimens
g. Geological models
h. Field equipments
i. Field trips

12. RESOURCE GEOLOGY

COURSE DESCRIPTION

The course introduces the student to the nature and uses of numerous resources of the world. This course covers such topics as formation, distribution, extraction and use of minerals, fossil fuels, nuclear and other energy resources, soil, water and industrial resources.

The course studies in detail the various mineral and energy resources, incorporating (and to understand better) the political and socio-economic consequences of resource discovery, resource depletion and the environmental impact of extraction processes. Most historic periods began with major discoveries and led to various technological advances. Several ended rather abruptly because of resource depletion and/or insufficient technological capabilities and have caused economic disruptions and war.

COURSE / LEARNING OBJECTIVES

The main objective of this course is:

1) to identify the earth resources that are the bases of present and future human survival,
2) to understand how these resources formed in geologic terms, which is the basis for the discovery of new resource deposits, the estimation of reserves and the planning of resource use, and
3) to understand the environmental consequences of the extraction, utilization and disposal of resources.

At the end of the course the student is expected to have developed skills in information assimilation and interpretation, graphic presentation of information (e.g. posters) and professional work such as core logging. Exposure trips are encouraged specifically to selected mining districts and various energy related industries.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITES / *COREQUISITES*

a. 4th year standing
b. Principles of Geology
c. Mineralogy
d. Petrology
e. Stratigraphy and Historical Geology
f. Geomorphology
g. Structural Geology and Tectonics
h. Geology of the Philippines and Southeast Asia
i. Geology, Mining and Environmental Laws, Energy Policies and Ethics

COURSE CONTENT/ OUTLINE

a. Introduction to the Earth
b. Rocks and minerals
c. Plate tectonics
d. Types of ore minerals
   - Magmatic, hydrothermal and epithermal ore deposits
   - Nature and morphology of ore deposits, classification of ore paragenesis, zoning and dating of ore deposits
e. Mining methods and surface consequences
f. Energy resources
g. Fossil fuels
   - Petroleum source rock deposition, maturation and migration
   - Characteristics of petroleum reservoirs
   - Economic deposits developed in sedimentary rocks, including coal
h. Consequences of fossil fuel use: acid rain, global warming
i. Energy alternatives: solar, hydropower, geothermal
j. Nuclear power
k. Water resources
l. Soil resources

m. Resource development and international trade

EQUIPMENT AND FACILITIES

a. Computers
b. LCD projectors
c. Internet access
d. Ore specimens
e. Sample preparation laboratory
f. Analytical laboratories (AAS, XRD)
g. Exposure trips
h. Field equipments

13. SEMINAR IN GEOLOGY

COURSE DESCRIPTION

The course puts emphasis on readings and discussions of current researches on selected geologic topics of interest. The topics could be from current local and international literatures. Emphasis is on deepening students' knowledge of selected subjects and improving oral presentation and argumentation skills.

COURSE / LEARNING OBJECTIVES

Instructors and students would work together in understanding the current state of knowledge in Geology, the existing problems/controversies, and the possible future research directions. The course will largely involve student-led presentation, discussions and debate, some invited guest lectures, and occasional instructor lectures. At the end of the course, students are expected to be: a) knowledgeable about research trends in one specific geological subject and b) skilled in oral presentation and argumentation, including the use of power point (PPT).

CREDITS: 2 units

PREREQUISITE

a. 4th year standing

COURSE CONTENT/ OUTLINE

Dependent on the instructor's/students' preferred topics

EQUIPMENT AND FACILITIES

a. Computers
b. LCD projectors
c. Internet access

14. STRATIGRAPHY AND HISTORICAL GEOLOGY

COURSE DESCRIPTION

The course focuses on the dynamics of sedimentation processes in the classification, organization and correlation of stratified rocks in the Earth's crust. The analyses of geological processes operating in the different sedimentary basins of different plate tectonic settings are included. The analyses of stratified rocks would provide better understanding of their original sedimentary origin and their sequence of emplacement in local and regional rock records.

The course also covers historical events and geological processes that shaped the earth for the past 5 billion years. The interactions between the lithosphere and the biosphere provide records of the past changes in life which more likely would shape the future. The development of life has had a major effect on the surface of the Earth as well as on the composition of the atmosphere and the oceans. Historical geology is also the basis of most mineral exploration projects and geologic hazard assessments.

COURSE / LEARNING OBJECTIVES

The student is expected to a) develop the competence of recognizing the lithology of different stratified rocks, b) understand the geologic processes that led to their formation, c) analyze the impact of sedimentary and tectonic environments in producing their unique and diagnostic features, d) evaluate their overall geographic and temporal significance, f) be familiar with the methods of stratigraphic classification, g) appreciate the international stratigraphic code which governs the rules in the classification of stratigraphic units, h) understand the local, regional and global evolution of the earth through the recognizable span of geologic time, i) appreciate the significance and importance of Stratigraphy in the exploration of the earth's resources associated with stratified rocks (eg. oil, gas, coal, nuclear fuel, non-metallic minerals, ground water, etc.)

Students are also expected to use the different methods of geological investigation in understanding historical events and processes through geological time. In addition the students should be able to trace the history of earth's life, atmosphere, continents, and ocean basins.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITES / COREQUISITES

a. Principles of Geology
b. Mineralogy
c. Petrology
d. Structural Geology and Tectonics
e. Geomorphology

f. Paleontology

COURSE CONTENT/ OUTLINE

a. Introduction to Stratigraphy and Historical Geology
b. Principles of Stratigraphy
c. Stratigraphic data
   - Data Base (Sources of Stratigraphic Data)
   - Sedimentary Rock Description
   - Sedimentary Structures
d. Environments of Deposition
   - Recognition of deposition of environments in terms of lithology, primary and secondary structures, sequence, paleontological components of the rock (Concept of Facies – Lithofacies and biofacies, geographic distribution, etc.) tectonic domains.
   - Ancient vs. Recent sedimentary environments
e. Stratigraphic Sequence (Classification)
   - Local section
   - Breaks in Rock Record (different types of unconformities)
   - Correlation of Lithologic units (Methods/Techniques)
   - Synchronization of Stratigraphic units (Methods/Techniques) in intrabasin, interbasin and regional setting.
   - Sequence Stratigraphy (Methods/Techniques)
     - E-logs
     - Seismic Stratigraphy
     - Magneto Stratigraphy
     - Stable-Isotope Stratigraphy
f. Principles of Historical Geology
   - Early history of Earth
   - Precambrian history of Earth
   - Early life
   - Radiations & mass extinctions
   - Invasion of the land: land plants & vertebrates
   - Supercontinents and their fragmentation
   - Pangaean paleoclimates
   - Dinosaurs and reptiles
   - Mammals and hominids
   - Cenozoic climates
   - The Ice Ages
g. Geochronology (Geologic Time)
   - Relative
   - Absolute
h. Chrono-Stratigraphy
   - Integrated Correlation
     - Local Scale
     - Regional Scale
     - Global Scale
   - Standard Geologic Column
   - Local and International Stratigraphy Code Applications

i. Sedimentary – Tectonic Evolution
   - Philippine Archipelago
   - SEA Asia
   - The Earth in a Global Plate Tectonic Setting

j. Importance of Stratigraphy in the Exploration of the Earth's resources associated with stratified Rocks
   - Energy Resources (oil, gas, coal, nuclear)
   - Non-Metallic Minerals
   - Water Resources

EQUIPMENT AND FACILITIES

a. Computers
b. LCD projectors
c. Internet access
d. Stereozoom microscopes with accessories (e.g. camera)
e. Fossil specimen models
f. Exposure trips
g. Field equipments (Sample pick, Brunton compass, altimeter, measuring tape)
h. Hand lens/binocular microscope for examining samples
i. Topographic and geologic maps

15. STRUCTURAL GEOLOGY AND TECTONICS

COURSE DESCRIPTION

The course introduces the students to concepts necessary in the understanding of structural geological deformation (tectonics, stress, strain) and the characterization of geological field structures (e.g. bedding, folds, joints, faults) observed to affect the different types of rocks. These concepts are used in understanding the tectonic character and history of a given region, with special attention to the Philippines. Detailed discussions on the structural concepts such as the dynamic and kinematic analysis of rocks in two dimensions, understanding stress and strain, and the formation and classification of folds and folds are included.

COURSE / LEARNING OBJECTIVES

The course aims to equip the student with the necessary ability to conduct a structural geological mapping of a specified area. It is expected that students would have a good background on streographic analysis of planes and lines, analysis of folds, analysis of faults, strain measurements, interpretation of geological maps and computer aid analysis of structural data.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITES / *COREQUISITES*

a. Mineralogy
b. Principles of Geology
c. Petrology
d. Stratigraphy and Historical Geology
e. Geomorphology

COURSE CONTENT/ OUTLINE

a. The Dynamic Earth: A Review of the Earth's Internal Structure and Plate Tectonics Mechanics of Deformation.
b. Primary Structures
c. Secondary Structures
d. Tectonic Regimes
e. Philippine Active Tectonics
f. Philippine Inactive Tectonics and Tectonic History
g. Simple Shear Experiment & Strain Estimation
h. Mohr Diagram and Stress Concept
i. Three-Point Problem
j. True and Apparent Dips – Graphical Method, Trigonometric Method
k. Plane Intersections and Plunges – Graphical Method
l. The Stereonet – True and Apparent Dips, Plane Intersections, Stress Analysis from Fault Sets
m. Cross Sections – Busk Method and other techniques (Balancing?)
n. Outcrop patterns – Bed Thickness, Rule of V's
o. Construction of Structural Maps and Cross Sections – Standard Symbols/Legend
p. Structural Geological Field Mapping (area to be specified) – results to be submitted in the form of written report and presented orally in class.

EQUIPMENT AND FACILITIES

a. Computers
b. LCD projectors
c. Internet access
d. Laboratory room
e. Exposure trips
f. Field equipments (e.g. brunton compass, lens, meter-tape, etc)

II. COURSE DESCRIPTIONS OF GEOLOGY ELECTIVES

1. APPLIED GEOCHEMISTRY

COURSE DESCRIPTION

The course incorporates various geochemical techniques and methods in geology, mineral exploration and environment. Geochemical prospecting uses the different principles and methods of geochemistry with the use of pathfinders and trace elements in rocks and soils. The application looks

into the identification of primary and secondary dispersion patterns, geochemical anomalies and their interpretation.

COURSE / LEARNING OBJECTIVES

The lectures will provide the students basic information on the practical applications of geochemistry. They are focused on prospecting and monitoring methods - lithogeochemical prospecting, soil metallometry, hydrogeochemical prospection, stream sediment survey, atmo-geochemical survey, biogeochemical and geobotanical survey. Emphasis is put on the applicability of geochemical methods in monitoring the quality of the environment. The students are also instructed in data handling and presentation of results.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITE

a. 4th year standing
b. Geochemistry

COURSE CONTENT/ OUTLINE

a. Introduction to applied geochemistry
b. Applied geochemistry and the environment
c. Geochemical fields
d. Geochemical anomaly
   - Primary aureoles
   - Secondary aureoles
e. Geochemical barriers
f. Lithogeochemical survey
g. Atmogeochemical survey
h. Soil metallometry
i. Hydrogeochemical survey
j. Stream sediment survey
k. Biogeochemical and geobotanical survey
l. Data treatment

EQUIPMENT AND FACILITIES

a. Computers
b. LCD projectors
c. Internet access
d. Exposure trips
e. Laboratory equipment and chemicals needed for Geochemical Prospecting

2. APPLIED GEOPHYSICS

COURSE DESCRIPTION

The course applies geophysical techniques and methods to geology. Application to geophysical exploration is reviewed. This would include data collection and problem solving using resistivity, conductivity, seismic reflection, seismic refraction, gravity, magnetics and borehole geophysical techniques. The course looks into the details of seismology and seismic prospecting as well as the reflection and refraction methods. Incorporated are the gravity principles and the principles of geomagnetism and magnetic prospecting. Included also are discussions on the other prospecting methods like electrical, electromagnetism, geoelectric and resistivity. Geophysical instrumentation, application and interpretation with field examples are considered. Application of integrated geophysical methods for oil, mineral and groundwater prospecting with the use of case studies are incorporated.

COURSE / LEARNING OBJECTIVES

The course provides the student an array of geophysical techniques applicable to solving geoscience and engineering problems in resource exploration and development, natural hazards, and pollution control. The course is intended for students to be more practical, hands-on, field-oriented course on the applications of geophysics to various problems. Each topic will proceed from basic principles (theory) through methods and applications then to case histories. Applications will be emphasized; theory will be kept to the essentials. The basic principles and operational procedures of each method will be presented, along with discussions of where the method is and is not applicable. Case histories will be included to illustrate applications.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITE

a. 4th year standing
b. Geophysics

COURSE CONTENT/ OUTLINE

a. Seismic principles
   - Refraction and Reflection analyses and interpretations
   - Hydrocarbon exploration: case studies and applications
b. Gravity principles
c. Magnetics principles
   - Gravity/magnetics interpretations and case studies
d. GPS acquisition, analysis, applications and case histories
e. Electrical/hydraulic properties of rocks
f. Resistivity principles, interpretations and case studies

g. Electromagnetics principles, interpretations and case studies
h. Induced polarization, self potential - theory, acquisition, interpretation
i. The borehole environment

EQUIPMENT AND FACILITIES

a. Computer
b. LCD projectors
c. Internet access
d. Exposure trips
e. Laboratory and field equipment for Geophysical Surveying / Prospecting

3. ENVIRONMENTAL GEOLOGY

COURSE DESCRIPTION

The course deals with the relationship between geology and human activities. It puts emphasis on geologic process and hazards influencing human activities and on human activities influencing our soils, water, atmosphere and energy resources. It is important that people understand the science behind environmental issues so that sound policy decisions can be made. The course looks into the nature and occurrences of geohazards such as earthquake, volcanic eruption, mass wasting, and flooding; and man-induced modifications on local and global environments. It incorporates details on the dynamics of the geo-environment, pollution of water and land and types of contaminants (speciation and toxicity). Details such as carbonate equilibria, pH control and chemical composition of water, trace metals in aquatic systems and water quality criteria are included. Effects on the environment due to mining, quarrying, utilization of minerals, oil and acid mine drainage will also be discussed.

