

**CURRICULUM
OF
GEOLOGY**

For

**BS (HONS)
MS (HONS)**

(2006)



**HIGHER EDUCATION COMMISSION
ISLAMABAD**

CURRICULUM DIVISION, HEC

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PREFACE

Curriculum of a subject is said to be the throbbing pulse of a nation. By looking at the curriculum one can judge the state of intellectual development and the state of progress of the nation. The world has turned into a global village; new ideas and information are pouring in like a stream. It is, therefore, imperative to update our curricula regularly by introducing the recent developments in the relevant fields of knowledge.

In exercise of the powers conferred by sub-section (1) of section 3 of the Federal Supervision of Curricula Textbooks and Maintenance of Standards of Education Act 1976, the Federal Government vide notification no. D773/76-JEA (Cur.), dated December 4, 1976, appointed University Grants Commission as the competent authority to look after the curriculum revision work beyond class XII at bachelor level and onwards to all degrees, certificates and diplomas awarded by degree colleges, universities and other institutions of higher education.

In pursuance of the above decisions and directives, the Higher Education Commission (HEC) is continually performing curriculum revision in collaboration with universities. According to the decision of the special meeting of Vice-Chancellors' Committee, curriculum of a subject must be reviewed after every 3 years. For the purpose, various committees are constituted at the national level comprising senior teachers nominated by universities. Teachers from local degree colleges and experts from user organizations, where required, are also included in these committees.

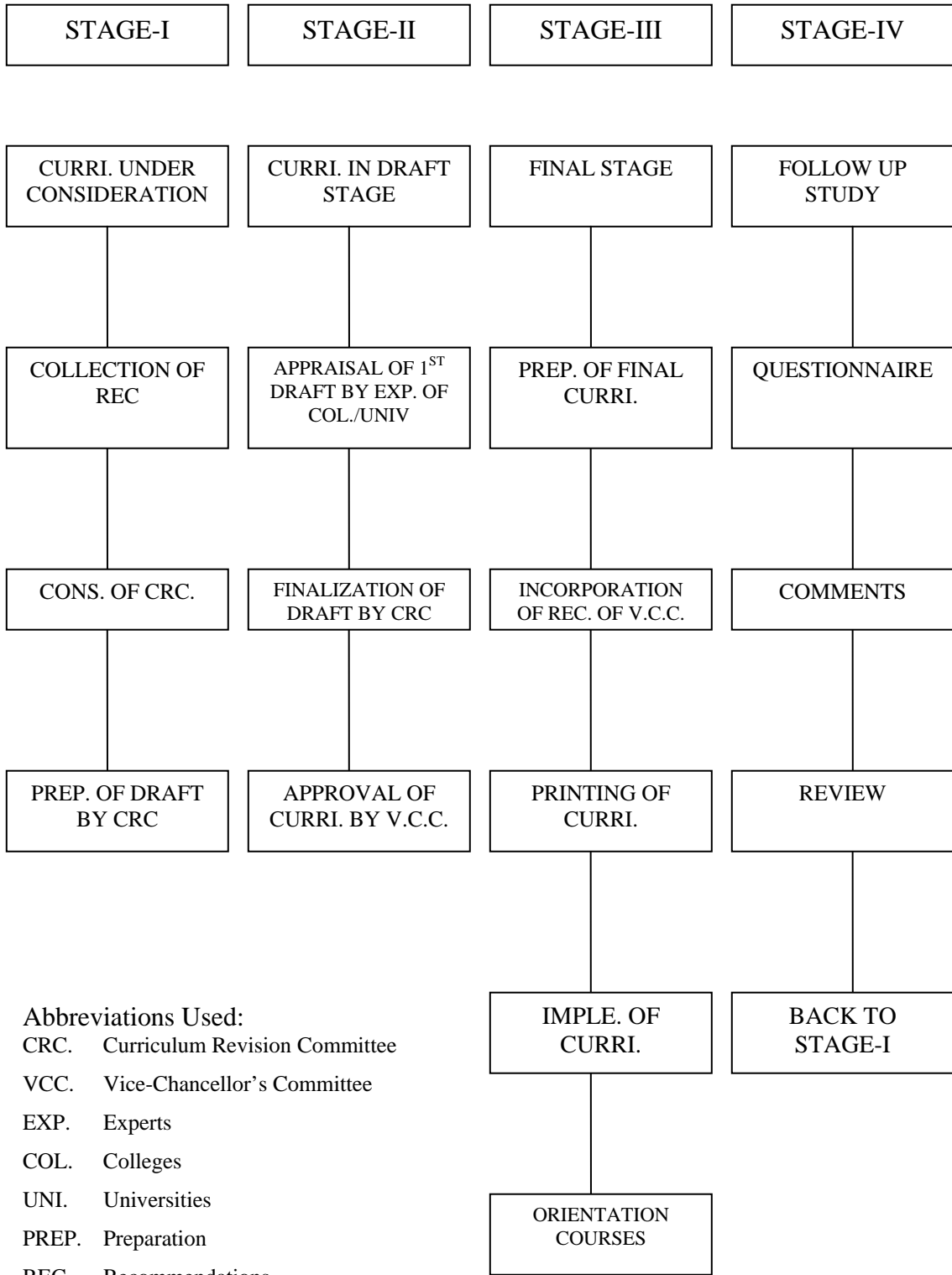
The National Curriculum Revision Committee for Geology in its meeting held in April 24-26, 2006 at the HEC Regional Centre, Peshawar revised the curriculum after due consideration of the comments and suggestions received from universities and colleges where the subject under consideration is taught.

The final draft prepared by the National Curriculum Revision Committee duly approved by the Competent Authority is being circulated for implementation by the institutions.

(PROF. DR. ALTAF ALI G. SHAIKH)
Adviser (Acad/R&D)

August 2006

CURRICULUM DEVELOPMENT



- Abbreviations Used:**
- CRC. Curriculum Revision Committee
 - VCC. Vice-Chancellor's Committee
 - EXP. Experts
 - COL. Colleges
 - UNI. Universities
 - PREP. Preparation
 - REC. Recommendations

INTRODUCTION

Final meeting of the National Curriculum Revision Committee (NCRC) in Geology was held at HEC Regional Center, Peshawar from 24-26 April, 2006. Earlier, a draft syllabus was prepared in the preliminary meeting held from December 1-3, 2005 at Peshawar. The committee finalized the curricula for 4-year BS (Hons) and 2-year MS (Hons). The following attended the meeting:

1. Prof. Shamim A. Sheikh, Convener
Department of Geology,
University of Karachi,
Karachi
2. Dr. Amir Haider Malik, Member
HEC Foreign Expert,
COMSATS Institute of Information Technology,
Abbottabad.
3. Dr. Gul Daraz Khan, Member
Associate Professor,
NWFP Agricultural University,
Peshawar
4. Dr. I.U. Cheema, Member
Director,
Pakistan Museum of Natural History,
Shakarparian,
Islamabad.
5. Dr. Irshad Ahmad, Member
Associate Professor,
Centre of Excellence in Geology,
University of Peshawar, Peshawar
6. Prof. Dr. Izhar-ul-Haq Khan, Member
Professor/ (Ex-Member Science PCSIR),
University of Education,
148-D, Model Town, Lahore
7. Dr. M. Ahmad Khan, Member
Associate Professor,
Department of Geology,
University of Sargodha, Sargodha.
8. Dr. Muhammad Arif, Member
Professor,
Department of Geology,
University of Peshawar, Peshawar

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| 9. | Prof. Muhammad Hanif,
Associate Professor,
Department of Geology,
University of Peshawar, Peshawar. | Member |
| 10. | Dr. Muhammad Ishaq Ghaznavi,
Director Research Coordination,
Director Admission, Students & Academic Affairs,
Balochistan Univ: of Information Tech:
& Management Sciences,
Samungli Road, Quetta. | Member |
| 11. | Prof. Dr. M. Tahir Shah,
Professor,
Centre of Excellence in Geology,
University of Peshawar, Peshawar. | Member |
| 12. | Dr. Muhammad Zafar,
Department of Earth & Environmental
Sciences,
Bahria University, Naval Complex,
E-8, Islamabad. | Member |
| 13. | Prof. Dr. Parveen Akhtar Usmani,
Director,
Centre for Pure & Applied Geology,
University of Sindh, Jamshoro | Member |
| 14. | Dr. Riaz Ahmad Sheikh,
Associate Professor,
Institute of Geology,
University of the Punjab, Lahore | Member |
| 15. | Dr. Syed Mohammad Ali Shah,
Chairman,
Department of Mining Engineering,
Mehran University of Engg: & Tech.,
Jamshoro | Member |
| 16. | Dr. Shahid Nadeem Qureshi,
Associate Professor,
Department of Earth Sciences,
Quaid-i-Azam University, Islamabad. | Member/
Secretary |

Minutes of the meetings

The preliminary meeting started with the recitation of the Holy Qur`an. Prof. Dr. Altaf Ali G. Shaikh, Adviser (Acad/R&D) HEC, Islamabad, welcomed the participants on behalf of the Chairman Higher Education Commission. He briefed the participants regarding the obligations of the Commission for review, revision and development of curricula.

Dr. Shaikh, in his opening remarks, informed the members that the HEC is striving hard to enhance quality of education by making curricula of the universities more compatible with international standard, job oriented and to match the needs of society. He informed the members of the committee of different academic programs of the commission which are aimed at to facilitate the universities in the execution of their programs, including repair and maintenance of laboratories, provision of books for libraries, indigenous and overseas scholarships, digital library, provision of computers and other modern tools like internet and e-mail etc.

He pointed out the need to revise/prepare/update the curricula for 4-year BS and 2-year MS in Geology. This should be standard curricula for all HEC recognized Universities/Institutions for quality education and uniformity at the national level. This will facilitate student to continue higher education abroad and compete in international job market.

Dr. Shaikh requested the participants to select a Convener for the NCRC meeting for the Geology Curriculum Development. Prof. Shamim A. Sheikh, Department of Geology, University of Karachi was unanimously selected as Convener and Dr. Shahid Nadeem Qureshi, Associate Professor, Department of Earth Sciences, Quaid-i-Azam University, Islamabad as Secretary.

Mr. Muhammad Tahir Ali Shah, Assistant Director (Curriculum) acted as meeting coordinator and facilitated all the technical sessions and logistics. He also briefed the participants about the procedure for HEC review/revision of the curricula

Prof. Shamim A. Sheikh thanked the house for posing confidence in him. The committee, after three days discussion prepared the 1st draft curriculum for 4-year BS and scheme of study for 2-year MS.

In the final meeting of NCRC in Geology, Mr. Farman Ullah Anjum, Director, HEC Regional Centre, Peshawar reiterated the aims and objectives of the revision of the curricula. He thanked the participants for sparing their time to enhance the quality of higher education in the country.

The Committee, after indepth discussion on the initial draft for three days, recommended the final draft for implementation in institutions/universties as under:-

ELIGIBILITY FOR ADMISSION IN 4-YEAR BS (HONS) PROGRAM

Intermediate Science (or Equivalent) with minimum 2nd Division from the following groups:

1. Pre-Medical Group
2. Pre-Engineering Group
3. Other Groups (studied at least two subjects from the following:
Chemistry, Physics and Mathematics)

SCHEME OF STUDY FOR 4-YEAR BS (HONS) IN GEOLOGY

Semester I	Course	Credit Hours (CH)	Total CH
Eng. 301	English I	3	3
Isl. St./Eth. 301	Islamic Studies/Ethics	2	2
Math. 301	Mathematics I	3	3
Phy. 301	Physics I	2+1	3
Chem. 301	Chemistry I	2+1	3
Geol. 301	General Geology	2+1	3
Total			17

Semester II	Course	CH	Total CH
Eng. 302	English II	3	3
Pk. St. 302	Pakistan Studies	2	2
Math. 302	Mathematics II	3	3
Phy. 302	Physics II	2+1	3
Chem. 302	Chemistry II	2+1	3
Geol. 302	Geomorphology	2+1	3
Total			17

Semester III	Course	CH	Total CH
Eng. 401	Communication skills (English III)	2	2
Math. 401	Mathematics III	3	3
Phy. 401	Physics III	2+1	3
Chem. 401	Chemistry III	2+1	3
Geol. 401	Paleontology	2+1	3
Geol. 403	Stratigraphy	2+1	3
Total			17

Semester IV	Course	CH	Total CH
Eng. 402	Tech. Report Writing (Eng. IV)	2	2
Comp.-Stat. 402	Computing & Geostatistics	2+2	4
Phy. 402	Physics IV	2+1	3
Chem. 402	Chemistry IV	2+1	3
Geol. 402	Crystallography, Optical Mineralogy & Petrography	2+1	3
Geol. 404	Geological Fieldwork – I	2	2
Total			17

Semester V	Course	CH	Total CH
Geol. 501	Geo-tectonics	2+1	3
Geol. 503	Structural Geology	2+1	3
Geol. 505	Sedimentology	2+1	3
Geol. 507	Sequence Stratigraphy	2+1	3
Geol. 509	Mineralogy	2+1	3
Geol. 511	Igneous & Metamorphic Petrology	2+1	3
Total			18

Semester VI	Course	CH	Total CH
Geol. 502	Geophysics	2+1	3
Geol. 504	Geochemistry	2+1	3
Geol. 506	Petroleum Geology	2+1	3
Geol. 508	Field Geology	2+1	3
Geol. 510	Economic Geology	2+1	3
Geol. 512	Geological Fieldwork - II	2	2
Total			17

Semester VII	Course	CH	Total CH
Geol. 601	Geology of Pakistan	3	3
Geol. 603	Remote Sensing & GIS	2+1	3
Geol. 605	Environmental Geology	2	2
Geol. 607	Engineering Geology	2+1	3
Geol. 609	Hydrogeology	2+1	3
Geol. 611	Micropaleontology & Bio-stratigraphy	2+1	3
Total			17

Semester VIII	Course	CH	Total CH
Geol. 602	Special Paper I	3+1	4
Geol. 604	Special Paper II	3+1	4
Geol. 606	Thesis	6	6
Total			14

Note: Internship is recommended in public/private sector organizations during/after the last four semesters, whenever possible.

DETAILS OF COURSES

Geol. 301: General Geology

Introduction and scope of geology its importance and relationship with other sciences. Earth as a member of the solar system; its origin, age, composition and internal structure. Minerals and their physical properties. Introduction to rocks. Moon, Earth's neighbors, meteorites, earthquakes and volcanoes. Weathering and erosion and related land forms. Primary sedimentary, igneous and metamorphic structures. Introduction of folds, faults, joints, cleavage, foliation, lineation and unconformities. Isostasy; Introduction to plate tectonics, mountain building processes.

Lab: Study of relief features with the help of models and topographic maps. Simple geological maps and drawing of cross-sections. Use of field instruments viz, Brunton compass/clinometer.

Books Recommended:

1. Principles of Physical Geology by Holmes, A., 1978, Nelson.
2. Foundation of Structural Geology by Park, R.G., 1983, Blackie.
3. Elementary Exercises upon Geological Maps by Platt, J.I., **latest Ed.**, Thomas Murby & Co.
4. An Introduction of Geological Structures and Maps by Bennison, G.M., **latest Ed.**, Edward Arnold.
5. **Physical Geology by Plummer, McGeay & Carlson, 2005.**
6. Lab Manual for Physical Geology by Jones, Norris. W., Johnes, Charles E., 2005, McGraw-Hill.
7. How Does Earth Work: Physical Geology and Process of Science by Smith, G. and Pun, A., 2006, Prentice Hall.
8. The Mapping of Geological Structures by McClay, K.R., 1987, Open University Press.

Geol. 302: Geomorphology

Geomorphic cycles and associated landforms. Uses and interpretation of topographic maps, aerial photographs and satellite imageries. Interpretation of geological structures. Glaciers and their erosional and depositional land forms. Geological work of wind. Erosional and depositional work of running water, valley and base-level development and its types, drainage pattern, stream meandering and development of flood plains. Occurrence and geological work of ground water. The erosional and depositional work of sea, development of coastal land forms. Landforms produced by tectonics and volcanic activity.

Lab: Terrain analysis using topographic maps, aerial photographs and satellite imageries. Techniques of photogeological mapping.

Books Recommended:

1. Geomorphology of Earth Surface Processes and Form by Aharma, V.K., 1986, McGraw Hill.
2. Geomorphology by Chorley, R.J., 1984, Methuen.
3. Image Interpretation in Geology by Drury, S.A., 1986, Allen & Unwin.
4. Remote Sensing and Image Interpretation by Lillis, T.M. and Kiefer, R.W., 1987, John Wiley & Sons.
5. Principles of Geomorphology by Thornbury, W.D., 1991, John Wiley & Sons.
6. **Process Geomorphology by Ritter, Kochel & Miller, 2002.**

Geol. 401: Paleontology

Fossils and their significance; modes of fossilization. Study of morphology, range and broad classification of major invertebrate phyla viz. coelenterata, brachiopoda, mollusca, arthropoda (trilobite) and echinodermata (echinoidea). Introduction to micro fossils. Introduction to Paleobotany. Evolution and classification of vertebrates.

Lab: Megascopic identification and description of fossils related to phyla studied.

Books Recommended

1. Invertebrate Fossils by Moore, R.C., Lalicker, C.G. & Fischer, A.G., 1952, McGraw Hill.
2. Principles of Paleontology by Raup, D.M. & Stanley, S.M., 1985, W.H. Freeman & Co.
3. Vertebrate Paleontology by Romer, A.S., 1966, University Chicago Press.

Geol. 403: Stratigraphy

Principles of stratigraphy; laws of superposition and faunal succession. Classification and nomenclature of stratigraphic units: lithostratigraphic unit, biostratigraphic unit and chronostratigraphic unit. Geological time scale. Stratigraphic Code of Pakistan. General stratigraphic correlation.

Outline of regional geology of Pakistan. Study of stratigraphic type sections of Khewra gorge, Nammal gorge, Chichali gorge, Murree Brewery gorge and Bara nala. Type sections of Rawalpindi Group and Siwaliks.

