UGC

UGC MODEL CURRICULUM

EARTH SCIENCES

UNIVERSITY GRANTS COMMISSION
NEW DELHI

2001

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Printed in December 2001

Printed and Published by *Shri Prem Varma,* Sr. Printing Officer, on behalf of *University Grants Commission,* Bahadur Shah Zafar Marg, New Delhi-110002, and printed at *Aakriti Graphics,* B-62/10, Naraina Industrial Area, Phase-II, New Delhi-110028, Phone: 5700089.

FOREWORD

Renewing and updating of the Curriculum is the essential ingredient of any vibrant university academic system. There ought to be a dynamic Curriculum with necessary additions and changes introduced in it from time to time by the respective university with a prime objective to maintain updated Curriculum and also providing therein inputs to take care of fast paced development in the knowledge of the subject concerned. Revising the Curriculum should be a continuous process to provide an updated education to the students at large.

Leaving a few, there have been many universities where this exercise has not been done for years together and it is not uncommon to find universities maintaining, practicing and teaching still on the Curriculum as old as few years or even more than a decade. Not going through the reasons for this inertia, the University Grants Commission, realising the need in this context and in relevance to its mandate of coordinating and maintaining standard of higher education, decided to adopt a pro-active role to facilitate this change and to ensure that the university Curriculum are soon updated to provide a standard education all over the country.

Curriculum Development Committee for each subject was constituted with the respective Convenor as its nodal person. The Committee besides having five subject experts drawn from the university system, was given a wider representation of various sub subject experts attending meetings of the Committee as the esteemed co-opted members which kept on changing from time to time as the need arose. The Committees, therefore, had representations from a large number of experts and had many meetings before final updated Model Curricula were presented to UGC.

The University Grants Commission and I as its Chairman are grateful to the nodal persons, a large number of permanent and co-opted members in different subjects and their sub disciplines for having worked seriously with committed devotion to have produced a UGC Model Curriculum in 32 subjects within a record period of 18 months.

The exercise would not have been possible without the support of our entire academic community. We can only hope that the results will fulfil their expectations and also those of university community and Indian society.

The UGC Model Curriculum has been produced to take care of the lacuna, defects/ shortcomings in the existing Curricula in certain universities, to develop a new Model Curriculum aiming to produce the one which is compatible in tune with recent development in the subject, to introduce innovative concepts, to provide a multi disciplinary profile and to allow a flexible cafeteria like approach including initiating new papers to cater to frontier development in the concerned subject.

The recommendations have been compiled by panels of experts drawn from across the country. They have attempted to combine the practical requirements of teaching in the Indian academic context with the need to observe high standards to provide knowledge in the frontier areas of their disciplines. It has also been aimed to combine the goals and parameters of global knowledge with pride in the Indian heritage and Indian contribution in this context.

Today all knowledge is interdisciplinary. This has been duly considered. Flexible and interactive models have been presented for the universities to extend them further as they would like. Each institution may have to work out certain uniform structures for courses at the same level, so that effective interaction between subjects and faculties is possible. The tendency across the country is now to move from the annual to the semester system, and from award of marks to award of credits. There is perceptible growing interest in modular framing as well.

The recommendations while taking all these features into account, have also made provisions for institutions who may not be in a position to undertake radical structural reform immediately. In any country, especially one as large and varied as India, academic institutions must be allowed enough autonomy and freedom of action to frame courses according to specific needs. The recommendations of the Curriculum Development Committees are meant to reinforce this. The purpose of our exercise has been to provide a broad common framework for exchange, mobility and free dialogue across the entire Indian academic community. These recommendations are made in a spirit of openness and continuous improvement.

To meet the need and requirement of the society and in order to enhance the quality and standards of education, updating and restructuring of the curriculum must continue as a perpetual process. Accordingly, the University Grants Commission constituted the Curriculum Development Committees. If you need to seek any clarification, you may contact Dr. (Mrs.) Renu Batra, UGC Deputy Secretary and Coordinator of CDC who shall accordingly respond to you after due consultation with the respective nodal person of the concerned subject.

The University Grants Commission feels immense pleasure in forwarding this Model Curriculum to the Hon'ble Registrars of all Universities with a request to get its copies made to be forwarded also to the concerned Deans and Heads of Departments requesting them to initiate an early action to get their Curriculum updated. The University Grants Commission Model Curricula is being presented to the Registrar of the university with **options** either to adopt it in toto or adopt it after making necessary amendments or to adopt it after necessary deletion/ addition or to adopt it after making any change whatsoever which the university may consider right. This UGC Model Curriculum has been provided to the universities only to serve as a base and to facilitate the whole exercise of updating the Curriculum soon.

May I request Hon'ble Vice Chancellor and the Hon'ble Registrar including the esteemed Deans, Heads of Departments, Members of the Faculty, Board of Studies and Academic Council of the Universities to kindly update their Curriculum in each of the 32 subjects in consultation with Model Curriculum provided here. This has to be done and must be done soon. May I request the Academic administration of the universities to kindly process it immediately so that an updated Curriculum is adopted by the university latest by July, 2002.

The University Grants Commission requests the Hon'ble Registrars to confirm that this time bound exercise has been done and send a copy of the university's updated Curriculum in each subject to UGC by July 31, 2002. It is a must. It has to be done timely, failing which, the UGC may be forced to take an appropriate unpleasant action against the concerned university.

The UGC looks forward for your active participation in this joint venture to improve the standards to achieve excellence in higher education.

December 2001

HARI GAUTAM
MS (SURGERY) FRCS (EDIN) FRCS (ENG)
FAMS FACS FICS FIACS DSc (HON CAUSA)
CHAIRMAN, UGC

CONTENTS

PREAMBLE

Need of a New Syllabus

Under the subject of GEOLOGY we study the Earth. The term Earth Sciences is a further enlargement of the perspectives covered under Geology and is defined as the science dealing with all aspects of Earth in which we live. A thorough understanding of the Earth processes and their ramifications have great relevance to the societal development and the progress of the nation. At present, GEOLOGY as an independent subject is being taught at many Universities and Colleges. However, there is hardly any uniformity in the contents of the syllabi of these courses. In spite of the fact that syllabus revision is a continuous process in the University education system and is mandatory on the part of the concerned Departments, most Geology Departments are continuing with several years old course contents, oblivious of on-going rapid advancements in the field of Geological Sciences. With many natural calamities like earthquakes, landslides and floods affecting the nation and the society, it has become imperative that GEOLOGY, which incorporates the science of these natural hazards, should be taught rather effectively at the school and the University level. The course contents at the University level, should therefore, keep pace with the development in the modern sciences without forgetting our national heritage and ancient wisdom in a variety of Sciences.

In view of the need of a model syllabus for GEOLOGY (or Earth Sciences) which could be ideally followed by various Universities or which could provide a basic framework for formulating one's own syllabus, the University Grants Commission constituted a Curriculum Development Committee for Earth Sciences and nominated Prof. V.K. Gairola, Department of Geology, Banaras Hindu University, as its nodal person along with Prof. A.M. Pathan, Vice Chancellor, Karnataka University and Prof. D.M. Banerjee, Department of Geology, Delhi University as Members of the Core Committee. Dr. Surender Singh, Education Officer, UGC functioned as the Member Secretary to the Committee.

Mechanism of Consultations

Suggestions for the formulation of a new Curriculum for GEOLOGY courses in the Indian Universities were invited from experts from different parts of the country. This exercise was undertaken to get feed back from a wider cross section of the academia and organizations involved in disseminating the knowledge about our Earth. Constructive responses were received from Dr. S.V. Srikantia (Bangalore), Prof. K. S. Valdiya (Bangalore) Prof. K.L. Rai, (Raipur), Prof.

A.K. Gupta (Allahabad), Dr. S. Mukherjee (New Delhi); Prof. R.K. Lal (Varanasi), Prof. M. Joshi (Varanasi), Prof. G.C. Chaudhary (Varanasi), Dr. M.P.Singh (Varanasi), Dr. Satyendra Singh (Varanasi), Dr. V. N. Bajpai (Delhi) and Prof. P.K.Bose (Jadavpur). Several other experts were also contacted and invited for discussion, but due to other compulsions they could not spare time for this task.

Participants in CDC Meetings

Four meetings of the C.D.C. for Earth Sciences were held at the UGC premises in New Delhi between December, 2000 and February, 2001. These meetings were attended by experts representing different branches of Geology where they deliberated upon all aspects of Earth Science Curricula and identified the lacunae in the existing system. These experienced experts, mostly drawn from leading teaching institutions, have remained parts and parcels of our present educational system for several decades and are thoroughly conversant with all the weaknesses and strengths of our educational and social systems. Considering the fact that uniformity of syllabi in all teaching institutions of the country may not be feasible, due to shortage of finances, manpower or political will, an attempt has been made by the present Committee to provide a model syllabus so that inter-institutional and inter-state movement of students becomes feasible without much difficulty. The meetings were held with different sets of participants in order to concentrate on specific subjects in each meeting. The meetings were held in the following order with names of the participants in each meeting.

Core Committee Members remained common to all the meetings.

1st Meeting

Prof. Ashok SAHNI, Panjab University, Chandigarh
Prof. Somnath DASGUPTA, Jadavpur University, Calcutta
Prof. Ashok M. PATWARDHAN, Poona University, Pune

2nd Meeting

Prof. Pratul Kumar SARASWATI, Indian Institute of Technology, Mumbai
Prof. Vedharaman RAJAMANI, Jawaharlal Nehru University, New Delhi
Prof. Sampat Kumar TANDON, University of Delhi, Delhi
Prof. Mihir DEB, University of Delhi, Delhi

3rd Meeting

Prof. Vinod Kumar GAUR, Indian Institute of Astrophysics, Bangalore
Prof. Kharag Singh VALDIYA, Jawaharlal Nehru Centre for Advanced Research, Bangalore
Prof. R.K.S. CHAUHAN, Indian School of Mines, Dhanbad
Prof. R.C. LAKHERA, Indian Institute of Remote Sensing, Dehradun

4th Meeting

Only Core Committee Members attended this meeting

Apart from formal meetings, ideas were exchanged over e-mail with large number of geoscientists and their suggestions have been incorporated in the final report. Informal discussion and exchange of notes with some members (Prof. K.B. Powar, New Delhi; Prof. Thigale, Pune; Prof. Chavadi, Dharwar) of last Earth Science Panel of UGC was of great help in formulating the present syllabi. The wisdom contained in the last revision of the Geology Syllabus under the stewardship of Prof. Gaur and Prof. Dave has been incorporated, wherever feasible.

