KANNUR UNIVERSITY

(Abstract)

M.Sc. Geology Programme-Scheme, Syllabus and Pattern of Question Papers under Choice Based Credit Semester System(Outcome Based Education System-OBE) in Affiliated Colleges-implemented with effect from 2023 Admission-Implemented-Orders issued.

ACADEMIC C SECTION

ACAD C/ACAD C1/17357/2023 Dated: 25.08.2023

Read:-1. U.O No. Acad C2/429/2017 Dated 08.09.2020

2. U.O.No. Acad C1/21246/2019 Dated 07.12.2020

3. U.O. No. Acad/C1/21246/2019 Dated 16.02.2023.

4. U.O. No. Acad/C1/21246/2019 Dated 20.04.2023

5. Minutes ofthe meeting of the CSMC& Conveners of Adhoc committee held on 15.06.2023

6. Orders of the Vice Chancellor in the file No. Acad C1/21246/2019 Dated 05.08.2023.

7. U.O. No. Acad/C1/21246/2019 Dated 09.08.2023

8. The Minues of the meeting of the Ad hoc Committee for M.Sc. Geology Programme held on 10.08.2023

9. Syllabus of M.Sc. Geology Programme submitted by the Convenor, Ad hoc Committee for M.Sc. Geology Programme vide e-mail dated 17.08.2023

ORDER

1. A Curriculum Syllabus Monitoring Committee comprising the members of Syndicate was constituted for the Syllabus revision of U G& P G Programmes in Affiliated Colleges, vide paper read (1) above and as per the recommendation of this Committee in its meeting held on 20.11.2020, constitute a sub Committee to prepare the Regulation for PG programmes in Affiliated Colleges vide paper read (2) above.

2. As the reconstitution of Board of Studies of the University is under the consideration of the Hon'ble Chancellor, and considering the exigency of the matter, Ad hoc Committees were constituted vide paper read (3) above and it has been modified vide paper read (4) above, to revise the Curriculum and Syllabus of PG Programmes in Affiliated Colleges w.e.f 2023-24 academic year.

3. The combined meeting of the Curriculum Syllabus Monitoring Committee & Conveners of Ad hoc committee held on 15.06.2023 at syndicate room discussed in detail the draft Regulation, prepared by the Curriculum Syllabus Monitoring Committee, for the PG programmes under Choice Based Creditand Semester System to be implemented in Affiliated Colleges w.e.f 2023 admission and proposed the different phases of Syllabus revision process such as subject wise workshop, vide the paper read (5) above.

4. The revised Regulations for Post Graduate Programmes under Choice Based Credit and Semester System (In OBE-Out Come Based Education System) was approved by the Vice-chancellor on 05.08.2023 and implemented w.e.f 2023 Admission vide Paper read (7) above.

5. Subsequently, as per the paper read (8) above, the Ad hoc Committee for M.Sc. Geology programme finalized the Scheme, Syllabus and Pattern of Question Papers of M.Sc. Geology programme to be implemented with effect from 2023 Admission

6. As per the read (9) above, the Convener, Ad hoc Committee for M.Sc. Geology programme submitted the finalized copy of Scheme, Syllabus, Pattern of Question Papers and Firsty semester Model Question paper of M.Sc. Geology programme for implementation with effect from 2023 Admission.

7. The Vice Chancellor after considering the matter in detail and in exercise of the powers of the Academic Council conferred under section 11(1) Chapter III of Kannur University Act, 1996 and all other enabling provisions read together with ***accorded sanction to implement the scheme, Syllabus, Pattern of Question Papers and First Semester model question paper of M.Sc.Geology programme under Choice Based Credit Semester System (in OBE-Outcome Based Education System) in Affiliated Colleges under the University with effect from 2023 Admission, subject to report to the Academic Council.***

8.The Scheme, Syllabus and Pattern of Question Papers of M.Sc. Geology programme under Choice Based Credit and Semester System (in OBE- Outcome Based Education System) in Affiliated Colleges under the University with effect from 2023 Admission is uploaded in the University website.

9. Orders are issued accordingly.

Sd/-
Sajesh Kottambrath
Assistant Registrar1
For REGISTRAR

To:
1. Principals of Affiliated Colleges offering M.Sc.Geology Programme
2. Convenor, Curriulum Syllabus Monitoring Committee.
3. Convenor, Adhoc Committee for M.Sc. Geology Programme.

Copy To:
1. The Examination Branch (Through PA to CE)
2. PS to VC/ PA to PVC/ PA to R/ PA to FO
3. DR/ AR 1(Acad) /Computer Programmer
4. IT Centre (for uploading on the website).
5. EG 1/EX C1(Exam)
6.SF/DF/FC

Forwarded / By Order
SECTION OFFICER

KANNUR UNIVERSITY
CIVIL STATION P.O.
KANNUR
Pin-670 002
THAVAKKARA

KANNUR UNIVERSITY

POSTGRADUATE PROGRAMME

(OBE – OUTCOME BASED EDUCATION CBCSS)

KUCBCSSPG2023

MASTER OF SCIENCE DEGREE IN GEOLOGY SYLLABUS

(2023 Admission onwards)

PREPARED BY

AD HOC COMMITTEE

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CONTENT

INTRODUCTION

Outcome based education (OBE) is a student centric teaching and learning methodology in which the course delivery, assessment are planned to achieve stated objective and outcome. It incorporates clear and measurable criteria for assessing the student's learning outcome. Kannur University introduced outcome-based education (OBE) in the curriculum for undergraduate students in 2019. In continuation to that pattern Kannur University is introducing the same in Post Graduate curriculum and syllabus from 2023 onwards.

The aim of the OBE based MSc Geology programme is to develop a holistic mind-set among stakeholders towards environmental friendly and sustainable future of our planet. This will be made possible through the understanding of the fundamental concept of origin and evolution of earth, its internal and external processes, study of its landforms and evolution, deep knowledge of ore and ore forming processes and also through learning techniques to solve its mysteries. This programme will enable the stakeholders to tap the academic, research and professional opportunities in Geology and related fields such as planetary science, environmental science, civil engineering, exploration of mineral resources, climatic studies etc... This programme also aims to address societal problems such as groundwater scarcity, natural hazards, quest for new mineral and energy resources for the future development and in a larger canvass, inter planetary exploration for common future of the mankind.

The present M.Sc. Programme in Geology follows Outcome based Education with Credit Based Semester System has been so meticulously designed as to suit the changing needs of Post-Graduates in geology by enabling them to compete with others and excel in National Level Examinations like Geologists Examinations, UGC/CSIR- NET, etc. Post – Graduates in Geology with good academic record are employed as Junior Geologists in Geological Survey of India (GSI) and Junior Hydrogeologists in Central Ground Water Board (CGWB), Geologist in Oil & Natural Gas Corporation (ONGC), Scientists in Atomic Mineral Directorate (AMD) , Indian Space Research Organization (ISRO), Centre for Earth Science Studies(CESS),Centre for Water Resources Development and Management (CWRDM), National Institute of Hydrology (NIH), National Institute of Oceanography (NIO). Assistant Professors in Universities, affiliated Colleges and IITs, Assistant Geologists in State Departments of Mining& Geology, Geological Assistants in State Ground Water Board, with B.Ed. as Junior Lecturers in the State Higher Secondary Schools, Senior/Junior Research Fellows in University Grants Commission / Council for Scientific and Industrial Research projects, Department of space and at its various centres, Regional Remote Sensing Centres, State Remote Sensing Application Centres, National Remote Sensing centres, All India soil and Land use Survey, National Bureau of Soil Survey & Land use planning, Town and Country Planning, Remote Sensing Laboratories of various Universities, Companies engaged in GIS and its application studies. etc.

VISION

To establish a teaching, residential and affiliating University and to provide equitable and just access to quality higher education involving the generation, dissemination and a critical application of knowledge with special focus on the development of higher education in Kasaragod and Kannur Revenue Districts and the Manandavady Taluk of Wayanad Revenue District.

MISSION

- To produce and disseminate new knowledge and to find novel avenues for application of such knowledge.
- To adopt critical pedagogic practices which uphold scientific temper, the uncompromised spirit of enquiry and the right to dissent.
- To uphold democratic, multicultural, secular, environmental and gender sensitive values as the foundational principles of higher education and to cater to the modern notions of equity, social justice and merit in all educational endeavours.
- To affiliate colleges and other institutions of higher learning and to monitor academic, ethical, administrative and infrastructural standards in such institutions.
- To build stronger community networks based on the values and principles of higher education and to ensure the region's intellectual integration with national vision and international standards.
- To associate with the local self-governing bodies and other statutory as well as non-governmental organizations for continuing education and also for building public awareness on important social, cultural and other policy issues.

PROGRAMME OUTCOME (POs)

- **PO 1**. Advanced Knowledge and Skills: Postgraduate courses aim to provide students with in-depth knowledge and advanced skills related to their chosen field. The best outcome would be to acquire a comprehensive understanding of the subject matter and develop specialized expertise.
- **PO 2.** Research and Analytical Abilities: Postgraduate programs often emphasize research and analytical thinking. The ability to conduct independent research, analyze complex problems, and propose innovative solutions is highly valued.
- **PO 3.** Critical Thinking and Problem-Solving Skills: Developing critical thinking skills is crucial for postgraduate students. Being able to evaluate information critically, identify patterns, and solve problems creatively are important outcomes of these programs.

- **PO 4.** Effective Communication Skills: Strong communication skills, both written and verbal, are essential in various professional settings. Postgraduate programs should focus on enhancing communication abilities to effectively convey ideas, present research findings, and engage in academic discussions.
- **PO 5.** Ethical and Professional Standards: Graduates should uphold ethical and professional standards relevant to their field. Understanding and adhering to professional ethics and practices are important outcomes of postgraduate education.
- **PO 6.** Career Readiness: Postgraduate programs should equip students with the necessary skills and knowledge to succeed in their chosen careers. This includes practical skills, industry-specific knowledge, and an understanding of the job market and its requirements.
- **PO 7.** Networking and Collaboration: Building a professional network and collaborating with peers and experts in the field are valuable outcomes. These connections can lead to opportunities for research collaborations, internships, and employment prospects.
- **PO 8.** Lifelong Learning: Postgraduate education should instill a passion for lifelong learning. The ability to adapt to new developments in the field, pursue further education, and stay updated with emerging trends is a desirable outcome.

PROGRAMME SPECIFIC OUTCOME (PSO)

- **PSO 1**: Knowledge of Earth Sciences: Graduates will demonstrate a comprehensive understanding of key concepts, theories and principles in geomorphology, mineralogy, geochemistry, stratigraphy, micropaleontology, petrology, sedimentology, hydrogeology, geoinformatics, remote sensing, ore and economic geology and exploration geology.
- **PSO 2**: Fieldwork Skills: Graduates will possess the skills necessary to plan, execute and analyze fieldwork in various geological settings, including the ability to identify and interpret geological features, collect representative samples, and apply appropriate field techniques and instrumentation.
- **PSO 3:** Analytical and Research Skills: Graduates will be proficient in conducting laboratory analysis, using advanced instruments and techniques, for mineralogical, geochemical, and petrological investigations. They will also demonstrate competence in scientific documentation, research design, data analysis, and interpretation.
- **PSO 4**: Geological Mapping and Interpretation: Graduates will be able to create geological maps and cross-sections, interpret geological structures, and analyze stratigraphic relationships to understand the geological history and evolution of an area.