Lab: Preparation of stratigraphic columns and their correlation.

Books Recommended

1. Principles of Stratigraphy by Weller, J.M., 1962, Harper Brothers.
2. Stratigraphy of Pakistan by Shah, S.I., 1977, Geological Survey of Pakistan.
3. Principles of Sedimentology and Stratigraphy by Boggs, S., 2001, Prentice Hall.
4. Stratigraphic Code of Pakistan, Geological Survey of Pakistan, 1962, Memoris of GSP, V.IV, Part-I.

Geol. 402: Crystallography, Optical Mineralogy & Petrography

Introduction to Crystallography; elements of symmetry, crystal notation, study of normal classes of crystallographic systems. Introduction to polarizing microscope. Optical properties of non-opaque minerals in plane polarized light and under crossed nicol. Description of optical properties of common rock forming minerals. Major rock types and their important characteristics. Mineral composition. Texture, mode of occurrence, classification and origin of common igneous, sedimentary and metamorphic rocks.

Lab: Identification and description of common minerals. Study of crystal models. Study of rocks and minerals in thin section, texture and composition, volume estimates and other elementary petrographic techniques.

Books Recommended:

1. Principles of Mineralogy by William. H.B., 1990, Oxford University Press.
2. Mineralogy by Perkins, D., 2002, Prentice Hall.
3. Optical Mineralogy by Kerr, P.F., 1959, McGraw Hill.
4. Minerals and Rocks by Klein, C., 1989, John Wiley & Sons.
5. Igneous and Metamorphic Petrology by Best, M.G., 1982, W. H. Freeman & Co.

6. Minerals in Thin Sections by Perkins, D., 2000, Prentice Hall.
7. Petrography of Igneous and Metamorphic Rocks by Philpotts, A.R., 1989, Prentice Hall.
8. Atlas of Rock-Forming Minerals in Thin Section by MacKenzie, W.S. Guilford, C.P., 1980, John Wiley & Sons.
9. Introduction to Optical Mineralogy by Nesse, W.D., 2003, Oxford University Press.
10. An Atlas of Minerals in Thin Section by Schulze, D.J., 2003, CD-RM, Oxford University Press.

Geol. 404: Geological Fieldwork - I

During the first two years students will perform at least four weeks of fieldwork. It will lead to become familiar with major rocks and structures. Field trips will be followed by report writing and Viva Voce / Evaluation.

Books Recommended:

1. Field Geology by Lahee, F.H. 1961, McGraw Hill.
2. Geology in the Field by Compton, R.R. 1985, John Wiley & Sons.
3. Basic Geological Mapping by Barnes, J.W. & Lisle, R.J., 2004, John Wiley & Sons.

Geol. 501: Geo-tectonics

Plate tectonics theory. Historical perspective. Internal structure of Earth. Geological evidences for continental drift. Continental reconstruction. Marine magnetic anomalies and sea-floor spreading. Plates and plate boundaries. Relative and absolute plate motions. Oceanic ridges. Continental rifts. Intraoceanic islands. Hot spot and Mantle plumes. Subduction zones. Transform and transcurrent faults. Mechanism of plate tectonics. Driving mechanisms for plate movement. Geophysical techniques in tectonics (seismic, gravity, geo-magnatics). Introduction to neo-tectonics and related hazards.

Lab: Specified assignments/projects.

Books Recommended:

1. Tectonics by Moores, E.M. & Twiss, R.J., 1995, W.H. Freeman and Co.
2. Global Tectonics by Keary, P. & Vine, F.J., 1996, Blackwell.
3. Plate Tectonics: How it Works by Cox, A. & Hort, R.B., 1986, Blackwell.
4. The Evolving Continents by Windley, B.F., 1984, John Wiley & Sons.

Geol. 503: Structural Geology

Stress: concepts, classes, ellipsoid, Mohr circle of stress. Strain: concept, measures of strain, classes, ellipse and ellipsoid, stress-strain diagram. Factors which control the mechanical behaviour of materials. Folds: morphology, classification based on morphology, geometry, vergence and mechanics of fold formation. Faults: terminology, slip and separation, geometrical and genetic classification and recognition of faults. Structures in compressional and extensional regimes, transform faults and fault mechanics. Joints: terminology, geometry and classification. Foliation: terminology, classification and relationship with bedding. Lineation: terminology and classification. Unconformity: concept, classification and recognition.

Lab: Map exercises and construction of geological and balanced cross-sections. Orthographic projections (geometrical exercises): dimension calculations. Introduction to stereographic projections: plotting a plane, a line on a plane. Determination of the rake of a line; plunge and bearing from rake. True and apparent dip. Determining the intersection of two planes. Pole to a plane; angles between lines and planes.

Books Recommended:

1. Foundation of Structural Geology by Park, R.G., 1983, Blackie.
2. Structural Geology of Rocks and Regions by Davis, G.H. & Reynolds, S.J., 1996, John Wiley & Sons.
3. Laboratory Exercise Book in Structural Geology by Ghauri, A.A.K., 1989, National Centre of Excellence in Geology, University of Peshawar.
4. An Introduction to Geological Structures and Maps by Bennisen, G.M., 1975, Edward Arnold.
5. Structural Geology by Twiss, R.J. & Moores, E.M., 1995, W.H. Freeman & Co.

Geol. 505: Sedimentology

Introduction to sedimentology, origin, transportation and deposition of sediments. Texture of sedimentary rocks and their statistical parameters. Sedimentary structures, their classification, morphology and significance. Classification and description of sedimentary rocks. Provenance of sediments. Diagenesis. Concepts of sedimentary facies and facies associations. Physico-chemical controls of the sedimentary environments. Diagnostic features of fluvial, lagoonal, lacustrine, deltaic, tidal and marine environments. Tectonic controls of sedimentation.

Lab: Grain size analysis of sediments and sedimentary rocks. Megascopic and microscopic study of sedimentary rocks. Separation and identification of heavy minerals. Study of sedimentary structures.

Books Recommended:

1. Sand and Sandstone by Pettijohn, F.J., Potter, P.E. & Siever, R., 1972, Springer-Verlag.
2. Principles of Sedimentology by Friedman, G.M. & Sanders, J.E., 1978, John Wiley & Sons.
3. Depositional Sedimentary Environments by Reineck, H.E. & Singh, I.B., 1980, Springer-Verlag.
4. Carbonate Sedimentology by Tucker, M.E. & Wright, V.P., 1990, Blackwell.
5. Sedimentary Environment and Facies by Reading, H.G., 1986, Blackwell.
6. Applied Sedimentology by Selly, R.C., 1988, Chapman & Hall.
7. Petrology of Sedimentary Rocks by Boggs Jr. S., 1992, Merrill Publishing Co.
8. Sedimentary Rocks by Pettijohn, F.J., 1975, Harper and Row.
9. Sedimentary Geology by Prothero, D. & Schwab, F., 1996, W.H. Freeman & Co.

Geol. 507: Sequence Stratigraphy

Introduction, history, concept and significance of Sequence stratigraphy. Seismic reflections and facies. Sea level changes, their causes and effects. Accommodation, eustatic sea level curve. Hierarchy of sequence stratigraphic elements. Types of sequences and systems tracts.

Lab: Interpretation of seismic reflections. Surface and seismic facies and identification of sequences.

Books Recommended:

1. Silici-clastic Sequence Stratigraphy in Well Logs, Cores and Outcrops by Van Wagoner, J.C., et al., 1990, AAPG Meth Expl. Ser. No.7.
2. Sea-level Changes an Integrated Approach by Wilgus, B.S., et al., 1988. SEPM.
3. Seismic Stratigraphy: Application to H-carbon Exploration by Payton, C.W., 1977, AAPG Mem. 26.
4. Sequence Stratigraphy and Facies Association by Posamentier, H.W., et al., 1993, Blackwell.
5. Sequence Stratigraphy by Emery, D. & Myers, K.J., 1996, Oxford, Blackwell.

Geol. 509: Mineralogy

Classification of minerals. Study of internal structure, polymorphism and isomorphism, crystal chemistry, paragenesis, and physical and optical properties of the common silicate and non-silicate mineral groups. Introduction to X-Ray diffractometry and universal stage and their applications. Phase equilibrium studies. One component, binary and ternary system.

Lab: Megascopic and microscopic identification of common rock forming minerals. Construction and interpretation of phase diagrams from given experimental data. Lab work related to XRD and Universal stage.

Books Recommended:

1. Principles of Mineralogy by William, H.B., 1990, Oxford University Press.
2. Optical Mineralogy by Kerr, P.F., 1959, McGraw Hill.
3. Minerals and Rocks by Klein, C., 1989, John Wiley & Sons.
4. A Color Atlas of Rocks and Minerals in Thin Section by Mackenzie, W.S. & Adams, A.E. 1996, John Wiley & Sons.
5. Atlas of Rock-Forming Minerals in Thin Section by Mackenzie, W.S., Donaldson, C.H. & Guilford, C.P., 1980, John Wiley & Sons.
6. An Introduction to Rock Forming Minerals by Deer, W.A., Howie, R.A. & Zussman, J., 1992, Longman.

Geol. 511: Igneous & Metamorphic Petrology

Composition, origin, differentiation and evolution of magma. Classification of igneous rocks. Petrography and occurrence of the following series: Tholeiitic and alkali-olivine basalt. Basalt – andesite series. Study of granites, granodiorite, syenite, carbonatite, mafic and ultramafic rocks. Lamprophyres. Facies analysis of volcanic rocks.

Types of metamorphism. Grades, zones and facies of metamorphism. Metamorphic diffusion and differentiation. Study of thermal and regional metamorphism of argillaceous, calcareous and arenaceous rocks. ACF and AKF diagrams. Metamorphism in relation to plate tectonics. Development of textures and structures.

Lab: Megascopic and microscopic identification and description of igneous and metamorphic rocks.

Books Recommended:

1. Igneous and Metamorphic Petrology by Best, M.G., 2002, Black Well.
2. Petrology of Igneous and Metamorphic Rocks, by Hyndmann, D.W., 1995, McGraw Hill.
3. Igneous Petrogenesis by Wilson, M., 1989, Unwin Hyman.

4. Petrology: Igneous, Sedimentary, & Metamorphic by Blatt, H., Tracy, R. & Owens, D., 2005, W.H. Freeman & Co.
5. Metamorphism and Plate Tectonic Regimes by Ernst, W.G, 1975, Hutchison & Ross, Inc.
6. Metamorphic Petrology by Turner, F.J., 1981, McGraw Hill.
7. Introduction to Igneous and Metamorphic Petrology, Winter, J.D., 2001, Prentice Hall.
8. Petrogenesis of Metamorphic Rocks by Winkler, H.G.F., 1987, Springer-Verlag.
9. Petrogenesis of Metamorphic Rocks by Bucher, K. & Frey, B., 1994, Springer-Verlag.
10. Igneous Rocks: A Classification and Glossary: Recommendations of the IUGS Sub-commission, Maitre, R.W., Le Bas, M.J., Streckeisen, A., Zanettin, B. & Bonin, B. (eds.), 2005.
11. Metamorphic Petrology by Miyashiro, A., 1994, Oxford University Press.

Geol. 502: Geophysics

Definition and relation of geophysics with other sciences. Classification and brief description of various branches of geophysics such as seismology, geomagnetism, geoelectricity, tectonophysics, gravimetry, geo-thermy and geodesy.

Introduction to various geophysical techniques for exploration of mineral deposits, oil and gas and engineering works. Geophysical data processing. Earthquake seismology and geodynamics of Earth.

Lab: Analysis and interpretation of geophysical data and computer modelling.

Books Recommended:

1. Applied Geophysics by Telford, W.M., Geldart, C.P., Sheriff, R.E. & Keys, D.A., 1976, Cambridge University Press.
2. Introduction to Geophysics by Garland, G.D., 1971, W.B. Saunders Co.
3. Seismic Exploration by Al-Sadi, H.N., 1980, Birkhauser Verlag.
4. Introduction to Geophysical Prospecting by Dobrin, M.B. & Savit, C. H., 1988, McGraw Hill.
5. An Introduction to Geophysical Exploration by Kearey, P., & Brooks, M., 1991, Osney Mead.
6. Basic Exploration Geophysics by Robinson, E.S. & Coruh, C., 1988, John Wiley & Sons.
7. Geophysical Methods in Geology by Sharma, P.V., 1987, Elsevier.

Geol. 504: Geochemistry

Development of geochemistry as a discipline. Composition of meteorites. Origin and cosmic abundance of elements. Geochemical structure of the earth. Geochemical classification of elements. Polymorphism and pseudomorphism. Geochemical cycle; mobility and dispersion of elements under different geochemical environments. Introduction to geochemistry of igneous, metamorphic and sedimentary rocks. Geochemical anomalies and their application in mineral exploration.

Lab: Geo-chemical sampling and analytical techniques. Processing and interpretation of geo-chemical data.

Books Recommended:

1. Introduction to Geochemistry by Krauskopf, K.B., 1967, McGraw Hill.
2. Principles of Geochemistry by Mason. B., 1966, John Wiley & Sons.
3. Geochemistry in Mineral Exploration by Rose, A.W., Hawkes, H.H. & Webb, J.S., 1983, Whitstable Litho Ltd.
4. Inorganic Geochemistry by Henderson, P., 1982, Pergamon Press Ltd.
5. Geochemistry by Brownlow, A.H., 1996, Prentice Hall.
6. Geochemistry by Beaumont, E.A., & Foster, N.H., 1988, AAPG Special Bulletin, Publication No.8.

Geol. 506: Petroleum Geology

The nature of petroleum hydrocarbons, their origin, migration and accumulation. Source sediments, reservoir rocks, and trapping mechanism for oil and gas. Prospecting and exploration of oil and gas. Basic concepts of exploration seismology; geochemical methods; drilling and well logging. Reservoir characteristics, drive mechanism, energy and pressure maintenance. Secondary and enhanced recovery. Recent advances in reservoir engineering. Petroleum basins and world distribution of oil and gas with emphasis on Pakistan and Middle East.

Lab: Preparation of various kinds of subsurface maps, e.g., isopachs, isochore, isoliths etc. Preparation of fence diagrams. Visits to well/drilling sites.

Books Recommended:

1. Petroleum Geology by North, F.K., 1985, Allen & Unwin.
2. Geology of Petroleum by Levenson, A.I., 1970, W.H. Freeman & Co.
3. Geology and Tectonics of Pakistan by Kazmi, A.H. & Jan, M.Q., 1997, Graphic Publishers.
4. Geology of Pakistan by Bender, F.K. & Raza, H.A., (eds.) 1995, Gebruder Borntraeger.

5. Hydrocarbons from Coal by Law, B.E., & Rice, D.D., 1993, AAPG Studies in Geology # 38
6. Principles of Petroleum Development Geology by London, R.C., 1996, Prentice Hall.

Geol. 508: Field Geology

Instruments used in field mapping. Introduction to topographic and geological maps. Methods and techniques of surface and subsurface geological mapping. Correlation techniques. Field description of igneous, metamorphic and sedimentary rocks. Modes of geological illustration including structural contour, isopach and lithofacies maps, block and fence diagrams. Field mapping, preparation of geological maps and cross sections.

Lab: Uses of field instruments. Introduction to topographic and geological maps. Field data acquisition and interpretation. Geological fieldwork and report writing of an assigned area.

Books Recommended:

1. Elements of Field Geology by Himus, G.W. & Sweeting, G.S., **latest Ed.**, University Tutorial Press Ltd.
2. Field Geology by Lahee, F.H., 1961, McGraw Hill.
3. Geology in the Field by Compton, R.R., 1985, John Wiley & Sons.

Geol. 510: Economic Geology

Introduction to economic minerals and rocks and their classification. Processes of formation of economic mineral deposits: magmatic segregation, hydrothermal solution, metasomatism, sedimentation, evaporation, residual and mechanical concentration and metamorphism. Relationship of mineral deposits to plate tectonic settings. Introduction of geological exploration/prospecting. Brief description of hydrocarbons, coal, gemstones, copper, lead, zinc, iron, gold, chromite, manganese, salt, gypsum, bauxite, sulphur, barite, fluorite, clays, phosphorite, building stones, industrial rocks and radioactive minerals and rocks with special reference to deposits in Pakistan.

Lab: Identification and description of ores and industrial minerals/rocks. Grade and reserve estimation of deposits.

Books Recommended:

1. Directory of Mineral Deposits of Pakistan, by Zaki, A., 1969. Geological Survey of Pakistan.
2. Ore Deposits by Park, C.F. & MacDiarmid, R.A., 1970, W. H. Freeman & Co.

3. Economic Mineral Deposits by Jenssen, M.L. & Bateman, A.M., 1972, John Wiley & Sons.
4. Mineral Prospecting Manual by Chausier, J.B., 1987, North Oxford Academic Press.
5. An Introduction to Ore Geology by Evans, A.M., 1987, Blackwell.
6. Atlas: Economic Mineral Deposits by Dixan, C.J., 1979, Chapman Lordin & Hall.
7. Metallogeny and Mineral Deposits of Pakistan by Kazmi, A.H. & Abbas, S.G., 2001, Orient Petroleum Inc.
8. Handbook of Exploration Geochemistry, Govett , G.J.S. (ed.), 1995, Elsevier
9. Ore Deposit Geology by Edward, R. & Atkinsons, K., 1986, Chapman and Hall.

Geol. 512: Geological Fieldwork - II

Observation and plotting of physical features on topographic sheet. Study of geomorphic features. Measurement of stratigraphic sections. Recognition of structural features. Study of fossils, primary and secondary structures. Field description of sedimentary, igneous and metamorphic rocks. Report writing of an assigned area.

Books Recommended:

1. Elements of Field Geology by Himus, G.W. & Sweeting, G.S., **latest Ed.**, University Tutorial Press Ltd.
2. Field Geology by Lahee, F.H. 1987, McGraw Hill.
3. Geology in the Field by Compton, R.R. 1985, John Wiley & Sons.
4. Basic Geological Mapping by Barnes, J.W. & Lisle, R.J., 2004, John Wiley & Sons.