Basic Framework of the Proposed Undergraduate Syllabus

Most Universities have a three-year long undergraduate level course leading to the degree of B.Sc. (Honours). Those opting for B.Sc. Hons course in Geology, study Geology along with two other subsidiary subjects in the first two years. In the third year, the students concentrate only on the Honours subject. The undergraduate curriculum has been prepared keeping this aspect in mind. As Geology is not taught at the pre-University or the 10 + 2 level (except in few cities), teaching of this subject would require special attention and treatment. In view of this fact, the CDC participants felt that in the First Year of the undergraduate course, the students should be given exposure to all the branches of Geology. Hence, emphasis has been given to those aspects of Geology which would make students aware of larger perspectives of the subject and develop interest in the study of Earth processes. In the Second and Third years, the same sub-branches and some new branches of Geology will be covered at higher academic levels, incorporating certain topics which are normally covered at the Masters' level. This has become necessary in view of the rapid advancements in the field of Earth Science and the necessity of keeping pace with the modern developments. The concept of jumping steps in the ladder has become a necessity in order to catch up with the pace in which science is progressing today. The courses have therefore been framed, keeping in mind the rapid developments in the field of Earth Science, perception of the society to the science *per se* and ultimate needs of the country.

Basic Framework of the Proposed Postgraduate Syllabus

The post-graduate course in most Universities is of two years duration. Some educational institutions give instructions for three years and award M.Sc. (Applied Geology) or M.Tech degrees. The proposed Syllabus is targeted for the two-year course in the Indian Universities. We have proposed TWELVE CORE COURSES, ONE SPECIAL PAPER and ONE project oriented DISSERTATION. Emphasis has been laid on intensive and extensive field training which constitutes the backbone of geological studies. The curriculum for the First year consists of EIGHT theory papers, accompanying practicals and TWO field training sessions. The curriculum for the

Second year consists of FOUR theory papers, ONE special paper of double weightage and ONE field based / project oriented DISSERTATION work also of double weightage. Choices for special papers could be many. Only a selected few have been included in the proposed syllabus. Special paper as well as choice of dissertation topics will enable the students to make decision about their future activities, whether to go for advanced research or prepare for jobs immediately after obtaining the Master's degree.

Special Recommendation

The expert members strongly felt that Geology or Earth Sciences as a teaching subject should be included at the 10 + 2 level. Through this report, we are urging UGC to negotiate with the Board of Secondary Education for introduction of Geology/Earth Sciences as a subject at the Secondary Education level.

Acknowledgements

The Members of the Core Committee for the Curriculum Development in Earth Sciences are grateful to all the subject experts for their cooperation and help in formulating the new Syllabus. Thanks are especially due to the expert members for sparing their valuable time and coming all the way to New Delhi for participating in deliberations of the meetings. Dr. Surender Singh, Member Secretary arranged and coordinated all meetings at the UGC premises and provided *required* facilities for healthy deliberations. Being trained as a geoscientist, Dr. Surender Singh actively participated in the scientific deliberations of the CDC and gave important suggestions. It was only through the technical inputs given by the participating members that the present syllabus could be formulated within the stipulated time frame. At the end, we would like to put in record, that the primary credit goes to Professor Dr. Hari P. Gautam, Chairman, University Grants Commission, for recognizing the need of updating the Curriculum in our Universities especially in the field of Earth Sciences and for giving free hand to the Core Committee Members as far as the functioning of the expert group was concerned. We appreciate his interactive role in this matter.

(V.K. GAIROLA)
Nodal Person

(A.M. PATHAN)
Member Core Committee

(D.M. BANERJEE)
Member Core Committee

Dated: April 10, 2001

OPTIMUM CONTACT HOURS AND MARKING SCHEME FOR B.Sc. COURSE

FIRST YEAR

		Theory	Practical	Field Work
Marks		100 in each paper	50 in each practical	50
Paper I	Introduction to Geology – I	75 hours	100 hours	
Paper II	Introduction to Geology – II	75 hours	100 hours	10 days

Total Marks: Theory: 200 + Practical: 100 + Field Work: 50=350

SECOND YEAR

		Theory	Practical	Field Work
Marks		100 in each paper	50 in each practical	100
Paper III	Earth's Processes and Resources	75 hours	100 hours	
Paper IV	Petrology and Earth's History	75 hours	100 hours	10 days

Total Marks: Theory: 200 + Practical: 100 + Field Work: 100 = 400

THIRD YEAR

		Theory	Practical	Field Work
Marks		100 in each paper	50 in each practical	150
Paper V	Dynamics of the Earth	80 hours	160 hours	
Paper VI	Structural Geology	80 hours	100 hours	
Paper VII	Natural Environment (including elements of Remote Sensing, Hydrogeology and Engineering Geology)	80 hours	100 hours	20 days
Paper VIII	Energy Resources and Mineral Exploration	80 hours	100 hours	

Total Marks: Theory: 400 + Practical: 200 + Field Work: 150 = 750

DETAILS OF UNDERGRADUATE SYLLABUS

FIRST YEAR COURSES

Paper I : Introduction to Geology — 1

Geology and its perspectives. Earth in the Solar System: origin, size, shape, mass, density, rotational and revolution parameters. Formation of core, mantle, crust, hydrosphere, atmosphere and biosphere and elemental abundance in each constituent. Convection in the earth's core and production of its magnetic field. Radioactivity and age of the Earth. Introduction to basic tenets of ancient Indian perspectives about the origin of the Universe and evolution of the solar system.

Elementary ideas of continental drift and plate tectonics. Origin of oceans, continents and mountains. Earthquake and earthquake belts, measurement of earthquakes. Volcanoes: types and distribution.

Generation of oceanic currents, surface currents and global ocean Conveyor system; wave erosion and beach processes; ocean as a thermostat for the earth's surface heat balance.

Atmospheric circulation, weather and climate changes. Land-air-sea interaction, Earth's heat budget and global climatic changes.

Rock weathering. Erosion and transportation by wind, rivers, glaciers and oceanic currents. Soil formation, soil profile and soil types. Sediment transport by the wind, rivers and glaciers. Glacial periods: causes of glacial ages and glacio-eustasy.

Study of outcrops. identification of bedding, data measurement, effects of topography, outlier, inlier and forms of igneous bodies. Unconformity, onlap and offlap. Simple deformational structures: folds, faults, joints.

Elementary ideas about crystal structure. Crystal: faces, edges, solid angles, and zone. Crystallographic axes and axial angles. Parameters and indices. Crystal symmetry and classification of crystals into seven systems.

Chemical bonding and compound formations. Minerals: definition and classification, physical properties and chemical composition. Silicate structure.

Petrological microscope: its parts and functioning. Optical mineralogy: refractive index, twinkling, birefringence, pleochroism, interference colours, extinction angle and twinning.

Practical

Study of important geomorphological models. Reading topographical maps.

Use of Clinometer and Brunton Compass. Laboratory exercises on structural geology problems: Completion of outcrops, drawing and interpretation of cross-sections through elementary representative geological structures.

Study of elements of symmetry of at least one representative crystal from normal classes of seven crystal systems.

Study of physical properties of minerals in hand specimen.

Study of the optical characters of important minerals using polarizing microscope

Paper II : Introduction to Geology — 2

Magma: definition, composition, origin, Bowen's reaction series. Magmatic differentiation and assimilation. Texture, structure and classification of igneous rocks.

Sediments: origin, transportation, deposition, consolidation and diagenesis. Sedimentary fabrics and textures. Classification of sedimentary rocks: Terrigenous and chemical sedimentary rocks.

Metamorphic rocks: agents, texture, structure and classification. Metamorphic facies, facies series and isograds. Relationship between metamorphism and deformation.

Definition and scope of palaeobiology, process of fossilization, preservation potential of organisms. Elementary ideas about origin of life, evolution and fossil record. Systematic classification of organisms–their characters, environmental factors and geological distribution of mollusca, brachiopoda, echinodermata and arthropoda.

Principles of stratigraphy, geological time scale, lithostratigraphic, chronostratigraphic and biostratigraphic units, stratigraphic correlation. Physical and structural subdivisions of Indian subcontinent and their characteristics. A brief account of the different geological formations of India.

Introduction to common rock forming, ore forming and industrial minerals. Atomic minerals. Fossil fuels. Classification of mineral deposits. Basic ideas about the methods of mineral exploration, mining, conservation and utilization of natural resources in ancient India.

Application of statistics, trigonometry, algebra and calculus to the study of Geology. Use of computer in geological studies.

Practical

Study of megascopic and microscopic characters of important rock-forming and ore-forming minerals.

Study of morphological characters of phyla included in the theory syllabus.

Preparation and study of stratigraphic maps

Geological Field Training

Students will be required to carry out field work for 7-10 days in a suitable geological area to study the elementary aspects of field geology and submit a report thereon.

SECOND YEAR COURSES

Paper III : Earth Processes and Resources

Factors controlling mineral availability. Global mineral reserves and resources. Distribution of mineral deposits in space and time.

Conventional and non-conventional energy resources: coal, petroleum, atomic minerals; and water, sun, wind, hot springs and sea waves.

Rock forming minerals - silicates, oxides and sulfides: chemical composition, physical properties and systematic classification.

Ore forming minerals: metallic and non-metallic. Processes of formation of ores: magmatic concentration, hydrothermal solutions and skarns. Secondary enrichment. Sedimentation as a process of ore formation. Replacement and bacterial precipitation. Colloidal deposition. Weathering products and residual deposits: oxidation and supergene enrichment. Evaporation of brine and metamorphism as ore forming process.