COURSE / LEARNING OBJECTIVES

This course is intended to provide the students better understanding of the natural geological systems, processes and hazards and the adverse impact of human activities on the geologic environments and looking for ways on how to minimize their impacts are included. It would provide students venues of appreciating the scientific method and apply quantitative reasoning skills using geology as a framework.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITES

a. 4^{th} year standing

COURSE CONTENT/ OUTLINE

a. Foundations

- An overview of the planetary earth
- Rocks and Minerals

b. Internal Process
- Plate Tectonics
- Earthquakes
- Volcanoes
- Surface Processes
- Streams and Flooding
- Coastal Zones and Processes
- Mass Movements
- Geology and Climate

c. Resources
- Water
- Soil
- Minerals
- Fossil Fuels
- Alternative Energy Sources

d. Waste Disposal and Pollution
- Waste Disposal
- Water Pollution
- Air Pollution

e. Environmental Law
- Environmental Law
- Land-use planning and Engineering Geology

EQUIPMENT AND FACILITIES

a. Computer
b. LCD projector
c. Internet access
d. Exposure trips

4. GEODYNAMICS AND TECTONICS

COURSE DESCRIPTION

The course deals with the mechanics of deformation of the crust and mantle with emphasis on the importance of the different rheological descriptions such as brittle, elastic, linear and non linear fluids and viscoelastic. It looks into the driving mechanisms of plate motion; reflection and refraction seismology, magnetism, gravity, heat flow, tomography and mantle convection. Understanding the oceanic and continental lithosphere in active tectonic regions is included. Structure and geometry of lithospheric plates and plate boundaries; mechanisms of divergent, convergent, and transform boundaries; orthogonal and oblique subduction; triple junctions; mantle plumes, nature and origin of large igneous provinces and sedimentary basin and Phanerozoic orogenic belts are also discussed. The course studies as well large and small-scale

phenomena in oceanic, atmospheric, and land surface fluids, properties of gases and liquids, surface body forces, statics, flow analysis, Darcy's Law and related dimensional analyses.

COURSE / LEARNING OBJECTIVES

This course is designed to introduce the students to the basics of geodynamics and plate tectonics. The main objectives of this course are to get the students to think of geological problems in terms of physics and mechanics and to provide them with a few tools necessary to begin applying physics to geologic problems.

CREDITS: 3

NUMBER OF HOURS: 3 hours per week

PREREQUISITE

a. 4th year standing
b. Structural Geology and Tectonics

COURSE CONTENT / OUTLINE

a. Review of continuum physics, forces, stress, vectors, etc.
b. Deformation: Strain, rotations, deformation gradient tensor
c. Plate motions: Poles of rotation, reference frames, measurement techniques
d. Inverse problems as applied to geodynamics and plate tectonics
e. Stress and strain in elastic and non-elastic materials, flexure of the Earth's lithosphere, subduction, seamounts, mountain belts
f. Diffusion: Heat transfer, flow in porous media, heating of subducted lithosphere, cooling of oceanic lithosphere, basin subsidence, thermal anomalies near faults
g. Gravity: Constraints on flexure, isostasy, geoid anomalies Fluid mechanics: Mantle convection, isostatic rebound, continuum models of Earth deformation
h. Faulting: Elastic solutions, creep, aseismic deformation

EQUIPMENT AND FACILITES

a. Computer
b. LCD projector
c. Internet access
d. Exposure trips

5. GEOHAZARDS

COURSE DESCRIPTION

The course provides students the opportunity to understand the geological and natural processes that catastrophically affect the human environment. Geohazards at some point are products of human interventions to natural

geologic processes. These are studied in terms of geological concepts, prediction, mitigation, avoidance and policy/safety issues. The course puts emphasis on the nature of earthquakes and volcanoes, and how society confronts the dangers posed by these natural phenomena. Students will be introduced to the scientific basis and technical issues of geologic hazards. In order to gain global and local perspectives, case studies of recent and past geohazard events will be discussed, focusing on both the geological contents of the hazard and its impact on society and individuals. Discussions on public policy issues and citizen responsibilities related to hazard prediction, volcanic and seismic risk analysis and long term planning to mitigate human and economic losses are also included.

COURSE / LEARNING OBJECTIVES

By the end of the course, the students should be able to quantitatively understand the geological and natural processes that affect the human environment. They will be able to appreciate prediction, mitigation and formulation of risk management policies through specific case studies of recent geohazard events. Students are encouraged to work collectively on hazard problems that would require in-depth analyses in both scientific and social aspects.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITES

a. 4th year standing

COURSE CONTENT / OUTLINE

a. Introduction to Geohazards
b. Volcanic Hazards: Monitoring and Mitigation
c. Earthquake Hazards: Monitoring and Mitigation
d. Tsunamis
e. Soil Erosion and Desertification
f. Streams and Flooding
g. Groundwater geohazards
h. Subsidence and Collapse
i. Landslides
j. Fire Hazards
k. Severe Weather: Thunderstorms, Lightning, Tornadoes, Hurricanes
l. Coastal Hazards
m. Public policy and (hazard) ethics

EQUIPMENT AND FACILITIES

a. Computers
b. LCD projectors
c. Internet access

d. Exposure trips
e. Field equipments (compass, measuring tapes, sample pick etc.)

6. GEOSTATISTICS

COURSE DESCRIPTION

The course reviews the principles, concepts, and models behind Geostatistics. It examines the bases, implications, uses, and limitations of prevailing geostatistical models. It would introduce the students to probability, random experiments, events and sample space. Their application to geological observations and processes will be the focus of the course. The course would also be an introduction to statistical inference sampling distributions, point and interval estimation, hypothesis testing involving one and two univariate populations, linear models ANOVA, linear and multiple regression, multivariate techniques, factor analysis, and linear discriminant analysis.

COURSE / LEARNING OBJECTIVES

This course focuses on the application of Geostatistics in Earth Science Research which the students would find useful. The course is ideally suited for students who seek to develop more in-depth skills and understanding of the concepts behind modern tools for detecting, describing, and estimating spatial patterns and trends.

CREDITS: 2 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITES

a. 3rd year standing
b. Statistics

COURSE CONTENT/ OUTLINE

a. Geostatistics: An overview, Course Topics and Case Studies
b. Exploratory Data Analysis
c. Quantification of Spatial Continuity
d. Spatial Estimation (Kriging)
e. Stochastic Simulation
f. Scaling and Sample Support
g. Application of Analysis of Uncertainty

EQUIPMENT AND FACILITIES

a. Computer
b. LCD projector
c. Internet access
d. Geostatistical / computational software

7. GEOTECHNICAL ENGINEERING / ENGINEERING GEOLOGY

COURSE DESCRIPTION

The course introduces the student to the different geological approaches in evaluating engineering issues. It incorporates studies on rock and soil mechanics and slope stability with emphasis on the geophysical investigation of rock and soil properties. These could be achieved through field and laboratory measurements and analyses of rock and soil geotechnical parameters. It looks into the role of geology in engineering using minerals, rocks, superficial deposits, rocks and soils as engineering materials. Considerations are given to hydrologic influences as well as the geology of the engineering sites. Different approaches are introduced that of mapping and identification of rock mass classifications used in empirical design and geological engineering of underground excavations, slopes, reservoirs, and dam sites. This course incorporates topics such as the physical properties of rocks; stress and strain measurements; thermal, hydraulic and mechanical properties of rock masses; applications of the elasticity theory in rock mechanics; rock discontinuities; rock slope engineering and underground excavations in rock.

COURSE / LEARNING OBJECTIVES

The course would provide the students knowledge of engineering concepts and their relation to geology. The students will have the opportunity to understand the different classification of rocks and soils for engineering purposes, the methods of analyses and the measurements of engineering properties and their applications. The course also gives the students some background on basic engineering geology, the relation between engineering characteristics and geological condition or process, and the management of destructive processes. At the end of the course, the students will be able to perform various techniques of engineering geology.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITE

a. 4th year standing

COURSE CONTENT/ OUTLINE

a. The Earth and its systems
b. Review of rocks and minerals
c. Rock mechanics
d. Structural deformation and discontinuities
e. Weathering and erosion
f. Soils, soil hazards and land subsidence
   - Soil composition and classification
   - Stress and shear strength analysis

g. Mass movement and slope stability
h. Bearing capacities and Foundations
i. Ground investigations

EQUIPMENT AND FACILITIES

a. Computers
b. LCD projectors
c. Internet access
d. Laboratory and field equipments for engineering geology

8. GEOTHERMAL RESOURCES

COURSE DESCRIPTION

The course introduces the student to the geology, geochemistry, and geophysics of geothermal resources, looking into the various techniques of exploration, evaluation, and development. The course introduces the student to the nature and origin of the Earth's heat energy. In includes the definition and classification of geothermal systems, heat flow, geothermal anomalies and their plate tectonic framework. Also considered are the prospecting for geothermal resources, the water chemistry in geothermal exploration, the estimation of reservoir temperatures, effects of mixing and underground boiling. The course also looks into heat extraction from geothermal reservoirs. Geothermal resource assessment and environmental aspects of geothermal energy development are well introduced to the students.

COURSE / LEARNING OBJECTIVES

This course is designed to teach the students selected major aspects of earth science investigations in geothermal energy exploration and development.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITE

a. 4th year standing

COURSE CONTENT/ OUTLINE

a. Geothermal Systems: Definition and Classification
b. Prospecting for Geothermal Reservoirs
c. Application of Water Chemistry to Geothermal Exploration and Reservoir Engineering
d. Heat Extraction from Geothermal Reservoirs
e. Geothermal Resource Assessment
f. Environmental Aspects of Geothermal Energy Development

EQUIPMENT AND FACILITIES

a. Computer
b. LCD projector
c. Internet access
d. Exposure trips to geothermal fields

9. GEOTHERMY

COURSE DESCRIPTION

The course introduces the student to the basic principles behind the nature and origin of the Earth's heat energy. It includes the definition and classification of geothermal systems, heat flow, geothermal anomalies and their plate tectonic framework.

COURSE / LEARNING OBJECTIVES

This course is designed to provide the students fundamental concepts of thermodynamics in understanding better the generation of heat energy and availability of various tools in earth science investigations for geothermal energy exploration and development.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITE

a. 4th year standing

COURSE CONTENT/ OUTLINE

a. Geothermal Systems: Definition and Classification
b. Basic concepts of thermodynamics and chemical equilibria
c. Application of Water Chemistry to Geothermal systems and processes
d. Heat generation in geothermal systems
e. Applications in geothermal resource assessment

EQUIPMENT AND FACILITIES

a. Computer
b. LCD projector
c. Internet access

10. HYDROGEOLOGY

COURSE DESCRIPTION

The course is an introduction to the science of hydrology and to the role of water as a resource, a hazard, and an integral component of the Earth's climatic, biological, and geological systems. The course looks into the

nature and occurrences of ground and surface water systems; exploration and extraction methods; assessment of water quality and rehabilitation of contaminated water systems. The course puts emphasis on precipitation analysis; determination of evaporation and infiltration quantities and calculation of surface runoff. It studies the behavior and properties of water in the geologic environment with emphasis on subsurface water, including studies of flow patterns, chemistry, behavior in various geologic materials, and pollution problems. It reviews the hydrologic cycle; porosity and permeability of aquifers, aquifer testing; groundwater flow and water pollution. It also incorporates studies on land surface hydrology, transport of water, vapor, and heat in soils and the near surface atmosphere and the effects of vegetation, topography, and water table on runoff, evapotranspiration and recharge. The quantitative aspects of groundwater hydrogeology in the development of the equations governing the flow of water in aquifers, the identification of appropriate initial and boundary conditions and the methods of groundwater monitoring and field techniques are all included in the course.

COURSE / LEARNING OBJECTIVES

This course will introduce the students to hydrology, surface and groundwater processes and watershed responses. In this course they will learn to appreciate more both the pure and applied uses of hydrology and the interfaces between hydrology and other sciences. The course provides the students better understanding on how perturbations such as climate change and land use affect the hydrologic cycle.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITES

a. 4^{th} year standing

COURSE CONTENT/ OUTLINE

a. Water for the world
b. The global hydrological cycle
c. Catchment hydrology: Land-atmosphere interactions
d. Structure and properties of water
e. Principles of fluid dynamics
f. Open channel hydraulics
g. Catchment hydrology: Streams, floods and droughts
h. Goundwater flow
i. Groundwater transport
j. Water in the unsaturated zone
k. Monitoring and assessing processes
l. Modeling hydrologic processes
m. Water quantity
n. Water quality
o. Managing water resources: Towards a sustainable future

EQUIPMENT AND FACILITIES

a. Computer
b. LCD projector
c. Internet access
d. Exposure trips
e. Laboratory and field equipment for hydrogeology

11. IGNEOUS AND METAMORPHIC PETROLOGY

COURSE DESCRIPTION

The course looks into the classification, occurrences or petrogenesis, and the detailed megascopic and microscopic descriptions of igneous and metamorphic rocks. Given emphasis would be the recognition and interpretation of common igneous and metamorphic rocks, both in hand sample and in thin section and the relationships between rocks and the tectonic environments in which they formed.