Geol. 601: Geology of Pakistan

Physiographic and tectonic divisions and their descriptions. Geology and stratigraphy of the Indian plate, Karakoram plate, Afgan block and Arabian plate. Kohistan, Chagai and Ras Koh magmatic arcs. Makran subduction complex, Chaman transform zone, arcs, oroclines and suture zones. Regional metamorphism (Himalayan and Pre-Himalayan). Main episodes of magmatism and their relations to tectonics. Economic mineral and fuel deposits of Pakistan.

Books Recommended:

1. Geodynamics of Pakistan by Farah, A. & DeJong, K.A. (eds.), 1979, Geological Survey of Pakistan.

2. Geology of Himalaya, Karakoram, Hindukush in Pakistan by Tahirkheli, R.A.K., 1982, Geol. Bull., University of Peshawar.
3. Geology of Himalaya by Gansser. A., 1964, John Wiley & Sons.
4. Reconnaissance Geology of West Pakistan, 1961, Hunting Survey Report.
5. Geology and Tectonics of Pakistan by Kazmi, A.H. and Jan, M.Q., 1997, Graphic Publishers.
6. Geology of Pakistan by Bender, F.K. & Raza, H.A. (eds.), 1995, Gebruder Borntraeger.
7. Metallogeny and Mineral Deposits of Pakistan by Kazmi, A.H., & Abbas, S.G., 2001, Orient Petroleum Incorporation.

Geol. 603: Remote Sensing and GIS

An Overview-including background, history, need of remote sensing. Recent developments in remote sensing. Electromagnetic spectrum, source and sensor. Physical terms and units, Radiometric terms and units. Thermal properties. Interaction of different wave-lengths with the earth's surface and vegetation.

Aerial Photographs: Films and cameras. Scale and corrections, displacement. Distance, area, height and slope measurements. Techniques of photogeological mapping. Relation to topographic maps. Photo interpretation-drainage, vegetation, soils and rocks (with their structural attitude).

Aerial and Satellite Imagery: Multi-spectral scanners. Sideways-looking airborne radar. Introduction to Digital Image Processing and GIS. Analysis of digital and raster data. Introduction to Earth Resource Satellites. Classification of landforms, land cover and land use. Statics in field of geology and geomorphology.

Lab: Terrain analysis using topographic maps, aerial photographs and satellite imageries. Techniques of photogeological mapping. Digital analysis of satellite data.

Books Recommended:

1. Geomorphology: Earth Surface Processes and Form by Aharna, V.K., 1986, McGraw Hill.
2. Geomorphology by Chorley, R.J., 1984, Methuen.
3. Image Interpretation in Geology by Drury, S.A., 1986, Allen & Unwin.
4. Remote Sensing and Image Interpretation by Lilles, T.M. and Kiefer, R.W., 1987, John Wiley & Sons.
5. Monitoring the Earth by Vita-Finzi, C., 2003, Oxford University Press.
6. Fundamentals of Geographic Information Systems by Demers, M.N., 2002, John Wiley & Sons.
7. **Remote Sensing and Image Interpretation by Lillesand, T.M., et al., 2003.**

8. Concepts and Techniques of Geographic Information System by Yeung, Lo.C.P. & Lal, A.K., 2003, Prentice Hall.
9. Aerial Photography and Image Interpretation, Kiser, J.D., Paine, D.P., 2003, John Wiley & Sons.
10. Remote Sensing: Principles & Applications by Panda, B.C., 2005, Viva Books Pvt. Ltd.

Geol. 605: Environmental Geology

Introduction to environmental geology. Management of natural resources. Air pollution and global climatic changes. Environmental controls for erosion, desertification and coastal degradation. Geological hazards such as floods, landslides, earthquakes, volcanoes, glaciers and shoreline processes, their remedial measures. Environmental impact of mining, dams, reservoirs, highways, their assessment and controls. Cleaner sources of energy.

Industrial pollution, waste disposal, groundwater contaminations, river lake and marine pollution and their impact on human health. Geological aspects of human health. Trace elements and health hazards.

Lab: Sampling and analysis of air, water, soil and rocks.

Books Recommended:

1. Environmental Geology by Keller, E.A., **latest Ed.**, Chales E. Merrill Publishing Co.
2. Applied Chemical Groundwater Hydrology by Mazore, E., 1988, McGill.
3. Earthquake Risk and Damage by Liu, B.C., 1981, Westview.
4. Environmental Geology by Montgomery, C.W., 2005, McGraw Hill.
5. Radio Propagation and Remote Sensing of the Environment by Armanel, N.A., Polyakove, V.M., 2005, CRC Press.

Geol. 607: Engineering Geology

Rock and soil mechanics and its application in civil engineering. Rock mass characteristics. Elastic properties and rocks. Geological factors and strength of rocks. Classification of rocks. Study of geological factors in relation to the construction of buildings and foundations, roads, highways, tunnels, dams and bridges. Application of geophysical methods. Case histories of important engineering projects (small & mega) in Pakistan. Site investigation for engineering projects. Construction materials. Landslides, their causes and prevention.

Lab: Determination of physical and geotechnical properties of soils and rocks. Visits to the engineering projects.

Books Recommended:

1. Engineering Geology by Beavis, F.C., 1985, Blackwell.
2. Geology for Engineers by Blyth, F.G.H. & De Freitas, M.H., 1960, Butter & Tonner Ltd.
3. Geology and Engineering by Legget, R.F., 1962, McGraw Hill.
4. Fundamentals of Engineering Geology by Bell, F.A.G., 1983, Butter Worth.
5. Measuring Engineering Properties of Soil by Wray, W.K., 1986, Prentice Hall.
6. Engineering Geology by Goodman, R.E., 1993, John Wiley & Sons.

Geol. 609: Hydrogeology

The hydrologic cycle. Formation of aquifer system and types. Occurrence and movement of groundwater. Hydrologic properties of rocks and their measurements. Fluctuation of groundwater levels and causes. Recharge and discharge of ground water. Groundwater exploration by geological, hydrogeological and geophysical methods and remote sensing techniques. Well hydraulics, tube well drilling techniques, designing, development and pumping tests. Waterlogging and causes of water table declination. Groundwater chemistry, salinity, quality analysis and deterioration of water quality. Groundwater resources of Pakistan.

Lab: Inventory and monitoring of groundwater. Preparation of water table and piezometric surface maps. Study and preparation of hydrogeologic maps. Graphical presentation of chemical analysis of groundwater. Field visits to drilling sites.

Books Recommended:

1. Field Hydrogeology by Brassington, R., 1988, John Wiley & Sons.
2. Groundwater Hydrology by Todd, D.K., 1995, John Wiley & Sons.
3. Groundwater Resource Evaluation by Walton, W.C., **latest Ed.**, McGraw Hill.
4. Introduction to Groundwater by Michael, P., 1985, George Allen & Unwin.
5. Applied Hydrogeology by Fetter, C.W., 1994, MacMillan Pub. Co.
6. Groundwater by Ragnath, H.M., 1992, Wiley Eastern Ltd.
7. Atlas of WAPDA
8. Groundwater Hydrology by Bouwer, H., 1988, McGraw Hill.
9. Hydrology and Groundwater Resources of NWFP by Kruseman, G.P., 1988, WAPDA.

Geol. 611: Micropaleontology and Biostratigraphy

Introduction to Foraminifera, Bryozoa, Ostracoda, Conodonts, Algae, Pollen and Spores, organic walled microplanktons and nanno-fossils. Principles of bio-stratigraphy and bio-stratigraphic zones. Bio-stratigraphic techniques and procedures. Tertiary bio-stratigraphy with special reference to Pakistan.

Lab: Basic micro-paleontological and bio-stratigraphic techniques. Morphological and taxonomic studies of selected microfossils.

Books Recommended:

1. Microfossils by Brasier, M.D., 1980, Allen and Unwin.
2. Invertebrate Fossils by Fischer, G.A. and Moore, R.C., latest Ed., McGraw-Hill.
3. Introduction to Marine Micropaleontology by Haq & Boersma, 1980, Elsevier.
4. Paleontology by Tucker, V.C.T. and Noeld, E.W., 1985, Pergamon Press.
5. Plankton stratigraphy by Balli & Saunders, 1986, Oxford University Press.

Semester VIII (Special papers)

A number of areas of specialization have been identified and defined. A choice of courses will be available in each field of specialization (groups). In addition to thesis work a student must take two courses from the following groups directly relevant to the thesis.

GROUP-I: MINERALOGY AND PETROLOGY

This group comprises the following courses:

1. Geochemistry
2. Igneous Petrology;
3. Metamorphic Petrology;
4. Sedimentary Petrology
5. Advanced Mineralogy

1. Geochemistry

Classification and distribution of elements. Causes for the diversity in igneous rocks. Geochemical characteristics of igneous rocks as petrogenetic indicators. Processes which modify the composition of primary magmas. Geochemical characteristics of different magma series. Geothermometry and geobarometry. Metasomatism, its types and transfer of material involved

Lab. I: Characterization of igneous rocks on the basis of their (a) modal and (b) chemical composition. Calculation of normative composition from the major element chemistry of igneous rocks. The use of major and trace element composition of igneous rocks as a means to determine their paleotectonic setting.

Graphical representation of metamorphic mineral parageneses (ACF and AKF diagrams). Parentage of a variety of metamorphic rocks on the basis of their major and trace element geochemistry. The use of mineral chemical data for estimating pressure-temperature conditions of metamorphism.

Books Recommended:

1. Igneous and Metamorphic Petrology by Best, M.G., 1982, W. H. Freeman & Co.
2. Petrogenesis of Metamorphic Rocks by Butcher, K. & Frey, M., 1994. Springer-Verlag.
3. The Interpretation of Igneous Rocks by Cox, K.G., Bell, J.D. & Pankhurst, R. J., 1979. George Allen & Unwin.
4. Petrology of the Igneous Rocks by Hatch, F.H., Wells, A.K. & Wells, M.K., 1975, Murby.
5. Introduction to Geochemistry by Krauskopf, K.B., 1982, McGraw-Hill.
6. Petrology by Nockolds, S.R., Knox, R.W. O'B. & Chinner, G.A., 1978, Cox & Wyman.
7. Using Geochemical Data: Evaluation, Presentation and Interpretation by Robinson, 1993, Longman.
8. Geochemistry by Wedepohl, K.H., 1967, Holt, Rinehart & Winston.
9. Igneous Petrogenesis by Wilson, M., 1989, Academic Press.
10. Geochemistry, by Brownlow, A.H., 1996, Prentice Hall.

2. Igneous Petrology

Igneous rock associations. Petrogenesis of igneous rocks. Petrogenic provinces: Basaltic provinces. Granite-granodiorite provinces and mafic-ultramafic complexes.

Tectonism-magmatism relationship. Igneous activity related to convergent plate boundary and divergent plate boundary environments. Intracontinental hot spots. Continental rift related magmatism. Collisional and subduction environments and igneous activity. Ophiolites. Mantle-magma systems and source of magma. Physico-chemical factors in magmatic evolution.

Lab.II: Petrographic study of rock suits. Modal analyses.

Books Recommended:

1. Igneous Petrology by Hill, A., 1987. Longman Scientific & Technical.

2. Petrology: Igneous, Sedimentary and Metamorphic by Ehlers, E.G. & Blatt, H.W.H., 1982, W. H. Freeman & Co.
3. Petrology: Igneous and Metamorphic Rocks by Hyndman, D.W., 1972, McGraw Hill.
4. Igneous and Metamorphic petrology by Best, M.G., 1982, W.H., 1982, W. H. Freeman & Co.
5. Igneous and Metamorphic petrology by Turner, F.J. & Verhoogen, J. 1960, McGraw Hill.
6. Igneous Petrogenesis by Wilson, M., 1989, Unwing Hyman.
7. Igneous Petrogenesis by Carmichael, I.S.E., Turner, F.J. & Verhoogen, J., 1974, McGraw Hill.
8. Igneous Petrology by McBirney, A.R., 1984, Freeman Cooper & Co.
9. Introduction to Igneous and Metamorphic Petrology by Winter, J.D., 2001, Prentice Hall.

3. Metamorphic Petrology

Basic characteristics of metamorphic reactions and role of fluids. Concept of iso-grades and iso-reaction grades. Very low grade and ocean floor metamorphism. Cataclastic metamorphism. Metamorphic facies series. P-T gradients, Mineralogical characteristics of individual facies, Progress metamorphism of pelites, basic rocks and carbonates. High grade metamorphism, anatexis and migmatites. Tectonics of regional metamorphic belts . Paired metamorphic belts. Metamorphic structure of continental crust.

Lab. III: Construction and interpretation of ACF and AKF diagrams. Petrographic study of various rocks suites. Mineral and mineral phase equilibria and P-T conditions.

Books Recommended:

1. Petrology: Igneous, Sedimentary and Metamorphic by Ehlers, E.G. & Blatt, H.W.H., 1982, W. H. Freeman & Co.
2. Igneous and Metamorphic Petrology by Hyndman, D.W., 1972, McGraw Hill.
3. Igneous and Metamorphic Petrology by Best M.G., 1982, W. H. Freeman & Co.
4. Metamorphic petrology by Turner, F.J., 1981, McGraw Hill.
5. Metamorphism and Plate Tectonics Regimes by Ernst, W.G. 1975, Dowden, Hutchinsonson & Ross, Inc.
6. Petrology of the Metamorphic Rocks by Mason, R., 1981, George Allen & Unwin/Thomas Murby.
7. Introduction to Igneous and Metamorphic Petrology by Winter, J.D., 2001, Prentice Hall.

4. Sedimentary Petrology.

Classification of sedimentary rocks. Fabric and framework geometry of sedimentary rocks. Classification texture, composition and diagenesis of limestone, sandstones, conglomerate, argillaceous rocks and various other types of sedimentary rocks. Provenance of sedimentary rocks. Study of heavy minerals.

Lab. IV: Study of texture, mineral composition and diagenesis of various types of conglomerates sandstones and limestones in hand specimens and thin sections. Heavy mineral separation and analyses.

Books Recommended:

1. Principles of Sedimentology and Stratigraphy by Boggs, S., 2001, Prentice Hall.
2. Sedimentary Geology by Prothero, D., Schwab, F., 1996, W.H. Freeman & Co.
3. Sequence Stratigraphy by Emery, D. & Myers, K.J., 1996, Blackwell.
4. Sedimentary Petrology, An Introduction by. Tucker, M.E., 1981, Blackwell.
5. Sedimentary Rocks by Pettijohn, F. J., 1975, Harper and Row.
6. Sedimentary Petrology by Tucker, M. E., 1990, Blackwell.

5. Advance Mineralogy

Physical and chemical properties of minerals. Relationship between the structure chemistry and properties of Silicates, carbonates, oxides, sulphides, and Phosphate. Mechanisms of mineral nucleation and crystal growth. Importance of kinetics in mineral formation. Interpretation of mineral analysis: Recalculation of a mineral analysis in terms of fixed number of anions, and, where appropriate, cations.

Measurement of mineral triple junction angles, description of grain boundaries and their implication for the development of rock textures. Use of computer programs, including spreadsheets, to calculate mineralogical parameter. Triangular and X-Y plots. Related mineralogical information to the assessment and performance of industrial rocks and minerals.

Lab. V: Microscopic identification of the common rock forming minerals in thin section, using transmitted and reflected light microscopy. Identification of common ceramic refractory and slag minerals in thin section.

Books Recommended:

1. Mineralogy for Students by Battey, M. H., 1981, Longman.
2. Mineralogy by Berry and Masson, 1983, W. H. Freeman & Co.
3. Mineralogy by Perkins, D., 2002, Prentice Hall.
4. Minerals in Thin Sections by Perkins, D., 2000, Prentice Hall.

5. Petrography of Igneous and Metamorphic Rocks by Philpotts, A. R., 1989, Prentice Hall.
6. Atlas of Rock-Forming Minerals in Thin Section by MacKenzie, W. S., Guilford, C. P., 1980, John Wiley & Sons.
7. Introduction to Rock Forming Minerals by Deer, W.A., Howie, R.A. & Zussman, J., 1992, Longman.

GROUP-II: PALEONTOLOGY AND STRATIGRAPHY

This group comprises the following courses:

1. Advanced Stratigraphy
2. Micropaleontology
3. Invertebrate Paleontology
4. Vertebrate Paleontology
5. Palynology and Paleobotany

1. Advanced Stratigraphy

Remote sensing and lithostratigraphy: establishment of photo stratigraphical succession and facies analysis. Evolutionary concepts in Biostratigraphy: diachroneity, evolution and biochronology. Tectonic stratigraphy: interpretation of complex deformed terrains. Principles and practices in event stratigraphy, cyclostratigraphy, seismic and sequence stratigraphy. Stratigraphic applications of Isotope geochemistry. Global standard stratigraphy: chronostratigraphy. Interpretation of Stratigraphic record: facies analysis, sea level changes, paleoenvironment and paleoclimates.

Lab. 1: Specified Assignments/projects

Books Recommended:

1. International Stratigraphic, Guide: A Guide to Stratigraphic Classification, Terminology and Procedures by Salvador A, 1994, The International Union of Geological Sciences, Trondheim and Geological Society of America, Inc.
2. Remote Sensing Digital Image Analysis, An Introduction by Richards J.A., 1983, Springer-Verlag.
3. Principles of Stratigraphical Analysis by Blatt, H., Berry, W.B.N. & Brande, S., 1991, Blackwell.
4. The Geological Interpretation of Well Logs by Rider, M.H. 1986, Blackie.
5. **Seismic Stratigraphy: Hand Book of Geophysical Exploration Seismic Exploration by Hardage, B.A., 1987, Vol. 9, Geophysical Press Ltd.**
6. Sequence Stratigraphy, Sea Level-change, and Significance for Deep Sea by Haq, B.U., 1991, In Macdonald, D.I.M. (eds.) Sedimentation

Tectonics and Ecstasy, Sea Level Changes at Active Margins. Special Publication of International Association of Sedimentologists.

7. Facies Models: Response to Sea Level Change by Walker, R.G. & James, N.P., (eds.) 1992, Geological Association of Canada.