Global tectonics and metallogeny through geological times. Geological setting, mineralogical characteristics and Indian distribution of important mineral deposits related to metals like iron, manganese, chromium, copper, lead, zinc, gold, aluminum, and non-metals related to refractory, fertilizer, cement, chemical and gemstone industry including building stones. Examples from Indian stratigraphic records. Methods of mineral exploration, exploitation and processing.

Environmental implications of exploitation of mineral resources

Practical

Study of physical and optical properties of additional rock and ore forming minerals (other than those covered under Paper II). Study of association of ore forming minerals. Preparation of maps

showing distribution of important ores and other economic minerals in India. Study of metallogenic maps.

Paper IV : Petrology and Earth's History

Petrology: Rock associations in time and space. Concept of rock series, system, phase and component. Chemical potential and phase rule. Basic principles of equilibrium thermodynamics. Phase equilibria in two and three component silicate system. Mineralogical characteristics of acid-igneous, alkaline, basic igneous and ultra-mafic rocks.

Equilibrium and non-equilibrium reactions in metamorphic processes; composition - paragenetic diagrams; projective analysis; pressure-temperature-composition (including fluid) and evolution of pelitic, basic and calcareous rocks.

Chemistry of weathering processes. Diagenesis of terrigenous and chemical sediments. Dynamics of eolian, fluvial, near-shore and deep-sea environments. Concept of sedimentary facies; basic principles of palaeoenvironment and palaeoclimate analyses.

Earth's History: Ontogeny and variation in fossil assemblages. Identification of fossils: methods of description and illustration; taxonomic categories and codes of systematic nomenclature.

Applications of palaeontologic data in palaeoecology, evolution, stratigraphy and palaeogeographic reconstructions.

Morphology, environment and geological dsitribution of mollusca, brachiopoda, echinodermata, arthropoda and anthozoa.

Basic ideas about micropalaeontology and microfossils. A brief study of vertebrates and plant fossils.

Stratigraphic classification and correlation. Methods of collecting stratigraphic data, identification of stratigraphic contacts and unconformities. Facies concept in stratigraphy. Classification, geographic distribution, lithological characteristics, fossil contents and economic importance of Precambrian and Phanerozoic successions of India.

Practical

Study of morphological characters of important fossil phyla designated in theory paper.
Exercises in showing the major stratigraphic and lithotectonic units in hand drawn map of India. Study of important primary sedimentary structures in hand specimen and under microscope. Microscopic study of sedimentary textures and diagenetic featrures in sedimentary rocks. Microscopic study of major igneous and metamorphic textures. Laboratory exercises in graphic plots for petrochemistry and interpretation of paragenetic diagrams.

Geological Field Training

10 days of actual geological mapping and visit to economic mineral deposits in some appropriate area followed by laboratory processing of rock samples, ores and fossils collected during the field work.

THIRD YEAR COURSES

Paper V : Physics and Dynamics of the Earth

Crust and interior of the Earth: internal structure and chemical composition of various layers. Geochemical evolution of the Earth. Geophysical conditions of the Earth: gravity, magnetism and heat flow. Application of geophysics in understanding the dynamics of the Earth. Concept and theories of isostasy.

Earth movement through time: orogenic and epiorogenic phases, evidence of continental drift, evidence of sea floor spreading, origin and significance of mid-oceanic ridges and trenches, evolution of Plate Tectonics theory, nature and types of plate margins, geometry and mechanism of plate motion, and evolution of oceans and continents.

Tectonics of continental margins, continental shelves, divergent margins, active margins and marginal basins. Origin and distribution of island arcs. Relationship between orogeny, magmatism, metamorphism and metallogeny. Neotectonics: active faults, geomorphological indicators, drainage changes, recurrent seismicity. Causes and remediation of natural and man-made geohazards.

Practical

Morphometric analysis from topographical maps.

Study of sections across continental margins, island arcs and plate tectonics models.

Study of geohazard maps and introduction to basic geophysical instruments used for understanding the dynamics of the Earth.

Paper VI : Structural Geology

Geological significance and recognition of unconformities.

Fold morphology, geometric and genetic classifications. Mechanics and causes of folding.

Geometric and genetic classification of faults. Effects of faulting on the outcrops. Geometric and genetic classification of joints.

Foliation: descriptive terminology, origin and relation to major structures. Lineation: descriptive terminology, kinds and origin, relation to major structures.

Concept of rock deformation. Methods of analysis of simple tectonic structures. Stereographic projection and its use in structural analysis.

Practical

Exercises on structural geology problems. Stereographic projections of structural data. Geometrical problems on folds and faults. Drawing and the interpretation of profile sections across the geological maps.

Paper VII : Natural Environment (Including Elements of Remote Sensing, Hydrogeology and Engineering Aspects)

Concept and definition of Environmental Geology. Processes of soil formation, types of soils, soil degradation and mitigation. Concepts of natural ecosystems on the Earth and their mutual interrelations and interactions (Atmosphere, Hydrosphere, Lithosphere and Biosphere). Environmental changes due to influence of human-dominated environment over nature-dominated system.

Shifting of river courses: their impact on soil erosion, landslides and floods.

Environmental considerations in the location and construction of large dams, reservoirs and tunnels.

Application of remote sensing techniques in planning of large engineering structures and urban development. Introduction to aerial photographs, satellite imageries and preparation of photogeological maps. Application of remote sensing techniques mapping the soil cover, forest cover, degraded land and surface water reserves.

Hydrologic cycle. Groundwater reservoirs and their classification, classification of aquifers. Darcy's law and its validity. Groundwater provinces of India. Concept of watershed management.

Practical

Preparation and interpretation of water table maps. Introduction to geological interpretations of remote sensing data. Photogeological study of aerial photographhs. Introduction to modern analytical techniques of geological, geophysical and geobotanical surveys for environmental study. Case studies of environment related problems.

Paper VIII : Energy Resources and Mineral Exploration

Geology of fuels: definition, origin of coal stratigraphy of coal measures, fundamentals of coal petrology, peat, lignite, bituminous and anthracite coal. Indian Coal deposits.

Origin, migration and entrapment of natural hydrocarbons. Source and Reservoir rocks. Structural, stratigraphic and mixed oil traps. Exploration techniques: geophysical and geological. Onshore and off-shore distribution of petroliferous basins in India.

Radioactive minerals: Mineralogy, geochemistry, detection and measurement of radioactivity, prospecting techniques, distribution in India. Radioactive well logging. Nuclear waste disposal.

Mineral exploration: Surface and subsurface exploration methods including use of remote sensing techniques. Prospecting for economic minerals: drilling, sampling and assaying. Gravity, electrical, magnetic, airborne and seismic methods of exploration. Geobotanical and geochemical methods of exploration. Bore-hole logging and deviation testing.

Principles of mineral economics: Strategic, critical and essential minerals. Mineral production in India. Changing pattern of mineral consumption. National mineral policy. Mineral concession, rules, marine mineral resources and Law of Sea.

Practical

Hand specimen study of different types of coals, selected radioactive minerals and their host rocks. Exercises in showing distribution of various mineral deposits, fuel resources and hydrocarbon resources on map of India. Laboratory exercises in solving exploration related problems.

Geological Field Training

20 days' fieldwork including geological mapping of structurally complex area. The field report should be based on the mapping as well as laboratory work on the rock samples collected during the fieldwork.

OPTIMUM CONTACT HOURS AND MARKING SCHEME FOR M.Sc. COURSE

FIRST YEAR

		Theory	Practical	Field Work
Marks		100 in each paper	50 in each practical field work	150 in each
Paper I	Remote sensing in Geology, & Geomorphology	50 hours	67 hours	
Paper II	Structural Geology & Tectonics	50 hours	67 hours	
Paper III	Igneous and Metamorphic Petrology	50 hours	67 hours	
Paper IV	Sedimentology	50 hours	67 hours	
Paper V	Mineralogy, Instrumentation and Analytical Techniques	50 hours	67 hours	2 x 21 days
Paper VI	Ore Geology and Mining Geology	50 hours	67 hours	
Paper VII	Palaeobiology and Stratigraphy	50 hours	67 hours	
Paper VIII	Geochemistry	50 hours	67 hours	

Total Marks: Theory: 800 + Practical: 400 + Field Work: 300 =1500

SECOND YEAR

		Theory	Practical	Field Work
Marks		100 in each paper	50 in each practical	
Paper IX	Hydrogeology	50 hours	67 hours	
Paper X	Fuel Geology	50 hours	67 hours	
Paper XI	Geophysical Exploration and Engineering Geology	50 hours	67 hours	
Paper XII	Environmental Geology	50 hours	67 hours	
Marks		**300 including theory and practical**		
Paper XIII	Special Paper	100 hours	150 hours	
Marks		**300 including field work, seminar and dissertation**		
Paper XIV	Project Oriented Dissertation		320 hours	30 Days
Total Marks:	Theory : 400 + Practical: 200 + Special Paper: 300 + Project Oriented Dissertation: 300 =1200			
Grand Total	First Year : 1500 + Second Year: 1200 = 2700			

DETAILS OF POSTGRADUATE SYLLABUS

FIRST YEAR COURSES

Paper I : Remote Sensing in Geology, and Geomorphology

Principles of remote sensing: general idea about electromagnetic spectrum, aerial photographs and their geometry, photogrammetry: recent advancements and applications. Satellite remote sensing. Global and Indian space missions. Different satellite exploration programs and their characteristics: LANDSAT, METEOSAT, SEASAT, SPOT, IRS. Image interpretation and digital processing techniques.

Geological Studies: image characters and their relations with ground objects based on tone, texture and pattern; principles of terrain analysis, evaluation of groundwater potential, rock type identification; and interpretation of topographic and tectonic features.

Geomorphological Studies: dynamics of geomorphology, geomorphic processes and resulting landforms and their discrimination on photos and images. Morphometric analysis. Geomorphological mapping based on genesis of landforms. Terrain evaluation for strategic purpose. Principles and applications of Geographic Information System

Practical

Study of nature of aerial photographs: resolution, mosaics, symbols, gully pattern and drainage analysis, image parallax. Determination of scale, height, dip, slope, vertical exaggeration and image distortion. Exercises on MSS, TM, FCC, IR, Thermal IR, Radar, and SPOT images for geological and geomorphological mapping and in (georesources) vegetation, water and mineral resource evaluation. Making false color composites, and study of multi-spectral scans and spectral patterns. Exercises on digital image processing. Study of environmental hazard maps.