Igneous petrology studies the mode of occurrence of igneous rocks, their texture and structure, mineralogical and chemical classifications as well as the chemical conditions governing solid-liquid equilibrium. Discussed are the crystallization paths of binary and ternary systems, magmatic differentiation, assimilation and partial melting.

Metamorphic petrology looks into the factors controlling metamorphism; types of metamorphism; transient geotherm pressure-temperature regimes; protolith types and characteristic metamorphic minerals; metamorphic textures; projection in positive and negative space; ACF, AKF and AFM diagrams; metamorphic facies and facies series; metamorphic zones; thermodynamic principles of metamorphic reactions; regional metamorphism of pelitic, carbonate and mafic rocks; contact metamorphism; granulite, eclogite and migmatite; metamorphic differentiation, experimental studies on metamorphic reactions; metamorphic terranes in relation to plate tectonics.

COURSE / LEARNING OBJECTIVES

In this course, the students will learn to identify, describe, and classify igneous and metamorphic rocks and textures in hand specimen and thin section. They will also learn to interpret and understand the chemical and physical evolution of igneous and metamorphic rocks. Because there is a fundamental link between igneous and metamorphic processes and plate tectonics, these rocks are considered sensitive recorders of tectonic processes and Earth history. Students will also interpret their composition, textures, and occurrences in a plate tectonic context. Included would be a possible field trip to igneous and metamorphic terrains.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITES

a. 4th year standing

COURSE CONTENT/ OUTLINE

a. Introduction and classification/nomenclature
b. Igneous textures and structures
   - Volcanic rocks, field relations, and volcanism
   - Putonic rocks, field relations, emplacement mechanisms
   - Thermodynamics and phase equilibria, reaction series
   - Melt generation, ascent, and evolution - basalt generation
   - Differentiation and granitoid evolution
   - Lunar geology
c. Metamorphism and metamorphic rocks
   - Mineral assemblages, reactions and metamorphic facies
   - Metapelites
   - Meta-mafic rocks, high P/T ratio metamorphism
   - Meta-carbonate rocks, skarns, ultramafic rocks
   - Dynamic metamorphism, processes, mechanisms, and kinetics
   - Metamorphism and tectonics

EQUIPMENT AND FACILITIES

a. Computer
b. LCD projector
c. Internet access
d. Exposure trips
e. Petrographic microscope
f. Laboratory equipment for sample preparation and analysis

12. MARINE GEOLOGY

COURSE DESCRIPTION

The course examines the evolution of ocean basins and marginal seas, the changes in structure and composition of ocean basins throughout the last one billion years, and the contribution of oceanic geological processes to the chemistry and biochemistry of the earth. Also incorporated are the bathymetry and origin of ocean basins, as well as the sedimentation, marine stratigraphy and ocean history. Understanding waves and currents, beaches, continental shelves, continental slopes, trenches and canyons are part of the course. Deep ocean floor and various topographic features like ridges, seamounts and coral reefs are looked into. The stratigraphy and geochronometry of deep-sea deposits, chemistry of oceanic rocks, mineral deposits of the seabed are included.

COURSE / LEARNING OBJECTIVES

The goal of the course is to develop among students an understanding of the processes controlling the structure and evolution of the ocean basins,

and the tools and methods used by marine scientists in developing this understanding. Studies on plate tectonics and marine geology are heavily intertwined; an example would be that most modern plate boundaries reside in the oceans. The students will study the structure and composition of the oceanic crust produced at spreading centers, its subsequent alteration by on- and off-axis interaction with seawater and its burial by sediments and consumption in collision zones. The students will also look at the distribution and composition of major sediment types, and the use of the sedimentary record for deciphering the geological, climatological, and oceanographic histories of the oceans.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITE

a. 3rd year standing

COURSE CONTENT/ OUTLINE

a. Overview and history of marine geology
b. Geomorphology of the ocean basins
c. Ocean basin tectonics
d. Introduction to ocean margins
   - Passive continental margins
   - Active continental margins
e. Ocean circulation
   - Ocean-atmosphere interactions
f. Introduction to sea-level variations
   - Sequence stratigraphy
g. Introduction to ocean sediments
   - Calcareous sediments
   - Siliceous sediments
h. Paleoceanography

EQUIPMENT AND FACILITIES

a. Computers
b. LCD projectors
c. Internet access
d. Exposure trips
e. Laboratory and field equipment for Marine Geology

13. METALLIFEROUS DEPOSITS

COURSE DESCRIPTION

This course introduces students to metallic mineral deposits. Topics cover descriptions, ages, tectonic environments and genesis of these resources. The environmental impacts of the development of these resources are

also included. The course looks into the nature, occurrence, and origin of metalliferous deposits, including ore genetic models and ore-forming processes, paragenesis, and mineral associations. It also looks into the details of magma differentiation, hydrothermal systems, sedimentation and metamorphism in ore formation. Exercises using hand-specimen examination of fresh and altered host rocks are included. Complementing these would be the microscope study of ore minerals in polished sections with the proper identification of textures, structures, mineral associations, and sequences of mineral deposition. Exploration algorithm, design, and execution of geologic programs and applications of geologic principles in regional minerals search, including geochemical, geophysical, geological, and engineering methods will be used as tools to understand ore deposits.

Different types of deposits will be studied. These would include epigenetic and syngenetic deposits, orthomagmatic related deposits, pegmatitic and pneumatolitic deposits (skarn and metasomatic deposits). Also given emphasis would be hydrothermal processes, studies on modern ore solutions, aqueous transport of metals and deposition of metals from ore solutions (meteoric and juvenile). Included would be weathering, supergene enrichment and residual deposits. Sedimentary deposits (formed by mechanical transport and by chemical precipitation) as well as metamorphic and metamorphosed ore deposits will be discussed.

COURSE / LEARNING OBJECTIVES

On successful completion of the course, the students should have a better understanding of the various metallic resources and their environmental impacts in developing the resources. Students should be able to identify the common economic / ore minerals in hand samples and under the microscope, estimate the concentration of metals in rocks and understand the origin, occurrences and nature of the different metallic resources

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITES

a. 4th year standing

COURSE CONTENT/ OUTLINE

a. Description of ore deposits
b. Tectonic environments
c. Age and genesis of mineral deposits
d. Exploration and utilization of mineral deposits
e. Environmental Impacts in developing mineral deposits

EQUIPMENT AND FACILITIES

a. Computer
b. LCD projector

c. Internet access
d. Exposure trips
e. Ore specimen / samples
f. Polished thin sections of different ore minerals
g. Petrographic microscope
h. Sample preparation laboratory
i. Analytical instruments (AAS, XRD)
j. Laboratory and field equipment for metalliferous ore deposits

14. MICROPALEONTOLOGY

COURSE DESCRIPTION

The course introduces the student to animal and plant microfossils with emphasis to Foraminifera. The environmental distribution of foraminifera, the palaeoenvironmental interpretation using micro fossils, the morphology and geological distribution of ostracoda, calcareous nannofossils, radiolaria, conodonts and bryozoa, the role of micropalaeontology in hydrocarbon exploration specifically deep sea record and the stable isotopic study of foraminifera are all part of the course. Laboratory activities put emphasis on the identification of fossils in hand specimen and under the microscope. Surface and sub-surface sampling methods as well as sample processing techniques are reviewed.

COURSE / LEARNING OBJECTIVES

The course provides opportunity for students to study the classification, biology, distribution and diversity of major invertebrate animals with a fossil record. The course is designed to integrate modern biological concepts as applied to fossil organisms. Students will study fossil organisms and, upon completion of the course, will be able to communicate with the proper understanding of the principles of evolution, systematics, stratigraphic correlation, and paleoecology. It is expected that students use micropaleontology as a tool to explore the physical and biological history, processes, and events that distinguish our planet's past. Applications include problems in global climate change, ocean circulation, geologic history, paleoecology, paleobiology, and evolution. The purpose of the course is to learn how microfossils are applied to the study of earth history.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITES

a. 4th year standing
b. Paleontology

COURSE CONTENT/ OUTLINE

a. Planktonic foraminifers

b. Radiolarians
c. Diatoms
d. Calcareous nannofossils
e. Benthonic foraminifers
f. Principles of biogeography
g. Paleoceanography
h. Evolution
i. Biostratigraphy
j. Biogeochronology

EQUIPMENT AND FACILITIES

a. Computer
b. LCD projectors
c. Internet access
d. Microfossil specimen
e. Microscope
f. Laboratory and field equipment for micropaleontology

15. MINERAL ECONOMICS

COURSE DESCRIPTION

The course introduces the student to various principles of Economics specifically applied in the use of earth resources. It looks into the importance of strategic, critical and essential minerals. It also reviews the present status of mineral production in Asia and the whole world. Considered are the changing patterns of mineral consumption, the National Mineral Policy, the Mineral Concession Rules and Marine Mineral Resources and the Law of the Sea.

COURSE / LEARNING OBJECTIVES

This course aims to help students understand the global mineral industry as it presents a unique investment environment, which needs to be mastered to ensure the successful development of any venture into the minerals industry. It prepares students through various feasibility study exercises. Key methods (traditional, statistical and geostatistical) of resource estimation used in the minerals industry are introduced, applied and evaluated. Geological and engineering inputs to, and constraints on, resource estimation are highlighted, together with a review of the conversion of mineral resources to ore reserves.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITES

a. 4th year standing
b. Economics

c. Statistics

COURSE CONTENT/ OUTLINE

a. Fundamentals of Economics
b. Mineral markets
c. Resource estimation
d. Mine Feasibility Studies
e. Revenue
f. Cost Estimation
g. Taxation
h. Optimization and Risk Assessment

EQUIPMENT AND FACILITIES

a. Computer
b. LCD projector
c. Internet access

16. MINERAL RESOURCES OF THE PHILIPPINES

COURSE DESCRIPTION

The course introduces the student to the geology of (some) principal mineral resources of the Philippines, the analyses and interpretation of mineral distribution and geological maps and the better understanding of local and world mineral economics.

COURSE / LEARNING OBJECTIVES

Upon successful completion of the course, the students should have a better understanding of the mineral resources of the Philippines. Students should be able to appreciate the different economic minerals that are abundant in the Philippines and able to estimate their concentrations and distributions. Students will also have better descriptions and understanding of the origin, occurrences and nature of the different metallic and non metallic resources. Exposure trips would be helpful to the course appreciation.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITES

a. 4th year standing
b. Geology of the Philippines and Southeast Asia

COURSE CONTENT/ OUTLINE

a. Review of the description, ages, tectonic environments and genesis of metallic mineral and non metallic deposits
b. Geology and tectonic setting of the Philippines

c. Mineral resource distribution
   - Classification of mineral resources
   - Occurrence and origin of mineral resources
   - Resource availability

EQUIPMENT AND FACILITIES

a. Computer
b. LCD projector
c. Internet access
d. Exposure trips
e. Mineral (Philippine ore) specimen
f. Laboratory and field equipment

17. MINING GEOLOGY

COURSE DESCRIPTION

The course introduces the student to the various applications of geology in the exploration, development, and exploitation of, mineral deposits as well as to the mining methods and mine rehabilitation. The course incorporates discussions on the different classification of underground and surface mining methods. It would be an introductory course to the various operations in mining, drilling, blasting, haulage and hoisting, caving methods in underground mining, open-cast and open-pit mining, underground exploration and sampling of ore deposits and methods of ore resource computation. It would also provide an introduction to mineral economics classification of mineral resources, regulation and development of mines and the mineral industry, mineral taxation and conservation of mineral resources.

COURSE / LEARNING OBJECTIVES

It is expected that the students understand the basic concepts in the mineral industry, mining terminologies, basic exploration, development, production and concentration methods and mine valuation. The students should also have knowledge of mine haulage, mine explosives, mine supports, mine plants and equipment, mine ventilation, lighting and drainage. In specific cases the students should be able to develop a descriptive knowledge of the geologic processes resulting in the emplacement and concentration of gold, to become aware of events associated with the discovery and subsequent exploitation of gold in a region. To become familiar with several basic mining and extraction methods and to appreciate the impact of mining on a region

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITES

a. 4th year standing

COURSE CONTENT/ OUTLINE

a. Geology and Geological Characteristics of Mineral Deposits
b. Reconnaissance and Exploration methods
c. Mine Development and Exploitation
d. Resource (+Reserve) Analysis
e. Mineral Deposit / Resource Evaluation

EQUIPMENT AND FACILITIES

a. Computers
b. LCD projectors
c. Internet access
d. Exposure trips to mining companies

18. NON-METALLIFEROUS DEPOSITS

COURSE DESCRIPTION

This course introduces students to non-metallic mineral and rock deposits and energy resources such as coal and uranium. Course topics cover the descriptions, ages, tectonic environments and genesis of these resources. The environmental impacts of the development of these resources are also included. The course looks into the nature, occurrences, and origin of coal and certain industrial minerals and rocks as well as their exploration, evaluation, extraction, processing and marketing. Emphasis is given to studies on the geology of coal, including environments of deposition, coal petrology, and distribution. It includes understanding the techniques of coal exploration, drilling, geophysical logging, mapping, and economic analysis. Other fuel resources are considered. The mineralogy and geochemistry of radio-active minerals, the various types of uraniferous deposits, their characteristics and genesis and the metallogenic epochs and provinces of uranium mineralization are discussed as well as problems on uranium utilization and waste disposal.