- **PSO 5**: Hydrogeological Understanding: Graduates will have a sound understanding of groundwater systems, including the principles of groundwater flow, aquifer properties, and the assessment and management of water resources.
- **PSO 6**: Application of Geoinformatics and Remote Sensing: Graduates will be adapt at utilizing geoinformatics tools and remote sensing data to analyze and interpret geological features, identify potential mineral resources and contribute to geological hazard assessments.
- **PSO 7**: Exploration and Economic Geology Skills: Graduates will possess the knowledge and skills required for the exploration, evaluation, and economic assessment of mineral deposits, including the ability to apply geophysical, geochemical, and geological techniques in mineral exploration.
- **PSO 8**: Effective Communication and Scientific Writing: Graduates will be proficient in communicating geological concepts and research findings effectively through written reports, scientific papers, and oral presentations.
- **PSO 9:** Independent Research and Critical Thinking: Graduates will demonstrate the ability to independently plan, execute, and manage a research project as part of their dissertation, applying critical thinking skills, and utilizing appropriate methodologies and scientific vigor.

DURATION OF THE PROGRAMME

The duration of a Post graduate programme shall be four semesters inclusive of days of examinations distributed over a period of two academic years. The odd semesters (1, 3,) shall be from June to October and the even semesters (2, 4,) shall be from October/November to March. The minimum duration for completion of a two year Post graduate Programme in any subject is four semesters and the maximum period for completion is eight semesters from the date of registration.

ADMISSION

Eligibility for admissions and reservation of seats for various First semester (Post Graduate) Programmes shall be according to the rules framed by the University from time to time. **A pass in B.Sc. Degree Geology/Water Resource Management as core course with Chemistry/ Physics/ Mathematics/ Statistics/Remote sensing (any two) as complementary courses** is the eligibility for M Sc Geology programme.

COURSES

The programme consists of following courses.

Core courses	• 11 (eleven) theory • 04 (four practical) • 01 (one) Field based course (**MSGEO02C08)** • 01 Summer Internship/Mini project

	• 1 (one) Dissertation/project (**MSGEO04C18**) • 1 (one) viva voce (**MSGEO04C19**)
***Elective courses**	• 1 (one) Elective I • 1 (one) Elective II
***Open Elective/Multi-Disciplinary courses**	• 1 (one)

****Students can choose one course out of three choices***

COURSE EVALUATION

The evaluation scheme for each course shall contain two parts

- Continuous Evaluation (CE)
- End Semester Evaluation (ESE)

20% weightage shall be given to the Continuous Evaluation (CE) and 80% weightage shall be for the End Semester Evaluation (ESE)

CONTINUOUS EVALUATION (CE):

CE for theory papers

Component	**% of internal marks**
Two Written test	40
One assignment	30
One seminar	30

Mark distribution of CE for theory papers

Written test (Out of 4.8 mark)	**Assignment (Out of 3.6 mark)**	**Seminar (Out of 3.6 mark)**	**Total (Out of 12 mark)**

Continuous Evaluation for practical papers

Component	**% of internal marks**
One Written test	30
Lab involvement/skill	30
Record	40

\Mark distribution of CE for practical papers

Written test (out of 6 mark)	Lab involvement and skill (out of 6 mark)	Record (out of 8 mark)	Total (out of 20 mark)

Continuous Evaluation for Field mapping

There shall be a field mapping programme for all students carried out under the supervision of a teacher to understand, analyse and interpret the geology of an area and prepare a geological map and report in the second semester. The evaluation of this programme is internal. The students should submit a detailed geological map and report to the department for the evaluation. There is no external assessment for field mapping since it is particularly meant for the geological field skill development of the students. The continuous evaluation of field mapping can be done by teachers/ a guide who assisted the students in the field. Assessment of different components of field mapping and percentage of marks given to each component shall be as follows.

Components	% of marks
Involvement in the field	30
Field report and geological map preparation	30
Presentation/ Viva voce	40

Mark distribution of CE for Field mapping

Involvement in the field (out of 18 mark)	Field report and geological map preparation (out of 18 mark)	Presentation/ Viva voce (out of 24 mark)	Total (out of 60 mark)

Continuous Evaluation for Scientific documentation in Earth science

In order to inculcate critical thinking and research aptitude among students a core paper called **Scientific documentation in Earth science** is introduced. In this paper students will learn review literature methods, design of a scientific work, and proper methods in bibliography especially in earth science. The evaluation of this paper is done by an internal committee recommended Head of the Department.

Component	% of internal marks
One Written test	30
Assignment	30
Presentation of project design	40

Mark distribution of CE for Scientific documentation in Earth science

Written test (Out of 6 mark)	Assignment (Out of 6 mark)	Presentation of project design (Out of 8 mark)	Total (Out of 20 mark)

END SEMESTER EVALUATION (ESE)

End Semester Evaluation carries 80% of total marks. The End Semester Evaluation in theory courses are to be conducted with question papers set by external experts. The evaluation of the answer scripts shall be done by examiners appointed by the University based on a well-defined Scheme of valuation and answer keys provided by the University. After the End Semester Evaluation only marks are to be entered in the answer scripts. Marks secured for End Semester Evaluation only need be communicated to University. All other calculations including grading are done by the university by the Chairperson of Board of Examiners. The End Semester Evaluation in practical courses shall be conducted by two examiners (one internal and one external) appointed by the University. End Semester Evaluation of all semesters will be conducted in centralised valuation camps immediately after the examination. All question papers shall be set by the university.

SUMMER INTERNSHIP/MINI PROJECT EVALUATION

Students can engage in minimum 11 day summer internship programm at various national and state institute/industry with permission from concerned authority or can carry out mini project in the department itself in the second semester. If not completed within the semester, this programme can extend to the summer vacation of PG first year. The evaluation for this programme will be carried out in IVth semester along with project and comprehensive viva voce. The students should submit a report of their internship/mini project to department for the evaluation.

PROJECT/DISSERTATION EVALUATION

Project evaluation shall be conducted at the end of fourth semester as per the following general guidelines or by the guidelines framed by the Board of Studies concerned:

- Evaluation of the Project Report shall be done under Mark System.
- The evaluation of the project will be done at two stages:
  a) **Continuous Evaluation** (supervising teachers will assess the project and award internal Marks)
  b) **End Semester Evaluation** (external examiner appointed by the University)
- Marks secured for the project will be awarded to candidates, combining the Continuous Evaluation and End Semester Evaluation marks.

- The Continuous Evaluation to End Semester Evaluation components is to be taken in the ratio 1:4. Assessment of different components may be taken as below.
- Components of Continuous Evaluation and End Semester Evaluation of Project other than the following can be decided by the concerned Board of Studies.
- For internship/industry/academy/library visit BOS shall frame suitable evaluation methods including records presentation etc.

CE for Project/Dissertation (20% of total)

Component	Percentage of marks	Maximum mark
Punctuality	20	8
Literature review	10	4
Scheme of the work	20	8
*Mid semester progression evaluation	20	8
Presentation and Viva voce	30	12
Total	**100 %**	**40**

Mid semester evaluation is done in college level by three members of faculties decided by guide and HOD.

End Semester External Evaluation- (80% of total)

The external evaluation is carried out by one or two external examiner as per the availability and one internal examiner.

Component	Percentage of marks	Maximum mark
Relevance of the topic	10	16
Statement of the objective	10	16
Framework of the project	20	32
Data and analysis used	20	32
Result and analysis	20	32
*Viva related to project presentation	20	32
Total	**100 %**	**160 mark**

**** The student should present one copy of the Dissertation on project before the Viva voce board.***

End Semester External Evaluation for Viva Voce

Along with project viva voce, there shall be a comprehensive viva voce at the end of the IVth semester. This viva voce covers questions from all courses of the programme and questions from

summer internship. Students are required to submit a report on their summer internship/mini project programme. The viva voce shall be conducted by one external examiner and two teachers from the department.

Component	Percentage of marks	Maximum mark
Comprehensive viva voce	50	20
*Summer internship/mini project viva voce	50	20
Total	100 %	40 mark

** The student should present one copy of the report of their summer internship/mini project before the Viva voce board. This report carries 50 % mark of the viva voce of summer internship/mini project.*

CRIETERIA OF PROJECT PRESENTATION

- The students shall present power point of their project work before the external examiner and teacher representatives/M Sc students if available in the the department.
- The time for the presentation is 10 minutes which is extended up to 12 minutes.
- Presentation will be followed by viva voce. Project, summer internship/min project and comprehensive (all subject) questions will be asked in the viva voce.
- The whole viva voce including presentation exercise (presentation and viva voce) should not exceed not more than 30 minutes.

SEMINAR/CONFERENCE/WORKSHOP etc..

Students can participate in seminar/conference/workshop etc.. in various national and state institute and industry with permission from concerned authorities without hampering the regular classes and examinations. There shall no credit for participation in seminar/conference/workshop etc..

For detailed regulation of the P G programmes, please visit university website: https://www.kannuruniversity.ac.in/en/

M Sc GEOLOGY DEGREE PROGRAMME
(OBE BASED CREDIT AND SEMESTER SYSTEM) 2023 ONWARDS

SEM	Course code	Title	Hours/ Week	Total hours	Credit	Exam hour	Marks		
							External	Internal	Total
I	**MSGEO 01C01**	Geomorphology	5	90	5	3	48	12	60
	MSGEO 01C02	Advanced Mineralogy and Geochemistry	5	90	5	3	48	12	60
	MSGEO 01C03	Stratigraphy and Micro Palaeontology	5	90	5	3	48	12	60
	MSGEO 01C04	Structural Geology	5	90	5	3	48	12	60
	MSGEO 01C05	**Practical 1 :** Geomorphology, Micro palaeontology and Structural Geology	5	90	0	0	0	0	0
SEMESTER I TOTAL			**25**	**450**	**20**	**12**	**192**	**48**	**240**
II	**MSGEO 02C06**	Igneous and Metamorphic Petrology	5	90	5	3	48	12	60
	MSGEO 02C07	Sedimentology	5	90	5	3	48	12	60
	MSGEO 02E01 to 03	Elective I	4	72	4	3	48	12	60
	MSGEO 02C08	*Geological field mapping/Training in hydrogeology/ Geophysics/GIS*	3	54	2	--	--	60	60
	MSGEO 01C05	**Practical 1 :** Geomorphology, Micro palaeontology and Structural Geology	0	0	2	3	80	20	100
	MSGEO 02C09	**Practical 2:** Mineralogy, Petrology, and Geochemistry	5	90	2	3	80	20	100
	MSGEO 02C10	**Summer Internship/Mini project	3	54	0	0	0	0	0
SEMESTER II TOTAL			**25**	**450**	**20**	**15**	**304**	**136**	**440**
III	**MSGEO 03C11**	Hydrogeology	5	90	5	3	48	12	60
	MSGEO 03C12	Geoinformatics and Remote Sensing	5	90	5	3	48	12	60

	MSGEO 03C13	Ore and Economic Geology	5	90	5	3	48	12	60
	MSGEO 03O 01 to 03	Open Elective/Multi-disciplinary	5	90	5	3	48	12	60
	MSGEO 03C14	**Practical 3:** Hydrogeology, Remote sensing and Geoinformatics	5	90	0	0	0	0	0
SEMESTER III TOTAL			**25**	**450**	**20**	**12**	**192**	**48**	**240**
IV	**MSGEO 04C15**	Exploration Geology and Geophysics	4	72	4	3	48	12	60
	MSGEO 04E04 to 06	Elective II	3	54	3	3	48	12	60
	MSGEO 04C16	***Scientific documentation in Earth Sciences	1	18	1	--	0	20	20
	MSGEO 03C14	**Practical 3:** Hydrogeology, GIS, Ore Geology	0	0	2	3	80	20	100
	MSGEO 04C17	**Practical 4:** Exploration Geology and Ore Geology	2	36	1	3	80	20	100
	MSGEO 04C18	****Project/Dissertation	15	270	6	--	160	40	200
	MSGEO 04C19	Viva Voce	--	--	3	--	40	--	40
SEMESTER IV TOTAL			**25**	**450**	**20**	**12**	**456**	**124**	**580**
ALL SEMESTER TOTAL					**80**		**1144**	**356**	**1500**

- *3 hours per week is allotted for Geological field mapping/Training in hydrogeology/Geophysics/GIS training etc.. It will be engaged as theory classes and this programme will be carried out continuously for 54 hours (should be completed within 11 working days) during IInd semester.