Books Recommended

Miller, V.C., 1961: *Photogeology.* McGraw Hill

Sabbins, F.F., 1985: *Remote Sensing – Principles and Applications.* Freeman.

Ray. R.G., 1969: *Aerial Photographs in Geologic Interpretations.* USGS Prof. Paper 373.

Drury, S.A., 1987: *Image Interpretation in Geology.* Allen and Unwin.

Moffitt, F. H. and Mikhail, E.M.,1980: *Photogrammetry,* Harper and Row.

Lillesand, T.M. and Kieffer, R.W., 1987: *Remote Sensing and Image Interpretation.* John Wiley.

Paine, D.P., 1981: *Aerial photography and Image Interpretation for Resource Management.* John Wiley.

Pandey, S.N., 1987: *Principles and Applications of Photogeology.* Wiley Eastern, New Delhi.

Gupta, R.P., 1990: *Remote Sensing Geology.* Springer Verlag.

Paper II : Structural Geology and Tectonics

Mechanical principles and properties of rocks and their controlling factors. Theory of rock failure. Concept of stress and strain. Two-dimensional strain and stress analyses. Types of strain ellipses and ellipsoids, their properties and geological significance. Strain markers in naturally deformed rocks.

Mechanics of folding and buckling. Fold development and distribution of strains in folds.

Fractures and joints: their nomenclature, age relationship, origin and significance. Causes and dynamics of faulting, strike-slip faults, normal faults, overthrust and nappe.

Planar and linear fabrics in deformed rocks, their origin and significance.

Concept of petrofabrics and symmetry: objective, field and laboratory techniques. Graphic treatment. Types of fabrics, fabric elements and interpretation of fabric data on microscopic and mesoscopic scale. Use of Universal Stage in petrofabrics. Significance and limitations of π- and β-diagrams.

Geometrical analysis of simple and complex structures on macroscopic scale.

Plate Tectonics: recent advances, pros and cons. Dynamic evolution of continental and oceanic crust, Tectonics of Precambrian Orogenic Belts of India. Formation of mountain roots. Anatomy of orogenic belts. Structure and origin of the Alpine-Himalayan belt, the Applachian-Caledonian belt, The Andes, the North American Cordillera. Study of Map Projections.

Practical

Preparation and interpretation of geological maps and sections. Structural problems concerning economic mineral deposits. Recording and plotting of field data. Plotting and interpretation of petrofabric data and resultant diagrams. Study of large scale tectonic features of the Earth.

Books Recommended

Badgley, P.C., 1965: *Structure and Tectonics.* Harper and Row.

Ramsay, J.G., 1967: *Folding and Fracturing of Rocks.* McGraw Hill.

Hobbs, B.E., Means, W.D. and Williams, P.F., 1976: *An Outline of Structural Geology*, John Wiley.

Davis, G.R., 1984: *Structural Geology of Rocks and Region.* John Wiley.

Ramsay, J.G. and Huber, M.I., 1987: *Modern Structural Geology*, Vol. I & II. Academic Press.

Price, N.J. and Cosgrove, J.W., 1990: *Analysis of Geological Structure*. Cambridge Univ. Press.

Bayly B., 1992 : *Mechanics in Structural Geology*. Springer Verlag.

Ghosh S.K., 1995: *Structural Geology Fundamentals of Modern Developments*. Pergamon Press.

Moores, E and Twiss, R.J., 1995: *Tectonics*. Freeman.

Keary, P. and Vine, F.J, 1990: *Global Tectonics*. Blackwell.

Storetvedt, K.N., 1997: *Our Eevolving Planet: Earth's History in New Perspective*. Bergen (Norway), Alma Mater Fortag.

Valdiya, K.S., 1998: *Dynamic Himalaya*. Universities Press, Hyderabad.

Summerfield, M.A., 2000: *Geomorphology and Global Tectonics*. Springer Verlag.

Paper III : Igneous and Metamorphic Petrology

Igneous Petrology

Physics of magma generation in the mantle, their nature. Factors affecting magma and evolution of magma. Phase equilibrium of single, binary, ternary and quaternary silicate systems, its relation to magma genesis and crystallization in the light of modern experimental works.

Criteria for classification of the igneous rocks. Norms - CIPW, and Niggli values, Zavaritskii number; Rock suite, series: petrographic provinces and associations.

Petrogenesis of major igneous rock types such as ultramafic/komatiite, basaltic, granitic and alkaline rocks.

Metamorphic Petrology

Mineralogical Phase rule of closed and open systems..

A detailed description of each facies of low-pressures, medium- to high-pressures, and very high pressure with special reference to characteristic metamorphic zones and subfacies. Nature of metamorphic reactions and pressure-temperature conditions of metamorphism. Isoreactiongrad, Schreinmakers rule and construction of petrogenetic grids.

Metamorphic differentiation. Anatexis and origin of migmatites in the light of experimental studies. Regional metamorphism and paired metamorphic belts in reference to Plate Tectonics. Pressure-temperature-time paths. Ultra-high temperature, ultra-high pressure and ocean floor metamorphism.

Practical

Megascopic and microscopic study of igneous lithotypes. Calculation of CIPW Norms, Preparation of variation diagrams.

Megascopic and microscopic study of metamorphic rocks of different facies. Time relationship between deformation and recrystallisation. Graphic construction of ACF, AKF and AFM diagrams. Estimation of pressure and temperature from important models of geothermobarometry. Interpretation of reaction textures.

Books Recommended

Turner, F.J. 1980: *Metamorphic Petrology*, McGraw Hill, New York.

Yardley, B.W. 1989: *An Introduction to Metamorphic Petrology*. Longman New York.

Bucher, K. and Frey, M. 1994: *Petrogenesis of Metamorphic Rocks*, Springer - Verlag.

Philipotts, A, 1992: *Igneous and Metamorphic Petrology*. Prentice Hall.

Best,M.G., 1986: *Igneous Petrology*, CBS Publ.

McBirney, A.R., 1993: *Igneous Petrology*. Jones & Bartlet Publ.

Kretz, R., 1994: *Metamorphic Crystallization*, John Wiley.

Bose, M.K.,1997: *Igneous Petrology*. World Press.

Perchuk, L.L. and Kushiro, I. (eds), 1991: *Physical Chemistry of Magmas*. Springer Verlag.

Paper IV : Sedimentology

Earth Surface System: liberation and flux of sediments, processes of transport and generation of sedimentary structures, controls on the sedimentary rock record.

Sedimentary environments and facies. Continental alluvial-fluvial, lacustrine, desert-aeolian and glacial sedimentary systems. Shallow coastal clastics. Marine and continental evaporites. Shallow water carbonates. Deep sea basins. Volcanoclastic: on-land and marine. Palaeocurrents and basin analyses.

Evolution of sedimentary basins: tectonics and sedimentation.

Clastic petrofacies. Palaeoclimate and palaeoenvironment analyses.

Application of trace element, rare-earth element and stable isotope geochemistry to sedimentological problems.

Field and laboratory techniques in sedimentology: recording of sedimentary structures, preparation of lithologs, rock and thin section staining, cathodoluminescence, use of coulter counter.

Diagenesis and fluid flow. Diagenesis of mudstones, sandstones, and carbonate rocks: changes in mineralogy, fabric and chemistry.

Practical

Study of primary, secondary and biogenic sedimentary structures in hand-specimens, in photographic atlases, field photographs and wherever possible on the outcrops. Exercises related

to palaeocurrent data from different environments. Tilt corrections of palaeocurrent data. Exercises related to analysis and interpretation of depositional sedimentary environments using actual case histories from the Indian stratigraphic records. Determination of porosity in clastic and carbonate rock. Staining and mineral identification in carbonate rocks. Petrography of clastic and chemical sedimentary rocks. Detailed study of diagenetic features in thin sections. Microscopic study of heavy minerals. Exercises on mineralogical and geochemical data plots for environmental interpretations.

Books Recommended

Allen, J.R.L., 1985: *Principles of Physical Sedimentation*, George Allen & Unwin.

Allen, P., 1997: *Earth Surface Processes*. Blackwell.

Nichols, G., 1999: *Sedimentology and Stratigraphy*. Blackwell.

Reading, H.G. 1996: *Sedimentary Environments*. Blackwell.

Davis, R.A. Jr., 1992: *Depositional Systems*. Prentice Hall.

Einsele, G., 1992: *Sedimentary Basins*. Springer Verlag.

Reineck, H.E. and Singh, I.B.,1980: *Depositional Sedimentary Environments*. Springer-Verlag.

Prothero, D.R. and Schwab, F., 1996: *Sedimentary Geology*. Freeman.

Miall, A.D., 2000: *Principles of Sedimentary Basin Analysis*. Springer-Verlag.

Pettijohn, F.J., Potter, P.E. and Siever, R., 1990: *Sand and Sandstone*. Springer Verlag

Blatt, H, Murray, G.V. and Middleton, R.C., 1980: *Origin of Sedimentary Rocks*.

Bhattacharya, A and Chakraborti, C., 2000: *Analyses of Sedimentary Successions*.Oxford-IBH.

Boggs Sam Jr., 1995: *Principles of Sedimentology and Stratigraphy*, Prentice Hall.

Sengupta, S., 1997: *Introduction to Sedimentology*, Oxford-IBH.

Paper V : Mineralogy, Instrumentation and Analytical Techniques

Mineralogy

Systematic mineralogy (atomic structure, mineral chemistry and their PT-stability and mode of occurrence) of silicates, native elements, sulfides, sulfosalts, oxides, hydroxides and carbonates. Mineral assemblages. Gem and semi-precious minerals.