2. Micropaleontology

General techniques of collection and preparation of material. Morphological, taxonomic, stratigraphical and paleoecological studies of Foraminifera, Ostracoda, Chitinozoa, Organic walled micropalankton, Pollen and Spores and Miscellaneous group. Study of Nanno Fossils.

Lab. II: Sampling and laboratory techniques. Microscopic examination and identification of selected microfossils from stratigraphy of Pakistan. Preparation of thin section of large foraminifera and their identification.

Books Recommended:

1. Aspects of Micropaleontology by Banner, F.T. & Jord, A.R., 1982, Allen and Unwin.
2. Elements of Micropaleontology by Bignot, G., 1985, Graham & Trotman.
3. Stratigraphy of Fossils Foraminifera by Jenkins, D.G. & Murray J.W., 1981, Ellis Horwood.
4. Introduction to Microfossils by Jones, D.J., 1980, Hafner Pub. Co.
5. Introduction to Marine Paleontology by Haq and Boersma, 1980, Elsevier.
6. Plankton Stratigraphy by Bolli, H.M. & Saunders, 1986, Cambridge Press.

3. Invertebrate Paleontology

Organic evolution and fossil record through ages. Detail classification, evolution and geographical distribution of important invertebrate Phyla like (Brachiopoda, Molluska, Cnideria, Arthropoda (trilobite) and Echinodermata etc.).

Lab. III: Description and identification of invertebrate fossils.

Books Recommended:

1. Invertebrate and Evaluation by Clarkson, E.N.K., 1986, Allen & Unwin.
2. Invertebrate Fossils by Moore, R.C. **latest Ed.**, McGraw Hill.
3. Principles of Paleontology by Raup, D.M. & Stanely, S.M., 1985, W. H. Freeman & Co.
4. Palaeontology by Tucker, V.C.T. & Noeld, E.W., 1985, Pergamon Press.
5. Paleobiology of Invertebrate by Tasch, P., 1980, John Wiley & Sons.
6. **A Trip Through Time: Principles of Historical Geology by Cooper J.D., 1986,**

4. Vertebrate Paleontology

Vertebrate and plant life through ages. Study of some major groups of vertebrate fossils. Evolution of some well known selected Fishes, Amphibians, Reptiles, Dinosaurs and Mammals. Introduction to Paleobotany, Siwalik fauna and Gondwana flora.

Lab. IV: Description and identification of vertebrate fossils.

Books Recommended:

1. Paleobotany by Stewart, W.N., 1983, Cambridge Press.
2. Vertebrate Paleozoology by Olson, C.V., **latest Ed.**, Wiley & Interscience.
3. Vertebrate Paleontology by Romer, A.S., 1974, University of Chicago Press.
4. Geology of India by Wadia, D.N., latest Ed., Tata McGraw Hill.
5. Dinosaur Encyclopedia by Don Lessem & Donald F. Glut, 1993, Random House.

5. Palynology and Paleobotany

Introduction, Methods of study, techniques of collection and preparation of palynomorphs. Types and functions of spores. Pollen and spore morphology, development of homosporous. Suprageneric classification of trilete spores. Distribution of Palynomorphs during various geological periods with special reference to Pakistan. Scope and application of palynology in petroleum industry. Study of Nanofossils.

Introduction, aims and object of paleobotany. Taxonomy of fossil and study of various groups of fossil plants. Paleobotany of fossil fuel reserves

Lab: Specified assignment/Projects.

Recommended Books:

1. Microfossils by Braiser, M.D., 1980, Allen and Unwin
2. Introduction to Marine Paleontology by Haque and Boersman, 1980, Elsevier.
3. Paleobotany by Stewart, W. N., 1983, Cambridge Press.
4. Principles of Paleobotany by William, C. D., **Latest Ed**, Ronald Press.

GROUP-III: ECONOMIC GEOLOGY

This group comprises the following courses:

1. Ore Deposits
2. Mineral Exploration
3. Coal Geology
4. Mining Geology and Mineral Economics.
5. Metallogeny and Plate Tectonics

1. Ore Deposits

Magmatic deposits: The ultramafic-mafic Cr-Ni-PGE deposits, the mafic-ultramafic Fe-Ni-Cu sulphide deposits, the quartz monzonite-granodiorite Cu-Mo sulphide deposits, the anorthosite-gabbro Fe-Ti deposits. Ores associated with carbonatites. Hydrothermal vein deposits. Iron concentration of sedimentary affiliation. Manganese concentration of sedimentary affiliation. Stratiform sulphides deposits. Stratabound ores of sedimentary affiliation. Ores formed by metamorphic processes. Introduction to tectonic setting and mineralization.

Lab. I: Specified assignments/projects

Books Recommended:

1. Ore Deposits Geology by Edwards, R. & Atkinson, K., 1986, Chapman and Hall.
2. An Introduction to Ore Geology by Evans, A.M., 1980, Blackwell.
3. Mineral Deposits and Global Tectonic Settings by Mitchell, A.H.J. & Garson, M.S., 1981, Academic Press.
4. Mineral Deposits in Relation to Plate Tectonics by Sawkins, F.J., 1984, Springer-Verlag.
5. Ore Petrology by Stanton, R.L., 1972, McGraw Hill.
6. Metallogeny and Plate Tectonics by Strong, D.F. (ed.), 1976, Geol. Assoc. Canada.

2. Mineral Exploration

Geochemical exploration: principles of geochemical dispersion, choice of media for sampling, field methods and sampling theory, analytical methods and quality control, and data interpretation, geochemical and metallogenic provinces, rock, soil, water and stream sediments geochemical survey for mineral exploration. Case studies and exercise will be the part of practical. Extensive use is made of computer-based data analysis.

Geophysical exploration: principal geophysical techniques, including magnetic, electromagnetic, electrical, radiometric, gravity and seismic methods as applied to mineral exploration. Exercise will be the part of practicals.

Lab. II: Specified assignments/projects

Books Recommended:

1. Economic Evaluation in Exploration, by Friedrich, W.W., 1986, Springer-Verlag.
2. Statistics and Data Analysis in Geology, by Davis, J.C., 1986, John Willey & Sons.
3. Geological Problem Solving with Lotus 123 for Exploration and Mining Geology, by George, S. Koch, G.S Jr., 1990, Pergamon Press.

4. Geochemistry in Mineral Exploration by Rose, A.W., Hawkes, H.E. & Webb, J.S., 1983, Whitstable Litho Ltd.
5. Geochemical Exploration by Joyce, A.S., 1984, Australian Mineral Foundation.
6. Mineral Prospecting Manual by Chaussier, J.B. & Morer, J., 1987, North Oxford Academic.
7. Exploration and Mining Geology by Peters, W.C., 1978, John Wiley & Sons.
8. Techniques in Mineral Exploration by Reedman, J.H., 1979, Applied Science Publishers.
9. Exploration Methods: Course Notes by Claverino, J., Dawney, R. & Stephenson, P., 1994, Australian International Assistance Bureau.
10. Evaluation of Mineral Reserves by Journal, A.G., 2004, Oxford University Press.

3. Coal Geology

Definition, composition, classification and origin of coal. Lithotypes and coal macerals. Chemical and petrographical analysis. Application of coal petrography. Depositional environments of coal and coal bearing strata, coalification process, types of coal basins and their tectonic setting, concepts of cyclic deposition in coal basin, origin of splits and partings in coal seams. Comparison between modern and ancient coal forming environments, structural problems relevant to exploration & mining. Coal utilization and resource evaluation. Coal bearing sequences of Pakistan. Methods of coal exploration: geological, geophysical and drilling. Coal mining and its environmental issues.

Lab. III: Petrography of coal and associated rocks. Specified assignments/projects. Preparation of coal pellets, petrographic methods of coal analysis.

Books Recommended:

1. Significance of Coal Resources of Pakistan by Kazmi, A.H. & Raza, H.A., 1990, Geological Survey of Pakistan.
2. Sedimentology of Coal and Coal Bearing Sequences by Rehmani, R.A. & Flores, R.M. 1984, International Association of Sedimentologists, Blackwell.
3. Coal Geology and Coal Technology by Ward, C.R., 1984, Blackwell.
4. Terrigenous Clastic Depositional Systems, Application to Petroleum, Coal and Uranium Exploration by Galloway, W.E. & Hobday, D.K., 1983, Springer-Verlag.
5. Principles and Applications of Coal Petrology SEPM Short Course No.8 by Crelling, J.C. & Dutcher, R.R., 1980, Society of Economic Paleontologists and Mineralogists Indian University at Bloomington.
6. Stach's Textbook of Coal Petrology by Stach, E., et al., 1982, Gebruder Borntraeger.

7. International Handbook of Coal Petrology by International Committee for Coal Petrology, 1985, University of Newcastle Upon Tyne.
8. Coal: Typology, Chemistry, Physics & Constitution by Van Krevelen, D.W., 1981, Elsevier.
9. Coal Combustion and Gasification by Smoot, L.D. & Smith P.J., 1985, Plenum Press.

4. Mining Geology and Mineral Economics

Terms and definitions of mine workings. Openings through adits, shafts, inclines, vertical cross cuts. Choices of mining methods and modes of extraction. Structural controls in mining: bedding, faults, joints folds, fractures and intrusion. Correlation of data Spatial relationship of seams. Surface and underground, mapping methods. Calculation of grade ad tonnage of ore. Gases in mines, spontaneous combustion. Rock pressure and support, collapse of working faces, pillars, longwall timbering, benches, safety measures. Waste disposal management, impact of mining on land. Water, air and biological resources. Remedies, long term planning and rehabilitation. Practical work at an operative mine.

Estimation of ore reserves/ore resources: Factors affecting mine size grade and distribution of ore body, or reserves, prediction and estimation of cost. Expenditure: Capital cost, equipment cost, infrastructure cost and mine excavation cost, operation cost, power and fuel charges, labour charges, maintenance of plant and equipment, drilling and blasting charges, haulage, ore, grade control, administration cost, mineral prospecting cost and time exploration cost. Requirements of revenue calculation, quotation of metal prices, estimates of mine dilution, estimates of mill-recovery, estimates of smelter charges, royalties and levies, depreciation factor, amortization and depletion allowance. Taxable income, income tax, net profit after taxes, cash flow, time value money and net present value. Risk minimization, sensitively analysis and risk management, limiting financial losses, high grade mining priority, forward selling, limited resource project financing and gold loans. Development decisions based on economic evaluation.

Lab. IV: Specified assignments/projects, to develop an economic model for a mineral deposit.

Books Recommended:

1. Mining Geology by Mckinstry, H.B., **latest Ed.**, Prentice Hall.
2. Exploration and Mining Geology by Peters, W.E., **latest Ed.**, John Wiley & Sons.
3. Techniques in Mineral Exploration by Reedman, J.H., **latest Ed.**, ASP.
4. **International Mineral Economics by Goecht, W., Zant, II & Eggert, R.C., latest Ed.**
5. **A Guide to Mineral Resources Development by Woaks, M. & Carman, J.S., latest Ed.**

5. **Metageny and Plate Tectonics**

Introduction to ore deposits. Ore forming processes, Plate tectonic, geology and ore deposits. Ore deposits Models. Metal deposits of oceanic–type crust. Intercontinental hotspots and anorogenic magmatism. Deposits of the early and advanced stage rifting. Deposits of principal arc. Deposits of arc related rifts. Other arc related deposits. Metal deposits in relation to collisional events. Tectonic related mineralization in Pakistan.

Books recommended:

1. Metal Deposits in Relation to Plate Tectonics by Sawkins, F.J., 1990, Springer-Verlag.
2. Mineral Deposits and Global Tectonic Setting by Mitchell, A.H.G. & Garson, M.S., 1981, Academic Press.
3. Metallogenic Evolution of a Collisional Mountain Belt in Pakistan: A Preliminary Analysis by Sillitoe, R.H., 1978, Jour. Geol. Soc. London, vol. 135, pp. 377-387.
4. Metallogeny and Plate Tectonic by Strong, D.F. (ed.), 1976, Geol. Soc. Canada Special Publication 14.
5. An Introduction to Ore Geology by Anthony Evans, M., 1987, Blackwell.
6. Ore Deposit Geology, by Edward, R. & Atkinsons, K., 1986, Chapman & Hall.
7. The Earth: A Very Short Introduction by Martin Redfern, 2003, Oxford University Press.
8. Continents and Supercontinents by Rogers, J.J.W., 2004, Oxford University Press.
9. Tectonic Boundary Conditions for Climate Reconstructions by Crowley, T.J., 1998, Oxford University Press.
10. Plate Tectonics and Hydrocarbon Accumulation by Dickinson, W.R. & Yarborough, H., 1982, AAPG Education Course Note Series.

GROUP-IV: ENGINEERING GEOLOGY

This group comprises the following courses:

1. Rock Mechanics
2. Soil Mechanics
3. Seismotectnoics
4. Engineering Geology

1. Rock Mechanics

Fabric and mechanical nature of rocks. Determination of rock quality for engineering purposes. Stress strain behaviors of different rocks. Rock mass strength. Theories of failure. Types of fracture. Rock deformation in compression. Factors controlling mechanical behaviors of rocks. Excavation methods in rocks. Distribution of stresses around underground excavations.

Use of photo elasticity in rock mechanics. Measurement of stresses in situ. Wave propagation in rocks. Dynamic Models.

Lab. I: Specified assignments/projects.

Books recommended:

1. Rock Mechanics for Underground Mining by Brady, B.H.G. & Brown, E.T., 1985, Allen & Unwin.
2. Engineering Geology by Beavis, F.C., 1985, Blackwell.
3. Structural and Geotechnical Mechanics by Newark, N.M., **latest Ed.**, Prentice Hall.
4. Engineering Geology and Rock Mechanics by Duncan, N., **latest Ed.**, Leonar Hill.
5. Rock Engineering by Franklin, J.A. & Dusseault, M.B., 1989, McGraw Hill.

2. Soil Mechanics

Introduction and concept of soil mechanics. Soil formation and its classification, survey and sampling with its important engineering properties like density, permeability, shearing strength, bearing capacity, consolidation and settlements.

Lab. II: Index properties of soil determination of soil density, permeability, unconfined shearing and compressive strength of soil and Attenberg's limits.

Books recommended:

1. Problems in Engineering Soils by Capper, P.L. & Cassie W.E. & Geddes, J.D., latest Ed., John Wiley & Sons.
2. Engineering Geology by Beavis, F.C., 1985, Black well Scientific Publications.
3. Structural and Geotechnical Mechanics by Newark, N.M., latest Ed., Prentice Hall.
4. Engineering Geology and Rock Mechanics by Duncan, N., latest Ed., Leonar Hill.

3. Seismotectonics

Introduction to seismology. Seismology and interior of earth, progress of seismology. Application of seismology. Global mosaic of earthquakes, earthquake effects, depth of earthquake, tectonic pattern, types of seismic waves in earthquake shaking. Causes of earthquakes, size of an earthquake, stimulation of earthquake by water. Seismicity related with different plate boundaries: convergent plate boundary, divergent plate boundary, transforms plate boundary and intraplate setting.

Seismicity and tectonics: thin-skinned tectonics, thick-skinned tectonics and flake tectonics. Seismotectonics of Himalayas, Hindukush, Zagros, Alps and

cordillera orogenic belts. Seismotectonics of Basin and Range Province of USA.

Damage observations and earthquake intensity. Determination of focal depth, location of epicenter, earthquake source mechanism and fault plane solution, seismicity and seismic zoning maps, earthquake prediction and modification, seismic site investigation and surveillance, model test in earthquake engineering.

Seismotectonic study for engineering structures, Nuclear plants, Highways, Dams, Bridges, Buildings, Waste disposal and slope instability.

Lab. III: Specified assignments/projects

Books recommended:

1. Active Tectonics. National Academy Press Washington, 1986.
2. Engineering Seismology by Agrawal, P.N., 1991.. Oxford and IBH publisher company.
3. An introduction to Seismological Research History and Development by Benjamin., Howell, J.K., 1990., Cambridge University press.
4. Earthquakes a Primer by Boit, B.A., 1978, W.H. Freeman and Company.
5. Geodynamics of Pakistan by Farah, A., and DeJong, K. A., 1979. Geological Survey of Pakistan.
6. Zagros-Hindukush-Himalaya, Geodynamic Evolution by Gupta, H.K., and Delaney, F.M., 1981. Geodynamic Series, vol. 3. American Geophysical Union Washington, D.C., Geological society of America.
7. Tectonics of the Western Himalayas by Malinconico, L.L., and Lillie, R.J., 1989, Special paper, 232, Geological Society of America Colorado, USA.
8. Geological Structures and Moving Plates by Park, R.G., 1988, Chapman and Hall publisher.
9. [Geology of Earthquakes by Roberts S.Yeats, 1997, Oxford University Press.](#)
10. Elementary Seismology by Richter, C.F., 1958, W. H Freeman and Company.
11. Geophysical Method in Geology by Sherma, P.V., 1986, Elsevier.
12. Neotectonics of North America by Slemmons, D.B., Engdahl, E.R., Zoback, D. & Blackwell, D.D., Geological Society of America.
13. Gravity Field Seismicity and Tectonics of the Indian Peninsula and the Himalayas by Verma, R.K., 1985., Allied Publishers.
14. Geodynamics of the Indian Peninsula and the Indian Plate margin by Verma, R.K., 1991, Oxford and IBH Publication Company.
15. Physical geology exploring the earth by Wincander, R., 2001, A Division of Thomson Learning Canada.
16. The evolving continents, second edition, by Windlay, B.F.,1982, John Wiley and Sons.

4. Engineering Geology

Preliminary and geological and geophysical surveys and the use of aerial photographs. Drilling methods, drilling equipments and application of results obtained by drilling. Well logging, disturbed and undisturbed samples. Other exploratory methods like, tunnels, edits, test pits etc. Field testing and applications.