- **Students can engage continuously minimum 11 working days summer internship programme at various national and state institute/industry with permission from concerned authority or can carry out mini project in the department itself in the second semester. The evaluation for this programme will be carried out in IVth semester.

- ***Scientific documentation in Earth Science will only have internal evaluation. Evaluation is carried out within the department by a committee headed by project guide and HOD.

- ****15 hours per week is allotted for Dissertation. It will be engaged as theory classes and this programme will be carried out continuously for 54 working days in the IVth semester.

GEOMORPHOLOGY

SEMESTER	COURSE CODE	CONTACT/ WEEK	CONT ACT/ SEMESTER	CREDIT	EXTERNAL MARKS	INTERNAL MARKS
I	MSGEO01C01	5	90	5	48	12

COURSE OUTCOME

At the end of the semester students will be able to: -

CO1: Understand the definitions, concepts and fundamental theories of geomorphology.
CO2: Study the development and history of Geomorphology.
CO3: Acquire skill in applications of geomorphological concepts.
CO4: To develop models of geomorphological and morpho-tectonic setup of a terrain.
CO5: Understanding of coastal geomorphology and ocean floor geomorphology.
CO6: Build relation between tectonics and geomorphology.

MODULE I

Fundamental concepts in geomorphology: History of the development of geomorphic ideas—Ancient and modern. Different models in the Evolution of landscape: Davis, Penck, King, Gilbert and Hack--Peneplain and Pediplain concepts.

Analysis of geomorphic agents and processes: gradational processes—climatic influences upon geomorphic processes. Evolution of hill slopes: slope elements and parameters—role of water, vegetation and climate on slopes. Influence of lithology, structure and climate on geomorphic processes and landforms. **(20 hours)**

MODULE II

Morphometric analysis of drainage basins: Morphometric elements and parameters—laws of drainage composition, drainage density, stream frequency, basin shape, stream hydraulics—stream ordering—long profile and transverse profiles—hypsometry. Application of morphometric analysis.

Fluvial geomorphology: Fundamental concepts—base level—relations between channel width, depth and current velocity, sediment transport and erosion—types of load and modes of transportation—competence and capacity—concept of grade, meandering and braided rivers—fluvial deposits, erosional and depositional landforms. Concept of rejuvenation and interruptions in the cycle of erosion. **(25 hours)**

MODULE III

Coastal geomorphology: Definition of coastal zone—coastal processes: erosion, transportation and deposition by waves, tides and currents—reflection, refraction and breaking of waves—long shore drift and related landforms— coastal submergence and emergence. Critical study of coastal classification.

Seal level changes. Shoreline processes and associated landforms - coastal dynamics. Ocean floor geomorphology. **(25 hours)**

MODULE IV

Tectonic Geomorphology: -Plate Tectonics-Seismo - tectonics-Kinematics of relative movements of plates--processes at accreting and consuming plate boundaries.

Applied geomorphology – Applications of geomorphology in civil engineering, Hydrogeology and Mineral exploration. Planetary geomorphology: Mars - Crustal dichotomy, Olympus Mons, Valles Marineris; Moon- High land, Mare basalt. Crater chronology.

(20 hours)

REFERENCE
Bloom, A.L., 1992, Geomorphology, 2nd edn., Prentice Hall of India Pvt. Ltd., New Delhi.
Condie, K.C., 1979, Plate Tectonics and Crustal Evolution, Pergamon Press. Cox, A., 1973, Plate Tectonics and Geomagnetic Reversals, Freeman.
Gass, I.G., at. al., (Editors.), 1971, Understanding the Earth, I edn., Academic Press.
Holmes, A., 1981, Principles of Physical Geology, 3rd edn., ELBS, Thomas Nelson.
King, C.A.M., 1972, Beaches and Coasts, Arnold, London.
Leopold, L.B., Wolman, M.G. & Miller, J.P., 1964, Fluvial Processes in Geomorphology, Freeman.
Roy, A.B., 2010, Fundamentals of Geology, Narosa Pub. House, New Delhi.
Small, R.J., 1992, The Study of Landforms, 2nd edn., Cambridge Univ. Press.
Smith, R. M., 1983, Images of the World--An Atlas of Satellite Imagery and Maps, Collins, Longman.
Sparks, B.W., 1972, Geomorphology, Longman Group Ltd.
Strahler, A. N., 1971, Earth Sciences, 2nd edn., Harper & Row.
Thornbury, W.D., 1968, Principles of Geomorphology, Wiley.
Turner, F.J., Weiss, M.P., et. al., 1972, The Earth, Holt, Reinhard & Winston

ADVANCED MINERALOGY AND GEOCHEMISTRY

SEMESTER	COURSE CODE	CONTACT/ WEEK	COTACT/ SEMESTER	CREDIT	EXTERNAL MARKS	INTERNAL MARKS
I	MSGEO01C02	5	90	5	48	12

COURSE OUTCOME

At the end of the semester students will be able to: -

CO1: Solve stereographic projection, Axial ratio, zone and zone symbols, Napier's rule and to evaluate Interference colours and Optical accessories

CO2: Experiment with Interference Figures, Universal Stage, Dispersion, Optic Orientation, Extinction etc.

CO3: Evaluate structure, physical, chemical and optical properties, paragenesis and association of the mineral groups

CO4: To develop a solid foundation in the fundamental principles of geochemistry.

CO5: To understand the behaviour of elements and isotopes in Earth's systems.

CO6: To analyse the geochemical processes that shape the composition of rocks and minerals

CO7: Understand the basic principle, methodology, data analysis and applications of various geochemical instruments

MODULE I

Crystal projections- stereographic projection, Gnomonic projection, Axial ratio, zone and zone symbols, Napier's rule. Herman- Moughins symbols. Interference colours, Optical accessories: Unit retardation plate, quartz wedge, mica plate, Berek compensator, Biquartz wedge and Bertrand ocular. Wave surface and indicatrices. Dichroism and Pleochroism. Conoscopic study and Interference Figures- Uniaxial and Biaxial. Optic Axial Angle and determination by Mallard's method. Optic Sign and determination.

Universal Stage: basic principles--adjustment of the Universal Stage and the use of the Wulff's Net. Method of determining the following: Anorthite content and Twin laws of plagioclase feldspars. Dispersion and dispersion types. **(25hours)**

MODULE II

Optic Orientation, Extinction and Extinction Angle, Metamictisation, fracturing, discoloration and pleochroic haloes. Optic anomalies. Clay mineralogy: classification and structure of clay minerals. Clay mineral identification by X-rays and DTA. Different methods of clay mineral separation

Structure, physical, chemical and optical properties, paragenesis and association of the minerals of the following groups: Olivine, Epidote, Garnet, alumino silicates. Pyroxenes, Amphiboles, Micas, Zeolites, Feldspars and Feldspathoids.

(20hours)

MODULE III: Geochemistry: Origin and cosmic abundance of elements, Oddo-Harkin Law. Geochemical Classification of elements: siderophile, chalcophile, lithophile, atmophile. Primary differentiation of elements. Thermodynamics and crystal chemistry: Isomorphism, atomic substitution and polymorphism.

Distribution and behavior of major, trace and Rare Earth Elements (REE) in igneous, sedimentary and metamorphic environments and their application in petrogenesis. Geochemistry of crust, mantle and core of the earth. Meteorites and their classification. Geochemical Cycle. Mobility of elements, Eh-pH diagrams.

(20 hours)

MODULE IV:

Study of different radioactive systematics and their application to geochronology and petrogenesis. Rb-Sr, K-Ar, Sm-Nd, U-Th-Pb, 207Pb-206Pb systematics. 14C and fission track methods of dating. Stable isotope studies- Delta notation and its significance, significance of stable isotopes of Carbon, Oxygen and Sulphur in petrology. Isotope hydrogeology.

Analytical techniques: methods based on emission and absorption spectra, principles and methodology. Flame Photometer, Spectrophotometer, Atomic Absorption Spectrometer (AAS), Inductively Coupled Plasma Atomic Emission Spectrometer (ICP-AES), Isotope Mass Spectrometers and X-ray Fluorescence Spectrometer (XRF). Methods based on electron properties: X-ray diffraction and Electron microprobe (EPMA). Geochemical Data visualization and interpretation.

(25 hours)

REFERENCE

Albarede F. (2003) Geochemistry- An introduction, Cambridge university press.

Brian Mason, 1966, Principles of Geochemistry, Wiley.

Faure, G. (1998). Principles of Isotope Geology. John Wiley & Sons.

Gill, R. (1989) Chemical fundamentals of geology, Unwin Hyman, London

Krauskopf, E.B. (1979) Introduction to geochemistry, McGraw Hill Book Company, New Delhi.

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

Lampman, G.M., Kriz, G.S., & Engel, R.G. (2013). Introduction to Spectroscopy (5th ed.). Cengage Learning.

Mason, B., & Moore, C.B. (1982). Principles of Geochemistry (4th ed.). John Wiley & Sons.

Philpotts, A.R., & Ague, J.J. (2009). Principles of Igneous and Metamorphic Petrology (2nd ed.). Cambridge University Press.

Rollinson, H. (1993). Using Geochemical Data: Evaluation, Presentation, Interpretation. Longman Scientific & Technical.

Rollinson, H.R. (1993) Using geochemical data: Evaluation, presentation, interpretation. Longman scientific and Technical, New York.

Skoog, D.A., Holler, F.J., & Crouch, S.R. (2017). Principles of Instrumental Analysis (7th ed.). Brooks/Cole.

Taylor, S.R., & McLennan, S.M. (1985). The Continental Crust: Its Composition and Evolution. Blackwell Scientific Publications.

Wedepohl, K.H. (1995). The Composition of the Continental Crust. Geochimica et Cosmochimica Acta, 59(7), 1217-1232.

STRATIGRAPHY AND MICRO PALAEONTOLOGY

SEMESTER	COURSE CODE	CONTACT/ WEEK	COTACT/ SEMESTER	CREDIT	EXTERNAL MARKS	INTERNAL MARKS
I	MSGEO01C03	5	90	5	48	12

COURSE OUTCOME

After the completion of the course, the student will able to;

CO1: Understand the concept of Geological time scale and analyse various criteria of its evolution.