Instrumentation and Analytical Techniques

Sampling and sample preparation, thin section and polished section making, dissolution procedures in geological and environmental samples. Sample etching, staining and modal count techniques. Techniques in photomicrography. Principles and geological application of cathodoluminiscence, thermoluminiscence, atomic absorption spectrophotometry, inductively coupled plasma-atomic emission spectrometry, X-ray fluorescence spectrometry, scanning and transmission electron microscopy, electron-probe microanalysis, X-ray diffractometry, thermal ionization and gas source mass spectrometry.

Practical

Microscopic study of rock forming minerals using optical accessories. Depending upon availability of facility, exercises in sample dissolution, determination of elemental composition of minerals and rocks by flame photometer and AAS, sample preparation for powder diffraction by XRD and interpretation of x-ray diffractograms of common minerals and components of the bulk rocks. Exercises on thin section and polished section making, etching and staining.

Books Recommended

Deer, W.A., Howie, R.A. and Zussman, J., 1996: *The Rock Forming Minerals.* Longman.

Klein, C. and Hurlbut, Jr., C.S., 1993: *Manual of Mineralogy.* John Wiley.

Putnis, Andrew, 1992: *Introduction to Mineral Sciences.* Cambridge University Press.

Spear, F.S. 1993: *Mineralogical Phase Equilibria and Pressure - Temperature-Time Paths.* Mineralogical Society of America Publ.

Phillips, Wm, R. and Griffen,D.T., 1986: *Optical Mineralogy*, CBS Edition.

Hutchinson, C.S., 1974: *Laboratory Handbook of Petrographic Techniques.* John Wiley.

Paper VI : ORE GEOLOGY AND MINING GEOLOGY

Ore Geology

Modern concept of ore genesis; spatial and temporal distribution of ore deposits — a global perspective. Comparison between Earth's evolutionary history and evolutionary trends in ore deposits. Ore deposits and Plate Tectonics.

Mode of occurrence of ore bodies — morphology and relationship of host rocks. Textures paragenesis and zoning of ores and their significance. Concept of ore bearing fluids, their origin and migration; wall-rock alteration; structural, physico-chemical and stratigraphic control of ore localization.

Chemical composition of ores — bulk chemistry, trace elements, REE and isotopes (stable and radiogenic). Organic matter in ores and their significance.

Fluid inclusion in ores: principles, assumptions, limitations and applications.

Petrological ore associations with Indian examples wherever feasible: Orthomagmatic ores of mafic-ultramafic association - diamonds in kimberlite; REE in carbonatites; Ti-V ores; chromite and PGE; Ni ores; Cyprus type Cu-Zn. Ores of silicic igneous rocks - Kiruna type Fe-P; pegmatoids, greisens, skarns, porphyry associations; Kuroko-type Zn-Pb-Cu. Ores of sedimentary affiliation – chemical and clastic sedimentation, stratiform and stratabound ore deposits (Mn, Fe, non-ferrous ores), placers and palaeoplacers. Ores of metamorphic affiliations - metamorphism of ores, metamorphogenic ores. Ores related to weathering and weathered surfaces - laterite, bauxite, Ni/Au laterite.

Contemporary ore-forming systems e.g., black smokers, mineralized crusts, Mn nodules. Mineralogy, genesis, use and Indian distribution of ore minerals related to: Fe, Mn, Cr, Cu, Pb, Zn, Al, Mg, Au, Sn, W and U.

Mining Geology

Application of rock mechanics in mining. Planning, exploration and exploratory mining of surface and underground mineral deposits involving diamond drilling, shaft sinking, drifting, cross cutting, winzing, stoping, room and pillaring, top-slicing, sub-level caving and block caving. Cycles of surface and underground mining operations. Exploration for placer deposits. Open pit mining. Ocean bottom mining. Types of drilling methods. Mining hazards: mine inundation, fire and rock burst.

Practical

Megascopic study of structures and fabrics of different ores and their associations. Mineralogical and textural studies of common ore minerals under ore-microscope and petrological study of other industrial and non-metallic minerals Exercises in the determination of reflectivity and microhardness of common ore minerals. Diagrammatic representation of open cast and underground mining. Methods of mining survey. Exercises on mine sampling and determination of tenor, cut-off grades and ore reserves.

Books Recommended

Craig, J.M. & Vaughan, D.J., 1981: *Ore Petrography and Mineralogy*. John Wiley.

Evans, A.M., 1993: *Ore Geology and Industrial Minerals*. Blackwell.

Sawkins, F.J., 1984: *Metal deposits in relation to plate tectonics*. Springer Verlag.

Stanton, R.L., 1972: *Ore Petrology*, McGraw Hill.

Torling, D.H., 1981: *Economic Geology and Geotectonics*. Blackwell Sci Publ.

Barnes, H.L., 1979: Geochemistry of Hydrothermal Ore Deposits. *John Wiley.*

Klemm, D.D. and Schneider, H.J., 1977: *Time and Strata Bound Ore Deposits*. Springer Verlag.

Guilbert, J.M. and Park, Jr. C.F., 1986: *The Geology of Ore Deposits*. Freeman.

Mookherjee, A., 2000: *Ore genesis – a Holistic Approach*. Allied Publisher.

McKinstry, H.E., 1962: *Mining Geology*. II Ed. Asia Publishing House.

Clark, G.B., 1967: *Elements of Mining*. III Ed. John Wiley.

Arogyaswami, R.P.N., 1996: *Courses in Mining Geology*. IV Ed. Oxford IBH.

Paper VII : Palaeobiology and Stratigraphy

Palaeobiology

Species concepts, biometrics, molecular systematics, phylogenetic analysis. Mechanisms of evolution; origin of life, origin of metazoa, major events in the history of Precambrian and Phanerozoic life. Growth and allometry, theoretical morphology; functional morphology and evolutionary trends in mollusks, brachiopods, echinoderms and trilobites.

Taphonomy, limiting environmental factors. Stable isotopes and palaeoclimates. Palaeobiogeographic provinces.

Classification and significance of vertebrate palaeontology and micropalaeontology.

Stratigraphy

Controls on the development of stratigraophic records. Lithostratigraphy, correlation and stratigraphic code. Biostratigraphy: controlling factors zonation, time significance, quantitative stratigraphy. Magnetostratigraphy, cyclostratigraphy, event stratigraphy, pedostratigraphy seismic stratigraphy, and sequence stratigraphy. Geochronology and chrnostratigraphy. Geophysical and chemostratigraphic correlation.

Completeness/incompleteness of stratigraphic records; preservation and net rates of accumulation in various basinal settings.

Study of palaeogeography, palaeoclimate and igneous and mountain building activities in the Indian subcontinent.

Practical

Recognition of fossil groups in an assorted assemblage and identification of their classes. Study of important fossils from Indian stratigraphic horizons. Measurement of dimensional parameters and preparation of elementary growth-curves and scatter-plots. Exercises on stratigraphic classification and correlation. Exercises on interpretation of seismic records for stratigraphy Study of palaeogeographic maps of all geological periods.

Books Recommended

Clarkson, E.N.K., 1998: *Invertebrate Palaeontology and Evolution.* IV Ed. Blackwell.

Stearn, C.W. & Carroll, R.L., 1989: *Palaeontology – the Record of Life.* John Wiley.

Smith, A.B., 1994: Systematics and the Fossils Record–Documenting Evolutionary Patterns. *Blackwell .*

Prothero, D.R., 1998: Bringing Fossils to Life – An Introduction to Palaeobiology. *McGraw Hill.*

Pomerol, C., 1982: *The Cenozoic Era: Tertiary and Quaternary.* Ellis Harwood Ltd.

Goodwin, A.M., 1991: *Precambrian Geology : The Dynamic Evolution of Continental Crust.* Academic Press.

Boggs, Sam Jr., 1995: *Principles of Sedimentology and Stratigraphy*, Prentice Hall

Doyle, P. and Bennett, M.R., 1996: *Unlocking the Stratigraphic Record*. John Wiley.

Brenner, R.E. and McHargue, T.R., 1988: *Integrative Stratigraphy: Concepts and Applications*. Prentice Hall.

Naqvi, S.M. and Rogers, J.J.W., 1987: *Precambrian Geology of India*, Oxford Univ.Press.

Pascoe, E.H., 1968. *A Manual of Geology of India and Burma*, Vol.I-IV, Govt of India Press.

Paper VIII : Geochemistry

Origin and abundance of elements in the Solar system and in the Earth, and its constituents.

Atomic structures and properties of elements in the Periodic Table. Special properties of transition and rare earth elements. Geochemical classification of elements.

Radiogenic isotopes. Radioactive decay schemes of U-Pb, Sm-Nd, Rb-Sr, K-Ar, and growth of daughter isotopes. Radiometric dating of single minerals and whole rocks.

Stable isotopes: nature, abundance, and fractionation. Fluid interactions and biological processes.

Laws of thermodynamic; concept of free energy, activity, fugacity and equilibrium constant, thermodynamics of ideal, non-ideal and dilute solutions. Principles of ionic substitution in minerals; element partitioning in mineral/rock formation and concept of simple distribution coefficients and exchange reaction distribution coefficients; element partitioning in mineral assemblages and its use in the pressure-temperature estimation.

Chemistry of natural waters. Mineral stability in Eh-pH diagram. Rock weathering and soil formation. Elemental mobility in surface environment. Concept of geochemical-biogeochemical cycling and global climate.

Practical

Rock/soil/sediments/water analysis in conjunction with Practical listed for Paper-V. Calculation of mineral formulae from the concentration of various oxides in minerals. Calculation of normative mineralogy from rock composition. Calculation of weathering indices in soil and sediments. Presentation of analytical data.

Books Recommended

Mason, B. and Moore, C.B., 1991: *Introduction to Geochemistry*, Wiley Eastern.

Krauskopf, K.B., 1967: *Introduction to Geochemistry*. McGraw Hill.

Faure, G., 1986: *Principles of Isotope Geology*. John Wiley.

Hoefs, J., 1980: *Stable Isotope Geochemistry*. Springer Verlag.

Marshal, C.P. and Fairbridge, R.W., 1999: *Encyclopaedia of Geochemistry*. Kluwer Academic.

Govett, G.J.S. (Ed), 1983: *Handbook of Exploration Geochemistry*. Elsevier.