Classification of dams, gravity, buttress, arch earth fill and rock fill dams. Forces acting on dams, Investigation for dam foundation. Abutments, reservoir and borrow areas. Causes of failures of the dams with examples. Design criteria, influence of topography and geological features on the selection of site and type of dam. Problems associated with dams, seepage control, grouting materials and methods. Sliding and uplift of the dam. Case histories of various dams in Pakistan.

Behaviour of different materials on the slopes. Factors controlling stability of slopes. Failure mechanics in different materials. Analysis for the stability condition and slope protection. Various kinds of buildings and their foundations. Investigation for different types of building. Field exploration and testing. Laboratory investigations. Foundation analyses and evaluation of the design parameters. Various methods of tunnel excavation in different materials, investigation and purposes, sporting techniques. Investigation for the sub-grade materials. Highway and building aggregate, evaluation of various materials.

Lab. IV: Specified assignments/projects.

Books recommended:

1. Principles of Engineering Geology by Attewell, P. B. & Farmer, I. W., latest Ed., John Willey & Sons.
2. Engineering Geology by Beavis, F.C., 1985, Blackwell Scientific Publications.
3. Principles of Engineering Geology by Johnson, R.B. & Degraff, J. V., latest Ed., John Willey & Sons.
4. Fundamentals of Engineering Geology by Bell, F.A.G., 1983, Butter Worth.
5. Engineering Geology by Goodman, R.E., 1993, John Wiley & Sons.

GROUP-V: PETROLEUM GEOLOGY

This group comprises the following courses:

1. Petroleum Geology
2. Sequence Stratigraphy.
3. Petroleum Engineering & Geophysical Methods.
4. Reservoir Geology.
5. Clay Mineralogy
6. Organic Geochemistry.
7. Petroleum Geology of Pakistan.

1. Petroleum Geology

Origin, migration and accumulation of natural hydrocarbons. Reservoir rocks, pore-spaces and fluid transmissibility, reservoir mechanics, conditions of temperature and pressure. Geological structure of oil and gas fields of Pakistan, review of important world hydrocarbon fields.

Lab. I: Megascopic and microscopic examination of various important sedimentary rocks in relation to sedimentary environments, sedimentary basin analysis and interpretation. Structural and map exercises concerning oil/gas fields. Laboratory tests on hydrocarbons.

Books Recommended:

1. The World of Petroleum by Deshpande, B. G., 1992, Wiley Eastern Limited.
2. Petroleum Engineering, Drilling and Well Completions by Hall, P., Englewood & Cliffs, N. J. Latest Ed., Carl Gatlin.
3. Hydrocarbons from Coal, by Law, B.E., and Rice, D.D., 1993, AAPG Studies in Geology # 38
4. Petroleum Geology by North, F.K., 1985, Allen Unwin.
5. Sedimentary Basins Evolution by Gerhard Einsele, 1991, Facies and Sediment Budget, (Springer-Verlage).
6. Dynamics of oil and gas accumulations by Perrodo, A., 1983 Elf Aquitaine, France.
7. World of Petroleum by Deshpande, B.G., 1996, Wiley Eastern limited , Delhi.
8. Geology of Petroleum by Laverson, A., 1967, Freeman, San Francisco.
9. Petroleum Geochemistry and Geology by Hunt, J. M., 1995, Freeman.
10. Elements of Petroleum Geology by Selley, R.C., 1998, Academic Press.
11. Well Log Formation Evaluation by Richard H. Merkel, 1986, AAPG course notes #14

2. Sequence Stratigraphy

Introduction and history: Seismic stratigraphy: seismic reflections and seismic facies, Sequence stratigraphy: concept and significance. Sea level changes, their causes and effects. Accommodation, eustatic sea level curve. Hierarchy of sequence stratigraphic elements. Types of sequences and systems tracts. Forced regressions. Sequence hierarchy and composite sequences. Key surfaces, their recognition and significance. Various approaches of sequence stratigraphy. Clastic and carbonate sequence stratigraphy e.g., curves of Galloway, Posser, Vail and Haq. Time stratigraphy, genetic sequence stratigraphy, fluvial sequence stratigraphy, sequence stratigraphy in core and wire line data sets. Application of sequence stratigraphy in tectonically active basins. Importance of trace fossils in sequence stratigraphy.

Lab. II: Interpretation and seismic reflections. Surface and seismic facies and identification of sequences.

Books Recommended:

1. Silici-clastic Sequence Stratigraphy in Well Logs, Cores and Outcrops by Van Wagoner, J.C., and others, 1990. Am. Assoc. Petrol, Geol. Meth Expl. Ser. No.7, 55pp.
2. Sea-level Changes an Integrated Approach by Wilgus, B.S. and others., 1988. SEPM.
3. Siesmic Stratigraphy: Application to H-carbon Exploration by Payton, C.W., 1977, AAPG Mem. 26.
4. Sequence Stratigraphy and Facies Association by Posamentier H.W. & Others, 199321, Blackwell Scientific Publications.
5. Sequence stratigraphy by Emery, D. & Myers, K.J., 1996, Oxford, Blackwell Science.
6. Seismic Stratigraphy II, An integrated Approach by Orville Roger Berg & Donald G. Woolverton, AAPG Memoir 39 Tulsa, Oklahoma, USA.
7. Reflection Seismology, A tool for Energy Resource Exploration by Kenneth H. Waters, 1981, Wiley and Sons.

3. Petroleum Engineering and Geophysical Methods

Drilling methods, equipment, fluids, their composition and function. Coring and core analysis. Oil well survey and logging. Well production and simulation. Well completion and extraction methods. Evaluation of the petroleum potential of bore-hole sections using techniques of geophysical logs, the direct evidence of drill cuttings, cores and mud logs.

Methods of geophysical prospecting with special emphasis on seismic methods. Evaluation of bore-hole sections for hydrocarbons and groundwater.

Lab. III. Specified assignments/projects

Books Recommended:

1. Introduction to Geophysical Prospecting by Dobrin, M.D. & Savil, C.H., 1988, McGraw Hill.
2. Geophysical Methods by Robbert, E.S., 1989, Prentice Hall.
3. Petroleum Engineering, Drilling and Well Completions by Gatlin, C., Latest Ed., Prentice – Hall.
4. Drilling of Oil and Gas by Sereda, N.G. & Solvyon, E.M., latest Ed., Wells Mir Pub.
5. Well Log Formation Evaluation by Merkel, R.H., 1986, AAPG course notes #14.

4. Reservoir Geology

Reservoir rock types: clastics, carbonates, and non-marine reservoirs. Reservoir properties, depositional and diagenetic controls. Fluid properties and their saturation. Hydrocarbon distributing and fluid contracts. Reservoir zonation and thickness mapping reservoir pore spaces configuration, mapping reservoir heterogeneity. Reservoir estimation and calculation of reservoir volumetric, material balance and production decline curve methods. Appraisal and development of reservoir basic concepts.

Introduction to Reservoir Engineering. Rock and fluid properties. Rock description. Diagenesis. Porosity permeability and fluid saturations. Driving mechanism, formation and evaluation. Core analysis. Well logs and well testing. Reservoir types; saturated and under saturated. Gas and gas condensate material balance equation.

Lab. IV: Specified assignments/projects.

Books Recommended:

1. Introduction to Petroleum Reservoir Analysis by Koederitz I.F. Heavey., A.H. and Honarpour 1989, Contribution in Petroleum /Geology and Engineering-6 Gulf Publishing Co.
2. Development and Exploration of Oil and Gas Field by Muravyor, R. et al., latest Ed., Peace publishers.
3. Petroleum Geology by North F.K. 1985. Allen & Unwin London.
4. Applied Subsurface mapping by Tearpock. D.J. & Bischke. R.E. 1991. Prentice Hall.
5. Basics of Reservoir Engineering by Coss, R., 1993, Editions Technip.
6. Reservoir Characterization by Lake, L.W. & Carrol Jr, H.B., 1986. Academic Press.
7. Modern well Test Analysis (A Computer Aided Approach) by Roland., H.N., 1995 Petrowy.
8. Geostatistical Reservoir Modeling by Clayton V. Deutsch, 2002, Oxford University Press.
9. Well Log Formation Evaluation by Richard H.Merkel,1986,AAPG course notes #14

5. Clay Mineralogy

Introduction, structure and classification of clay minerals. Introduction to analytical methods. Origin and diagenesis: clay minerals during diagenesis and low grade metamorphism. Geological significance: depositional environments; clay minerals and sedimentation; Significance of clay minerals in soils. Industrial applications.

Lab. V: Sample preparation. Identification of clay minerals.

Books Recommended:

1. Clay minerals by Grim R.E., 1986, McGraw Hill, New York.
2. X-Ray Identification and crystal structure of clay minerals by Brown G., latest Ed., Min. Soc. London.
3. Crystal Structure of Clay Minerals and their X-Ray Identification by Brindley and Brown, 1980, Min Soc. London.
4. X-Ray Diffraction and the Identification and Analysis of Clay Minerals by Moore & Renolds, 1989.

6. Organic Geochemistry

Composition of biogenic matters. Geochemical conditions for the accumulation and formation of hydrocarbons. Generation and composition of petroleum hydrocarbons and coal. Geochemical assessment of source rocks. Geochemical assessment of primary and secondary migration. Application of different geochemical prospecting and exploration methods. Geochemistry of oil well water.

Lab. VI: Specified assignments/projects.

Books Recommended:

1. Geochemistry, by Beaumont, E.A. and Foster, N.H., 1988, AAPG special publication, No.8.
2. Geochemical Model for Characterization of Hydrocarbon Gas Sources in Marine Sediments by Bernad B et al., latest Ed., Proceeding nine Offsh technical conference, John Wely and Sons.
3. Marine Geochemistry by Chester, R. 1990, Unwin Hyman, London.
4. Predictive Source Bed Stratigraphy by Demaison, G.J., 1984, Proceedings Eleven World Petroleum Congress., John Wiley and Sons.
5. Petroleum Geochemistry and Source rock Potential of Carbonate Rocks by Demaison, G.J. & Moonne. G.T. 1984, AAPG Special Publication No.
6. Geochemistry and Basin Evolution by Kantsler, A.J. et al., 1983, AAPG Memorial No.35.
7. Introduction to Exploration Geochemistry (organic) by Levinson, A.A., latest Ed., Applied Publishing Ltd.
8. Recent Advances in Coal Geochemistry by Lynnchi, L. & Chou, C.L., 1980, The Geological Society of America, Inc., Special Paper,248.
9. Advances in Organic Geochemistry by BJOROY et al., 1981, John Wiley and Sons.
10. Advances in Petroleum Geochemistry vol.2 by Jim Brooks & Dietrich Welte, Academic Press.
11. Organic Maturation Studies and Fossil Fuel Exploration.
12. Fossil Fuel Biomarkers, Applications and Spectra by Philip, R.P.,1985,Elsevier Science Publishers.
13. Illustrated Glossary of Petroleum Geochemistry by Miles,J.,1991,Oxford Science London.

14. *Geochemistry in Petroleum Exploration* by Waples, D.W., 1985, International Human Resource Development Corporation, Boston, USA.

7. **Petroleum Geology of Pakistan**

History of petroleum exploration. New trends for petroleum exploration. Tectonic framework. Sedimentary basins and their evolution and distribution. Tectonics, depositional settings and lithostratigraphic divisions of the rocks of various geological periods. Facies development and their association in depositional basins and such as Indus, Balochistan and offshore regions. General evaluation of petroleum potentials of rocks of different basins. Structural styles and petroleum play in the basins of Pakistan. Source rocks, geothermal gradients and their maturity. Productive and potential oil and gas reservoirs and their distribution in the basins. Case histories of oil and gas fields of Pakistan.

Lab. VII: Specified assignments/projects.

Books Recommended:

1. *Geodynamic of Pakistan* by Farah, A., & Dejong K.A., 1979, Geological Survey of Pakistan.
2. *Marine Geology and Oceanography of Arabian Sea and Coastal Pakistan* by Haq, B.U. & Milliman, G.D., 1984, Jan Nostrand Reinhold Co.
3. *Petroleum Geology of Pakistan* by Kadri, I.B., 1995, Pakistan Petroleum Limited.
4. *Petroleum Source Rocks of Pakistan* by Raza H.A. 1991, Int. Petroleum Seminar, Sp. Publ.
5. *Petroleum for Future* by Raza, H.A. & Sheikh, A.M., 1988, (HDIP),
6. *Geology and Tectonics of Pakistan* by Kazmi, A.H. and Jan, Q., 1997, Graphic Publishers.
7. *Geology of Pakistan* by Bender and Raza, 1995, Gebruder Borntraeger.

GROUP-VI: APPLIED GEOPHYSICS

This group comprises the following courses:

1. Seismic Methods and Seismic Stratigraphy
2. Earthquake Seismology
3. Geomagnetism, Paleomagnetism
4. Radiometric Methods
5. Electrical Methods and Bore-Hole Geophysics
6. Geophysical Data Processing
7. Gravity and Magnetic Methods

1. Seismic Methods and Seismic Stratigraphy

Physical principles and basic theory. Seismic waves. Types of seismic methods. Velocities of seismic waves in rocks and factors influencing these velocities. Surveying techniques. Seismic energy sources. Instruments. Data acquisition and processing techniques. Interpretation. Applications and case histories.

Fundamentals of Seismic Stratigraphy. Concepts and models of various depositional systems. Seismic reflections in response to strata surfaces and unconformities. Seismic sequence analysis. Integration of seismic data with geology. Seismic facies analysis. Reflection character analysis. Geologic interpretation and evaluation for reservoirs, source rocks and seals for structural and stratigraphic traps.

Lab. 1: Specified assignments on data processing, analysis and interpretation.

Books recommended:

1. Seismic Exploration by Al-Sadi, H.N., 1980, , Birkhauser Verlag. Basel.
2. Dobrin, M.B. and SAVIT, C. H., 1988, McGraw Hill.
3. Introduction to Geophysical Prospecting by Kearey, P. & Brooks, M., 1991, Osney Mead.
4. Basic Exploration Geophysics by Robinson, E. S. & Coruh, C., 1988, John Wiley and Sons.
5. Geophysical Methods in Geology by Sharma, P.V., 1987, Elsevier Scientific Publishing Company.
6. Applied Geophysics by Telford, W. M., Geldart, C.P., Sheriff, R.E. & Keys, D.A., 1976, , Cambridge University Press.
7. Seismic Stratigraphic Interpretation and Petroleum Exploration by Brown, Jr., L. F & Fisher, W. B, 1985, AAPG.
8. Field Geophysics by Milson, J. 1989, Open University Press.

2. Earthquake Seismology

Mathematical analysis of seismological processes on the basis of elastic wave theory. Seismic waves and their analysis in earthquake seismology. Frequency, magnitude, energy of an earthquake and their relationship. Source parameters and their determination. Composite fault plane solutions of earthquakes and their determination. Geographical distribution of important earthquakes. Earthquakes and their implication on the tectonics of the area.

Lab. II: Specified problems on data processing, analysis, fault solutions and interpretation.

Books recommended:

1. The Interior of the Earth its Structure, Constitution and Evaluation by Bott, M.H.P., 1982, Edward Arnold.
2. Introduction to Seismology by Bath, M. 1979, Birkhauser Verlag, Basel.
3. An Introduction to the Theory of Seismology by Bullen, K.E. and Bolt, B.A., 1985, Cambridge University Press.
4. Quantitative Seismology by Aki, K. & Richards, P.G. 1980, W.H. Freeman & Company.
5. Seismic Waves and Sources by Ben-Menahem, A. & Singh, S.S. 1981, Springer-Verlag.

3. Geomagnetism and Paleomagnetism

Fundamentals of geomagnetism. Magnetic properties of rocks. Description of magnetic field of the earth. Paleomagnetic sampling. Measurement of NRM. Magnetic cleaning techniques and field tests of Paleomagnetic stability. Paleointensity analysis. Palaeomagnetism and its applications.

Lab. II: Specified assignments/projects

Books recommended:

1. Palaeomagnetism by Tarling, D.H. 1983, Chapman and Hall.
2. Rock Magnetism by Nagata, T., latest Ed., Maruzen Co., Ltd.
3. Introduction to Geomagnetism by Parkinson, W.D., 1983, Scottish Acad., Press.

4. Radiometric Methods

Physical principles and basic theory. Radioactivity of rocks. Radioactive dating methods. Field surveys and instruments. Data processing and interpretation. Applications.

Lab. IV: Specified problems on data acquisition, processing and interpretation.

Books recommended:

1. Introduction to Geophysical Prospecting by Dobrin, M.B. and Savit, C. H. 1988, McGraw Hill.
2. An Introduction to Geophysical Exploration by Kearey, P. & Brooks, M., 1991, Osney Mead.
3. Basic Exploration Geophysics by Robinson, E. S. & Coruh, C., 1988, John Wiley and Sons.
4. Geophysical Methods in Geology by Sharma, P.V., 1987, Elsevier Scientific Publishing Company.
5. Field Geophysics by Milson, J., 1989, Open University Press.

6. Radon Mapping in the Search for Uranium by Telford, W.M., 1982, In; Fitch, A.A. (ed.) Developments in Geophysical Exploration Methods. Applied Science.

5. Electrical Methods and Bore-hole Geophysics

Fundamentals of current flow in the earth. Electrode arrangements and field procedures. Instruments. Processing and interpretation of resistivity data. Field procedure, data acquisition and interpretation of self-potential, Induced polarization and electromagnetic methods. Study of Case histories. Principles of well-logging and theory. Formation evaluation. Different types of logging techniques and their fundamentals. Interpretation and applications.

Lab. V: Specified assignments on data acquisition/processing and interpretation.