CO2: Understand and apply the different new stratigraphic methods in the developing GTS.

CO3: Appraise the early events in the Earth's history and build a concept for the evolution of lithosphere.

CO4: Review different Pre Cambrian and Phanerozoic events in Indian sub continent and establish a connection with stratigraphic division.

CO5: Critically analyse the major Phanerozoic events associated with Indian peninsula and their relation with mass extinction.

CO6: Remember and understand the fundamentals of Micropalaentology

CO7: Apply the use microfossils in palaeogeographic reconstruction and in petroleum exploration.

CO8: Review the morphology, palaeogeography and stratigraphic importance of different micro fossils families.

MODULE I

Detailed description of Geological time scale and its evolution. Global boundary Stratotype Section and Point (GSSP). Chronostratigraphy and Geochronology. Principles and fundamentals of Sequence stratigraphy, Seismic Stratigraphy, Chemo stratigraphy and Magneto stratigraphy. Correlation and its importance. Litho correlation, Bio correlation and Chrono correlation.

Major events in the earth history. Evolution of early life forms and markers. Evolution of atmosphere. Lithospheric evolution. Mass extinction of Earth history with special emphasis on P-T and K- T boundary. **(20 hours)**

MODULE II

Stratigraphy of Indian sub-continent-Cratonic evolution and stratigraphy of Dharwar, Bastar, Singhbhum, Aravalli and Bundelkhand cratons. Proterozoic sedimentary basins and stratigraphy of India. Mobile belts in India. Pandiayan and Southern Grannulitic Terrain (SGT). Eastern Ghat mobile belt. Delhi fold belt and Central Indian Tectonic Zone (CITZ).

Phanerozoic events in the earth history with special reference to India. Deccan Volcanism, Gondwana sedimentation and coal deposits. Evolution and tectonic elements of Himalaya. Hotspot activities with special reference to India- Kerguelen, Marion and Reunion. **(25 hours)**

MODULE III

Micropalaeontology – History and scope. Microfossils- Taxonomy and biological classification. Applications of micropalaeontology in petroleum exploration. Methods of sampling and collection of microfossils. Laboratory technique for preparation of microfossils.

Classification, morphology, ecology and stratigraphic importance of Benthic and planktonic formanifera, Radiolaria Coccolithophorids. **(20 hours)**

MODULE IV

Classification, morphology, ecology and stratigraphic importance of Diatoms and Silicoflagellates. Pollen and Spores – Morphology, Classification and applications.

Classification, morphology, ecology and stratigraphic importance of Dinoflagellates. Acritarchs, Conodonts and Ostracods

(25 hours)

REFERENCE
Dunbar, C.O. & Rogers, J., 1961, Principles of Stratigraphy, John Wiley & Co.
Gupta, V.J., 1975, Cenozoic Stratigraphy of India, Hind. Pub. House.
Gupta, V.J., 1976, Mesozoic Stratigraphy of India, Hind. Pub. House.
Gupta, V.J., 1977, Precambrian Stratigraphy of India, Hindustan Pub. House.
Krishnan, M.S., 2006, Geology of India and Burma, 6th edn., CBS Pub.
Krumbein, W.C. & Sloss, L.D., 1963, Stratigraphy & Sedimentation, Freeman.
Moore, R.C., 1958, An Introduction to Historical Geology, McGraw Hill.
Naganna, C., (Editor), 1975, Studies in Precambrian, Bangalore Univ. Press.
Naqvi, S.M. & Rogers, J.J.W., Precambrian Geology of India, Oxford University Press.
Neverson, E., 1962, Stratigraphic Palaeontology, Oxford University Press.
Pichamuthu, C.S., 1985, Archaean Geology, Oxford & I.B.H.
Prothero, D.R. & Schwab, F, 1996, Sedimentary Geology, W.H. Freeman & Co.
Ravindrakumar, 1985, Fundamentals of Historical Geology and Stratigraphy of India, Wiley Eastern Ltd.
Schoch, R.M., 1989, Stratigraphy: Principles and Methods, Von Nostrand Reinhold, New York.
Tiwari, S.K., 2004, A Text Book of Stratigraphy, Micropalaeontology and Palaeobotany, Kalyani Pub., N.D.
Weller, M.J., 1959, Stratigraphic Principles and Practice, Harper & Row.
Windley, B.F., 1977, The Evolving Continents, I edn., John Wiley.

STRUCTURAL GEOLOGY

SEMESTER	COURSE CODE	CONTACT/ WEEK	COTACT/ SEMESTER	CREDIT	EXTERNAL MARKS	INTERNAL MARKS
I	MSGEO01C04	5	90	5	48	12

COURSE OUTCOME

At the end of the semester students will be able to: -

CO1: Analyse stress and strain. Analyse and interpret geological structures at various scales. Recognize and interpret deformation mechanisms and processes.

CO2: Classify folds based on genesis, style and as proposed by Donath and Parker.

CO3: Build mechanism of folding, faulting, boudins, foliations and lineations.

CO4: Evaluate fracture and its types in relation to their origin.

CO5: Identify characteristics of shear zones, its types and associated rocks.

CO6: Elaborate the structural and petrofabric analysis. Apply advanced structural geology techniques for subsurface mapping and analysis.

MODULE I

Rock Deformation: Basic concept of rheology. Concept of Stress and Strain. Stress-strain relationship of Elastic, Plastic and viscous materials. Stress-strain ellipsoid. Mohr circle. Various states of stress and their representation by Mohr circles.

Techniques of strain analysis. Determination of palaeo stress. Behaviour of minerals and rocks and minerals under deformation conditions. Deformation in single crystals. Role of fluids in deformation processes. **(25hours)**

MODULE II

Folds: Classification of folds based on genesis and style. Fold classification by Donath and Parker: Cylindroidal, non-cylindroidal and conical folds. Superposed folds and interference patterns. Minor/Drag folds and their use in determining the major fold structures- Pumpelley's rule. Mechanics of folding. Fault-related folding. Faults: genetic classification—causes and mechanism of faulting.

Fractures: terminology and classification—tension fractures, shear fractures. Fracture termination and interaction. Deformation bands and fractures in porous rocks. Vein fill and growth mechanics, Syntaxial veins and antitaxial veins, Vein arrangements. **(25hours)**

MODULE III

Tectonites: Classification, tectonic fabric—Foliation: classification and origin-geometric relationship of cleavage to folding. Foliation as an aid in determining major structures. Lineation: types, significance in interpretation of tectonic history. Mechanics of development of boudins, foliations and lineations.

Shear zones: Characteristics and types-brittle, ductile and brittle-ductile shear zones. Shear-sense indicators and shear fabrics. Shear zone rocks - Mylonites and fragmental rocks produced by shearing. **(20 hours)**

MODULE IV

Concept of Structural analysis: principles—structural co-ordinates of Sander. Fundamentals of Kinematic, dynamic and geometric analysis-geometric analysis of folds and lineations—Stereographic and Equal area projections— and diagrams. Rock fabrics: Microfabric and petrofabric analysis. Symmetry concept in fabric analysis. Petrofabric diagrams. Universal stage and fabric analysis.

Principles of geological mapping and map reading. Orientation of structures. Graphical representation of orientation data: Histograms, Rose diagrams, spherical projections. Top and bottom criteria. Structural geology in hydrocarbon exploration and mining. **(20 hours)**

REFERENCE

Billings, M.P., 1974, Structural Geology, II edn., Prentice Hall.
Davis, G.H., 1984, Structural Geology of Rocks and Regions, John Wiley & Sons.
De Sitter, Structural Geology, II edn., McGraw Hill Co. Finkel, E.W. Jr.(Edr.). The Encyclopedia of Earth Sciences, Vol. XIII.
Garg, S.K., 1999, Physical and Engineering Geology, Khanna Publishers, New Delhi.
Hills, E.S., 1965, Elements of Structural Geology. I edn., Asia Publishing House.
Hobbs, B.E., Means, W.D. & William, P.F., 1976, An Outline of Structural Geology, John Wiley.
Philips, F.C., 1960, Stereographic Projection in Structural Geology. 2nd edn., Arnold.
Ragan, D.M., 1969, Structural Geology, I edn., Wiley.
Spencer E.P., 1969, Introduction to the Structure of the Earth, I edn, McGraw Hill.
Turner, F.J. & Weiss, L.E., 1963, Structural Analysis of Metamorphic Tectonites, I edn., McGraw Hill. Valdiya, K.S., Aspects of Tectonics, McGraw Hill, New Delhi.
Whitten, E.H.T., 1969, Structural Geology of Folded rocks, 2nd edn., Rand McNelly.

PRACTICAL I

GEOMORPHOLOGY, MICRO PALAENTOLOGY AND STRUCTURAL GEOLOGY

SEMESTER	COURSE CODE	CONTACT/ WEEK	CONT ACT/ SEMESTER	CREDIT	EXTERNAL MARKS	INTERNAL MARKS
I	MSGEO01C05	5	90	2*	80*	20*

GEOMORPHOLOGY **(25 hours)**

- Calculation of surface area and slope. Study of drainage pattern, Stream Ordering, tracing of drainage network and morphometric analysis.
- Determination of drainage density. Identification of lineaments and preparation of lineament maps.

MICRO PALAENTOLOGY **(25 hours)**

- Identification of micro fossils in slides, description of their environment, stratigraphy and significance

STRUCTURAL GEOLOGY **(40 hours)**

- Interpretation of complex geological maps – 20 Nos.
- Trigonometric, graphic and stereographic solution to problems in structural geology.
- Fabric diagrams, Rose diagrams and Histograms.
- Geometric analysis of planar and linear structures.
- Interpretation of topography, structures, metamorphism, lithology and geological history of Typical Precambrian terrains - 5Nos.

** Examination of Practical- I will be conducted at the end of IInd semester*

IGNEOUS AND METAMORPHIC PETROLOGY

SEMESTER	COURSE CODE	CONTACT/ WEEK	COTACT/ SEMESTER	CREDIT	EXTERNAL MARKS	INTERNAL MARKS
II	MSGEO02C06	5	90	5	48	12

COURSE OUTCOME

After the successful completion of the course, students will able to:-

CO1: Understand the mantle petrology and evaluate mechanism of magma generation.

CO2: Examine the melting and crystallization behaviour of different three component magma system and formulate your own melting/crystallization experiments.

CO3: Distinguish and standardize different classification schemes of igneous rocks.

CO4: Establish the importance of different thermodynamic rules and analyse different magma systems.

CO5: Analyse and interpret the processes, types, and agents of metamorphism, identification and characterization of metamorphic zones, facies, and their corresponding grade.

CO6: Recognition and interpretation of structures and textures in metamorphic rocks. Acquire the skills to apply thermodynamic principles, geo thermo-barometry techniques, and P-T-t to determine the pressure and temperature conditions during metamorphism, and interpret mineral paragenesis using chemographic diagrams.

CO7: Understand metamorphic processes of various rock types as well as the role of fluids in metasomatism and skarn formation.

CO8: Analyse the petrogenesis of various metamorphic rocks.