Nordstrorm, D.K. and Munoz, J.L.,1986: *Geochemical Thermodynamics*, Blackwell.

Henderson, P., 1987: *Inorganic Geochemistry*, Pergamon Press.

SECOND YEAR COURSES

Paper IX : Hydrogeology

Ground water: origin, types, importance, occurrence, reservoirs and movement. Renewable and non-renewable groundwater resources; Hydrologic properties of rocks: porosity, permeability, specific yield, specific retention, hydraulic conductivity, transmissivity, storage coefficient. Hydrographs. Water table contour maps, hydrostratigraphic units, hydrogeology of arid zones and wetlands.

Ground water quality, estimation and methods of treatment for various uses, Groundwater quality map of India. Water contaminants and pollutants: problem of arsenic and fluoride

Well hydraulics: confined, unconfined, steady, unsteady and radial flow. Water level fluctuations: causative factors and their measurements. Methods of pumping test and analysis of test data, evaluation of aquifer parameters.

Artificial recharge of groundwater, Consumptive and conjunctive use of surface and groundwater, problem of overexploitation, groundwater legislation.

Water well technology: well types, drilling methods, construction, design, development and maintenance of wells. Water management in rural and urban areas, salt water intrusion in coastal aquifers, remedial measures.

Surface and subsurface geophysical and geological methods of groundwater exploration, hydrogeomorphic mapping using various remote sensing techniques. Radio isotopes in hydrogeological studies.

Practical

Delineation of hydrological boundaries on water-table contour maps and estimation of permeability. Analysis of hydrographs and estimation of infiltration capacity. Chemical analysis of water in conjunction with practicals for Paper-V. Pumping test: time-drawdown and time-recovery tests and evaluation of aquifer parameters. Step drawdown tests, Electric resistivity sounding for delineation of fresh and saline aquifers. Study of geophysical well logs. Estimation of TDS using resistivity and SP logs. Exercises on groundwater exploration using remote sensing techniques in conjunction with practicals given for Paper-I.

Books Recommended

Todd, D.K., 1980: *Groundwater Hydrology*. John Wiley.

Davies, S.N. & De Wiest, R.J.M., 1966: *Hydrogeology*. John Wiley.

Freeze, R.A. & Cherry, J.A., 1979: *Ground Water*. Prentice Hall.

Fetter, C.W., 1990: *Applied Hydrogeology*, Merill Publishing.

Raghunath, N.M., 1982: *Ground Water*. Wiley Eastern.

Karanth, K.R., 1987: *Groundwater Assessment-Development and Management*. Tata McGraw Hill.

Alley, W.M., 1993: *Regional Ground Water Quality*. VNR, New York.

Subramaniam, V., 2000: *Water*. Kingston Publ. London.

Paper X : Fuel Geology (Coal, Petroleum and Atomic Minerals)

Coal

Definition and origin of kerogen and coal. Sedimentology of coal bearing strata. Rank, grade and type of coal. Indian and international classifications. Chemical characterization : proximate and ultimate analyses. Macroscopic ingredients and microscopic constituents, concept of 'maceral' and 'microlithotypes'.

Coal petrology, and its applications in solving industrial and geological problems. Preparation of coal for industrial purposes, coal carbonization (coke manufacture), coal gasification and coal hydrogenation. Application of coal petrology in hydrocarbon exploration.

Coalbed methane: a new energy resource. Maturation of coal and generation of methane in coalbeds. Coal as reservoir. Fundamentals of coalbed methane exploration and production.

Coal forming epochs in the geological past. Geological and geographical distribution of coal deposits in India. Detailed geology for some important coalfields of India.

Methods of coal prospecting and estimation of coal reserves. Coal production and problems of coal industry in India.

Petroleum

Its composition and different fractions. Origin, nature and migration (primary and secondary) of oil and gas. Transformation of organic matter into kerogen, organic maturation, thermal cracking of kerogen.

Characteristics of Reservoir rocks and Traps (structural, stratigraphic and combination).

Oilfield fluid - water, oil and gas occurrence. Prospecting for oil and gas, drilling and logging procedures.

Oil bearing basins of India and the world. Geology of the productive oilfields of India. Position of oil and natural gas in India, future prospects and the economic scenario

Atomic Fuel

Mode of occurrence and association of atomic minerals in nature. Atomic minerals as source of energy. Methods of prospecting and productive geological horizons in India.

Nuclear power stations of the country and future prospects. Atomic fuels and environment.

Practical

Megascopic characterization of banded coals. Proximate analysis of coal. Completion of outcrops in the given maps and calculation of coal reserves. Preparation of polished particulate mounts of coal. Microscopic examination of polished coal pellets (identification of macerals in coal).

Megascopic and microscopic study of cores and well cuttings. Study of geological maps and sections of important oilfields of India and world. Calculation of oil reserves. Study of geological sections of U-Th bearing rocks of the country. Megascopic study of some uranium and thorium bearing minerals and rocks.

Books Recommended

Taylor, G.H., Teichmuller, M., Davis, A., Diessel, C.F.K., Littke, R. and Robert, P., 1998: *Organic Petrology*. Gebruder Borntraeger, Stuttgart.

Chandra, D., Singh, R.M. and Singh, M.P., 2000: *Textbook of Coal (Indian Context)*. Tara Book Agency, Varanasi.

Singh, M.P. (Ed.), 1998: *Coal and Organic Petrology*. Hindustan Publ. Corp., New Delhi.

Stach, E., Mackowsky, M.T.H., Taylor G.H., Chandra, D., Teichmuller, M., and Teichmuller, R., 1982 : Stach's *Text Book of Coal Petrology*, Gebruder Borntraeger, Stuttgart.

Holson, G.D. and Tiratsoo, E.N., 1985: *Introduction to Petroleum Geology*. Gulf Publ. Houston, Texas.

Tissot, B.P. and Welte, D.H., 1984: *Petroleum Formation and Occurrence*. Springer- Verlag.

Selley, R.C., 1998: *Elements of Petroleum Geology*. Academic Press.

Durrance, E.M., 1986: *Radioactivity in Geology. Principles and Application*. Ellis Hoorwool

Dahlkamp, F.J., 1993: *Uranium Ore Deposits*. Springer Verlag.

Boyle, R.W., 1982: *Geochemical Prospecting for Thorium and Uranium Deposits*. Elsevier.

Paper XI : Geophysical Exploration and Engineering Geology

Geophysical Exploration

Variation of gravity over the surface of the earth. Principle of gravimeters. Gravity field surveys. Various types of corrections applied to gravity data. Preparation of gravity anomaly maps and their interpretation in terms of shape size and depth.

Geomagnetic field of the earth. Magnetic properties of rocks. Working principle of magnetometers. Field surveys and data reductions. Preparation of magnetic anomaly maps and their quantitative interpretation. Magnetic anomalies due to single pole and dipole. Introduction to Aeromagnetic survey. Three dimensional current flow, potential due to a point current source.

Resistivity method: basic principles, various types of electrode configurations, *Field procedure:* profiling and sounding. Application of electrical methods in ground water prospecting and civil engineering problems.

Seismic methods: fundamental principles of wave propagation, refraction and reflection surveys for single interface, horizontal and dipping cases. Concept of seismic channel and multi-channel recording of seismic data. End-on and split spread shooting techniques. CDP method of data acquisition, sorting, gather, stacking and record section. Seismic velocity and interpretation of seismic data.

Application in mineral and petroleum exploration. Description of borehole environment. Brief outline of various well-logging techniques. Principles of electrical logging and its application in petroleum, groundwater and mineral exploration.

Engineering Geology

Role of engineering geology in civil construction and mining industry. Various stages of engineering geological investigation for civil engineering projects. Engineering properties of rocks; rock discontinuities. Physical characters of building stones. Metal and concrete aggregates.

Geological consideration for evaluation of dams and reservoir sites. Dam foundation rock problems. Geotechnical evaluation of tunnel alignments and transportation routes, method of tunneling; classification of ground for tunneling purposes; various types of support.

Mass movements with special emphasis on landslides and causes of hill slope instability. Earthquakes and seismicity, seismic zones of India. Aseismic design of building. Influence of geological conditions on foundation and design of buildings.

Case history of engineering projects and geological causes for mishaps and failures of engineering structures.

Practical

Study of gravimeter, magnetometer and seismographs. Resistivity survey. Interpretation of underground structure on the basis of seismic data. Study of properties of common rocks with reference to their utility in engineering projects. Study of maps and models of important engineering structures as dam sites and tunnels. Interpretation of geological maps for landslide problems

Books Recommended

Sharma, P.V., 1986: *Geophysical Methods in Geology.* Elsevier.

Sharma, P.V., 1997: *Environmental and Engineering Geophysics*, Cambridge Univ. Press.

Vogelsang, D., 1995: *Enviromental Geophysics – A Practical Guide.* Springer Verlag.

Dobrin, M.B., 1976: *Introduction to Geophysical Prospecting.* McGraw Hill.

Parasnis, D.S., 1975*: Principles of Applied Geophysics.* Chapman and Hall.

Stanislave, M., 1984: *Introduction to Applied Geophysics*, Reidel Publ.

Krynine, D.H. and Judd, W.R., 1998 : *Principles of Engineering Geology.* CBS Edition

Paper XII : Environmental Geology

Time scales of global changes in the ecosystems and climate. Impact of circulations in atmosphere and oceans on climate, rainfall and agriculture.

Carbon di-oxide in atmosphere, limestone deposits in the geological sequences, records of *palaeotemperatures* in ice cores of glaciers. Global warming caused by CO_2 increase in present atmosphere due to indiscrete exploitation of fossil fuels, volcanic eruptions and afforestation.

Cenozoic climate extremes, evolution of life, especially the impact on human evolution.

Impact assessment of degradation and contamination of surface water and ground water quality due to industrialization and urbanization. Water logging problems due to the indiscrete construction of canals, reservoirs and dams. Soil profiles and soil quality degradation due to irrigation, use of fertilizers and pesticides.

Influence of neotectonics in seismic hazard assessment. Preparation of seismic hazard maps. Distribution, magnitude and intensity of earthquakes.