COURSE / LEARNING OBJECTIVES

Upon successful completion of the course, the students should have a better understanding of the non-metallic mineral and rock deposits and energy resources and the environmental impact in developing these resources. Students should be able to identify the common economic non-metallic minerals, in hand samples and under the microscope, estimate their concentration / volume and understand the origin, occurrences and nature of the different resources

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITES

a. 4th year standing

COURSE CONTENT/ OUTLINE

a. Description of the different non metallic deposits
b. Tectonic environments of formation
c. Age and genesis of the deposits
d. Exploration and development
e. Environmental impacts

EQUIPMENT AND FACILITIES

a. Computer
b. LCD projector
c. Internet access
d. Exposure trips
e. Sample specimen (non-metallic and energy)
f. Laboratory and field equipment
g. Analytical instruments

19. OPTICAL MINERALOGY

COURSE DESCRIPTION

The various optical properties of minerals are introduced in this course and a systematic approach is undertaken in identifying and understanding the different rock and ore forming silicates as well as non silicate minerals. The course intends to develop the essential skills and appreciation on the various techniques in using the microscope and other analytical methods necessary for studying minerals. This would include studies on the properties of light, polarisation, interference of light waves, measurement of RI, color, determination of pleochroic scheme, fast and slow ray vibration directions, measurement of birefringence, optic orientation in different crystallographic systems, extinction angles, determination of optic sign of uniaxial and biaxial minerals, determination of optic axial angle, principle of U-stage techniques and stereographic projections. The identification of minerals using X-ray diffraction methods is included.

COURSE / LEARNING OBJECTIVES

The main objective of the course is to provide the student a basic tool which is the microscope in understanding of what minerals are and the information they have to offer. The student is also provided with experiences and skills in gathering and interpreting the information. At the end, the student should be able to identify common minerals using the petrographic microscope, understand the relationships between optical properties to crystal structures, and the chemical composition and physical properties of minerals. The student should also be familiar to the use of the microscope and techniques used in the identification of minerals.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITES

a. Principles of Geology
b. Mineralogy

COURSE CONTENT/ OUTLINE

a. Mineral identification and classification
b. Optical properties of minerals
c. Basics of light behavior
d. Optical principles behind the use of the microscope
e. The Petrographic Microscope
f. The Immersion method
g. Isotropic substances
h. The Uniaxial Mineral
i. The Biaxial Minerals
j. Universal Stage

EQUIPMENT AND FACILITIES

a. Computers
b. LCD projectors
c. Internet access
d. Sample preparation laboratory
e. Grain mounts and mineral thin sections
f. Petrographic microscope
g. X ray

20. ORE MICROSCOPY

COURSE DESCRIPTION

The course introduces the students to microscopy as a means of studying ore minerals specifically using reflecting light microscopes, and analyzing in detail ore textures and paragenesis. The application of ore microscopy in mineral technology and fluid inclusion studies are also discussed. Geothermometry and geobarometry of ore assemblages, the study of phase diagrams related to ore assemblages and construction of stability diagrams and stable isotopic studies of ores are reviewed as well.

COURSE / LEARNING OBJECTIVES

The course provides the students a better understanding of the principles behind the use of the incident light microscope, sample preparation and reflected light optics. Understanding the optical properties of ore minerals, the determination of reflectivity and microhardness of ore minerals, ore textures and paragenesis are as well given emphasis. The students are

expected to be skillful in the application of ore microscopy in mineral technology and fluid inclusion studies.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITE

a. 4th year standing

COURSE CONTENT/ OUTLINE

a. Introduction and basic principles of ore microscopy
b. Microscopic study of ore minerals
c. Classification of ore deposits
d. Morphology of ore deposits
e. Textures of ore Deposits
f. Mineralogical, geochemical and geochronological techniques used for studying ore deposits (under the microscope)
g. Magmatic Ore Deposits
h. Hydrothermal Ore Deposits
i. Volcanogenic Massive Sulfides
j. Porphyry Cu deposits
k. Base Metal Lode Deposits
l. Epithermal Deposits
m. Sediment hosted and Sedimentary Ore Deposits (stratiform, stratabound & placer)

EQUIPMENT AND FACILITIES

a. Computer
b. LCD projector
c. Internet access
d. Petrographic microscope
e. Ore mineral samples in polished sections
f. Sample preparation equipment
g. Exposure trips

21. PETROGRAPHY

COURSE DESCRIPTION

The course compliments petrology as it looks into the genesis, classification, textures of constituent minerals, structures and modes of occurrence of igneous, sedimentary and metamorphic rocks using the microscope. The optical properties of minerals and microscopic methods of analyzing rocks will be the foundation of the course. The petrogenesis of the different rock types is appreciated if there are good description, classification and interpretation generated from hand specimen and thin-section analyses.

COURSE / LEARNING OBJECTIVES

Students would have the ability to identify the common rock forming minerals and the common igneous, metamorphic and sedimentary rocks in hand specimen and under the microscope. The observations generated by the students would be interpreted in terms of rock forming processes.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITES

a. Principles of Geology
b. Mineralogy
c. Optical Mineralogy
d. Petrology

COURSE CONTENT/ OUTLINE

a. Mineral identification and classification
b. Optical mineralogy
c. Optical principles and the Petrographic microscope
d. Rocks under the microscope

EQUIPMENT AND FACILITIES

a. Computers, LCD projectors, internet access
b. Rock (and mineral) specimen
c. Rocks (and minerals) in thin sections and grain mounts
d. Petrographic microscope
e. X-ray
f. Chemical analysis
g. Sample preparation laboratory

22. PETROLEUM GEOLOGY

COURSE DESCRIPTION

The course looks into the occurrence, origin, and accumulation of petroleum as well as the exploration methods in search for oil. It tackles details on the nature and occurrence of oil and natural gas in the earth's crust, hydrocarbon exploration and economic evaluation. Studies on the origin and composition of petroleum, source, reservoir and cap rocks, reservoir traps, physical and chemical properties of oil, uses and geologic distribution are incorporated.

COURSE / LEARNING OBJECTIVES

The objectives of this course are to teach the students the importance of energy in their lives, the very significant role that fossil fuels like petroleum (crude oil and natural gas) and coal have in supplying this energy, the environmental effects of producing, transporting, refining, using and

burning these fuels, how petroleum is found and wells are drilled to produce it, what are the conditions in nature required for petroleum formation and trapping, the role that geologists and geophysicists have in petroleum exploration and production, and how market factors affect jobs for us in the energy industry. They will find the course to be very useful whether working for an oil company, as environmental or hydro-geologists, or just want to be an informed geologists / citizens.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITES

a. 4th year standing

COURSE CONTENT/ OUTLINE

a. Concepts, Terms, and History of Petroleum and Energy Use
b. What is Petroleum
c. Reservoir Rocks and their Fluids
d. Porosity and Permeability
e. Diagenesis and Secondary Porosity
f. Chemistry of Petroleum
g. Drilling and Logging a Well
h. The Subsurface Environment of Sedimentary Basins-Chemistry, Temperature, and Pressure
i. Generation and Migration of Petroleum-Maturation and Expulsion of Oil and Gas from source rocks
j. Traps and Seals
k. Structural and Stratigraphic Traps
l. The Petroleum System, Plate Tectonics and Basin Formation-Case Histories

EQUIPMENT AND FACILITIES

a. Computer
b. LCD projector
c. Internet access
d. Exposure trips

23. PHOTOGEOLOGY AND REMOTE SENSING

COURSE DESCRIPTION

The course reviews the various concepts, identification, and interpretation of Earth features or objects on photo imagery, the methods of procurement and processing of these images from airborne sensors or space platforms and their applications and the use of case studies. Incorporated are details on the elements of airborne and space borne remote sensing systems, including aerial photography, radar, thermal, and multi spectral

imagery. Emphasis is on the use of remotely sensed images for geological mapping, environmental monitoring, resource assessment, and land use. The course looks into various topics such as the fundamental concepts of remote sensing; electromagnetic energy and its interactions in the atmosphere and with terrain features; elements of photographic systems; aerial photointerpretation and geological applications, the fundamentals of photogrammetry, satellite remote sensing, multi-spectral scanners, thermal scanners, microwave remote sensing and the fundamentals of image interpretation and geological applications. The course also introduces students to digital image processing, Geographic Information System, spatial data models and data structures, visualization and query of spatial data, overlay analysis and the different geological applications of GIS. Laboratory exercises could include topographical map interpretation, airphoto interpretation for geological and geomorphological applications, interpretation of satellite images, basic photogrammetry exercises like parallax measurements for height determination, introduction to digital image processing and GIS application packages.

COURSE / LEARNING OBJECTIVES

The course would provide the students a better understanding of the principles of remote sensing techniques, spectral signatures and the interpretation of unknown reflectance spectra of minerals, water, vegetation, rock, soil and atmospheric targets. It will be an opportunity for students to interpret remote sensing data in order to understand the processing and enhancement of satellite images for identifying geological structures and vegetation coverage, recognize coastal morphology from space and recognize global changes and environmental monitoring with data from special sensors.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITE

a. 4th year standing

COURSE CONTENT/ OUTLINE

a. Basic Principles of Imaging Spectrometry
b. Imaging spectrometry, analysis and interpretation
c. Spectral analysis for Earth science investigations
d. Concepts in data and image interpretation
e. Sensors and platforms
f. Applications: geosphere, hydrosphere, biosphere and atmosphere

EQUIPMENT AND FACILITIES

a. Computers
b. LCD projectors

c. Internet access
d. Remote sensing images
e. Stereoscope
f. Remote sensing data interpretation software

24. QUATERNARY GEOLOGY

COURSE DESCRIPTION

This course seeks to describe and understand the changes in global and regional geologic systems and climate that occurred during the Quaternary period. The studies would need to consider the methods of data acquisition, dating techniques and methods, and the interpretations drawn from the acquired data.

COURSE / LEARNING OBJECTIVES

This course will provide the students the opportunity to examine environmental change over the last 2 million years (The Quaternary Period). Particular focus will be placed on the evidences and explanations of Quaternary cycles of climatic change; ecological change that occurred on the terrestrial environments; and human evolution and impacts on the Earth's environments. The specific goals of the course are: to develop an understanding of Quaternary environments, to acquire insight into the techniques, which are utilized to investigate Quaternary environmental alterations and to develop an appreciation of global environmental change that occurred during the Quaternary Period.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITE

a. 3rd year standing

COURSE CONTENT/ OUTLINE

a. The Quaternary Period – An Introduction
b. Prelude to the Quaternary
c. Understanding Past & Present Climates
d. Cycles of Climate Change: Evidence & Explanation
e. Terrestrial Environments & Climate Change
f. Human Evolution and Environmental impacts
g. Environmental Changes: Past, Present & Future

EQUIPMENT AND FACILITIES

a. Computer
b. LCD projector
c. Internet access
d. Exposure trips

e. Laboratory and field equipment for Quaternary Geology

25. SEDIMENTARY PETROLOGY

COURSE DESCRIPTION

The course involves the detailed study of sediments and sedimentary rocks; their classification and sedimentology. Studied are the texture, composition and structure of sediments and sedimentary rocks. The origin, diagenesis and classification of conglomerate, sandstone, shale, limestone, dolomite, chert, phosphorites, evaporites and iron bearing sediments are also considered. Understanding provenance, palaeocurrent, environment and facies, and knowing the characteristics of various non-marine, transitional and marine environments are given emphasis. Considered as well are sedimentation and tectonics. Basin classifications and descriptions could provide an idea about basin analysis.