Books recommended:

1. Introduction to Geophysical Prospecting by Dobrin, M.B. and Savit, C. H., 1988, McGraw Hill.
2. Applied Geophysics by Telford, W. M., Geldart, C.P., Sheriff, R.E. & Keys, D.A., latest Ed., Cambridge University Press.
3. Field Geophysics by Milson, J. 1989, Open University Press.
4. Interpretation Theory in applied Geophysics by Grant, F.S. & West, G.F., latest Ed., McGraw-Hill.
5. Interpretation Theory in Applied Geophysics by Grant, F.S. & West, G.F., latest Ed., McGraw-Hill.
6. Drilling Practices Manual by Moone, P.L., 1986, Pen Well.
7. Basic Well Log Analysis for Geologists by Asquith, G.B., and Gibson, C.R., 1982, Am. Assoc. Petroleum Geologists.
8. The Geological Interpretation of Well Logs by Rider, M.H., 1986, Blackie.
9. Fundamentals of Well Log Interpretation, 1. The Acquisition of Logging Data Serra, O., 1984, Elsevier.
10. Fundamentals of Well Log Interpretation, 2. The Interpretation of Logging Data Serra, O., 1986, Elsevier.

6. Geophysical Data Processing

Programming fundamentals. Analysis of geophysical data: analogue to digital; Sampling theorem; variance, regression and cluster analysis; Polynomial, Trend surface, least square methods. Time series and spectral analysis. Generation of digital filters. Linear and recurrent filters and filter performance. Wave shaping filters. Programming to processing and interpret data.

Lab. VI: Specified assignments/projects

Book recommended:

1. Statistics for Geoscientists: Techniques and applications by Pal, S.K., 1998. Concept Publishing Company.
2. Statistics and Data Analysis in Geology by Davis, J.C., latest Ed., John Wiley.
3. Geomathematics by Agterberg, F.P., latest Ed., Elsevier.
4. Spectral Analysis in Geophysics by Bath, M., latest Ed., Elsevier.
5. Fundamental of Geophysical Data Processing by Claerbout, J.F., latest Ed., McGraw Hill.
6. Introduction to Digital Filtering in Geophysics by Kulhanek, O., latest Ed., Elsevier.

7. Gravity and Magnetic Methods

Physical principles and basic theory. Instrumentation. Planning of the survey and evaluation of errors. Different survey methodologies. Rock densities/rock susceptibilities and their measurements. Isostasy. Data acquisition and reduction. Gravity/magnetic anomalies. Interpretation: Regional fields and residual anomalies, Derivatives, continuation of the field, Two and three-dimensional modeling. Application and Case histories.

Lab. VII: Specified problems on data acquisition. Processing and interpretation.

Book recommended:

1. Introduction to Geophysical Prospecting by Dobrin, M.B. & Savit, C. H., 1988, McGraw Hill.
2. An Introduction to geophysical Exploration by Kearey, P. & Brooks, M., 1991, Osney Mead.
3. Basic Exploration Geophysics by Robinson, E.S. & Coruh, C., 1988, John Wiley and Sons.
4. Geophysical methods in geology by Sharma, P.V., 1987, Elsevier Scientific Publishing Company.
5. Applied Geophysics by Telford, W. M., Geldart, C.P., Sheriff, R.E., and Keys, D.A., latest Ed., Cambridge University Press.
6. Interpretation Theory in applied Geophysics by Grant, F.S. & West, G.F., latest Ed., McGraw-Hill.
7. Theory of the Earth's Gravity Field by Pick, M., Picha, J. & Vyskocil, V. 1973, Elsevier Sci. Publ. Company.
8. Field Geophysics by Milson, J. 1989, Open University Press.

GROUP-VII: GEOCHEMISTRY

This group comprises the following courses:

1. Thermodynamics
2. Geochemical Exploration
3. Isotope Geochemistry
4. High Temperature Geochemistry
5. Low Temperature Geochemistry

1. Thermodynamics

Introduction and definitions of thermodynamic properties such as system, components, entropy enthalpy, and chemical potential. Laws of thermodynamics. Gibbs's energy and equilibrium G-X and T X diagrams. Henry's Law. Osmosis and osmotic pressure. Ideal and real solutions. Solid solutions. The phase rule with examples of different mineral associations. The ionization of weak electrolytes. Chemical equilibrium of gas and general solution reactions. Calculation of entropy changes in reversible and irreversible process.

Lab. I: Specified assignments/projects

Books Recommended:

1. Basic Chemical Thermodynamics by Waser., J., latest Ed., the Benjamin Cummings Publishing Company.
2. Equilibrium Thermodynamics in Petrology by Powell. R., latest Ed., Harper & Raw Publishers.
3. Thermodynamics in Geology by Fraser, D.G. latest Ed., D. Riedel Publishing Company.
4. Elementary Applied Thermodynamics by Granet. I., latest Ed., John Wiley & Sons, Inco.
5. Elements of Chemical Thermodynamics by Yeregin, E.H., 1986, Mir Publishers.
6. Geochemistry by Brownlow, A.H., 1996, Prentice Hall.

2. Geochemical Exploration

Basic principles for geochemical exploration. Geochemical dispersion, geochemical mobility and association of elements. Classification of mineral deposits. Types of geochemical anomalies in bed-rock, residual and over burden, drainage sediments, and natural waters. Role of path finder elements in mineral exploration. Decay pattern in stream sediments. Statistical interpretation of geochemical data. Geochemical methods and selection of sediments in mineral exploration with emphasis on litho stream

sediments and soil survey. Geochemical evaluation and appraisal of ore deposits.

Lab.II: Preparation of histogram, frequency diagrams and geochemical maps.

Books Recommended:

1. Geochemistry in Mineral Exploration by Rose, A.W. Hawkes, H.E. & Webb, J.S., 1981, Academic Press.
2. Exploration Geochemistry by Bradshaw, P.M.D., Clew, D.R. & Walker, J.L., latest Ed., Barringer Research, Rexadale.
3. Geochemical exploration by Joyee, A.S. 1984, Australian Mineral Foundation. Incorporated.
4. Geochemical Exploration by Elliott, I.L. & Fletcher, W.K., latest Ed., Elsevier Scientific Publishing Company.
5. **Petroleum Geochemistry and Basin Evaluation by Gerard Demaison & Relof J. Murriss, 1984, AAPG Memoir 35.**

3. Isotope Geochemistry

Theoretical and experimental principles. General characteristics of isotopes. Isotope fractionation processes, isotope exchange, kinetic effects. Mass spectrometry.

Oxygen and Hydrogen isotopes: Introduction, isotope composition of waters from various sources. Oxygen fractionation of rock forming minerals. Oxygen and hydrogen isotopes in igneous sedimentary and metamorphic rocks. Carbon isotopes: Introduction, fractionation mechanism, kinetic fractionation, photosynthesis, primary carbon in igneous rocks, application of isotope study of carbonates and hydrothermal ore deposits. Sulphur isotopes: Introduction, Biogenic fractionation, isotopic fractionation in sulphide minerals and ore fluids. Isotopic evolution of sulphates in marine and non marine sediments.

Criteria for useful radioactive nuclides, Radio active decay mechanisms. The Rb, Sr. Methods of dating: Geochemistry of rubidium and strontium, dating of Rb-bearing minerals in igneous rocks. Dating of igneous, sedimentary and metamorphic rocks. The Carbon 14 method of dating Principles of carbon – 14 dating, variation and causes of radiocarbon content of the atmosphere, causes for secular variation, dating of carbonate samples. U-Pb method: Geochemistry of uranium, decay series of uranium. The U-Pb Concordia diagram and alternate models.

Lab.III: Oxygen and Hydrogen Isotope relationship in Hydrothermal mineral deposits. Problems related to hydrothermal mineral deposits. Dating of samples by using $^{235}\text{U}/^{207}\text{Pb}$ method. Dating of samples by using $^{87}\text{Sr}/^{86}\text{Sr}$ ratio.

Books Recommended:

1. Principles of Isotope Geology by Foure, G., 1986, John Wiley & Sons.
2. Stable Isotope Geochemistry by Hoefs, J., 1980, Springer-Verlag.

4. Low Temperature Geochemistry

Factors affecting element distribution in sedimentary rocks. Chemical weathering and rock decomposition. Change in rock composition. Sequence of mineral alteration. Various stages of weathering. Differential loss of elements during weathering. Environments/agents of chemical weathering. General nature of weathering reactions such as solution and hydration, weathering of carbonates. Oxidation, hydrolysis of silicates. Transport, formation/deposition and alteration of silica, alumina, and clay minerals. CaCO_3 in surface water. The system CaCO_3 - CaMgCO_3 (sediments and diagenesis). Evaporites and their formation. Oxidation and reduction in sedimentation of iron, manganese and sulphur. Other oxidation and reduction processes. Organic material in sediments such as carbon and its compounds, organic matter in black shales. Carbon compounds as reducing agents. **Role of bacteria in the formation of sedimentary ores.** Diagenesis of iron minerals.

Lab. IV: Calculation of gains and losses during weathering. Characterization of sedimentary rocks on the basis of their chemistry. The use of geochemical data on sedimentary rocks as a guide to source rock composition, weathering condition and environment of deposition.

Books Recommended:

1. Chemical Fundamental of Geology by Gill, R.C., 1985, Harper Collins.
2. Petrology of Sedimentary Rocks by Greensmith J.T., latest Ed., Gerge Allen & Unwin.
3. Introduction to Geochemistry by Kranskopf, 1982 McGraw Hill.
4. Sedimentary Carbonate Minerals by Lippman, F., latest Ed., Springer-Verlag.
5. Aqueous Environmental Geochemistry, Langmuir, D., 1997 Prentice Hall

5. High Temperature Geochemistry

Geochemical characteristics of igneous rocks as petrogenetic indicator; Binary variation diagrams and fractionation indices. Triangular variation diagrams. Geochemical characteristics of primary magmas. Processes which modify the composition of primary magmas. Convection and mixing in magma chambers, fractional crystallization, crystal containment, zone refining, liquid immiscibility, gaseous transfer processes. Geochemical characteristics of different magma series.

Distribution of elements in metamorphic rocks. Behaviour of trace elements during the metamorphism of pelitic rocks. Geochemical criteria for distinguishing between ortho and para amphibolites and ortho and para gneisses. Geochemistry of granulite facies rocks and problems of their origin. Graphical presentation of metamorphic mineral paragenesis (ACF and AKF diagrams). Metasomatism, its types and transfer of material.

Lab. V: Characterization of igneous rocks on the basis of their model and chemical composition. Calculation of normative composition from the major element chemistry of igneous rocks. The use of major and trace element composition of igneous rocks as a means to determine their paleotectonic setting. The use of mineral chemical data for estimating pressure temperature conditions of metamorphism.

Books Recommended:

1. Principles of Isotope Geology by Faure, G., 1986, John Wiley & Sons.
2. Geochemistry in mineral exploration by Rose, A.W. Hawkes, H.E. & Webb, J.S., 1981, Academic Press.
3. Igneous petrogenesis by Wilson M. 1989, Unwin Hyman.
4. The interpretation of igneous rocks by Cox K.G. Bell J.D. & Pankhurst, R.J. 1987, George Allen & Unwin.
5. Chemical Fundamentals of Geology by Gill R.C. 1985, Hper Collins.
6. Archean Geochemistry by Kroner, A., Hanson, G.N. & Goodwib., 1984, Springer-Verlog.

GROUP-VIII: SEDIMENTOLOGY

This group comprises the following courses:

1. Clastic Sedimentology
2. Carbonate Sedimentology
3. Sedimentary Petrology
4. Basin Analysis
5. Quaternary Geology
6. Clay Mineralogy

1. Clastic sedimentology

Texture of clastic sedimentary rocks. Sedimentary structures, their classification, and hydrodynamic conditions. Pealeocurrent analysis and provenance of clastic rocks. Sedimentary environments and facies. Continental environments: Deserts, rivers lakes, glaciers and wind. Transitional environments; Delta, estuary, interdeltaic complexes. Marine environments: shelf, slope and deep marine.

Lab.1: Petrographic study of clastic rocks. Heavy mineral analysis. Recording, plotting and analysis of Paleocurrent data. Field techniques for study of clastic sedimentary rocks.

Books Recommended:

1. Sedimentary Environments and Facies by Reading, H.G. 1986, Blackwell Scientific Publications.
2. Ancient Sedimentary Environments by Selley, R.C., 1978, Chapman & Hall.
3. Origin of Sedimentary Rocks by Blatt. H., Middleton, G & Murrey, R., latest Ed., Prentice Hall.
4. Depositional Sedimentary Environments by Renieck, H.E. & Singh, I.B., 1980, Springer-Verlag.
5. Sand and Sandstones by Pettijohn by F.J., Potter, P.E. & Sever, R., latest Ed., Springer Verlag.
6. Principles of Sedimentology by Friedman, G.M. & Sanders, J.E. 1978, John Wiley & Sons.
7. Petrology of Sedimentary Rocks by Boggs Jr. S., 1992, Merril Publishing Co.
8. Sedimentary Rocks by Pettijohn, F.J., latest Ed., Harper & Row.
9. Depositional Systems, A Genetic Approach to Sedimentary Geology by Davis, R. A. Jr. 1983. Prentice-Hall.
10. Sedimentary Petrology, An Introduction by Tucker, M.E., 1981, Black Well Scientific Publications Osney Mead.
11. Terrigenous Clastic Depositional Systems, Application to Petroleum, Coal and Uranium Exploration by Galloway, W. E. & Hobday, D. k., 1983, Springer-Verlag, New York, Inc.
12. [A Practical Guide to the Study of Glacial Sediments by David J. Evans, 2004, Oxford University Press.](#)

2. Carbonate Sedimentology

Carbonate mineralogy and chemistry: structure of aragonite, calcite and dolomite, trace elements and isotopes, Dolomite and dolomitization models: Modern and ancient examples. Dolomitization reactions, trace element geochemistry of dolomites, dolomite petrography. Depositional textures and structures: Carbonate constituents, algal stromatolites. Classification of carbonates by Folk and Dunham. Porosity types. Concept of microfacies and microfacies types of Wilson. Major controls on carbonate sedimentation. Depositional processes and facies in carbonate rocks. Carbonate depositional models, platforms, rimmed shelves, ramps, epeiric platforms and isolated platforms. Cyclicity in carbonates. Modern carbonate environments of Bahamas, Florida and Persian gulf. Carbonate depositional systems; Lacustrine, shore line, peritidal reefs, shallow and deep water. Diagenetic processes: sequences and models.

Lab. II: Identification of carbonate sediments in hand specimen and then sections. Microfacies interpretations. Staining and XRD techniques.

Books Recommended:

1. Carbonate Sediments and their Diagenesis by Bathurst, R.G., latest Ed., Elsevier.
2. Marine Carbonate by Milliman, J.D., 1974, Springer-Verlag.
3. Carbonate Depositional Environment by Scholle, P.A. Bebout, D.G. & Moore, C.H., AAPG Mem.
4. Carbonate Sedimentology by Tucker, M.E. and Wright, V.P., 1990, Blackwell Scientific Publications.
5. Carbonate Depositional Environments by Scholle, P.A., Bebout, D.G. & Moore, C.H., 1993, Mem. Am. Assoc. Petrol. Geol.

3. Sedimentary Petrology

Classification of sedimentary rocks. Fabric and framework geometry of sedimentary rocks. Classification, texture, composition and diagenesis of limestones sandstones, conglomerates, argillaceous rocks and various other types. Provenance of sedimentary rocks. Inclusions, heavy minerals.

Lab. III: Study of texture, mineral composition and diagenesis of various types of conglomerates, sandstones and limestones in hand specimens and thin section. Heavy mineral separation and analysis.

Books Recommended:

1. Sedimentary Rocks by Pettijohn, F.J., latest Ed., Harper & Row.
2. Sand and Sandstones by Pettijohn, F.J. Potter, P.E. & Sever, R., latest Ed., Springer-Verlag.
3. Sedimentary Rocks by Greensmith, J.T., latest Ed., George Allen & Unwin.

4. Basin Analysis

Basin classification Sedimentation and plate tectonics. Basin model concept. Divergent plate margin basins, convergent plate margin basins. Transform margins and pull apart basins. Basins associated with sutures. Cratonic basins. Clastic petrofacies. Factors controlling basin stratigraphy and tectonic mechanism. Eustatic sea level changes; causes and response. Vail and Haq Curves: tectonic vs. eustatic controls. The basin fill depositional style, depositional system and facies models. Continental, coastal, near shore and deep sea depositional systems. Sedimentary basins of Pakistan.

Lab. IV: Stratigraphic columns and their correlation. Textural data interpretation. Paleocurrent data interpretation. Basin mapping methods.

Clastic petro facies analysis, interpretation of depositional basins and source area.

Books Recommended:

1. Basin analysis: Principles and Applications by Allen, P.A. and Allen, J.R. 1990 Blackwell Scientific Publications.
2. Foreland Basins by Allen, P.A. and Homewood. P & Wilium, G.D., 1986, Blackwell Scientific Publications.
3. Sedimentary Basin Evolution, Facies and Sediment Budget by Einsle, G., 1992.
4. Sedimentary Environment and Facies by Reading, H.G., 1986, Blackwell Scientific Publications.
5. Geology and Tectonics of Pakistan by Kazmi, A.H. and Jan, Q., 1997, Graphic Publishers.
6. Geology of Pakistan by Bender and Raza, (ed.) 1995, Gebruder Borntraeger.
7. Sedimentary Petrology by Tucker, M.E., 1991, Blackwell Publications.
8. Principles of sedimentary Basin Analysis by Andrew D. Mial, 1990, Springer-Verlag, New York Inc.

5. Quaternary Geology

The Quaternary period: character, duration, development and climatic changes Morphological evidence. Landforms. Pleistocene glaciation, and sea level changes. Lithological evidence of environments. Types of sediments. Isotopes in deep-sea sediments. Biological evidence; plant fossils and animal remains. Dating methods; Quaternary stratigraphy and correlation. Neotectonics. Quaternary deposits of Pakistan.

Lab.V: Sampling techniques. Assignments on specified topics.

Books Recommended:

1. Principles of Geomorphology by Thornbury, W.D., 1991, Wiley Eastern Ltd.
2. Geology and Tectonics of Pakistan by Kazmi, A.H. and Jan, Q., 1997, Graphic Publishers.
3. Geology of Pakistan by Bender and Raza, (ed.) 1995, Gebruder Borntraeger.