MODULE I

Mantle petrology. Homogeneous and heterogeneous mantle. Mantle melting mechanism and generation of basaltic magma - Thermal perturbation, volatile influx and adiabatic decompression melting. Primary and parent magma. Isotopic, REE and Trace pattern of Enriched and depleted mantle. Tectonic discrimination diagrams.

Magma generation in different tectonic settings; Oceanic Intraplate volcansim, Mid Oceanic Ridge (MOR) volcanism, Island arc and Continental arc igneous activity and Continental flood basalt. Ophiolite suite and its importance. Variation diagrams and its use in magma evolution modelling-Bivariate and triangular plot. **(25 hours)**

MODULE II

Phase equilliburia. Importance of Le Chatelier's principle. Phase rule and its application in the study of the important three component systems: Anorthite – Fosterite - Diopside, Forsterite – Anorthite - Silica. Diopside – Albite - Anorthite. Diopside – Forsterite - Silica and Orthoclase – Anorthite – Albite.

TAS classification and Irvin˜ Baraggar classification. Use of Variation Diagrams and Ternary (AFM) diagrams for igneous rock classification. Petrology, texture, mode of occurrence and classification of Granite, Basalt, Kimberlite, Carbonatite, Peridotite, Anorthosite, Lamprophyres and Lamproite.

(20 hours)

MODULE III: Metamorphic agents and changes, types of metamorphism. Concept of metamorphic zones, facies, facies series and grade. Isograds and Reaction Isograds. Paired metamorphic belt.

Structures and textures of metamorphism. Phase rule in metamorphic systems. Mineral Paragenesis and Chemographic diagrams: Composition plotting: ACF, AKF and AFM diagrams. Thermodynamics of metamorphic reactions: geothermobarometry and P-T-t paths.

(20 hours)

MODULE IV: Metamorphism of pelitic sediments, calcareous and carbonaceous rocks. Role of fluids in metamorphism: metasomatism and skarn formation.

Petrogenesis and petrography of the following rocks: Slates, Phyllites, Schists, Gneisses, Marble, Quartzites, Amphibolites, Charnockites, Khondalites, Migmatites. Granulite facies rocks with special reference to Charnockites and of Southern Granulite Terrain.

(25 hours)

REFERENCE

Best, M. G. (2002). Igneous and Metamorphic Petrology. CBS Publishers and Distributors.
Brown, M. (2007). Metamorphic Conditions and Partial Melting. In Metamorphism and Tectonics: From Granite to Gneiss (pp. 215-238). Elsevier.
Bucher, K., & Martin, F. (2002). Petrogenesis of Metamorphic Rocks. Springer.
Bucher, K., & Grapes, R. (2011). Petrogenesis of Metamorphic Rocks. Springer.
Holland, T. J. B., & Powell, R. (2011). An Introduction to Metamorphic Petrology. Cambridge University Press.
Miyashiro, A. (1972). Metamorphism and Metamorphic Belts. Allan & Unwin.
Phillpotts, A. (1990). Principles of Igneous and Metamorphic Petrology. Prentice Hall.
Ramberg, H. (1962). The Origin of Metamorphic and Metasomatic Rocks. University of Chicago Press.
Sawyer, E. W., & Brown, M. (2008). Petrology: The Study of Igneous, Sedimentary, and Metamorphic Rocks. Cambridge University Press.
Soman, K. (2004). Geology of Kerala. Geological Society of India.
Spear, F. S. (1993). Metamorphic Phase Equilibria and Pressure-Temperature-Time Paths. Mineralogical Society of America Monograph Series.
Thompson, A. B. (1976). Metamorphic Geology: An Introduction to Tectonic and Metamorphic Processes. John Wiley & Sons.
Turner, F. J., & Verhoogen, J. (1960). Igneous and Metamorphic Petrology. CBS Publishers & Distributors.
Turner, F. J. (1968). Metamorphic Petrology. McGraw-Hill.
Tyrrell, G. W. (1963). Principles of Petrology. Methuen & Co.
Vernon, R. H. (2018). A Practical Guide to Rock Microstructure. Cambridge University Press.
Vernon, R. H., & Clarke, G. L. (2008). Principles of Metamorphic Petrology. Cambridge University Press.
Vernon, R. H. (1976). Metamorphic Processes. Murby.
Winkler, H. G. F. (1974). Petrogenesis of Metamorphic Rocks (5th ed.). Springer-Verlag.
Winter, J. D. (2010). Principles of Igneous and Metamorphic Petrology. Prentice Hall.

SEDIMENTOLOGY

SEMESTER	COURSE CODE	CONTACT/ WEEK	COTACT/ SEMESTER	CREDIT	EXTERNAL MARKS	INTERNAL MARKS
II	MSGEO02C07	5	90	5	48	12

COURSE OUTCOME

At the end of the semester students will be able to: -

CO1: Understand textural properties of rocks and its quantitative grain size analysis.

CO2: Analyse palaeo-environment by menace of texture and structure of sedimentary rocks

CO3: Identify and interpret sedimentary structures, including bedding, cross-bedding, and biogenic structures.

CO4: Understand the depositional environments and facies of sedimentary rocks.

CO5: Analyse and interpret sedimentary rocks and their textures, structures, and mineralogy.

CO6: Develop comprehend knowledge on the diagenetic processes, Paleogeography, formation and evolution of sedimentary basins and Sequence stratigraphy.

MODULE I

Fundamentals of fluid flow – Laminar and turbulent flow. Froude Number, Reynold's Number. Sediment movement by fluid flow-- Flow in pipes and channels. Competence and capacity. Bed load and suspension load transport – Hjulstrom diagram. Clastic sedimentary textures: grain size, shape and fabric. Frequency distribution and statistical parameters.

Sedimentary structures: Stratification, ripples, dunes and anti dunes, Structures formed by scour, wave, tide and wind. Flow regimes and processes of sediment transport. Mass flows, Turbidity currents. Penecontemporaneous deformation structures, Biogenic sedimentary structures. Stromatolites – Classification and significance. Palaeo-environment analysis using structure.

(30 hours)

MODULE II

Study of following specific depositional environment and facies. Continental environment – Fluvial, Eolian, Lacustrine and Glacial systems. Mixed environment – Delta, beach and estuarine system.

Siliciclastic marine environment – Shelf and deep water system. Carbonate environment- Shelf system. Evaporate environment.

(20 hours)

MODULE III

Provenance studies: Mobility of oxides, mineral stability, mineralogical and textural maturity, minerals of sedimentary rocks and source rocks. Importance of heavy mineral suits. Paleogeography: Paleoslope and palaeo current studies

Diagenesis of clastic rocks – Compaction, Cementation, Authigenesis, Recrystallization and Replacement. Diagentic structures. Non clastic diagenesis and environment. **(20hours)**

MODULE IV

Descriptive sedimentary petrology- Classification of sandstone (Folk scheme) conglomerate and breccia. Carbonate sedimentary rock – components of limestone and classification (R L Folk's scheme)

Sedimentary basins: Controls of sediment accumulation. Basin related to lithospheric extension, subduction, crustal loading, strike slip movement and hybrid basins. Sedimentary basins of India. Basin analysis. **(20 hours)**

REFERENCE

Donald, R.P. & Fred, S., 1996, Sedimentary Geology, W.H. Freeman & Co.

Folk, R.L., 1968, Petrology of Sedimentary Rocks, Hemphill's University Station, Texas. Friedman, G.M. and Sanders, J.E., 1978, Principles of Sedimentology, John Wiley & Sons.

Krumbein, W.C. & Sloss, L.D., 1963, Stratigraphy & Sedimentation, Freeman. Krumbein, W.C. & Pettijohn, F.J., 1938, Manual of Sedimentary Petrology. Appleton Century Co. Miall, A.D., 1990, Principles of Sedimentary Basin Analysis, 2nd edn., Springer-Verlag. Pettijohn, F.J., Potter P.E. & Siever, R., 1972, Sand and Sandstone, Springer-Verlag. Pettijohn, F.J., 1957, Sedimentary Rocks. Harper & Row. Prothero, D.R. & Schwab, F., 1996, Sedimentary Geology, W.H. Freeman & Co. Schoch, R.M., 1989, Stratigraphy--Principles and Methods, Von Nostrand Reinhold, New York. Solley, R.C., 1972, Ancient Sedimentary Environments, Cornwall University Press. Tarling, D.H., 1983, Palaeomagnetism, Chapman & Hall. Thompson, R. & Oldfield, F., 1986, Environmental Magnetism, Allen & Unwin, London.

PRACTICAL II - MINERALOGY, PETROLOGY AND GEOCHEMISTRY

SEMESTER	COURSE CODE	CONTACT/ WEEK	COTACT/ SEMESTER	CREDIT	EXTERNAL MARKS	INTERNAL MARKS
II	MSGEO02C09	5	90	2	48	12

MINERALOGY (20hours)

- Identification of typical mineral hand specimens based on physical properties.
- Determination of the following optical characters of minerals by classical methods
  Relative Refringence, Order of Interference colour, Sign of Elongation, Birefringence, Scheme of Pleochroism and Absorption Formula, Optic Orientation, Optic Axial Angle, Extinction Angle, Optic Sign
- Stereographic and Gnomonic of Normal class of Isometric System. --3 exercises.
- Axial ratios, Zone symbols and Napier's rule.

IGNEOUS PETROLOGY (30 hours)

- Megascopic and Microscopic identification of the following rocks with special stress to genetic significance - Granite, Syenite, Diorite, Pegmatite, Lamprophyre, Gabbro, Dolerite, Basalt, Dunite, Peridotite, Pyroxenite, Anorthosite and Kimberlite.
- Calculation of Niggli values and Peacock's Alkali Lime Index—2
- Exercises. Graphical representation: Variation Diagrams--Harker, Larsen, Allen and Nickold, Niggli –2 each.
- AFM diagrams for classification of igneous rocks—3 Nos.
- Phase diagrams: Eutectic, Solid solution, and Peritectic—1 each.

METAMORPHIC PETROLOGY (20 hours)

- Megascopic and microscopic studies of the following rocks with special reference to genetic significance. - Slate, Phyllite, Schist, Charnockite, Khondalite, Gneiss, Pyroxene granulite, Amphibolite, Mable, Quartzites.
- Graphical representation of metamorphic mineral paragenesis—5 Exercises.
- ACF and AKF diagrams of the following facies --1 each - Greenschist, Amphibolite, Granulite, Eclogite, Albite-Epidote-Hornfels, Hornblende-hornfels, Pyroxene-hornfels and Sanidinite facies.

SEDIMENTARY PETROLOGY (20 hours)

- Textural analysis of sediments: Sieve analysis, settling analysis, thin sections, size analysis, measurement and calculation of Shape parameters, plotting and interpretation of such data.
- Size analysis using G- Stat software
- Heavy mineral separation.

- Study of thin sections and hand specimens of Limestone, Sandstone, Shale, Conglomerate, Breccia, Grit and Arkoses. Preparation of grain mounts - 5 Nos.
- Study of grain mounts of Magnetite, Ilmenite, Monazite, Garnet, Sillimanite, Zircon, Rutile, Leucoxene and Chromite.

GEOCHEMISTRY

- Mineralogical calculations using chemical analysis data of minerals – Garnet, Pyroxene, Feldspar, Olivine, Feldspathoid.