COURSE / LEARNING OBJECTIVES

The purpose of this course is to give the students a broad understanding of how sedimentary rocks form and how they evolve as they undergo burial. This starts with understanding sediment composition and how this can be used to infer source area characteristics. They will study how sediments after deposition become lithified. This includes both chemical and physical transformations that lead to major changes in the original petrophysical (porosity and permeability) characteristics of sediments and sedimentary rocks as lithification and diagenesis occur.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITES

a. 4th year standing

COURSE CONTENT/ OUTLINE

a. Introduction to weathering, geochemical cycles, and the origin of sedimentary rocks
b. Carbonate grains: mineralogy and origin
c. Carbonate grains in thin section; carbonate diagenesis
d. Carbonate diagenesis: meteoric and burial settings
e. Introduction to clastic sedimentary rocks
f. Sand and sandstones: framework grains; classification
g. Clastic rock diagenesis I: Authigenic minerals
h. Mudrocks; clay mineralogy; classification
i. Chemical and biochemical sedimentary rocks: chert; phosphorite; evaporites.
j. Interpreting siliciclastic sedimentary rocks

k. Quantitative analysis of sedimentary rocks

EQUIPMENT AND FACILITIES

a. Computer
b. LCD projector
c. Internet access
d. Exposure trips
e. Petrographic microscope
f. Laboratory and field equipment for Sedimentary Petrology

26. SEDIMENTOLOGY

COURSE DESCRIPTION

The course studies the properties and classification of clastic and carbonate sediments and sedimentary rocks; the processes that form, transport, and deposit sediments; the environments of deposition; diagenesis and methods of analysis. Also to be discussed are lithologic classification, correlation, and paleoenvironmental interpretation of sediments and sedimentary rocks. Subsurface data are also studied using cores and geophysical well logs. Fieldtrips could be arrange to supplement lectures

COURSE / LEARNING OBJECTIVES

The course will enable students to appreciate a given outcrop with the use of correlation diagram, or other representations of a stratigraphic section in interpreting the depositional history of the sequence and develop a sound hypothesis about the relative importance of sediment supply, subsidence, and the base level in creating the sequence. Also with a given tectonic setting, they should be able to predict what types of sedimentary processes and depositional environments would result and what their stratigraphic signature would be. They should be able to at the end, design, carry out, and analyze experiments that focus on sedimentary processes.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITES

a. 4th year standing

COURSE CONTENT/ OUTLINE

a. An introduction to the History of Sedimentology and its Applications
b. Origin of Clastic Sediments
c. Grain Characteristics
d. Fluid Flow
e. Sediment Transport and Deposition

f. Wave Dynamics
g. Sedimentary Structures
h. Siliciclastic Sedimentary Rocks
i. Carbonate Sedimentary Rocks
j. Facies
k. Continental Environments
l. Marginal-Marine Environments
m. Siliciclastic Marine Environments
n. Carbonate and Evaporite Environments

EQUIPMENT AND FACILITIES

a. Computer
b. LCD projector
c. Internet access
d. Exposure trips

27. SEISMOLOGY

COURSE DESCRIPTION

The course looks into the nature and origin of seismic events and the methods and theoretical underpinnings of seismology which include elastic wave propagation, reflection / refraction and transmission, surface waves, earth structures and seismic sources. A review of the different modern analytical techniques is included. The course incorporated details on the physical properties of earth materials and the formulation of deformation and stress.

COURSE / LEARNING OBJECTIVES

At the end of the course, the students are expected to have a better understanding of the principles behind the propagation of reflected and refracted waves in layered media, the processing and interpretation of seismic reflection and refraction data with applications to petroleum exploration, engineering properties for structures and geological hazard assessment.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITES

a. 4th year standing
b. Geophysics

COURSE CONTENT/ OUTLINE

a. Stress and Strain
b. Seismic Wave Equation and Solutions
c. Surface Waves

d. Earthquake Magnitude
e. Waveform Modeling
f. Synthetic Seismograms

EQUIPMENT AND FACILITIES

a. Computer
b. LCD projector
c. Internet access
d. Laboratory and field equipments for Seismology

28. URBAN GEOLOGY

COURSE DESCRIPTION

The course introduces the student to the concepts and techniques of geology as applied to planning, development, and construction of public and private structures in urban communities. The geologic conditions and processes that affect the urban environment are examined with emphasis on highly urbanized areas. Urban planning to avoid geological hazards is investigated.

COURSE / LEARNING OBJECTIVES

In this course, students would learn via lectures, reading assignments and videos about the geologic processes, hazards and resources which affect the urban environment. At the end of the course, the students would be able to appreciate the significance of regional and local geological features and processes in land use.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITE

a. 4th year standing

COURSE CONTENT/ OUTLINE

a. Population and urbanization
b. Construction and the environment
c. Volcanoes
d. Earthquakes
e. Flooding
f. Coastal hazards
g. Mass wasting
h. Natural resources (water, minerals and ore, energy, alternatives)
i. Global climate change

EQUIPMENT AND FACILITIES

a. Computer

b. LCD projector
c. Internet access
d. Exposure trips

29. VOLCANOLOGY

COURSE DESCRIPTION

The course offers a well rounded understanding of volcanic activity and the hazards associated with the different types of eruptions. Emphases are on the physical and chemical processes that take place within volcanoes and the methods used to study them. It also looks into the causes of volcanic activity with studies on geochemistry and experimental petrology interrelated to the generation of lavas. The analysis of volcanic eruption processes, the Interpretation of volcanic deposits in the evaluation of volcanic hazards, risk, and geologic history are also studied. This course may include a term paper, and reading/discussion of scientific papers on volcanoes. Field trips to classic volcanic settings could be arranged to observe, record, and analyze volcanic deposits in the evaluation of volcanic hazards, risk, eruption processes, and geologic history.

COURSE / LEARNING OBJECTIVES

The students will be able to study the physical properties of magmas, the eruptive mechanisms, volcanic products, and the relationship between volcanism and tectonism. The course is designed to introduce the student to the diversity of volcanism and its deposits within the geologic record.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITES

a. 3rd year standing

COURSE CONTENT/ OUTLINE

a. Introduction to magmas
b. Magma physical properties
c. Generation, rise and storage of magmas
d. Lava flows and characteristics
e. Craters and calderas
f. Eruptive mechanisms
g. Eruptive styles: Hawaiian, Surtseyan, Strombolian eruptions
h. Volcanic domes; pyroclastic cones
i. Volcanic cones
j. Airfall pyroclastic (Tephra) deposits
k. Peléean, Plinian, Vulcanian eruptions
l. Pyroclastic flow deposits

m. Pyroclastic surge deposits; lahars

EQUIPMENT AND FACILITIES

a. Computer
b. LCD projector
c. Internet access
d. Exposure trips
e. Field and sampling equipments

III. COURSE SPECIFICATIONS OF NON-GEOLOGY ELECTIVES

1. FLUID MECHANICS

COURSE DESCRIPTION

The course introduces the student to the different properties of fluids; fluid statics and kinematics; forces, energy and momentum in fluid flow; fluid flow in closed and open channels; and fluid measurements. The course includes stress and strain rate descriptions, fluid statics, use of differential and finite control volume analysis with continuity, momentum, and energy equations, Bernoulli and Euler equations, vorticity, potential flow, incompressible viscous flow using Navier-Stokes equations, dimensional analysis, pipe flow, boundary layers, separation and introduction to turbulence.

COURSE / LEARNING OBJECTIVES

After the course, the students are expected to have learned to use control volume analysis to develop basic equations and to solve problems. This would provide students the opportunity to understand and use differential equations to determine pressure and velocity variations in internal and external flows. Provide also the ability to understand the concept of viscosity and where viscosity is important in real flows, learn to use equations in combination with experimental data to determine losses in flow systems and learn to use dimensional analysis to design physical or numerical experiments and to apply dynamic similarity.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITE

a. 4^{th} year standing

COURSE CONTENT/ OUTLINE

a. Fluid Statics
b. Conservation of mass and momentum

c. Bernoulli equation
d. Equations of motion in integral form
e. Equations of motion in differential form
f. Kinematics
g. Potential flow
h. Dimensional analysis
i. Viscous flows, exact solutions, pipe flow
j. Laminar boundary layers
k. Boundary layer solution methods
l. Turbulence

EQUIPMENT AND FACILITIES

a. Computer
b. LCD projector
c. Internet access
d. Laboratory facilities related to Fluid Mechanics

2. MATERIALS SCIENCE

COURSE DESCRIPTION

The course introduces the student to the structure and composition of materials, their properties and behavior in service environments. These materials include metals, polymers, ceramics and composite materials. Studies of industrial minerals are included as they are used in the industry. This would include the processing of raw materials for optimal use as abrasives, ceramics and construction materials, for electronic and optical uses, as fillers, filters and absorbents, gem materials, glass-raw materials, mineral pigments and refractories. Also induced are well-drilling fluids.

COURSE / LEARNING OBJECTIVES

It is expected that after the course, the students would be familiar to the different properties of solid materials, including metals, ceramics, plastics, and semiconductors, as well as the properties of solid materials from atomic and macroscopic points of view.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITE

a. 4th year standing

COURSE CONTENT/ OUTLINE

a. Introduction to materials science
b. Electronic structure of atoms
c. Crystallography and diffraction

d. Solid solutions and crystal imperfections
e. Phase diagrams
f. Optical and electron microscopy / Scanned probe microscopy
g. Solidification, grain structure and texture
h. Solid diffusion
i. Processing of metals
j. Stress and strain, mechanical testing
k. Plastic deformation in metals, recovery and recrystallization
l. Strengthening of metals by cold work, solute atoms and grain boundaries
m. Fracture and fatique
n. Creep and stress rupture
o. Common engineering alloys
p. Ceramics, their structure, processing and properties / Glasses
q. Corrosion, electrochemistry, types of corrosion / Oxidation
r. Electrical properties, the energy band model of metals, semiconductors & insulators
s. Magnetic materials, permeability, susceptibility and six types of magnetism
t. Polymers and composite materials

EQUIPMENT AND FACILITIES

a. Computer
b. LCD projector
c. Internet access
d. Laboratory facilities related to Materials Science

3. BUSINESS MANAGEMENT

COURSE DESCRIPTION

The course reviews the considerations faced by entrepreneurs planning to establish and manage a business venture. It includes discussions on the legal forms of ownership, financial planning and resources, and the basic considerations in operations and control. The course puts emphasis on the opportunities and challenges of managing a business.

COURSE / LEARNING OBJECTIVES

Students will learn about management, what managers do, and the skills necessary to become a successful manager, whether as supervisor or executive. It is expected that students will develop an understanding of the complexity of interdependence that leads to the establishment of more businesses likely to join those already in existence. Students will learn contemporary business concepts, how a business is formed and why management is the key ingredient to business success.

Students will also be able to understand business terminologies and the importance of social responsibility in business operations. Students will be

exposed to the ethical issues surrounding the ownership and operation of a business venture. At the end of the course, they should be able to expand their leadership skills and abilities, and obtain an awareness of the many activities, problems, and decisions involved in management.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITE: None

COURSE CONTENT/ OUTLINE

a. Introduction to Management
b. Manager as Leader
c. Management Functions and Decision Making
d. Planning and Organizing
e. Implementing and Controlling
f. Human Resource Planning
g. Employee and Organizational Development
h. Organizational Communication

EQUIPMENT AND FACILITIES

a. Computer
b. LCD projector
c. Internet access
d. Laboratory facilities related to Materials Science

4. ECONOMICS

COURSE DESCRIPTION

Economics is an important tool used in a wide range of disciplines including law, public policy, health, banking, business, forestry, wildlife management, and agriculture. Economists typically explore economic questions within the confines of an economic model. In this course, the core concepts of modern economics are introduced. As an introductory course, the fundamental microeconomic principles are initially discussed followed by the macroeconomic concepts. Without a good foundation in micro and macroeconomics, the development of certain analytic tools and skills are difficult to relate directly to real world economic problems. The course introduces the students to the basic concepts of supply & demand, fiscal/monetary policy, trade unionism, economic development, entrepreneurship and the global economy.

COURSE / LEARNING OBJECTIVES

Students who successfully complete the course should have a better understanding of economics and the modern economy in general. They are expected to be equipped with new tools abilities to analyze and

interpret contemporary economic policy issues. Also by the end of the course, the students will have a better understanding of basic economic concepts, theories and principles and be able to effectively participate in the society as citizens, producers and consumers.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITE: None

COURSE CONTENT/ OUTLINE

a. Economic Systems
b. Microeconomics
c. Macroeconomics
d. Demand and Supply
e. Market Structures
f. Entrepreneurship
g. Taxation
h. Deficit Spending/Keynesianism
i. Gross Domestic Product
j. Unemployment/Inflation/Deflation
k. International Economics

EQUIPMENT AND FACILITIES

a. Computer
b. LCD projector
c. Internet access

5. MARINE SCIENCE

COURSE DESCRIPTION

Marine science is integrative among four scientific sub-disciplines: biological, chemical, geological, and physical oceanography. In order to understand the oceans, one must first know the fundamental concepts within each of the sub-disciplines. This course provides an introduction to the flora and fauna of the marine environment. It is designed as an introductory marine biology course. Selected groups of marine organisms will be studied with an objective of understanding biological principles and processes that are basic to all life forms in the sea. The ocean's role in our climate and weather will also be discussed as well as the importance of ocean currents and upwelling.

COURSE / LEARNING OBJECTIVES

By the end of the course, the students should have understood the principles underlying marine science. They should be able to relate the information learned to recent oceanographic discoveries, current issues,

and environmental problems. They should also have a clearer definition of the field (of marine science) and the wonderful opportunities that exist within it.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITE: None

COURSE CONTENT/ OUTLINE

a. Introduction and history of Marine Science
b. Plate tectonics
c. Continental margins and ocean basins
d. Sediments
e. Ocean structure
f. Seawater chemistry
g. Ocean and atmospheric circulation
h. Introduction to Primary Production/Biogeochemical cycles
i. Waves and tides
j. Coasts and coastal processes
k. Oceans and climate change

EQUIPMENT AND FACILITIES

a. Computer
b. LCD projector
c. Internet access

6. ORGANIC CHEMISTRY

COURSE DESCRIPTION

This course studies the chemistry of carbon compounds and their properties, structures and reactions. It puts emphasis on aliphatic and aromatic compounds, which in conjunction with selected experiments, gives an understanding of the mechanisms of organic reactions.