GROUP-IX: HYDROGEOLOGY

This group comprises the following courses:

1. Hydrology
2. Groundwater Investigations
3. Groundwater Engineering
4. Hydrochemistry & Groundwater Pollution

1. Hydrology

The role of groundwater in the hydrological cycle. Groundwater occurrence in different aquifer types and climates. Methods of estimating recharge and discharge. Physical and mathematical description of groundwater problems. Flow nets, tube wells, drains and ditches. Consideration of time-variant flow and steady-state flow. Field and laboratory measurements of hydraulic properties of different geological materials. Groundwater modeling techniques and resource management. Soil water balance and water budget estimate of aquifers.

Lab.I: Measurement of hydrogeologic properties of water-bearing formations. Practical applications of mathematical ground water model.

Books Recommended:

1. Groundwater and Wells by Driscoll, F.G., 1989. Johnson Filtration System Inc. St. Paul.
2. Groundwater Hydrology by Todd, D.K., 1980, John Wiley and Sons.
3. Groundwater by Freeze, R.A. & Cherry, J.A., 1979, A. Simo and Schuster Company.
4. Principles of Hydrology by Ward, R.C. & Robinson, M., 1990, McGraw-Hill Book Company.
5. Physical and Chemical Hydrogeology by Domenico and Schwartz, 1996, John Willey and Sons.
6. Applied Hydrogeology by Fetter, W, 1988, Merrill.
7. Introducing Grounds Water by Price, M., 1995, Allen and Unwin.

2. Groundwater Investigation

Groundwater exploration techniques, geological and hydrogeological maps, aerial photographs and satellite imageries. Use of various geophysical methods in groundwater exploration. The application of surface geophysical surveying to groundwater problems including identification of aquifer geometry, aquifer properties and water quality. Principles and application in hydrogeology of well logging techniques.

Lab. II: Field survey and interpretation of available data.

Books Recommended:

1. Field Hydrogeology by Braisington, R., 1998, John Wiley and Sons.
2. Groundwater Resource Evaluation by Walton, W.C., latest Ed., McGraw-Hill Kogakusho, Ltd.
3. Groundwater and Wells by Driscoll, F.G., 1989, Johnson Filtration System Inc. St. Paul.

3. Groundwater Engineering

Groundwater problems in site selection and construction of dams and other huge structures. Geotechnical logging and grouting techniques. Groundwater table and its flow into excavations. The principles and applications of dewatering. The effect of groundwater on soil and rock strength. Deep aquifers testing and groundwater flow analysis into underground workings. Hydrogeology of mining areas. The analysis of ground subsidence related to groundwater obstruction.

Lab. III: Case studies related to dam site selection.

Books Recommended:

1. Engineering Hydrology by Wilson, E.M., 1991, MacMillan Education Ltd.
2. Field Hydrogeology by Brassington R. 1988, John Wiley and Sons.
3. Groundwater by Freeze, R.A., & Cherry, J.A., 1979, A Simon and Sechuster Company.

4. Hydrochemistry & Groundwater Pollution

Laws of chemistry related to water and its reaction with the aquifer matrix. Principles and processes controlling composition of natural water. Methods of water sampling and analysis. Properties and constituents of water. Presentation, evaluation and interpretation of water analysis data.

Sources, nature and effects of groundwater pollution. Transport of pollutants and chemical processes occurring in aquifers. Groundwater contaminations prevention and remedies. Water treatment and techniques for the removal of physical biological and chemical contaminants. Saline intrusions in coastal and estuarine sediments.

Lab. IV: Groundwater sampling for chemical analysis. Graphic presentation of chemical analysis data. Preparation of subsurface hydrochemical maps. Identification of the source and extent of contamination.

Books Recommended:

1. Domestic Water Treatment by Lehr, J.H., Grass, T.E. Pettyjohn. W.A. & Marie, J. De., 1988, National Water Well Association Ohio.

2. Ground Water and Wells by Driscoll, F.G., 1989, Johnson Filtration System Inc. St. Paul.
3. Study and Interpretation of the Chemical Characteristics of Natural Water by Hem, J.D., 1992, US Geological Survey Water.
4. The Global Water Cycle by Berner, F.K., & Bernes, R.A., 1987, Prentice Hall.

GROUP-X: INDUSTRIAL MINERALOGY

This group comprises the following courses:

1. Industrial Mineralogy
2. Geology & Technology of Industrial Minerals and Rocks
3. Instrumental Techniques
4. Mining Geology and Mineral Economics

1. Industrial Mineralogy

Physical and chemical properties of minerals. Relationship between the structure, chemistry and properties of carbonates, sulphates, silica minerals, feldspars, clay minerals, nepheline, serpentinite, amphiboles, micas, olivines and phosphates. Mechanisms of mineral nucleation and crystal growth. Importance of kinetics in mineral formation.

Interpretation of mineral analysis Recalculation of a mineral analysis in terms of fixed number of anions, and where appropriate cations. Plotting a phase diagram from experimental data. Interpretation of phase diagrams including the SiO_2 - SiO_2 , Al_2O_3 - SiO_2 - Al_2O_3 - K_2O - SiO_2 , CaO - MgO - SiO_2 , Al_2O_3 - CaO . Drawing of isothermal sections through ternary phase diagram and their relevance. Plotting data on triangular diagrams. Measurement of mineral triple junction angles, description of grain boundaries and their implication for the development of rock textures. Use of a variety of computer programs, including spreadsheets, to calculate mineralogical parameters. Triangular and X-Y plots. Relating mineralogical information to the assessment and performance of industrial rocks and minerals.

Lab. 1: Microscopic identification of the common rock forming minerals in thin section, using transmitted and reflected light microscopy. Identification of common ceramic, refractory and slag minerals in thin section.

Book recommended:

1. Mineralogy for Students by Battey, M.H., 1981, Longman.
2. Process Mineralogy of Ceramic Materials by Baumgart, W., Dunham, A.C. & Amstutz, G.C., 1988, Enke, Stuttgart.
3. Crystal structures of clay minerals and their X-ray Identification by Brindley, G.W. & Brown, G., 1980, Mineralogical Society.

4. An Introduction to the Rock-Forming Minerals by Deer, W.A., Howie, R.A. & Zussman, J., 1992, Longman.
5. A practical introduction to optical mineralogy by Gribble, C.D. & Hall, A.J., 1985, George Allen & Unwin.
6. Applied Mineralogy by Jones, M.P. 1987, Graham and Trotman.
7. X-ray diffraction and the identification and analysis of clay mineral by MOORE, D.M. & Reynolds, Jr., R.C., 1989, Oxford University Press.
8. An introduction to Metamorphic Petrology by Yardley, B.W.D., 1989, Longman.

2. **Geology & Technology of Industrial Minerals and Rocks**

The geological setting, mineralogy, physical and chemical properties, beneficiation, search methods and uses of the following: Sands and gravels, Hard rock aggregates, dimension stone, slate, limestone and dolomite, magnesite, clays (Common clay/shale, Kaolin, bentonite, and Fuller's earth), Silica sand, dunite and serpentinite, feldspars, Nepheline syenite. Natural abrasive raw materials, gypsum, anhydrite, chromite, barite and gemstones including diamond.

Mineralogy and chemistry of raw materials for cement, glass, agriculture, chemical and for refractories. Industrial minerals and their environmental impacts.

Lab. II: Specified assignments/projects

Books recommended:

1. Mineral Deposit Evaluation: a Practical Approach. By Annels, A.E., 1991, Chapman and Hall.
2. Geology of the Industrial Rocks and Minerals by BATES, R.L.. 1960. Dover.
3. Mineral Resources and Their Management by Lunden, J.B., 1985, Longman.
4. The Chemistry and Technology of Lime and Limestone by Boynton, R.S., 1980, John Wiley & Sons.
5. Structural Clay Products by Brownell, W.E., 1976. Springer-Verlag.
6. Aggregates: Sand, Gravel and Crushed Rock Aggregates for Construction Purposes by Collis, L. & Fox, R.A. 1985. The Geological Society.
7. Refractories for Iron- and Steelmaking by Chesters, J.H., 1974, The Metals Society.
8. Alkali-silica Reaction in Concrete by Hobbs, D.W., 1988. Thomas Telford Ltd, London.
9. Industrial Geology by Knill, J.L., 1978, Oxford University Press.

10. The Chemistry of Cement and Concrete by Lea, F.M., 1970, Edward Arnold.
11. Industrial Minerals and Rocks by Lefond, S.J., 1983, American Institute of Mining, Metallurgical and Petroleum Engineers.
12. Geology of Construction Materials by Prentice, J.E., 1990, Chapman and Hall.
13. Mineral Processing Technology by Wills, B.A., 1988, Pergamon Press.

3. Instrumental Techniques

Theory of X-ray diffraction for mineral investigation of geological materials. Methods of sample preparation. Software programme. Calibration curve for quantitative analysis and identification of minerals by XRD and JCPDS card files. Theory and practical aspects of DTA (Differential Thermal Analysis). TG (Thermogravimetric) analyzer.

Physical properties: Particle size measurements, sieving, sedimentation, density/SG, automated methods (Coulter counter). Surface area measurements. Gas absorption, BET equation, permeability. Colour specifications, atomic absorption spectrophotometric curves. CIE system and their importance to industry.

Lab. III: Liquid and plastic limit of clays. Froth floatation and scrubbing of sands. Separation of clays by hydrocyclone. Viscosity measurement by Bookfield viscometer.

Books Recommended:

1. Atomic Absorption Spectroscopy by Welz, B., 1976, Verlag, Chemie. Weinheim.
2. Differential Thermal Analysis by MacKenzie, R.C., latest Ed., Academic Press.
3. Introduction to Mass Spectrometry and its Applications by Kiser, R.W., latest Ed., Prentice-Hall.
4. Elemental Analysis in Geochemistry by Volborth, A., latest Ed., Elsevier Publishing Company.
5. Introduction to X-ray spectrometry by Williams, K.L., 1987, George Allen & Unwin.
6. Laboratory Handbook of Petrographic Techniques by Hutchison, C.S., latest Ed., John Wiley & Sons.

GROUP-XI: MARINE GEOLOGY

This group comprises the following courses:

1. Physical and Chemical Oceanography
2. Marine Geology
3. Coastal Geomorphology
4. Geology of Arabian Sea
5. Plate Tectonics

1. Physical and Chemical Oceanography.

Fundamental oceanographic principles. Physical properties of sea water, salinity, temperature, density, Sigma-t, water masses, thermohaline circulation, Oceanic budgets of heat, water and salt. Circulations and currents, waves, tides, tsunamis, monsoonal reversals. Estuarine circulation, sea water stratification, ocean acoustics, acoustic attenuation in marine sediments. Chemical properties of sea water. Residence time, paleo-oceanic circulation. Classification of marine environment. Typical distribution of sea water characteristics. Surface and deep ocean water circulation. Worldwide heat budget study. Sampling devices. Handling and storage methods of samples. Sea water chemistry. Marine Pollution.

Lab. I. Specified assignments/projects

Books recommended:

1. Marine Geochemistry by Chester. R.. 1990, Unwin-Hyman.
2. Sea Surface Studies by Devoy. R.J.N., 1987, Croom Helm.
3. General Oceanography by Dietrich. G. et al, 1981, John Willey and Sons.
4. Waste water management for coastal cities by Gunnerson. C.G. & Hills. L., 1996, Springer.
5. Environmental Technologies and Trends by Jain, R. et.al., 1996, Springer.
6. An Introduction to Marine Biogeochemistry by Libes. S.M., John Willey.
7. Physical Oceanography by Pickard. G.L. & Emery. W.J.. 1982, Pergamon
8. Heavy Metals by Salomons. W.F. & Mader, P., 1995, Springer.
9. Geology and Geochemistry of Abyssal Plain by Wervar, P.P., 1997, Geol. Soc. Pub. U.K.
10. Soil Pollution by Yaron, B. Calcet. R. & Prost. R. 1996, Springer.

2. Marine Geology

Development of Geological Oceanography. Geomarine techniques. World wide sea level changes through time. Oxygen-Isotope. Stratigraphy, Magneto-stratigraphy. Carbonate stratigraphy. Study of continental margins. Nature and distribution of sediments in continental shelf , slopes and abyssal plane. Coastal erosion and sedimentation processes.

Lab. II: Specified assignments/projects

Books recommended:

1. General Circulation of the Ocean by Abarbanel, H.D.I. & Young, W.R., 1987, Springer Verlag.
2. Applied Oceanography by Bishop, J.M., 1984, John Willey and Sons.
3. Sea Surface Studies by Devoy, R.J.N., 1987, Croom Helm.
4. Oceanography by Gross, M.G., 1986, Prentice Hall.
5. Geochemical Processes Water & Sediment Environment by Lerman, A., 1979, John Willey and Sons.
6. Physical Oceanography by Pickard, G.K. & Emeegey, W.J., 1982, Pergaman.
7. The Sea Floor by Seibold, E. & Bergen, W.H., 1982, Springer.
8. Submarine Geology by Shepard, P.P., 1983, Harper and Row.
9. Essentials of Oceanography by Thurman, H.V., 1983, Mecill.

3. Coastal Geomorphology

Coastal and near shore geology. Waves and wave dominated coasts. Neotectonic. Shoreline morphodynamics. Tidal and Lake coast. Long term development of coast. Sea level changes. Sub-tidal and tidal ecosystem. The management of coastal water. Land and sediments, Coastal hazards and Coastal dunes. Development of delta.

Lab. III: Specified assignments/projects.

Books recommended:

1. Coastal Environment by Carter, W., 1988, Academic Press.
2. Manual of Remote Sensing by Colwell, R.N., 1983, Falls Church, Virginia American Society of Photogrammetry.
3. Geomorphological Techniques by Goudie A.S. & Contributor. 1990, Unwin Hyman Ltd.
4. Principles of Remote Sensing by Curran, P.J., 1985, Longmann.
5. Geomorphology in Arid Region by Donald O.D. 1980, Alien and Unwin.
6. Coasts (An Introduction to Coastal Geomorphology) by Eric, C.F. Birds, 1984, Basil Blackwell Publishing Co.
7. Global Geomorphology by Michael A.S., 1991, Longman Scientific and Technical.
8. Principles of Geomorphology by Thornbury. W.D., 1991, Wiley Eastern Ltd.

4. Geology of Arabian Sea

Major development, physiographic feature and sediments of Arabian Sea floor. Sedimentary rocks and processes of Arabian Sea sediments. Geometry and tectonics of continental shelves of Sindh and Makran. Indus fan morphology and sediments. Makran subduction zone and nature of sediment.

Lab. 1V: Specified assignments/projects.

Books recommended:

1. Deltas by Reading, H.G. & Elliot, T., 1978, Elsevier.
2. Geodynamics of Pakistan, Farah. A and Dejong, Kees A., 1979, Geological Survey of Pakistan.
3. Marine Geology and Oceanography of Arabian Sea and Coastal Pakistan by Millman, J.D. 1984, Van Nostrand Rein Hold Co.
4. River Deltas by Daines, R.A. (ed.), Coastal Sedimentary Environment Wright, I.D. 1978, Springs.

5. Plate Tectonics

Continental drift. Sea-floor Spreading. Plate Tectonics Theory. Historical Perspective. Internal structure of Earth. Geological evidences for Continental Drift. Continental reconstruction. Marine magnetic anomalies and sea-floor spreading. Plates and plate boundaries. Relative and absolute plate motions. Ocean ridges. Continental rifts. Intraoceanic islands. Hot Spot and Mantle Plumes. Subduction zones. Transform and transcurrent faults. Mechanism of plate tectonics. Driving mechanisms for plate movement

Lab. V: Specified assignments/projects.

Books recommended:

1. Tectonics by Moores, E. M. & Twiss, R. J., 1995, Freeman and Co.
2. Global Tectonics by Keary, P. & Vine, F.J. 1996, Blackwell Science
3. Plate Tectonics: How it Works by Cox, A. & Hort, R. B. 1986,. Blackwell Science

GROUP-XII: ENVIRONMENTAL GEOLOGY

This group comprises the following courses:

1. Environmental Geology
2. Soil and Water Resources
3. Environmental Hazards
4. Hydrological Systems and Environment
5. Environmental Impact Assessment and Management.

1. Environmental Geology

Introduction to environmental geology. Management of land, water and mineral resources. Environmental controls for erosion: desertification and coastal degradation. Geological hazards and their remedial measures. Environmental impact of mining and geotechnical projects such as dams, reservoirs, highways, their assessment and control. Cleaner sources of energy. Industrial pollution: impact on human health. Environmental parameters of urbanization.

Lab. I: Specified assignments/projects

Books Recommended:

1. Environmental Geology by Keller, E. A., 1979, Merrill.
2. Environmental Geology by Montgomery, C., 1985, J. Wiley.
3. Applied Chemical Groundwater Hydrology by Mazore, E., 1988, McGill.
4. Earthquake Risk & Damage by Liu, B. C., 1981, Westview.
5. [The Encyclopedic Dictionary of Environmental change by John A. Mathews, 2003, Oxford University Press.](#)

2. Soil and Water Resources

Soil erosion and land use. Predicting and controlling soil erosion. Soluble salts in soils. aerosol particulate matter. Hydrological System and agriculture. Natural water resources and policy making. Hydrological cycle. Erozen water reserves. Global warming and surface water resources. Surface water storage and ecological system. Ground water msvement. Water logging and Salinity.

Lab. II: Specific assignment/projects.

Books recommended:

1. Global Environmental Charges by Moore, P. D., 1996. Mc Graw Hill.
2. Air Pollution and Engineering Management by Davis, W. T., 2000. John Willey & Sons.
3. [Environmental Chemistry of Soil by Murray B. M.,1994, Oxford University Press.](#)

3. Environmental Hazards

Flood control, information on river flooding. Effects on agro-economy, slope stability in hilly areas. Types of landslides. Their causes and remedial measures. Methods of analysis of slopes. Landslide inventory mapping, Information on landslides and their effects on socio-economic conditions. Study of case histories in Pakistan and abroad. Snow avalanches. Subsidence mechanism and related problems. Earthquake hazards.

Hazardous minerals in mining. Safety and health standards, legislations, regulations and controls, effect on global environment.