Practical

Study of seismic and flood-prone areas in India. Analyses for alkalinity, acidity, pH and conductivity (electrical) in water samples. Classification of ground water for use in drinking, irrigation and industrial purposes. Presentation of chemical analyses data and plotting chemical classification diagram. Evaluation of environmental impact of air pollution groundwater, landslides, deforestation, cultivation and building construction in specified areas.

Books Recommended

Valdiya, K.S., 1987: *Environmental Geology – Indian Context.* Tata McGraw Hill

Keller, E.A., 1978: *Environmental Geology*, Bell and Howell, USA

Bryant, E., 1985: *Natural Hazards*, Cambridge University Press.

Patwardhan, A.M., 1999: *The Dynamic Earth System.* Prentice Hall

Subramaniam, V., 2001: *Textbook in Environmental Science*, Narosa International.

Bell, F.G., 1999: *Geological Hazards.* Routledge, London.

Smith, K., 1992: *Environmental Hazards.* Routledge, London.

Paper XIII : Special Paper

A list of suggested courses is given here. Other topics may be added to the list depending upon the interest and specialization available in the concerned Faculty. Students will have the choice of selecting any one of these courses.

1. Advance Remote Sensing in Geosciences

Types and geometry of aerial photograph, tilt and relief distortion. Elements of photogrammetry, stereoscopy, stereovision, flight planning. Height and slope rectification of aerial photographs. Aerial photo-interpretation techniques. Recognition of photo-elements and terrain elements like tone, texture, pattern, shape, size; terrain elements like drainage pattern, density, type, landform characteristics, erosion behavior of rocks and soil material, vegetation characteristics, land use and associations.

Electromagnetic energy, electromagnetic spectrum, image characteristics. Physics of remote sensing, black body radiation, laws of radiation, atmospheric interaction. Scattering, reflection, absorption, transmission. Remote Sensing data products, geometric and radiometric corrections, thermal and microwave remote sensing. Digital Image Processing Space missions, Indian Remote Sensing Satellites. Remote Sensing: data source, platforms and sensors Acquisition of remote sensing data. Remote Sensing techniques in Geosciences: Visual Interpretation of satellite images: Techniques of image interpretation using spectral, spatial and temporal information. Signature of the natural objects.

Interpretation of lithology: rock types, discrimination of igneous, sedimentary and metamorphic terrain under different climatic conditions. Photo-interpretation of structural and landform elements. tectonic features, features of glacial, fluvial, coastal, eolian and denudation landforms. Geomorphologic mapping and terrain evaluation.

Terrain Analysis for Engineering projects: principles, terrain classification, terrain mapping, properties of material and masses. Application of Remote Sensing techniques in site selection of dams, bridges, air strips, roads, tunnels, canals. Studies in slope failure, rock failure and soil creep. Study of soils and relationship of rock types and geomorphology to various soil types, Soil mapping and land use and land cover mapping. Forest types, their distribution and relationship of vegetation to rock types. Relationship between vegetation and geomorphic parameters.

Geographic Information System: components, data presentation, vector and raster methods, input and output devices, software and definition of equipments. Database design and structure. Data analysis and cartographic modeling. Digital elevation model. Data representation and techniques of data integration.

Books Recommended

Drury, S.A., 1987: *Image Interpretation in Geology.* Allen and Unwin.

Lillesand, T.M.and Kiefer, R.W., 1987: *Remote Sensing and Image Interpretation.* John Wiley.

Siegal, B.S. and Gillespie, A.R., 1980: *Remote Sensing in Geology.* John Wiley.

And other books suggested under Course-I

2. Rock Deformation and Structural Analysis

Stress-strain relationship. Three dimensional strain and stress analyses and its application in deformed rocks. Brittle failure and ductile deformation.

Experimental simulation of structures in laboratory. Experimental deformation of natural rocks. Significance of fractures, and brittle and ductile shear zones. Metamorphic foliation, their types and origin. Determination of fabrics in deformed rocks, and interpretation. Use of X-ray texture goniometer.

Mechanism of deformation, intracrystalline and intercrystalline slip; microstructures associated with them. Fold shape classifications and Projection Techniques of fold orientations. Mechanism of single-layer and multi-layer folds and associated structures. Superposed folds.

Use of stereographic and equal-area projections for representing different types of fabrics. Processes of structural analysis on mesoscopic and macroscopic scales.

Books Recommended

Ramsay, J.G., 1967: *Folding and Fracturing of Rocks*. McGraw Hill.

Turner, F.J. and Weiss, L.E.,1963: *Structural Analysis of Metamorphic Tectonites*. McGraw Hill.

Ramsay, J.G. and Huber, M.I., 1987: *Modern Structural Geology*, Vol. I & II. Academic Press.

Price, N.J. and Cosgrove, J.W., 1990: *Analysis of Geological Structure*. Cambridge Univ. Press.

Ghosh S.K., 1995: *Structural Geology Fundamentals of Modern Developments*. Pergamon Press.

3. Exploration Geochemistry

Historical background and developments. Geochemical cycle, mobility and dispersion patterns. *Geochemical exploration methods:* Lithogeochemical Hydrogeochemical and HM surveys. Atmogeochemistry. Geochemistry of coal and petroleum. Geochemical aspects of geothermal resources. Biogeochemistry and geobotanical surveys.

Books Recommended

Pacal, Z. (ed), 1977: *Geochemical Prospecting Methods*. Ustrendi

Brooks, A.R., 1972: *Geobotany and Biogeochemistry in Mineral Exploration*. Harper & Row.

Rose, A.W., Hawkes, H.E. and Webb, J.A., 1979: *Geochemistry in Mineral Exploration*. Academic Press.

4. Sedimentary Environment and Sedimentary Basins

Modern laboratory techniques in sedimentological studies.

Detailed study of volcanoclastics, chemical precipitates. *Clay deposits:* mineralogy, physical

properties, chemistry and genesis. Processses of dolomitization and phosphatization. Origin of various types of cements.

Use of trace fossils, stromatolites, thrombolites and related structures in palaeoenvironmental analysis. Methods of palaeocurrent determination and basin analysis.

Tectonics and evolution of the sedimentary basins. Sedimentary cycles, rhythms and cyclothems. Analysis of sedimentary facies and preparation of facies maps. Lithofacies, biofacies, dynamics and primary structures associated with the following environments: Deserts, Alluvial Fans, River Plains, Glaciers, Deltas, Estuaries, Clastic Shorelines, Clastic Shelves, Marine Evaporite Basins, Carbonate Platforms, Deep Sea and Ocean Bottom, Deep Sea Trench and Rise.

Sedimentation pattern and depositional environment of selected undeformed and deformed sedimentary basins of India representing Precambrian, Phanerozoic and Contemporary basins.

Books Recommended

Reading, J.G., 1986: *Sedimentary Environment & Facies*. Blackwell.

Reineck, H.E. & Singh, I.B., 1975: *Depositional Sedimentary Environment*. Springer-Verlag..

Carver, R.E., 1971: *Procedures in Sedimentary Petrology*. Wiley Interscience. John Wiley.

Tucker, M., 1988: *Techniques in Sedimentology*. Blackwell.

Friedman, G.M. and Sander, J.E., 1978: *Principles of Sedimentology*. John Wiley.

Guy Plint, A., 1995: *Sedimentary Facies Analysis*. Spl.Publ IAS No.22, Blackwell.

Miall, A.D., 1996: *The Geology of Fluvial Deposits*. Springer-Verlag.

Miall, A.D., 1997: *The Geology of Stratigraphic Sequences*. Springer-Verlag.

And books recommended for course IV.

5. Experimental Petrology and Mathematical Geology

Experimental Petrology: High temperature-pressure techniques: hydrothermal apparatus and piston cylinder, Experiments on solid-solid dehydration and decarbonation reaction.

Thermodynamics: Gibb's Energy and equilibrium constant, mole fraction, activity coefficients - regular and subregular solutions. Standard states, fugacity and activity. Raoult's Law, Henry's Law. Heat capacity, evaluation and tabulation of thermodynamic data. Isobaric thermal expansion and isothermal compressibility of calculation of volume of minerals at different temperatures and pressures. Calibrations of geothermometers and geobarometers from thermodynamic and experimental data. Reduced activity of water from dehydration reactions. Log fO_2 from oxidation reactions.

Geostatistics: t-test, linear regression, multivariate regression. Computer programming of petrological data. Application of data display programs.

Books Recommended

Chatterjee, N.D., 1991: *Applied Mineralogical Thermodynamics*. Springer-Verlag,

Koch, G.S. and Link, R.F., 1970: *Statistical Analysis of Geological Data*. John Wiley.

Powell, R., 1978: *Equilibrium Thermodynamics in Petrology, An Introduction*. Harper & Row.

Wood, B.J. and Fraser, D.G., 1976: *Elementary Thermodynamics for Geologists*. Oxford Univ.Press

6. Vertebrate Palaeontology and Palaeobotany

Vertebrate Palaeontology

Characteristics of vertebrates. Vertebrate skeleton, teeth and their modifications. Nature of vertebrate fossil records. Methods of collection and preparation of vertebrate fossil remains. Classificatory characters and divisions of the vertebrates: Agnathans, Fishes, Amphibia, Reptilia, Aves and Mammalia. Origin of Vertebrates. Vertebrate life through ages and landmarks in their evolution. General account of the Gondwana Vertebrates, and Siwalik Mammals and the causes of their extinction. Dinosaurs and their extinction. Evolutionary trends in Equidae, Proboscidae and Hominidae. Evolution of Man. Tool culture. Study of important genera of fossil vertebrates with particular reference to their distribution in the Indian Subcontinent.

Palaeobotany

Origin and distribution of plant life. Dispersal and migration of plants. Floral Provinces. Plant life through ages. Study of important world flora with special reference to pre-Gondwana, Gondwana, Intertrappean and Tertiary Flora of India. A brief morphological study of different plant fossils. Methods of preservation and kinds of fossil plants. Nature of the palaeobotanical records. Modern techniques of palaeobotanical studies. Classification of fossil plants. Nomenclature and concept of genera and species. Plant fossils and major divisions of the geologic times. Anatomy, systematic position, environmental significance and geological range of important plant genera.