COURSE / LEARNING OBJECTIVES

At the end of the course, each student should be able to discuss the bonding properties of carbon, appreciate the use of theories (models) of varying complexity to rationalize chemical structure and reactivity, explain the relationship between structure and physical and chemical properties, explain in several ways how the vast amount of information in the field of organic chemistry be organized, explain the important role of organic chemistry in life, both biological and economical and solve problems in a systematic and logical manner.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITE

a. General Chemistry

COURSE CONTENT/ OUTLINE

a. Chemical Bonding and Structure
b. Acids and bases
c. Alkenes
d. Stereochemistry
e. Alkyl halides, alcohols, glycols, epoxides, ethers, thiols and sulfides
f. Infrared spectroscopy and mass spectrometry
g. Nuclear Magnetic Resonance Spectroscopy
h. Alkynes
i. Benzene and Aromaticity
j. Aryl halides, vinylic halides and phenols
k. Aldehydes and ketones
l. Carboxylic acids and nitriles
m. Enolate ions, enols and unsaturated carbonyl compounds
n. Amines
o. Carbohydrates
p. Amino acids

EQUIPMENT AND FACILITIES

a. Computer
b. LCD projector
c. Internet access

7. PHYSICAL CHEMISTRY

COURSE DESCRIPTION

This is an introductory course to chemical thermodynamics and chemical kinetics with applications to gases, solutions and phase equilibria. It provides firm foundation for understanding the physical principles that govern chemical and biological systems. It also provides the theoretical basis for explaining and interpreting chemical systems focusing on the energy and time involved as these systems change. The course will attempt to understand many of the basic principles and phenomena of chemical systems in equilibrium, including gases and their properties, chemical thermodynamics, phase relationships and diagrams, chemical equilibrium, and electrochemistry.

COURSE / LEARNING OBJECTIVES

The students are expected, by the end of the course, to have understood the theoretical and practical aspects of physicochemical methodologies in

chemistry concerning specifically on substance structure, the energy and kinetic aspects of various physical and chemical processes, and on the conditions of equilibrium.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITE

a. General Chemistry

COURSE CONTENT/ OUTLINE

a. Thermodynamics
b. Kinetic theory
c. Solution and phase equilibria
d. Chemical equilibria
e. Photochemistry
f. Chemical kinetics

EQUIPMENT AND FACILITIES

a. Computer
b. LCD projector
c. Internet access

8. STATISTICS

COURSE DESCRIPTION

This course is intended to introduce students to the basic concepts of study design, data collection, data analysis and statistical inference. Topics include graphical and numerical descriptive statistics, probability distributions for simple experiments and random variables, sampling distributions, confidence intervals and hypothesis testing for the mean and proportion in the one sample case. The emphasis is on developing statistical reasoning skills and concepts.

COURSE / LEARNING OBJECTIVES

The objectives of this course are for students to develop an understanding of the basic concepts of probability and statistics and to help students be informed and critical readers on various quantitative arguments. By the end of the course, the students should have sufficient skills to enable them to apply simple statistical techniques to various problems.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITE: None

COURSE CONTENT/ OUTLINE

a. Statistical Methods
b. Data collection strategies
c. Descriptive statistics
d. Probability distributions
e. Simulation of random variables
f. Sampling distributions
g. Estimation and hypothesis testing
h. Regression
i. Chi-Square test for categorical data
j. Simple design of experiments
k. Nonparametric methods
l. Statistical software

EQUIPMENT AND FACILITIES

a. Computer
b. LCD projector
c. Internet access
d. Statistical softwares

IV. COURSE SPECIFICATIONS OF REQUIRED NON-GEOLOGY COURSES

1. ENGINEERING DRAWING

COURSE DESCRIPTION

The course introduces the student to basic sketching and drawing; orthographic and multi-view projections as well as to Computer Aided Designs.

COURSE / LEARNING OBJECTIVES

The course aims to provide students the ability to communicate information by graphical means and to develop an interest in engineering drawing and graphical communication at intermediate level. This will be achieved through the ability to visualize and understand spatial relationships; the ability to apply geometrical principles and to select and use appropriate graphical methods for communicating information, analyzing engineering problems and representing design concepts.

CREDITS: 2 units

NUMBER OF HOURS: 6 hours per week

PREREQUISITES: None

COURSE CONTENT/ OUTLINE

a. Plane geometry
b. Solid geometry
c. Drawing
d. Graphical Communication

EQUIPMENT AND FACILITIES

a. Laboratory facilities related to engineering drawing
b. Computer
c. LCD projector
d. Internet access

2. SURVEYING METHODS

COURSE DESCRIPTION

The course introduces the student to the different principles and methods of surveying; traditional and modern survey techniques as well as instrumentation which include a detailed discussion on Global Positioning Systems (GPS). The course looks into studies on the shape of the earth; reference ellipsoids; positioning on earth surface; map projections scale and distortion; 2-d and 3-d coordinate transformation; model of measurement; error and error propagation; mapping and map updating techniques.

COURSE / LEARNING OBJECTIVES

The course aims to provide students an understanding of basic principles of surveying and mapping techniques both theoretical and practical aspects.

CREDITS: 2 units

NUMBER OF HOURS: 2 hours per week

PREREQUISITES: None

COURSE CONTENT/ OUTLINE

a. Definition of Surveying
b. History of Surveying
c. Geodetic and Plane Surveying
d. Shape of Earth Surface
e. Geoid, Reference Ellipsoid and Spheroid
f. Coordinate Systems, Datum
g. Theory of Measurements and Errors
h. Measurement of Horizontal Distances and Angles
i. Horizontal and Vertical Positioning Methods

j. Three-dimensional Positioning by GPS
k. Introduction to Map Projections
l. Coordinate Transformation
m. Mapping & Map Updating Techniques
n. Pacing and reconnaissance
o. Introduction to theodolite & Measurements of horizontal and vertical angles
p. Traversing
q. Introduction to leveling

EQUIPMENT AND FACILITIES

a. Computer
b. LCD projector
c. Internet access
d. Laboratory facilities related to surveying
e. Exposure trips

V. COURSE DESCRIPTIONS FOR OPTIONAL COURSES

1. APPRENTICESHIP, INTERSHIP OR ON-THE-JOB TRAINING (OJT)

COURSE DESCRIPTION

This course (program) would provide students the necessary training skills and competencies that the industry requires. This program (with the involvement of industry) will provide the students a transition work experience from school to industry. Activities under this collaborative program include the use of industry and school laboratories and facilities for research with lectures by specialists on topics specific to the needs of industry.

COURSE / LEARNING OBJECTIVES

By the end of the course, students would have gained the necessary oral and written communication skills, computer skills, conceptual and analytical abilities, specific technical skills and inter personal skills. It is expected that with this hands-on training, the students will have the knowledge and competencies the industry needs with students benefiting through possible employment.

CREDITS: 3 units

NUMBER OF HOURS: 9 hours per week

PREREQUISITE

a. 4th year standing

COURSE CONTENT/ OUTLINE

a. On-the-job training within the facilities of the company
b. Lectures by industry and academe specialists

EQUIPMENT AND FACILITIES

a. Industry (and school) facilities and laboratories

2. UNDERGRADUATE THESIS / RESEARCH PAPER

COURSE DESCRIPTION

The course looks into the fundamentals of research design, data gathering, and technical writing. Emphasis is the preparation of a manuscript addressing a specific geological problem. The course incorporates the application of geologic concepts, principles, and methods on the solution of a simple geologic problem on an area chosen by and worked on independently by the student. The output is a submission of a formal study proposal and a bound thesis copies.

COURSE / LEARNING OBJECTIVES

At the end of the course, students are expected to be competent in basic research design and technical writing.

CREDITS: 3 units

NUMBER OF HOURS: 3 hours per week

PREREQUISITE

a. 4^{th} year standing

COURSE CONTENT/ OUTLINE

a. Research design
b. Technical Writing

EQUIPMENT AND FACILITIES

a. Computer
b. LCD projector
c. Internet access
d. Exposure trips

ANNEX II

LIST OF SUGGESTED TEXTBOOKS AND REFERENCES

I. SUGGESTED TEXTBOOKS AND REFERENCES FOR REQUIRED GEOLOGY COURSES

1. COMPUTER APPLICATIONS IN GEOLOGY

a. Applicable software manuals and reference books

2. FIELD GEOLOGY

a. Compton. 1985. *Geology in the Field.* John Wiley and Sons. New York
b. Aurelio & Pena. 2006. *Geology of the Philippines: MGB (Available only in CD)*
c. Spencer. 2000. *Geologic maps*

3. GEOCHEMISTRY

a. Anderson GM & Crerar DA. 1993. *Thermodynamics in Geochemistry- the Equilibrium Model.* Oxford Press. NY
b. Aswathnarayana U. 1985. *Principles of Nuclear Geology*, Oxford Press. in Faul H (Ed.), Nuclear Geology, Wiley 1954
c. Faure G. 1991. *Inorganic Geochemistry.* Prentice Hall
d. Faure G. 1998. *Principles and Applications of Geochemistry*
e. Fletcher P. 1993. *Chemical Thermodynamics for Earth Scientists.* Longman Scientific and Technical. London
f. Glasstone S. 1947. *Thermodynamics for Chemists.* East-West
g. Krauskopf KB. 1979. *Introduction to Geochemistry*
h. Krauskopf KB. 1994. *Introduction to Geochemistry.*Mc Graw Hill
i. Krauskopf KB & Bird DK. 1995. *Introduction to Geochemistry*, McGraw-Hill International edition
j. Mason B. 1982. *Principles of Geochemistry.* Wiley Eastern
k. Nordstrom DK & Munoz JL. 1985. *Geochemical Thermodynamics.* The Benjamin/ Cummings Publishing Co., Inc.
l. Wood BJ & Fraser DG. 1977. *Elementary thermodynamics for geologists.* Oxford

4. GEOLOGY OF THE PHILIPPINES AND SOUTHEAST ASIA

a. Aurelio M. *Tectonics of the Philippines Revisited.* Geol. Soc. Phil. vol. 55
b. *Geology & Mineral Resources of the Philippines.* Mines and Geosciences Bureau
c. *Geology of the Philippines.* Mines and Geosciences Bureau
d. Hutchison C. *Geological Evolution of Southeast Asia.* Geological Society of Malaysia
e. Lectures from several local and international seminars and conferences

5. GEOLOGY, MINING AND ENVIRONMENTAL LAWS, ENERGY POLICIES AND ETHICS

a. Buck S. 1996. *Understanding Environmental Administration and Law.* Island Press

b. Ferry S. 2001. *Environmental Law: Examples and Explanations.* 2nd edition. Aspen Law and Business
c. Hartwick JM & Olewiler ND. 1986. *The Economics of Natural Resource Use.* "Chapter 8 Nonrenewable Resources Use: The Theory Of Depletion." Harper and Row. New York
d. Moya OL & Fono AL. 2001. *Federal Environmental Law: The Users Guide.* 2nd edition. West Group
e. Percival RV, Miller AS, Schroeder CH & Leape JP. 2000. *Environmental Regulation: Law, Science and Policy.* Aspen Law and Business
f. Plater, Abrams, Goldfarb & Graham. 1998. *Environmental Law and Policy: Nature, Law and Society.* West Group
g. Revesz RL. 1997. *Foundations of Environmental Law and Policy.* Oxford University Press

6. GEOMORPHOLOGY

a. Ahnert F. 1996. *Introduction to Geomorphology*
b. Ritter DF, Kochel RC & Miller JF. 2002. *Process Geomorphology*
c. Summerfield MA. 1991. *Global Geomorphology*

7. GEOPHYSICS

a. Fujita & Sleep. *Principles of Geophysics.* Blackwell Science
b. Tucker. *Global Geophysics.* Elsevier
c. Sharma. *Geophysical Methods Geology.* Elsevier
d. Fowler. *The Solid Earth.* Cambridge UP
e. Garland. *Introduction to Geophysics.* Saunders
f. Telford. *Applied Geophysics.* Cambridge U.P.
g. Parasnis. *Principles of Applied Geophysics.* Chap-Hall
h. Keary. *Introduction to Geophysical Exploration.* Blackwell

8. MINERALOGY

a. Buerger. *Elementary Crystallography*
b. Deer, Howie & Zussman. *An Introduction to the Rock-forming Minerals*
c. Evans. *Crystal Chemistry*
d. Hurlbut and Klein. *Dana's Manual of Mineralogy*
e. The Mineral Gallery: http://mineral.galleries.com:/scripts/search.exe
f. Philips. *Crystallography*
g. Bloss. *An Introduction to the Methods of Optical Crystallography*
h. Craig and Vaughan. *Ore microscopy and Ore petrography*
i. Kerr. *Optical Mineralogy*

9. PALEONTOLOGY

a. Beerbower JR. *Search for the Past: An Introduction to Paleontology.* Prentice-Hall, Inc. New Jersey
b. Black RM. *The Elements of Paleontology.* Cambridge University Press. Cambridge
c. Clarkson ENK. *Invertebrate Paleontology and Evolution*
d. Haynes JR. 1981. *Foraminifera.* John Wiley
e. Kinney FK. *Exercises in Invertebrate Paleontology.* Blackwell Scientific Publication, Inc. Boston

f. Mintz LW. *Historical Geology: The Science of a Dynamic Earth.* Charles E. Merrill Publishing Company. Ohio
g. Moore RC. *Treatise on Invertebrate Paleontology.* The Geological Society of America and the University of Kansas Press. 30 vols
h. Moore RC, Lalicker, CG & Fischer, AG. *Invertebrate Fossils.* McGraw-Hill Book Co. Inc. New York
i. Murray JW. 1985. *Atlas of Invertebrate Macrofossils.* Longman
j. Prothero DR. *Bringing Fossils to Life.* McGraw-Hill
k. Rays DM and Stanley SM. *Principles of Paleontology.* WH Freeman and Co. New York
l. Shrock RR and Twenhofel WH. *Principles of Invertebrate Paleontology.* McGraw-Hill Book Company, Inc
m. Stanley SM. *Earth and Life Through Time.* W.H. Freeman and Co. New York
n. Woods H. 1966. *Palaeontology Invertebrate.* International Book Bureau