HYDROGEOLOGY

SEMESTER	COURSE CODE	CONTACT /WEEK	COTACT/ SEMESTER	CREDIT	EXTERNAL MARKS	INTERNAL MARKS
III	MSGEO03C11	5	90	5	48	12

COURSE OUTCOME

At the end of the semester students will be able to: -

CO 1: Understand the definition, ideas, scope and concepts of hydrogeology.
CO 2: Acquire skill on exploration, identification and characterization of aquifer material.
CO 3: Basic understanding of groundwater modelling.
CO 4: Acquire skill to conduct aquifer tests, data collection, process and analysis to resolve problems on groundwater movement.
CO 5: Acquire skill on develop and maintain groundwater harvesting structures.
CO 6: Understand the significances groundwater quality and quantity.

MODULE I

Origin of ground water: Meteoric, Juvenile and connate waters. Subsurface movement and vertical distribution of groundwater. Classification of rocks with respect to their water bearing properties- Aquifers, Aquicludes, Aquitards and Aquifuges. Geologic materials as aquifers: unconsolidated materials and consolidated rocks. Hydrostratigraphic units. Types of aquifers: Unconfined, Confined, Semiconfined, Semi-unconfined, leaky and coastal aquifers.

Hydrogeological properties of rocks: porosity, void ratio, permeability, hydraulic conductivity, transmissivity, storativity, specific yield, specific retention. Laboratory methods of determining aquifer properties. Concept of Hydro geological environment: rock types, geological frame work, rock matrix, fractures, weathered hard rocks and surficial rocks.

(20 hours)

MODULE II

Movement of ground water: forces causing ground water movements, fluid potentials, water table, piezometric surface. Theory of ground water flow: Darcy's law and its experimental verification--Range of validity of Darcy's law. Differential equation governing groundwater flow. Hydrogeological boundaries. Flow nets. Application of isotope studies and tracer techniques in ground water flow.

Ground water exploration: Geological methods—lithological and structural mapping, fracture trace analysis. Hydrogeological methods—lithological classification with respect of hydrological properties. Geophysical methods: Electrical Resistivity methods—Wenner and Schlumberger methods. Seismic Refraction methods. Well logging: Spontaneous Potential Logging, Radiation logging, Gamma-gamma ray logging. Use of Aerial photos and satellite imageries in ground water prospecting. **(25 hours)**

MODULE III

Well hydraulics: Aquifer tests, Pumping tests data analysis and recovery test. Drawdown, Steady Radial flow into a well in confined and unconfined aquifers –Theim's equation, Dupuit-Forhemeir equation. Unsteady Radial flow into wells—Theis, Chow's and Jacob's methods. Production well specifications and tests.

Well design: Types of wells, drilling methods: Cable-tool drilling, Hydraulic Rotary, Reverse Rotary and Down the Hole Hammer drilling. Water Well Design Criteria: Grain size distribution, screens and casings. Maintenance of wells. **(20 hours)**

MODULE IV

Groundwater recharge: natural and artificial recharges. Hydraulic budget. Quality of ground water: Methods of collection and analysis of water samples. Physical, chemical and biological measures of water quality and its interpretation. The general occurrence of various constituents in ground water. Graphical representation of groundwater quality data - Collin's, Piper Trilinear, Vector, Circular diagrams and Stiff's polygon. Quality of ground water standard for domestic, irrigation and industrial uses.

Coastal aquifers and saline water intrusion—Ghyben-herzberg equation and its uses—slope, shape and movement of interface. Identification of saline zones and interfaces. Prevention and control of saline water intrusion. Water conservation methods-rain water harvesting. Framework of National Water Policy. Ground Water Provinces of India. Ground water conditions of Kerala.

(25 hours)

REFERENCE

Alley, W.M., 1983, Regional Groundwater Quality.

Bouwer, H., 1978, Ground Water Hydrology.

Davies, S.N. & Dewiest, 1969, Hydrogeology.

John Wiley & Sons Inc. Dominico, P.A., Concepts and Models in Ground water Hydrogeology, McGraw Hill.

Fetter, C.W. ,1990, Applied Hydrology

Freeze, R.A. & Cherry, J.A.,1971, Groundwater.

Karanth, K.R., 1986, Groundwater and Wells, Science Pub., Jodhpur.

Linsley, R.K., Lohler, M.A. & Paulhus, J.L.H., 1975, Applied Hydrology, Tata McGraw Hill.

Raghunath, H.M., 2003, Groundwater, III edn., New Age International Ltd, Wiley Eastern.

Todd, D.K., 2006, Groundwater Hydrology, II edn., John Wiley & Sons.

Tolman, C.F., Ground water, McGraw Hill.

Walton, W.C., 1970, Groundwater Resource Evaluation, McGraw Hill Inc.

GEOINFORMATICS AND REMOTE SENSING

SEMESTER	COURSE CODE	CONTACT/ WEEK	COTACT/ SEMESTER	CREDIT	EXTERNAL MARKS	INTERNAL MARKS
III	MSGEO03C12	5	90	5	48	12

At the end of the semester students will be able to: -

CO1: Gain knowledge and comprehension of the practical applications of Electromagnetic energy, spectrum, and spectral signature curves.

CO2: Comprehend the significance of spectral, spatial, temporal, and radiometric resolution in the interpretation of satellite data.

CO3: Explain the fundamental principles behind multispectral remote sensing, hyperspectral remote sensing, and the characteristics of thermal and microwave satellites and sensors, along with the nature of the data they provide.

CO4: Basic understanding of geodesy, conversion of real time ground features to map layers.
CO5: Acquire practical skill on surveying and applications of GNSS.
CO6: Understand various geospatial software and acquire skill on use of various software tools to solve the geospatial problems.

MODULE I

Remote Sensing: Definition, Principles and methods of remote sensing - Active and Passive remote sensing - Remote Sensing platforms -Electromagnetic radiation- Spectrum- Blackbody radiation – Planck's law – Stefan – Boltzmann law-Whiskbroom scanner, Push-broom scanner.

EMR Interactions: Interaction with atmosphere scattering of EMR - Rayleigh, Mie, Non Selective and Raman Scattering. Back scattering Speckle EMR Interaction with water and Ozone Atmospheric windows and its significance. EMR interaction with the earth surface materials - Radiance, Irradiance, Absorbance, Transmittance, Reflectance- Specular- and diffuse surface- Spectral signature – and curves EMR interaction with soil, water and vegetation. Resolution - Spectral, Spatial, Radiometric, and Temporal. **(25 hours)**

MODULE II

Satellites classification based on orbit- Sun synchronous and Geosynchronous. Based on purpose- Earth resources satellites, Communication satellite, Weather satellites and Spy satellites.
Multi High resolution and Hyperspectral Remote Sensing. Thermal and Microwave sensors, Sensors characteristics. Satellites and their Specifications: LANDSAT, SPOT, ENVISAT, World- View, Quickbird, GeoEye, Sentinel-1/2, ASTER, RADARSAT and IKONOS. SLAR and SAR - Interferometry. Brief study of Indian Satellite missions. **(20 hours)**

MODULE III

Map projection: Basic geodesy - Geoid/Datum/Ellipsoid - Coordinate systems - Scale factor - Distortion on map – projections - Classification of map projections - Polyconic, LCC, Mercator. UTM projections - Map projection transformation – Surveying – Total Station – EDM – LIDAR.

GNSS: Satellite constellation - GPS signals and data - GPS receivers - Single point positioning - Measuring distance and timing - GPS accuracy - Error corrections - Differential GPS - Glonass and Galileo systems - Applications of GPS - Carrying out a GPS survey. Indian Navigation Satellite system – NavIC (IRNSS). **(20 hours)**

MODULE IV

Geographic data: Spatial and non-spatial data - Vector and raster data models - Vector and raster data structures - Data compression - Choice between raster and vector - Data transformations - Data sources & data input - Linking spatial and non-spatial data - Errors and quality control - Data storage - Data formats - Database concepts - Database management in GIS- Web GIS - 3DGIS - Object Oriented GIS - Mobile GIS.

Spatial Analysis – Geo-statistical analysis - Proximity analysis (buffering) - Overlay analysis – density analysis - Network analysis - Multi-criteria analysis - Site suitability analysis - Nearest neighbour analysis - Thiessen polygons - Surface mapping - Interpolation (including TIN) - Digital elevation model (DEM) - Terrain reclassification – Slope, aspect, angle of incidence. - Visibility (viewshed) analysis - Spatial and non-spatial query. **(25 hours)**

REFERENCE

Adrians, P. & Zantinge, D., 1996, Data Mining, Addison-Wesley, New York.
Burrough, P.A. & McDonnell, R.A., Principles of Geographical Information System, Oxford Pub.
Chang, Kang-Tsung., 2002, Introduction to Geographic Information Systems, Tata McGraw Hill Pub. Co. Ltd.
Clarke, K.C., Getting Started with Geographic Information System, Prentice Hall.

Davis, J.C., 1973, Statistics and Data Analysis in Geology, Wiley.
ESRI, Understanding Geographic Information System, The Arc-info Method, Wiley Publishers.
Gibson, P. J. & Power, C. H., 2000, Introductory Remote Sensing--Digital Image Processing and Applications.
Tarrytown, Geographic Information System for Geoscientists Modelling with GIS, Pergamon Press.

ORE AND ECONOMIC GEOLOGY

SEMESTER	COURSE CODE	CONTACT/ WEEK	COTACT/ SEMESTER	CREDIT	EXTERNAL MARKS	INTERNAL MARKS
III	MSGEO03C13	5	90	5	48	12

At the end of the semester students will be able to: -
CO 1: Gain comprehensive understanding of mineral deposits, their distribution.
CO 2: Understand principles of ore microscopy techniques, identification and interpretation of physical and optical properties of ore minerals, analyse various of ore textures and their genetic significance.
CO 3: Analyse the source, migration, and deposition mechanisms of ore minerals
CO 4: Understand the formation of various types of ore deposits
CO 5: Understand the concept of mineral economics, including the identification and classification of strategic, critical, and essential minerals in India, National Mineral Policy
CO 6: Understand the formation, and economic significance of polymetallic nodules and metalliferous muds.
CO 7: Understand the distribution and geological characteristics of various ore mineral deposits of India
CO 8: Understand the distribution and geological characteristics of various industrial mineral deposits of India

MODULE I
Mineral deposits, morphology of ore bodies, rock-ore association; syngenetic and epigenetic deposits. Spatial and temporal distribution of mineral deposits. Metallogenetic epochs and provinces. Role of plate tectonics in ore formation.

Ore microscopy: Parts of ore microscope and working principle. Physical and optical properties of ore minerals. Ore textures and their genetic significance. Paragenesis and zoning. Fluid inclusion studies in ore mineral assemblage. **(25 hours)**
MODULE II Ore forming processes- source and migration of ore constituents and ore fluid, mechanism of ore deposition. Types of ore deposits and their origin: magmatic and pegmatitic deposits (chromite, Ti-magnetite, diamond, Cu-Ni sulphide, PGE, REE, muscovite, rare metals); hydrothermal deposits (porphyry Cu-Mo, greisen SnW, skarn.

VMS and SEDEX type sulphide deposits, orogenic gold); sedimentary deposits (Fe, Mn, phosphorite, placer); supergene deposits (Cu, Al, Ni and Fe); metamorphic and metamorphosed deposits (Mn, graphite). **(20 hours)**

MODULE III: Basic Principles of Mineral Economics: Strategic, Critical and Essential minerals of India. India's Mineral Position. National Mineral Policy.