Evolution of flowering plants. Dendrochronology. Applications of palaeobotany with particular reference to Stratigraphic Correlation and Palaeoclimates.

Books Recommended

Romer, A.S., 1966: *Vertebrate Palaeontology* (3rd Edn.). Chicago Univ. Press.

Olson, E.C., 1971: *Vertebrate Palaeozoology*. John Wiley.

Benton, M.J., 1990: *Vertebrate Palaeontology*. Unwin Hyman.

Arnold, C.A., 1947: *An Introduction to Palaeobotany*. McGraw Hill.

Andrews Jr. H.N., 1961: *Studies in Palaeobotany*, John Wiley.

Seward, A.C., 1931: *Plant Life through the Ages*. Cambridge Univ. Press.

7. Marine Geology

Ocean morphology, deep ocean floor and various topographic features: ridges, sea mounts, coral reefs, continental shelf, continental slope, trenches and canyons; oceanic circulation, waves and currents; oceanic sediments and distribution of marine microfossils; stratigraphy, and geochronometry of deep-sea deposits; tectonic history of the oceans; chemistry of oceanic rocks; mineral resources of the oceans.

Books Recommended

Kennett, J.P. 1982: *Marine Geology*. Prentice Hall.

Seibold, E. and Berger, W.H. 1982: *The Sea Floor*. Springer-Verlag.

Pipkin, B.W., Gorsline, D.S., Casey, R.E. & Hammord, D.E., 1972: *Laboratory Exercises in Oceanography*. Freeman.

8. Micropalaeontology

Surface and sub-surface sampling methods, processing of samples. Morphology, classification and evolution of foraminifera; detailed study of major morphologic groups, morphology and biometrics of important larger foraminifera; stratigraphy of foraminifera with special reference to India; palaeoenvironmental interpretation using microfossils. Morphology and geological distribution of ostracoda, calcareous nannofossils, radiolaria, conodonts and bryozoa. Role of micropalaeontology in hydrocarbon exploration. Deep-sea records with reference to Indian Ocean. Stable isotopic study of foraminifera and interpretation of palaeoecology..

Practical

Processing of samples, picking and mounting of fauna, study of morphological characters of selected microfossils; preparation of oriented sections of foraminifera. Exercises in biometry. Stable isotopic analysis or interpretation of existing isotopic data for palaeotemperature and palaeoenvironment reconstructions.

Books Recommended

Haq, B.V. and Boersma, A., 1998: *Introduction to Marine Micropalaeontology*. Elsevier.

Haynes, J.R., 1981: *Foraminifera*. John Wiley.

Bignot, G., 1985: *Elements of Micropalaeontology*. Graham and Trotman.

9. Advanced Stratigraphy, Palaeogeography and Palaeoecology

Integrated comprehensive study of the state of the art in any selective/better known locality of India in a multi/interdisciplinary context. Systematics and macro-fossil based high resolution

biochronology with intra-basinal to intercontinental correlation (suprastage or higher), sea-level cyclicity, internationally correlatable coeval depositional sequences in context of sequence stratigraphy, coeval facies tracts and their characteristics from basin to margin vis-a-vis the international radio-chronologic, magneto-chronologic and sequence stratigraphic schemes.

Study and preparation of quantitative/qualitative faunal/floral similarity diagrams, correlation problems and tables, biofacies, maps, biostratigraphic range charts, palaeobiogeographic distribution maps and palaeogeographic maps of Stages or at higher level.

Palaeoecological analysis of the benthic macrofauna.

Community analysis (palaeosynecological aspects) - Community relics, fauna-substrate relationships, relation between benthic fauna and physico-chemical parameters of environments (e.g. salinity, oxygen, water energy, water depth etc.). Temporal pattern of communities - evolutionary changes in fauna with environments, transgression-immigration relationship, relation between transgression-regression and benthic faunas.

Books Recommended

Brenner, R.L.and Mcttargue, T.R., 1988: *Integrative Stratigraphy: Concepts and Applications*. Prentice Hall.

Bayer, U. and Seilacher, A., 1985: Sedimentary and Evolutionary Cycles. Springer-Verlag.

Moullade, M. and Nairn, A.E.M., 1983: Vol. I: Palaeozoic; Vol. II: Mesozoic A & B; Vol. III: Cenozoic. Elsevier.

Payton, C.E., 1977: *Seismic Stratigraphy-Applications to Hydrocarbon Exploration*. Amer. Assoc. Petrol. Geol. Publ.

Tarling, D.H., 1983: *Palaeomagnetism - Principles and Applications in Geology, Geophysics and Archaeology*. Chapman and Hall.

Sheriff, R.E., 1980: *Seismic Stratigraphy*. Internat. Human Resources Dev. Corp. Boston.

Ager, D.V., 1980: *Introduction to Palaeoecology*. McGraw Hill.

Ager, D.V., 1963: *Principles of Palaeoecology*. McGraw Hill.

Kennett, P. and Ross, C.A., 1983: *Palaeoecology*. Longman.

McKerrow, W.S., 1984: *The Ecology of Fossils*. Duckworth.

Dodd, J.R. and Stanton, R.J., 1983: *Palaeoecology: Concepts and Application*. John Wiley

Ladd, H.S., 1957: *Treatise on Marine Ecology & Palaeoecology*, Vol. 2 (Palaeoecology), Mem. Geol. Soc. America.

10. Advanced Ore Geology

Modern concepts of ore-genesis. Detailed study of all principal ore mineral groups, their textures and structures. Chemistry of ore minerals and host rocks. Paragenesis, paragenetic sequences and zoning in metallic ore deposits. Methods in geothermometry, geobarometry in ore-geology. Stable and radiogenic isotopes of ores and the host rocks.

Specialized models of ore deposits related to mafic and intermediate to felsic intrusions and vein-deposits and ore deposits related to subareal and submarine volcanism. Detailed study of ore

deposits formed as chemical precipitates, syngenetic clastic beds and by weathering. Significance of stratiform and strata-bound ore deposits of sedimentary affiliation and those of metamorphic affiliation. Plate Tectonics and ore-genesis. Ore deposits of oceanic crust, ocean floor and those related to plate subduction. Geological modeling for mineral exploration.Advance study of ore mineral textures and their application in paragenesis. Application of ore microscopy in mineral technology. Geochemical modeling of ore deposits.

Books Recommended

Wolf, K.H., 1976-81: *Hand Book of Stratabound and Stratiform Ore Deposits.* Elsevier.

Klemm, D.D. and Schneider, H.J., 1977: *Time- and Strata Bound Ore Deposits.* Springer Verlag.

Ramdohr, P., 1969: *The Ore Minerals and Their Intergrowths.* Pergamon Press.

And books mentioned under Paper VI

11. Applied Coal Petrology

The concept of maceral and microlithotype. Origin of macerals, methods and tools of microscopic examination of coal, coal seam identification using microscopic methods. Concept of coal rank, microscopic techniques for the evaluation of rank of brown and banded coals. Application of rank studies in determining coalification time and temperature, Palaeo-geothermal gradient and burial depth. Applications of coal petrological methods in geology including oil and natural gas prospecting and characterization of coals for carbonization, gasification and hydrogenation processes.

Books Recommended

As recommended for Fuel Geology, Paper X.

12. Advanced Hydrogeology

Hydrologic cycle. Hydrographic analyses, Water balance studies. Groundwater in hydrological cycle. Distribution of water in the Earth's crust. Springs (including thermal): origin and movement of water. Geologic structures favouring groundwater occurrence. Methods of identification of groundwater reservoir properties. Force and laws of groundwater movement. Groundwater recharge: artificial and natural, factors controlling recharge conjunctive and consumptive use of groundwater. Fluctuation of groundwater level.

Groundwater in arid and semiarid, coastal and alluvial regions. Groundwater in hard rocks and limestone terrain with reference to Indian situation. Chemical characteristics of groundwater in relation to various uses — domestic, industrial and irrigation purposes. Water pollution and treatment. Environmental impact of groundwater extraction. Wells - their construction and design. Prospecting for groundwater.

Books Recommended

Chow, V.T., 1988: *Advances in Hydroscience,* McGraw Hill.

Walton, W.C., 1988: *Ground Water Resource Evaluation.* McGraw Hill.

Black, W. & Others (Ed.), 1989: *Hydrogeology.* Geol. Soc. of America Publ.

Mahajan, G., 1990: *Evaluation and Development of Ground Water.* D.K. Publisher.

Singhal, B.B.S., 1986: *Engineering Geosciences.* Savita Prakashan.

13. Impact of Geology on Environment

Concept of Ecosystem/Ecology. Man and Environment.

Environmental Problems - Natural and Biological Problems including physical, chemical and physiological. Environmental pollution due to mining, industries, energy resources, urbanization, climatic effects and water, with Indian examples. Role of sediments in pollution studies.

Environmental Management: Environmental controls, agricultural, landscape and cultural developments. Environmental Laws.

Books Recommended

As given for Paper XII

14. Petroleum Exploration

Identification and characterization of petroleum source rocks. Amount, type and maturation of organic matter. Oil and source rock correlation. Locating petroleum prospects based on principles of petroleum generation and migration (Geological modeling). Quantitative evaluation of oil and gas prospects through geochemical modeling. Reconstruction of the ancient geothermal gradient. Migration modeling. Inputs for the assessment of accumulation of petroleum.
Elements of geophysical methods of exploration. Magnetic, gravity and seismic methods. Interpretation of seismic data in basin modeling and preparation of subsurface geological maps. Application of Remote Sensing techniques in basin analysis.

Elements of well drilling. Cable-tool drilling, rotary drilling, various types of drilling units. Elements of logging. Electric, radioactivity and the sonic logs. Nuclear magnetic resonance and dielectric logging. Application of logs in petrophysical analysis and facies analysis.

Books Recommended

North, F.K., 1985: *Petroleum Geology.* Allen and Unwin.

Tissot, B.P. and Welte, D.H., 1984: *Petroleum Formation and Occurrence.* Springer Verlag

Selley, R.C., 1998: *Elements of Petrolelum Geology.* Academic Press.