10. PETROLOGY

a. Blatt. *Sedimentary Petrology*
b. Folk. *Petrology of Sedimentary Rocks*
c. Huang. *Petrology*
d. Pettijohn. *Sedimentary Rocks*
e. Spry. *Metamorphic Textures*
f. Schmincke. *Pyroclastic Rocks*
g. Tucker. *Sedimentary Petrology*
h. Tucker. *Igneous and Metamorphic Petrology*
i. Leeder. 2003. *Sedimentology and sedimentary basins: From turbulence to tectonic*
j. Boggs. 1995. *Sedimentology and Stratigraphy*
k. Ehlers. 1972. *The Interpretation of Geological Phase Diagrams*
l. Winter. 2001. *An Introduction to Igneous and Metamorphic Petrology*
m. Williams, Turner and Gilbert. *Petrography: An Introduction to the Study of Rocks in thin Section*

11. PRINCIPLES OF GEOLOGY

a. Chernicoff and Fox. 2003. *Essentials of Geology.* 3rd Edition
b. Craig, Vaughn, and Skinner. 2001. *Resources of the Earth: Origin, Use, and Environmental Impact.* 3rd Edition.
c. Gilluly J, Waters A and Woodford A. 1975. *Principles of Geology*

12. RESOURCE GEOLOGY

a. Bates and Jackson. *Our Modern Stone Age*
b. Coal Association of Canada. 1990. *Coal Information Package*
c. Craig JR, Vaughan DJ & Skinner BJ. 1988. *Resources of the Earth.* Englewood Cliffs. NJ Prentice Hall
d. Energy, Mines and Resources, Canada. 1987. *The mineral and metals policy of the Government of Canada*
e. Evans AM. 1993. *Ore Geology and industrial minerals.* Blackwell
f. Freese B. *Coal: A human history*
g. Glennie K (ed). 1998. *Petroleum Geology of the North Sea.* 4th edition. Blackwell

h. Petroleum Resources Foundation.1985. *Our Petroleum Challenge: The New Era.* 3rd edition

13. SEMINAR IN GEOLOGY

a. To be arranged depending on selected topics.
b. Journal articles

14. STRATIGRAPHY AND HISTORICAL GEOLOGY

a. Dunbar CO & Rodgers J. *Principles of Stratigraphy.* John Wiley & Sons, Inc
b. *Geology and Mineral Resources of the Philippines.* Bureau of Mines and Geosciences
c. Grandstein FM, Ogg JG & Smith AG. *A Geologic Time Scale.* Cambridge University Press. UK
d. Mintz LW. *Historical Geology: The Science of a Dynamic Earth.* Columbus, Ohio. Charles E. Merrill Publishing Co
e. *North American Commission on Stratigraphic Nomenclature (NACSN).* North American Stratigraphic Code. AAPG Bulletin. vol. 67
f. Prothero DR. 1990. *The Rock Record.* Wilt. Freeman Series in the Geological Sciences. Ray Siever edition
g. Pena C, et al. *Philippine Stratigraphic Guide.* Journal Geological Society of the Philippines, vol. 56
h. Salvador A. *International Stratigraphic Guide: A Guide to Stratigraphic Classification, Terminology and Procedure.* International Subcommission of Stratigraphic Classification of IUGS International Commission on Stratigraphy, Co-published by IUGS and GSA, Inc
i. Schenck NG & Muller SW. *Stratigraphic Terminology.* Geological Society America Bulletin. vol. 52
j. Schoch RM. *Stratigraphy: Principles and Methods.* VanNostrand Reinhold. New York
k. Levin HL. 2006. *The Earth Through Time.* 8th edition
l. Port JM & Carlson RJ. *Historical Geology: Interpretations and Applications.* 6th edition
m. Stanley SA. 2005. *Earth System History.* 2nd edition. WH Freeman and Company. New York
n. Selley RC. *Ancient Sedimentary Environments: And Their Sub-Surface Diagnosis.* Nelson Thornes (Publishers) Ltd

15. STRUCTURAL GEOLOGY AND TECTONICS

a. Davis & Reynolds. *Structural Geology of Rocks and Regions.* Wiley
b. Ghosh SK. 1993. Structural Geology – Fundamentals and modern *development.* Pergamon
c. Hatcher and Hopper. *Laboratory Manual for Structural Geology*
d. Hobbs BE, Means WD & Williams PF. 1976. *An outline of structural geology.* John Wiley
e. Hobbs, Pearce & Williams. *Introduction to Structural Geology*
f. Marshak & Mitra. *Basic Methods of Structural Geology*
g. Paor D. 1996. *Structural Geology and Personal Computer.* Pergamon
h. Ragan. 1985. *Structural geology - An Introduction to Geometrical Techniques.* John Wiley

i. Ramsay JG. 1967. *Folding and fracturing of rocks.* McGraw Hill
j. Ramsay & Huber. *Techniques of Modern Structural Geology.* Academic Press
k. Rowland SM & Duebendorfer EM. 1994. *Structural Analysis and Synthesis.* Pergamon
Turner FJ & Weiss LE. 1963. *Structural Analysis of Metamorphic Tectonites.* McGraw Hill
l. Twiss & Moores. *Structural Geology*
m. Others: Any available in the web

II. SUGGESTED TEXTBOOKS AND REFERENCES FOR GEOLOGY ELECTIVE COURSES

1. APPLIED GEOCHEMISTRY

a. Evans AM. 1995. Introduction to Mineral Exploration. Blackwell Science. Oxford
b. Hawkes HE & Webb JS. 1980. Geochemistry in Mineral Exploration. Harper & Row

2. APPLIED GEOPHYSICS

a. Fowler CMR. 1990. *Solid Earth: An Introduction to Global Geophysics.* Cambridge University Press
b. Robinson ES & Coruh C. 1988. *Basic Exploration Geophysics.* John Wiley & Sons
c. Telford WM, Geldart LP & Sheriff RE. 1990. Applied Geophysics. Cambridge University Press

3. ENVIRONMENTAL GEOLOGY

a. Apello CAJ & Postma D. 1993. Geochemistry, Groundwater and Pollution.
b. Balkema Aswathnarayana U. Geoenvironment. Balkema
c. Keller E. Introduction to Environmental Geology
d. Fleet MF (ed). 1984 Environmental Geochemistry (short course handbook). Mineralogical Association of Canada, vol. 10
e. Montgomery CW. Environmental Geology, WCB/McGraw-H.U

4. GEODYNAMICS AND TECTONICS

a. Condie KC. 1989. *Plate Tectonics and Crustal Evolution.* 3rd edition. Pergamon. Oxford Press
b. Fung YC. 1969. *A first course in continuum mechanics.* Prentice Hall
c. Jaeger JC. 1962. *Elasticity, fracture and flow with engineering and geological applications.* Methuen & Co.
d. Kearey P & Vine FJ. 1996. *Global Tectonics.* Blackwell Science. Oxford
e. Turcotte DL & Schubert J. *Geodynamics.* 2nd edition. Cambridge University Press. , New York
f. Windley BF. 1977. *The Evolving Continents.* Wiley
g. Valdiya KS. 1984. *Aspects of Tectonics-Focus on South Central Asia.* Tata McGraw-Hill

5. GEOHAZARDS

a. Haddow GD and Bullock JA. 2003. *Introduction to Risk Management.* Butterworth Heinemann Publishing
b. Amdahl G. 2001. *Disaster Response: GIS for Public Safety.* ESRI Publishing
c. Bolt BA. *Earthquakes.* 5th edition
d. Fisher RV et al. *Volcanoes: Crucibles of Change*
e. Coch NK. 1995. *Geohazards, Natural and Human*, 1st edition. Prentice-Hall Inc.

6. GEOSTATISTICS

a. Cooley WW & Lohnes PR. 1971. *Multivariate data analysis.* John Wiley and Sons
b. Creighton JHC. 1994. *First course in probability models and statistical inference.* Springer-Verlag
c. Davis JC. 1986. *Statistics and data analysis in geology.* John Wiley
d. Johnson RA & Wichern DW. 1982. *Applied multivariate statistical analysis.* Prentice Hall Inc. New Jersey
e. Morrison DF. 1967. *Multivariate statistical methods.* McGraw-Hill
f. Pitman J. 1993. *Probability.* Springer Verlag (also Narosa Publ.)
g. Spiegel MR. 1982. *Probability and Statistics.* Schaums Outline Series. Asian Student edition. McGraw-Hill Intl. Singapore.
h. Walpole RE & Myers RH. 1989. Probability and statistics for engineers and scientists. Macmillan Publ. Co.

7. GEOTECHNICAL ENGINEERING / ENGINEERING GEOLOGY

a. Ingebritsen SE & Sanford WE. *Groundwater in Geologic Processes.* Cambridge Univ. Press
b. Craig RF. 2004. *Soil Mechanics.* 7th edition
c. Coduto DP. 1999. *Geotechnical Engineering: Principles and Practices.* Prentice-Hall, Inc
d. National Research Council. *Rock fractures and fluid flow—Contemporary Understanding and Applications.* National Academic Press

8. GEOTHERMAL RESOURCES

a. Ellis AJ & Mahon WAJ. 1977. *Chemistry and Geothermal Systems.* Academic Press, Inc.
b. Economides MJ & Ungemach PO (eds). 1987. *Applied Geothermics.* John Wiley and Sons Ltd.
c. Goguel J. 1976. *Geothermics.* McGraw Hill
d. Rummel F, Kappelmeyer O & Herde OA. 1991. *Geothermal Energy.* GEO-Me Systeme GmbH, Bochum.
e. Rybach L and Muffler LJP (eds). 1981. *Geothermal Systems.* John Wiley and Sons Ltd. New York

9. GEOTHERMY

a. Economides MJ & Ungemach PO (eds). 1987. *Applied Geothermics.* John Wiley and Sons Ltd.

b. Ellis AJ & Mahon WAJ. 1977. *Chemistry and Geothermal Systems.* Academic Press, Inc.
c. Goguel J. 1976. *Geothermics.* McGraw Hill
d. Rummel F, Kappelmeyer O & Herde OA. 1991. *Geothermal Energy.* GEO-Me Systeme GmbH, Bochum
e. Rybach L and Muffler LJP (eds). 1981. *Geothermal Systems.* John Wiley and Sons Ltd., New York

10. HYDROGEOLOGY

a. Bedient & Huber. 1988. *Hydrology and Floodplain Analysis.* Addison Wesley Reading, Mass.
b. Bras RL. 1990. *Hydrology: An Introduction to Hydrologic Science.* Addison Wesley. Reading, Mass.
c. Chow V, Maidment D & Mays L. 1988. *Applied Hydrology.* McGraw-Hill
d. Eagleson PS. 1970. *Dynamic Hydrology.* McGraw-Hill, Inc. New York
e. Gleick PH. 1993. *Water in crisis: A guide to the world's freshwater resources.* Oxford University Press. New York/London.
f. Linsley, Jr RK, Kohler MA, & Paulhus JL. 1982. *Applied Hydrology.* McGraw-Hill, Inc. New York
g. Maidment D (ed). *Handbook of Hydrology*
h. Shiklomanov IA. 2001. *World water resources at the beginning of the 21st century.* UNESCO. International Hydrological Series.
i. Viessman Jr W, Lewis GL & Knapp JW. 1989. *Introduction to Hydrology.* Harper and Row. New York

11. IGNEOUS AND METAMORPHIC PETROLOGY

a. Bhaskar Rao B. 1986. *Metamorphic Petrology.* IBH & Oxford
b. Carmichael ISE, Turner FJ & Verhoogen J. 1974. *Igneous Petrology.* McGraw Hill
c. Cox KG, Bell JD & Pankhurst RJ. 1979. *Interpretation of Igneous Rocks.* George Ullen & Unwin
d. Philopotts AR. 1994. *Principles of Igneous and Metamorphic Petrology.* Prentice Hall
e. Wilson M. 1990. *Igneous Petrogenesis.* Unwin Hyman
f. Yardley BWD. 1989. *Metamorphic Petrology.* Longman

12. MARINE GEOLOGY

a. Anderson RN. *Marine Geology: A Planet Earth Perspective*
b. Ballard and Moore. *Photographic Atlas of the Mid-Atlantic Ridge Rift Valley*
c. Fowler CMR. *The Solid Earth: An Introduction to Global Geophysics*
d. Heezen B & Hollister C. *The Face of the Deep*
e. Kennett JP. *Marine Geology*
f. Kurekian KK. 1990. *Ocean.* Prentice Hall
g. Seabold E & Berger WH. 1982. *The Sea Floor.* Springer Verlag
h. Seibold E & Berger W. *The Sea Floor: An Introduction to Marine Geology*
Shephard FP. 1973. *Submarine Geology.* Harper and Row
i. The Open University Course Team. *The Ocean Basins: Their Structure and Evolution*

j. The Open University Course Team. *Ocean Chemistry and Deep Sea Sediments*

13. METALLIFEROUS DEPOSITS

a. Evans AM. 1993. *Ore Geology and Industrial Minerals - An Introduction.* Oxford Blackwell Scientific Publications. London
b. Guilbert JM & Park CF. 1986. *Geology of Ore Deposits.* Freeman WH
c. Hutchinson CS. 1983. *Economic Deposits and their Tectonic Setting.* McMillan Press. London.
d. Jensen ML & Bateman AL. 1979. *Economic Mineral Deposits.* Wiley
e. Wilson M. 1989. *Igneous Petrogenesis.* Unwin Hyman. London.