Polymetallic nodules and metalliferous muds: Depth of occurrence, conditions of formation, economic importance. **(25 hours)**

MODULE IV: Distribution of mineral deposits in Indian shield. Geological characteristics of important ore deposits in India: chromite, diamond, Cu-Pb-Zn, Sn-W, Au, Fe-Mn.

Geological characteristics of important industrial minerals in india: bauxite, muscovite, minerals used in refractory, fertilizer, ceramic, cement, glass, paint industries; minerals used as abrasive, filler; building stones. **(20 hours)**

REFERENCE

Bateman, A.M., 1962, Economic Mineral Deposits, Wiley.
Brown, J.C. & Dey, A.K., 1936, India's Mineral Wealth, Oxford.
Edwards, A.B., 1960, Textures of the Ore Minerals, Aus. Inst. Min & Met.
Gokhale & Rao, Ore Deposits of India.
Hobson, G.D & Tiratsoo, E.N., 1981, Introduction to Petroleum Geology, Scientific Press Ltd.
Jensen, M.L. & Bateman, A.M., Economic Mineral Deposits III edn.,, John Wiley.
Levorsen, A.I., 1958, Geology of Petroleum, McGraw Hill.
Lindgren, W., 1933, Mineral Deposits, McGraw Hill.
McKinstry, H.E., 1960, Mining Geology, Asia Publishing House.
Nininger, R.D., 1956, Minerals for Atomic Energy, Von Nostrand.
Peters, W.C., Exploration and Mining Geology, John Wiley
Rankama, K. & Sahama, T.G., 1949, Geochemistry, Chicago Univ. Press.
Short, M.N., 1940, Microscopic Determination of Ore Minerals, USGS Bulletin No.914.
Shyam, M.R., Metals from the Seabed, Oxford & IBH.
Sinha, R.K. & Sharma N.L., Mineral Economics, Oxford & I.B.H. Publishers.
Sullivan, C.J., 1948, Ore and Granitisation, Econ. Geol., Vol. 43 pp. 47-489.
Wilson, H.D.B., 1953, Geology and Geochemistry of Base Metal Deposits, Econ. Geol., Vol.48,.P.370-40.

PRACTICAL III: HYDROGEOLOGY, REMOTE SENSING AND GEOINFORMATICS

SEMESTER	COURSE CODE	CONTACT/ WEEK	COTACT/ SEMESTER	CREDIT	EXTERNAL MARKS	INTERNAL MARKS
III	MSGEO03C14	5	90	*0	*0	*0

HYDROGEOLOGY **(40 hours)**

- Solution of problems based on Darcy's Law.
- Preparation and interpretation of water table contour maps.
- Computation of aquifer parameters from pumping data.
- Collection of well inventory data and Graphical representation of hydrochemical data:- Piper Trilinear diagram, Vector diagram, Circular diagrams, Stiff's polygon.
- Calculation of various parameters based on chemical data.
- Electrical resistivity survey and interpretation of data.

REMOTE SENSING AND GEOINFORMATICS **(20 hours)**

- Aerial Photography: Calculations based on aerial photos—photo scale, estimation of total number of photos required to cover a given area and determination of heights of objects.
- Interpretation of Satellite Imageries
- Geo referencing
- Creation of thematic layers
- Overlay analysis
- Terrain analysis
- Image classification- Supervised and unsupervised
- Map composition

IIIrd semester practical will be conducted along with IVth semester practical.

EXPLORATION GEOLOGY AND GEOPHYSICS

SEMESTER	COURSE CODE	CONTACT/ WEEK	COTACT/ SEMESTER	CREDIT	EXTERNAL MARKS	INTERNAL MARKS
IV	MSGEO04C15	4	72	3	48	12

COURSE OUTCOME

At the end of the semester students will be able to: -

CO1: Understand and differentiate Resource and reserve

CO2: Carry out ore estimation methods and measure its geological viability.

CO3: Understand and apply principles of geological and of geochemical exploration and methods

CO4: Understand the fundamental principles and concepts of advanced geophysics.

CO5: Evaluate subsurface survey methods using magnetic, gravity, seismic reflection and refraction, and electrical methods.

CO6: Interpret data and Bore-hole logging methods

MODULE I

Resource and Reserve. Classification of resource and reserve. Mc Kelvey and UNFC classification. Ore reserve estimation. Conventional methods of ore reserve estimation.

Principles and objective of Geological exploration. Stages of exploration – Reconnaissance, Prospecting, General exploration, Detailed exploration and Mine Exploration. Principles of Bio geochemical and Geo botanical exploration **(20 hours)**

MODULE II

Principles of Geochemical exploration. Mobility of elements. Geochemical environment. Dispersion and dispersion pattern. Types of dispersion pattern. Geochemical anomaly and its significance

Sampling methods and technique for exploration. Surface sampling and subsurface sampling. Litho, hydro, atmo and soil sampling methods. Drilling – coring and non-coring drilling technique. Bore hole logging. **(12 hours)**

MODULE III

Introduction to Geophysical Prospecting: Geophysical exploration techniques and their importance. Magnetic Surveys: Principles and Earth's magnetic field--survey methods, instrumentation, interpretation and applications.

Gravity surveys: Principles of Gravity survey, instrumentation, Bouger anomaly, latitude, elevation and terrain corrections survey methods interpretation of gravity curves of bodies of different shapes. Radiometric methods: Instrumentation and techniques. **(20 hours)**

MODULE IV

Seismic surveys: Methods of generation, propagation and sensing of seismic waves, wave types, travel-time graphs for different media and interfaces. Seismic velocities in geological materials. Seismic survey sources, recorders, reflections and refraction surveys and the interpretation of profiles.

Electrical surveys: Electrical properties of rocks, theory of current flow in different media, resistivity survey, application and interpretation of data. Self-Potential survey, applications and interpretation of data. Induced Polarization, application and interpretation of profiles. Theory, survey methods and interpretation of data. Bore-hole logging: Electrical, Radiometric, Sonic and Thermal logging of boreholes. **(20 hours)**

REFERENCE
Arogyaswamy, R.N.P., Courses in Mining Geology, Oxford & I.B.H. Publishing Co.
Babu, S.K. & Sinha, D.K., 1988, Practical Manual of Exploration and Prospecting, CBS Publishers, New Delhi.
Bagchi, T.C., Elements of Prospecting and Exploration, Kalyan Publishers.
Compton, R.R., 1968, Manual of Field Geology, Wiley Eastern Pvt. Ltd.
Dabrin, M.B., Introduction to Geophysical Prospecting, Pergamon Press.
Dabrin, M.B., Elements of Prospecting & Exploration, Kalyan Publishers.
Ginzburg, I.I., Principles of Geochemical Prospecting, Pergamon Press.
Griffithis, D.H. & Kind, R.F., Applied Geophysics for Geologists and Engineers, Pergamon Press
Kovalarkim, Biochemical Exploration for Mineral Deposits, Co-xinian Press.
Lahee, F.H., Field Geology, McGraw Hill Low, J.W., Geological Field Methods, Harper & Brothers
Malyuga, D.F., Biochemical Methods of Prospecting, Consultants Bureau, New York.
Mckinstry, H.E., 1960, Mining Geology, Asia Publishing House, Bombay.
Peters, W.C., Exploration and Mining Geology, John Wiley.
Ramam, P.K., 1989, Principles and Practices of Mineral Exploration, Geo. Soc. India, Bangalore.
Reedman, J.H., Techniques in Mineral Exploration, Allied Scientific Publishers.
Rose, A.W., Hawkes, H.E. & Webb, J.S., Geochemistry in Mineral Exploration, Academic Press.
Sinha, R.K. & Sharma N.L., 1988, Mineral Economics, 4th edn., Oxford & I.B.H. Publishers.

SCIENTIFIC DOCUMENTATION IN EARTH SCIENCE

SEMESTER	COURSE CODE	CONTACT /WEEK	COTACT/ SEMESTER	CREDIT	EXTERNAL MARKS	INTERNAL MARKS
IV	MSGEO04C16	1	18	1	--	20

COURSE OUTCOME
At the end of the course, student will able to:-
CO 1: To do critical and comprehensive literature survey of the research papers.
CO 2: Understand the plagiarism issue in research and able to tackle them
CO 3: Understand various methods of data collection and compile them for critical analysis
CO 4: Able to construct an experimental and project design and to write a research paper

MODULE I
Introduction to literature reviews. Comprehensive and critical literature review of research publications. Recent methods in research literature review and its documentation.- Software and tools
Activity 1: Write a model of review paper **(04 hours)**

MODULE II
Research ethics. Plagiarism. Types of plagiarism. Detection plagiarism. Plagiarism software. Fundamentals of experimental design.
Activity 2: Construct an Experimental design. **(04 hours)**

MODULE III
Research data. Types of research data. Primary, secondary and tertiary data. Collection and compilation of data. Critical analysis. **(04 hours)**

MODULE IV
Structure of a scientific paper.
Activity 3- Project proposal writing and its presentation **(06 hours)**

REFERENCE
From Research to Manuscript: A Guide to Scientific Writing, Michael Jay Katz, Springer, 2006.
How to Write & Publish a Scientific Paper, Robert A. Day, The Oryx Press, 1998.

How to Write a Lot: A Practical Guide to Productive Academic Writing, Paul J. Silvia, APA LifeTools; Second edition (September 1, 2018).
How to Write a Scientific Paper: An Academic Self-Help Guide for PhD Students, Jari Saramäki, 2018. How to Write and Publish a Scientific Paper: The Step by Step Guide, Luz Claudio.
Entering Research: A Curriculum to Support Undergraduate & Graduate Research Trainees, Janet L. Branchaw, Amanda R. Butz & Amber Smith. W. H. Freeman; Second edition (July 10, 2019).
Scientific Integrity and Research Ethics: An Approach from the Ethos of Science, David Koepsell, Springer; 2017.
Research Methods for Science, Michael P. Marder, Cambridge University Press, 2011.

PRACTICAL IV: EXPLORATION GEOLGY AND ORE GEOLOGY

SEMESTER	COURSE CODE	CONTACT/ WEEK	COTACT/ SEMESTER	CREDIT	EXTERNAL MARKS	INTERNAL MARKS
IV	MSGEO04C17	2	36	2	80	20

EXPLORATION GEOLOGY (18 hours)

- Ore reserve estimation – estimation of grade and tonnage
- Iso pach and isco chore method
- Triangular method
- Polygonal method
- Planar method
- Sectional method
-

ORE GEOLOGY (18 hours)

- Megascopic identification, characterization, paragenesis and occurrence of important ore minerals and economic resources of India--20 nos.
- Identification of ore minerals under ore microscope -- 10 Nos.
- Calculation and determination of metal content in ore --10 exercises.

ELECTIVE COURSE I

MSGEO02E01	Planetary Geology
MSGEO02E02	Quaternary Geology
MSGEO02E03	Mineral resources of India

PLANETARY GEOLOGY

SEMESTER	COURSE CODE	CONTACT/ WEEK	COTACT/ SEMESTER	CREDIT	EXTERNAL MARKS	INTERNAL MARKS
II	MSGEO02E01	4	72	4	48	12

COURSE OUTCOME

At the end of the semester students will be able to: -

CO1: Recall and describe key concepts and principles related to planetary science, including the formation of planets, celestial bodies, and the origin of atmospheres.