Lab. III: Specific assignment/projects.

Books recommended:

1. Environmental Geology by Montgomery, C. W., 1986, Wm.C. Brown Publishers.
2. Geology and Hazardous Waste by Hussain, S. E., 1996, Prentice Hall.

4. Hydrological Systems and Environment

Surface and groundwater resources, precipitation, evaporation, erosion and silting in catchment areas and reservoirs (DAMS). Surface and groundwater contamination and sources. Effect of mineralogy, mining activities, Industrial effluents. Heavy metal concentration. Contamination due to chemicals and sewage system, decomposable organic matter and pollutant agents (Industrial and Agricultural – Fertilizers etc.), dissolved gases, minerals and suspended impurities in surface and groundwater, biological contamination (viral, bacterial, protozoal and helminths).

Lab. IV: Specific assignment/projects.

Books recommended:

1. Groundwater Contamination by Badiant, P., 1999, Printice Hall.
2. Municipal Sewage sludge by Cecil, D., 1992, Technomic Publishing Co.
3. Sources and Fates of Aquatic Pollutants by Ronald A. Hites, 1987, Oxford University Press.

5. Environmental Impact Assessment and Management

Reclamation of agricultural land, landfill and land use, socio-economic uplift, underground drainage system, installation of tube wells and canal lining, vegetation, rock bolting, guniting and shotcreting. Identification of environmental hazards and evaluation of risks, slope and flood control instrumentation – gauges, extensometers and tiltmeters etc. Policy making about water distribution, use of pesticides, insecticides and fertilizers etc. Policy making about water distribution, use of pesticides, insecticides and fertilizers. Disposal of Industrial and Radioactive wastes.

Lab. IV: Specific assignment/projects.

Books recommended:

1. Solid Waste Management by Grever, V., 2000, Oxford & IBH (Ltd.).
2. Environmental Management by Mukharjee, B., 2000, Vikas Publishing Hon.

3. Environmental Assessment by Singleton, R., Castle, P., and Short, D., 1999, PB Kenedy (Donlin Ltd.).
4. Global Change in the Holocene by Anson Mackay, 2005, Oxford University Press.
5. Tectonic Boundary Conditions for Climate Reconstruction by Thomas J. Crowley, 1998, Oxford University Press.

GROUP- XIII: STRUCTURE, TECTONICS AND NEOTECTONICS

This group comprises the following courses:

1. Structural Geology
2. Metamorphic Structures
3. Applied Structural Techniques
4. Tectonics of Pakistan
5. Regional Tectonics
6. Neotectonics

1. Structural Geology

Strain analyses: concept of strain ellipse, distortion and rotation, heterogeneous strain, displacement vector fields and strain. Planar and linear fabrics: analyses of fabrics, axial plane foliations/cleavages and their types and origin, transposed foliations, lineation types and Origin. Fabrics as kinematics indicators. Structures in folded rocks: fold morphology and classifications (dimensions, shapes, fourier analyses, wavelength-amplitude analyses, axial trace constructions, symmetry, layer thickness variations, dip isogons), mechanisms of folding, strain and small scale structures in folds, superposed folding. Fault geometry and morphology: classification of fault systems, geometry of a) extension, 2) strike slip and 3) thrust fault systems. Fractures and joints: mechanical analyses of fractures, ductile and brittle shear zones, geometric classification of joints, analyses of joints in uniformly dipping strata and in folded rocks.

Lab. I: Specific assignment/projects.

Books recommended:

1. Structural Geology by Hatcher, R. D., 1995, Prentice Hall.
2. Structural Geology of Rocks and Regions by Davis, G. H. & Reynolds, S. J., 1996, Wiley
3. Structural Geology by Twiss, R. J. & Moores, E. M., 1992, Freeman.
4. An Outline of Structural Geology by Hobbs, B.E., Means, W. D. & Williams, P. F., 1976, John Willey & Sons.
5. Principals of Structural Geology by Suppe, J., 1985, Prentice Hall.
6. The Techniques of Modern Structural Geology. V.I Stress and Strain by Ramsay J.G. & Huber, M.I., 1983, Academic Press.

7. The Techniques of Modern Structural Geology. V.II Folds & Fractures by Ramsay J.G. & Huber, M.I., 1987, Academic Press.

2. Metamorphic Structures

Microstructures in deformed and metamorphosed rocks. Crystal defects, crystal plasticity, dislocations. Annealing recrystallization, recovery, primary-, secondary recrystallization, dynamic recrystallization, -stress induced recrystallization, strain induced recrystallization and associated microstructures, driving forces for dynamic recrystallization, dynamic recrystallization by subgrain rotation and grain boundary migration, controls on migration rates.

Mylonites. Terminology. microstructures, planar and linear ductile fabric and kinematic indicators. Petrofabrics: Factors controlling fabric development, fabric representation-pole and inverse pole figures, orientation distribution functions, measuring techniques, pressure solution and metamorphic differentiation, cataclastic deformation.

Lab. II: Specific assignment/projects.

Books Recommended:

1. Structural Analyses of Metamorphic Tectonites by Turner, F.J & Weiss, L. E., latest Ed., McGraw-Hill.
2. The Study of Fabrics of Geological Bodies by Sander, B., latest Ed., Pergamon Press
3. Metamorphic Textures by Spry, A. H., latest Ed., Pergamon Press.

3. Applied Structural Techniques

Elementary techniques: measurement of attitude and location, contour maps, attitude and dimension calculations, stereographic projections, stereographic poles and rotations, calculation of layer attitudes in drill holes, equal area. Projections and structural analyses. Practical strain measurements of a) initially circular and elliptical markers, b) lines and c) angles, methods and representation of strain state. Progressive displacement and progressive deformation. Interpretation of geological maps. Analyses of fracture array geometry. Constructing profiles and block diagrams of folds. Cross Section balancing for thrust and normal fault systems. Depth to detachment calculations

Lab. III: Specific assignment/projects.

Books Recommended:

1. Applied Subsurface Geological Mapping by Tearpook, D. J. & Bischke, R. E., 1991, Prentice Hall.
2. Basic Methods of Structural Geology by Marshak, S. & Mitra, S., 1988, Prentice Hall.
3. The Techniques of Modern Structural Geology by Ramsay, J. G. & Huber, M. I., 1983, Volume 1: Strain Analyses. Academic Press.
4. The Techniques of Modern Structural Geology by Ramsay, J. G. and Huber, M. I., 1987, Volume II: Folds and Fractures. Academic Press.
5. Structural Geology, an Introduction to Geometric Techniques by Ragan, D. M, 1985, John Willey & Sons).
6. Principals of Structural Geology by Suppe, J. 1985, Prentice Hall.

4. Tectonics of Pakistan

Concept of pangea and gondwana supercontinents. Permian separation of Afghan, Pamirs, Karakoram, Lahasa microcontinents, closure of palaeotethys and accretion tectonics at Urasia's southern margin. Early Cretaceous split and northward flight of India, closure of northern Neotethys and collision tectonics of the Shyok Suture. Himalayan orogeny; constraints on the timing of India-Eurasia collision; resultant physiography, structures, metamorphism, climatic changes. Tectonic zonation of Pakistan: Each zone to be studied in terms of its geomorphology, tectonics, stratigraphy, metamorphism, magmatism and mineral deposits. Karakoram plate.

Kohistan-Ladakh island arc terrane. The Himalayas: internal and external zones. Swat, Besham, Hazara, Kaghan (Nanaga Parbat) blocks. The hill ranges (Sammana, Kalachitta, Margala, Galiats). Kohat-Potwar plateaus and the salt ranges. The boundary faults and related tectonics: MMT, MCT, Panjal Thrust, MBT, MFT. Afghan-India collision zone: Kurram-Waziristan-Muslim Bagh-Bela ophiolite/melange belt. Sullaiman-Kirthar thrust-fold belt. Katawaz basin. Makran accretionary prism. Raskoh-chagai arc terrane. Indus platform and foredeep. offshore Pakistan: The Indus delta.

Lab. IV: Specific assignment/projects.

Books Recommended:

1. Geology and Tectonics of Pakistan by Kazmi, A. H. and Jan, M. Q., 1997, Graphic Publishers.
2. Geology of Pakistan by Bender and Raza, (ed.) 1995, Gebruder Borntraeger.
3. Geodynamics of Pakistan Farrah, A, and DeJong, K., 1979, Geological Survey of Pakistan.
4. Himalayan Tectonics by Treloar P. J. and Searle, M. P., 1998, Geological Society London, Special Publication.

5. Tectonics of Nanga Parbat and the Western Himalayas by Khan, M. A., Trelaor, P. J., Searle, M. P., and Jan, M. Q. 2000. Geological Society, London, Special Publications.

5. Regional Tectonics

Difference between tectonics and structural geology. Interior of earth and terrestrial Planets. Geophysical techniques in tectonics (seismic refraction, gravity anomalies, geomagnetism). Divergent margins and rifting. Transform faults, strike slip faults and fracture zones. Convergent margins. Collisions. anatomy of orogenic belts. Case studies of orogenic belts. The alpine-Himalaya orogenic belt. The Appalachian-Caledonin orogenic system. The north America Cordillera. The Andes.

Lab. IV: Specific assignment/projects.

Books recommended:

1. Tectonics by Moores, E. M. & Twiss, R. J., 1995, Freeman and Co.
2. Global Tectonics by Keary, P. & Vine, F.J. 1996, Blackwell Science.
3. Plate Tectonics: How it Works by Cox, A. & Hort, R. B. 1986, Blackwell Science.
4. The Evolving Continents by Windley, B. F., 1984, Wiley.

6. Neotectonics

Active tectonics and neotectonics: definitions, direct measurements of tectonic movements, direct measurement with geodetic networks. Triangulation of sites with reference to satellites. Global positioning systems. Neotectonic dating methods. Numerical methods (annual, radiogenic, Chemical and biological changes, correlation). Tectonic geomorphology; offset geological-geomorphological features (paleoseismic indicators, changes in elevations of coast lines, stream offsets, slope retreat, terraces). Neotectonic behavior of faults and folds. Hazards of active tectonics: Earthquakes, landslides and mass movements. Remote sensing. Applications in neotectonics and related hazards.

Recommended Books

1. Tectonics by Moores, E. M. & Twiss, R. J., 1995, Freeman and Co.
2. Tectonic Geomorphology by Burbank, D. & Anderson, R. 2001, Blackwell Science.

ELIGIBILITY FOR ADMISSION **IN 2-YEAR MS (HONS) PROGRAMME**

4-years education in Geology/Earth Sciences/Relevant Subjects after F.Sc. with minimum 50% marks will be compulsory for admission in 2-year MS (Hons) program.

SCHEME OF STUDIES FOR **2-YEAR MS (HONS) IN GEOLOGY**

Duration: 2-Years (8-Semesters)
Course work: 24 Credit Hours
Thesis: 12 Credit Hours

1st Semester:

12 Credit Hours course work

2nd Semester:

12 Credit Hours course work

3rd Semester:

Research for thesis including field and laboratory work

4th Semester:

Data compilation, thesis writing and defense

LIST OF SUBJECTS

- A. The following subjects are suggested for the course work.
- B. The details of course content and assigned Credit Hours will be decided by the Department/Supervisor.

Geol. 701 Advanced Geochemistry
Geol. 702 Igneous Petrogenesis
Geol. 703 Metamorphic Petrogenesis
Geol. 704 Advanced Mineralogy
Geol. 705 Geothermometry and Geobarometry
Geol. 706 Advanced Stratigraphy
Geol. 707 Micropalaeontology
Geol. 708 Invertebrate Palaeontology
Geol. 709 Vertebrate Palaeontology
Geol. 710 Palynology and Paleobotany
Geol. 711 Mineral Prospecting and Exploration

Geol. 712 Coal Geology
Geol. 713 Metallogeny and Plate Tectonics
Geol. 714 Coal Petrology
Geol. 715 Process Mineralogy
Geol. 716 Mineral Deposit Evaluation and Economics
Geol. 717 Rock Mechanics
Geol. 718 Soil Mechanics
Geol. 719 Seismotectonics
Geol. 720 Engineering Geology
Geol. 721 Petroleum Geology
Geol. 722 Sequence Stratigraphy
Geol. 723 Petroleum Engineering & Geophysical Methods
Geol. 724 Reservoir Geology
Geol. 725 Organic Geochemistry
Geol. 726 Petroleum Geology of Pakistan
Geol. 727 Seismic Methods and Seismic Stratigraphy
Geol. 728 Earthquake Seismology
Geol. 729 Geomagnetism
Geol. 730 Paleomagnetism
Geol. 731 Radiometric Methods
Geol. 732 Electrical Methods
Geol. 733 Bore-hole Geophysics
Geol. 734 Geophysical Data Processing
Geol. 735 Gravity and Magnetic Methods
Geol. 736 Engineering Seismology
Geol. 737 Thermodynamics
Geol. 738 Geochemical Exploration
Geol. 739 Isotope Geochemistry
Geol. 740 High Temperature Geochemistry
Geol. 741 Low Temperature Geochemistry
Geol. 742 Clastic Sedimentology
Geol. 743 Carbonate Sedimentology
Geol. 744 Sedimentary Petrology
Geol. 745 Basin Analysis
Geol. 746 Quaternary Geology
Geol. 747 Clay Mineralogy
Geol. 748 Applied Sedimentology
Geol. 749 Techniques in Sedimentology
Geol. 750 Advanced Hydrology
Geol. 751 Groundwater Investigations
Geol. 752 Groundwater Engineering
Geol. 753 Groundwater Planning & Management
Geol. 754 Hydrochemistry & Groundwater Pollution
Geol. 755 Modeling in Groundwater
Geol. 756 Industrial Mineralogy
Geol. 757 Technology of Industrial Minerals and Rocks

Geol. 758 Mining Geology and Mineral Economics
Geol. 759 Physical and Chemical Oceanography
Geol. 760 Advanced Marine Geology
Geol. 761 Coastal Geomorphology
Geol. 762 Geology of Arabian Sea
Geol. 763 Advanced Environmental Geology
Geol. 764 Soil and Water Resources
Geol. 765 Environmental Hazards
Geol. 766 Hydrological Systems and Environment
Geol. 767 Environmental Impact Assessment and Management
Geol. 768 Plate Tectonics
Geol. 769 Advanced Structural Geology
Geol. 770 Metamorphic Structures
Geol. 771 Applied Structural Techniques
Geol. 772 Tectonics of Pakistan
Geol. 773 Neotectonics
Geol. 774 Gemology
Geol. 775 Advanced Geomorphology
Geol. 776 Glacial Geology
Geol. 777 Remote Sensing
Geol. 778 Geographic Information System
Geol. 779 Mining Geophysics
Geol. 780 Geochronology
Geol. 781 Research Methodology
Geol. 782 Advanced Instrumentation
Geol. 783 Volcanology

RECOMMENDATIONS

The members of this meeting came from all parts of Pakistan representing both academicians and professionals including foreign faculty. They agreed with the following suggestions and recommendations:

Geology is the science of earth and deals with global-level phenomena. The materials provided to the students for the study in the laboratory give introduction of rocks, minerals, fossils etc. only and are in no way comparable to their actual occurrence in nature. For adequate training, a student must be fully exposed to observations in the field and as many segments of the earth as possible. Without this a geologist can neither have a conceptual grasp of the subject nor can cope with problems during his/her professional career.

At present in some of the universities there is semester system while in others there is annual system of examination. It is recommended that in future all the universities should be asked to adopt the semester system. Therefore, the eligibility criteria and curricula for 4-year BS (Hons) and 2-year MS (Hons) have been designed.

For BS (Hons), from semester I to VII all the courses will be compulsory and for semester VIII a number of areas of specialization have been identified and defined. A choice of courses will be available in each field of specialization (groups). In addition to thesis work a student must take two courses from the groups directly relevant to the thesis. At the same time the selection of courses offered would depend on the availability of teachers and facilities.

For MS (Hons), first two semesters will be course work (24 Credit Hours) and final two semesters will be thesis work (12 Credit Hours). The course title and contents will be decided by the department/supervisor from the suggested list (Geol. 701 to Geol. 783).

It is further recommended that:

1. The subject of Geology should be included at school and college levels for better understanding of the degree programs and to increase mass awareness regarding natural hazards and natural resources.
2. Student with Geology in Intermediate should be given special seats in BS (Hons) Program.
3. Degree courses should be more or less uniform in all universities which should meet the minimum requirement laid down in this document.
4. Fieldwork is an integral part of teaching and research in geology. This subject cannot be properly taught without geological fieldwork. As such, adequate facilities must be provided in terms of funding for field transport and other related expenses.

5. Internship should be provided by the professional organizations to the students and the universities should establish a liaison office and HEC should arrange for funds.
6. Every Geology department should be provided with sufficient computers, audio-visual facilities, free Internet/online access to research journals.
7. Laboratory and library facilities should be improved and staff strengthened.
8. Increased interaction between R & D organizations, academic institutions and industry is required regarding joint research projects, visits to sites, laboratories etc., which may be sponsored by these organizations and HEC. Seminars/training courses for faculty and students may also be jointly held.
9. Professionals from different organizations may be invited to deliver lectures on specific topics related to Earth Sciences. Small discussion groups consisting of professionals and academicians in the specialized fields may be set up whenever required to promote research activities.
10. Faculty should frequently be sent on short training courses within the country as well as abroad.
11. It is suggested that Lab. manual with an organized laboratory practical should be introduced for all the courses. Experts in various areas of geology should be encouraged to prepare such manuals. To encourage publication of these manuals, HEC and universities should provide incentives to the authors.
12. A pool of active researchers/professors (including retired) should be setup for supervising BS, MS and Ph.D. theses/dissertations with all benefits to the supervisors.
13. Faculty should get full funding for attending conferences, seminars, workshops and symposia in Pakistan and abroad. The process of NOC should be simplified by authorizing the head of the institution. The oral and poster presentations in conferences should be considered at par for funding.
14. The decision of the HEC regarding provision of minimum grade-17 jobs for 4-year BS (Hons) degree holder be implemented uniformly by public and private sectors.