14. MICROPALEONTOLOGY

a. Bignot G. 1985. *Elements of Micropalaeontology.* Graham and Trotman
b. Haq BU & Boersma A (eds). 1978. *Introduction to Marine Micropaleontology.* Elsevier
c. Haynes JR. 1981. *Foraminifera.* John Wiley and Sons
d. Murray JW. 1991. *Ecology and Palaeoecology of Benthic Foraminifera.* Longman

15. MINERAL ECONOMICS

a. Annels. 1991. *Mineral Deposit Evaluation.* Chapman & Hall
b. Begg D et al. 1991. *Economics* (3rd or later editions). McGraw-Hill
c. Evans. 1995. *Introduction to Mineral Exploration.* Blackwell Science
d. Gentry DW & O'Neil TJ. 1984. *Mine Investment Analysis.* Society of Mining Engineers of AIME. New York
e. Gentry DW & O'Neil TJ, 1984. *Mine investment analysis.* American Institute of Mining, Metallurgical and Petroleum Engineers. New York
f. Hartman HL. 1992. *SME mining engineering handbook.* 2nd edition. Society of Mining Engineers of AIME
g. Kernot C. 1991. *Mining Equities: evaluation and trading.* Woodhead Publishing. Cambridge
h. Webster & Oliver. 2001. *Geostatistics for Environmental Scientists.* John Wiley & Sons

16. MINERAL RESOURCES OF THE PHILIPPINES

a. Evans AM. 1993. *Ore Geology and Industrial Minerals - An Introduction.* Oxford Blackwell Scientific Publ. London
b. Francis W. 1961. *Coal.* Edward Arnold Ltd.
c. Guilbert JM & Park CF. *Geology of Ore Deposits.* WH Freeman
d. Mines and Geoscience Bureau. *The Geology and Mineral Deposits of the Philippines*

17. MINING GEOLOGY

a. Boyd JW. 1985. *Fundamentals of Coal and Mineral Valuations.* Krehbiel. Cincinnati, OH
b. Chatterjee KK. 1993. *An Introduction to Mineral Economics.* Wiley Eastern

c. Gentry DW & O'Neil TG. 1984. *Mine Investment Analysis.* SME, Littleton, CO
d. Hartman HL. 1987. *Introduction to Mining Engineering.* John Wiley and Sons
e. Hartman HL (ed). 1992. *SME Mining Engineering Handbook.* SME Littleton. CO
f. Sinha RK & Sharma NL. 1993. *An Introduction to Mineral Economics.* Wiley Eastern
g. Thomas LJ. 1978. *An Introduction to Mining.* Methuen. Brisbane
h. William PC. 1987. *Exploration and Mining Geology.* 2nd edition. Wiley, New York

18. NON-METALLIFEROUS DEPOSITS

a. Aswathanarayana U. 1985. *Principles of Nuclear Geology.* Oxford Press
b. Francis W. 1961. *Coal.* Edward Arnold Ltd.
c. Other references prescribed by the lecturer

19. OPTICAL MINERALOGY

a. Bloss. *An Introduction to the Methods of Optical Crystallography*
b. Craig and Vaughan. *Ore microscopy and Ore petrography*
c. Deer, Howie and Zussman. *An Introduction to the Rock-forming Minerals*
d. Hurlbut and Klein. *Dana's Manual of Mineralogy*
e. Kerr. *Optical Mineralogy*
f. Nesse. *Introduction to Optical Mineralogy*
g. Ramdohr. *The Ore Minerals and Their Intergrowths*
h. Short. *Microscopic Determination of the Ore Minerals*
i. Troger. *Optical Determination of Rock-forming Minerals*
j. Winchell. *Elements of Optical Mineralogy*

20. ORE MICROSCOPY

a. Craig JR & Vaughan DJ. 1994. *Ore Microscopy and Ore Petrology.* John Wiley, 2nd edition
b. Galopin R & Henry NFM. 1972. *Microscopic Study of Opaque Minerals.* McCrone Research Associates Ltd. London
c. Ramdohr P. 1980. *The Ore Minerals and their Intergrowths.* Pergamon Press, Oxford
d. Stanton RL. 1972. *Ore Petrology.* McGraw Hill
e. Krauskopf KB & Bird DK. 1995. *Introduction to Geochemistry.* 3rd edition. McGraw-Hill

21. PETROGRAPHY

a. Blatt. *Sedimentary Petrology*
b. Boggs. 1995. *Sedimentology and Stratigraphy.* Prentice Hall, New Jersey
c. Ehlers. 1972. *The Interpretation of Geological Phase Diagrams.* Freeman. San Francisco
d. Folk. *Petrology of Sedimentary Rocks*
e. Leeder. 2003. *Sedimentology and sedimentary basins: from turbulence to tectonics.* Blackwell

f. Huang. *Petrology*
g. Pettijohn. *Sedimentary Rocks*
h. Spry. *Metamorphic textures*
i. Schmincke. *Pyroclastic Rocks*
j. Tucker. *Igneous and Metamorphic Petrology*
k. Williams, Turner & Gilbert. 1982. *Petrography: An introduction to the study of rocks in thin section*. Freeman. San Francisco
l. Winter. 2001. *An Introduction to Igneous and Metamorphic Petrology*. Prentice Hall

22. PETROLEUM GEOLOGY

a. Gluyas & Swarbrick. *Petroleum Geoscience*
b. Selley R. *Elements of Petroleum Geology*. 2nd edition.

23. PHOTOGEOLOGY AND REMOTE SENSING

a. Bonham C. 1984. *GIS for Geoscientists-Modelling with GIS*. Elsevier
b. Lattman LH & Ray RG. 1965. *Aerial photographs in field geology*. McGraw Hill
c. Lillesand TM & Kiefer RW. 1987. *Remote sensing and Image Interpretation*. John Wiley
d. Pandey SN. 1987. *Principles and Applications of Photogeology*. Wiley Eastern
e. Sabnis FF. 1978. *Remote sensing-Principles and Interpretation*. WH Freeman and Co.
f. Way DS. 1973. *Terrain Analysis*. N3/4-ITC Delft, The Netherlands. Mc Graw Hill

24. QUATERNARY GEOLOGY

a. Williams M, Dunkerley D, De Deckker P, Kershaw P, & Chappell J. *Quaternary Environments*. 2nd edition

25. SEDIMENTARY PETROLOGY

a. Pettijohn FJ. 1975. *Sedimentary Rocks*. 3rd edition. Harper & Row
b. Sengupta SM. 1994. *Introduction to Sedimentology*. Oxford & IBH
c. Tucker ME. 2001. *Sedimentary Petrology*. 3rd edition. Blackwell Science. Oxford.

26. SEDIMENTOLOGY

a. Allen JRL. 2001. *Physical Sedimentology*. Blackburn Press
b. Boggs, Jr S. 2001. *Principles of Sedimentology and Stratigraphy*. 3rd edition. Prentice Hall
c. Boggs, Jr S. 2006. *Principles of Sedimentology and Stratigraphy*. 4th edition Prentice Hall
d. Boudreau BP. 1997. *Diagenetic Models and their implementation*. Springer
e. Dyer KR. 1986. *Coastal and Estuarine Sediment Dynamics*. John Wiley & Sons
f. Middleton GV & Southard JB. 1984. *Mechanics of Sediment Movement*. SEPM short course. 2nd edition. Providence

27. SEISMOLOGY

a. Aki & Richards. *Quantitative Seismology: Theory and Methods.* vol. I and II
b. Shearer. *Introduction to Seismology*

28. URBAN GEOLOGY

a. Dominey-Howes D & Minos-Minopoulos D. 2004. Perceptions of hazard and risk on Santorini. *Journal of Volcanology and Geothermal Research.* 137(4). p285-310
b. Jibson RW. 2005. Landslide Hazards at La Conchita California. *U.S. Geological Survey Open-File Report.* 2005-1067. 12 pp
c. Motavalli J, Abhat D, Dineen S, Jones T, Sanborn R & Slomkowski K. 2005. Cities of the Future. *E Magazine: The Environmental Magazine.* 16(5). p26-36
d. Pinsker LM. 2002. The Urban Evolution of U.S. Earthquake Monitoring. *Geotimes.* 47(10). p 20-26
e. Young RS, Cleary WJ, Bush DM, Coburn AS & Pilkey OH. 1999. Hurricanes Dennis and Floyd: Coastal effects and policy implications. *GSA Today.* 9(12). p. 1-6

29. VOLCANOLOGY

a. Bardintzeff J M & McBirney A R. Volcanology. 2nd edition. Jones and Bartlett Publishers. Sudbury, MA
b. Cas & Wright. Volcanic Successions. Allen and Unwin. New York
c. Fisher & Schmincke. Pyroclastic Rocks. Springer-Verlag. New York
d. MacDonald. Volcanoes. Prentice Hall. New Jersey
e. Rittman. Volcanoes and their activity. John Wiley and Sons. New York.
f. Various published papers from journals and proceedings

III. SUGGESTED TEXTBOOKS AND REFERENCES FOR NON-GEOLOGY ELECTIVES

1. FLUID MECHANICS

a. Smits AJ. 2000. *A Physical Introduction to Fluid Mechanics.* John Wiley & Sons
b. Van Dyke M. *An Album of Fluid Motion.* Parabolic Press

2. MATERIALS SCIENCE

a. Evans AM. 1994. *Ore-Geology and Industrial Minerals - An Introduction.* Blackwell Scientific Publications
b. Lefond SJ (ed.). 1975. *Industrial Minerals and Rocks.* AIME
c. Smith WF & Hashemi J. *Foundations of Materials Science and Engineering.* 4th edition. McGraw Hill

3. BUSINESS MANAGEMENT

a. Longenecker JG, Moore CW, Petty JW and Palich LE, 2006, *Small Business Management - An Entrepreneurial Emphasis*, 13th edition

4. ECONOMICS

a. Hall R and Taylor J, 1993 *Macroeconomics*, 4th edition Edition

5. MARINE SCIENCE

a. Sumich J. 1999, *An Introduction to the Biology of Marine Life*, WCB/McGraw Hill
b. Pinet PR. 2000, *Invitation to Oceanography,* 2nd edition, Jones and Bartlett Publishers, Sudbury, Massachusetts

6. ORGANIC CHEMISTRY

a. Carey F. 2003. *Organic Chemistry.* 5th edition. McGraw Hill.
b. McMurry J. 2004. *Organic Chemistry.* 6th edition. Thomson Learning Inc.

7. PHYSICAL CHEMISTRY

a. Atkins P. 2002. *Physical Chemistry.* 7th edition
b. Barrante JR. 2004. *Applied Mathematics for Physical Chemistry.* 3rd edition. Prentice-Hall
c. Levine IN. *Physical Chemistry.* 5th edition
d. McQuarrie DA and Simon JD. *Physical Chemistry-A Molecular Approach.*
e. Moelwyn-Hughes EA. *Physical Chemistry.* 2nd Edition
f. Bronwell A. *Advanced Mathematics in Physics and Engineering*
g. Moore WJ. *Physical Chemistry.* 3rd edition

8. STATISTICS

a. Devore J and Peck R, *Statistics: The Exploration and Analysis of Data,* 4th edition, Duxbury Publishers
b. Tamhane AC and Dunlop DD, 2000, *Statistics and Data Analysis: From Elementary to Intermediate*, Prentice Hall
c. Moore DS, *The Basic Practice of Statistics,* 3rd edition
d. Freedman D, Pisani R and Purves R, *Statistics*
e. Tanur J. et al, *Statistics: A Guide to the Unknown*

IV. SUGGESTED TEXTBOOKS AND REFERENCES FOR REQUIRED NON-GEOLOGY COURSES

1. ENGINEERING DRAWING

a. Baumeister. *Marks' Standard Handbook for Mechanical Engineers.* McGraw Hill
b. Bertoline G & Wiebe E. 2007. Fundamentals of Graphics Communication. 5th Edition. McGraw Hill
c. French TE, Vierck CJ & Foster RJ. Engineering Drawing and Graphic *Technology.* Latest edition. McGraw Hill

2. SURVEYING METHODS

a. Bannister A, Raymond S & Baker R. 1998. *Surveying.* 7th edition. Addison Wesley Longman Limited. England

b. Hofmann-Wellenhof B, Lichtenegger H & Collins J. 1997. *Global Positioning System: Theory and Practice.* 4th edition. Springer-Verlag. Berlin Heidelberg. New York
c. Wolf PR & Brinker RC. 1994. *Elementary Surveying.* 9th edition. HarperCollins College Publishers. New York

V. SUGGESTED TEXTBOOKS AND REFERNCES FOR OPTIONAL COURSES

1. APPRENTICESHIP, INTERSHIP OR ON-THE-JOB TRAINING (OJT)

a. Dependent on industry programs and activities

2. UNDERGRADUATE THESIS / RESEARCH PAPER

a. Dependent on instructor's/students' preferred topics.