CO2: Identify and categorize different planetary objects, such as moons, terrestrial planets, and outer planets, based on their characteristics and surface features.

CO3: Define and explain the geological processes and phenomena observed on various planetary bodies.

CO4: Interpret and explain the significance of geological factors on the formation and evolution of planets.

CO5: Compare and contrast the properties and characteristics of various planetary objects and their environments.
CO6: Utilize remote sensing techniques to study and interpret physical and chemical properties of celestial bodies.
CO7: Evaluate the significance and implications of historical and contemporary planetary exploration efforts.

MODULE I
Introduction to Planetary Science-Earth in space: Universe-Big Bang theory, Milky Way, solar system, and the Sun-Astronomical units-Inner planets and their physical attributes

Outer planets, planetoids, and moons-General survey of atmosphere, atmospheric temperature, and planetary surfaces-Structure of planets: Lithological makeup of crust and interior, and origin of the crust. **(14 hours)**

MODULE II
Origin and Atmosphere of Planets-Theories on the origin of planets: Nebular hypothesis, planetary hypothesis, double star hypothesis, condensation hypothesis, and Urey's hypothesis-Origin of Earth's atmosphere

Earth's moon: General features, surface aspects, and origin of lunar surface-Geology of the lunar surface: Surface cover, sediment, volcanic flows, and lunar craters-Structure of the moon: Crust and interior, absence of atmosphere, and origin and evolution of the moon. **(20 hours)**

MODULE III
Terrestrial planets: Mercury, Venus, and Mars: Martian isomorphic features:Olympus Mons-Tharsis bulge-Valles Marineris; Fluvial and glacial geomorphology-General survey of atmosphere, atmospheric temperature, and planetary surfaces-Structure of planets: Lithological makeup of crust and interior and origin of the Martian crust

Outer planets: Jupiter, Uranus, Saturn, and Neptune-General survey of atmosphere, atmospheric temperature, and planetary surfaces-Structure of planets: Lithological makeup of crust and interior, and origin of the crust-Other Planetary Objects and Planetary Exploration **(20 hours)**

MODULE IV
Planetary objects: Meteors, meteorites, asteroids, and comets-Classification of meteorites-Evidence of giant impacts, spinifex texture, tektites, and petrology of meteorites

In-depth exploration of Saturn: Observation methods, Saturn's rings, Saturn's moons, and the Kuiper Belt-Planetary exploration: Space crafts, Gemini series, Apollo missions, lunar rovers, first lunar landing-International Space Station (ISS) **(18 hours)**

REFERENCE
Gunter Faure, Tresa M. Mensing, 2007, Introduction to Planetary Science-The geological perspective
Carlson, D. and Plummer, C., 2010, Physical Geomorphology: Earth Revealed. 9th Edn., Mc-Graw Hill Co.
Cook, AH, 1973 Physics of Earth and planets. London: Macmillian
Kaula, WM, 1996 Theory of satellite geodesy. Blaisedell
Thompson, G. R. and Turk, J., 1997, Introduction to Physical Geology. 2nd Edn. Thompson Brooks Publishers. *www.pdsa.jpl.nasa.gov//planets*

QUATERNARY GEOLOGY

SEMESTER	COURSE CODE	CONTACT/ WEEK	COTACT/ SEMESTER	CREDIT	EXTERNAL MARKS	INTERNAL MARKS
II	MSGEO02E02	4	72	4	48	12

COURSE OUTCOME

At the end of the semester students will be able to: -

CO1: To understand the concept of Quaternary and its sub divisions and appreciate the control of past climate and its variability.

CO2: Categorize the different archives and categories of Quaternary period and analyze them with past climatic variability.

CO3: Understand and summarize about different Quaternary proxies and analyze them for different Quaternary environment.

CO4: Interpret and explain the significance of geological factors on the formation and evolution of planets.

CO5: Identify different causes for the glaciation and extend these causes for the Quaternary glaciation.

CO6: Relate different absolute dating technique to Quaternary dating.

MODULE I:

Quaternary: concept and significance. Subdivisions of Quaternary stratigraphy and its criteria. Climate and climate variability: various time scales of climate variability. Various Archives of Quaternary history; tree rings, corals, speleothems (cave deposits), peat deposits, dunes, lake sediments, marine sediments, glaciers, fluvial deposits.

Use of 'proxy indicators' for the reconstruction of Quaternary environments. Quaternary proxies: geological, geochemical, biological, sedimentological, isotopic and magnetic proxies. **(20 hours)**

MODULE II:

Quaternary glaciation. Palaeoceanographic changes during Cenozoic--Deducing sequence of climate changes and environment during Quaternary from the proxies--D-O Events, Bond Cycles and Heinrich Events - Quaternary history from marine sediments, land and ice core studies.

Tertiary-Quaternary boundary. Ice Ages during Quaternary--Factors controlling glacial cycles. Various stages in Quaternary glaciations. Eustatic Sea Level changes and their global significance. Astronomical theory of glaciation—Milankovitch cycles and its appreciation. **(20 hours)**

MODULE III:

Quaternary dating methods– Radiocarbon, Uranium series, Luminescence– TL & OSL, Dendrochronology, Varve chronology, Lichenology and layers in Ice cores.

Relative dating methods – Using surface weathering, Amino acids and obsidian hydration. Techniques for establishing age equivalence - Oxygen isotope chronostratigraphy, Tephro chronology and using paleosols. **(20 hours)**

MODULE IV:

Quaternary stratigraphy in Indian subcontinent– continental records (fluvial, glacial, aeolian, palaeosols and duricrust); marine records. **(12 hours)**

REFERENCE

Bowen, D.Q., 1978, Quaternary Geology, Pergamon Press, New York.
Bradley, R.S., 1985, Quaternary Palaeoclimatology, Allen & Unwin, London.
Krumbein, W.C. & Sloss, L.D., 1963, Stratigraphy & Sedimentation, Freeman.

Freeman & Co. Schoch, R.M., 1989, Stratigraphy--Principles and Methods, Von Nostrand Reinhold, New York.
Solley, R.C., 1972, Ancient Sedimentary Environments, Cornwall University Press.
Tarling, D.H., 1983, Palaeomagnetism, Chapman & Hall.
Thompson, R. & Oldfield, F., 1986, Environmental Magnetism, Allen & Unwin, London

MINERALS RESOURCES OF INDIA

SEMESTER	COURSE CODE	CONTACT/ WEEK	COTACT/ SEMESTER	CREDIT	EXTERNAL MARKS	INTERNAL MARKS
II	MSGEO02E03	4	72	4	48	12

COURSE OUTCOME

At the end of the semester students will be able to: -
CO 1: Appreciate country's fuel resource in terms of their origin and distribution
CO 2: Appraise the ferrous and non ferrous mineral deposits of India
CO 3: Inventory study of non metallic minerals resource of the country.
CO 4: Understand our mineral policy and its updation.

MODULE I

Mineral fuels: Coal resources: Gondwana coal and Tertiary coal. Origin, distribution and economic importance. Petroleum resources. Stratigraphy. structure and economic importance of different petroliferous basins of India. Nuclear fuel in India.

Uranium deposits; Important Uranium fields of India. Reserve and resource of U. Types of U deposits and their distributions in India. Thorium deposits: Important Thorium fields of India. Reserve and resource of Th. Types of Th deposits and their distributions in India. **(20 hours)**

MODULE II

Ferrous metallic minerals; Iron ore deposits – BIF: BMQ and BHQ. Type classification, mineralogy, distribution and state wise reserve of BIF deposits. Manganese deposits - Type classification, mineralogy, distribution and state wise reserve of BIF deposits.

Non ferrous metallic minerals; Type classification, mineralogy, distribution and state wise reserve of Bauxite, Chromium, Gold, Copper. Lead and Zinc **(20 hours)**

MODULE III

Non-metallic deposits – Type, classification, mineralogy, distribution and state wise reserve of Refractory minerals: silica and clay deposits, Kyanite, graphite, asbestos, Magnesite and dolomite. Fertilizer minerals phosphorite and apatite.

Type, classification, mineralogy, distribution and state wise reserve of Placer deposits India: Ilmenite and rutile, monazite, Zircon, Sillimanite, Garnet, silica sands. **(20 hours)**

MODULE IV

Type, classification, mineralogy, distribution and state wise reserve of Minerals used in Cement industry: limestone – gypsum. Minerals used in Chemical industry.

National Mineral policy - Introduction, background and important amendments. **(12 hours)**

REFERENCE

Banerjee (2001), Mineral Resources of India.
Geological Survey of India (2009), Miscellaneous publication no. 30, part-xxii: Geology and mineral resources of India,152p

Geological Survey of India, Detailed information dossier (DID) of ores in India, (Available at GSI portal: www.portal.gsi.gov.in).
Indian Bureau of Mines Bulletins of Mineral Information (availabile at IBM website) Ministry of Mines Annual Report 2011-12, 248p.
Ministry of Mines (2011), Report of the working group on mineral exploration & development (other than coal & lignite) for the 12th five year plan sub group – on survey and mineral exploration, 310p.
Nuclear Power in India Indian Nuclear Energy, http://www.world˜ nuclear.org/info/inf53.html
Prasad, U (2002), Economic Mineral Deposits, CBS Publishers, New Delhi.
Soman, K. (2001), Geology of Kerala, Geol. Soc. of India, Bangalore, 335p.

ELECTIVE COURSE II

MSGEO04E04	**Marine Geology**
MSGEO04E05	**Fuel Geology**
MSGEO04E06	**Mining and Engineering Geology**

MARINE GEOLGY

SEMESTER	COURSE CODE	CONTACT/ WEEK	COTACT/ SEMESTER	CREDIT	EXTERNAL MARKS	INTERNAL MARKS
IV	MSGEO04E04	3	54	3	48	12

COURSE OUTCOME

At the end of the semester students will be able to: -

CO 1: Understanding of the ocean floor morphologic and tectonic domains.

CO 2: Understand physiochemical characteristics and chemistry of seawater and Analyse and explain key parameters such as temperature, salinity, density, light transmission, and sound transmission in seawater.

CO 3: Understand of offshore exploration techniques, including the use of instruments and their measurements and apply these knowledge to conduct offshore exploration and data collection in marine environments.

CO 4: Understand the effects of sea level changes, concept of Carbonate Compensation Depth (CCD), and turbidity currents and turbidites.

CO 5: Analyse and evaluate the global ocean circulation patterns, understand the mechanisms of the Coriolis effect and Ekman spiral, evaluate the crucial role of the ocean in influencing global climate systems

CO 6: Analyse the origin and age of ocean basins, explain the principles of plate tectonics and the formation of various ocean basins. Understand the interactions between seawater and basalt, dynamics of hydrothermal vents and biota associated with the vents.

CO 7: Understand about Law of sea and assess the importance of coastal zone environment protection and its legal frameworks. Understand the factors contributing to marine pollution and control measures, and satellite oceanography.

MODULE 1

Ocean floor: Morphologic and tectonic domains. Bathymetric provinces--Submarine Canyons, Mid-Ocean ridges and Trenches. Morphologic and tectonic domains of Indian Ocean. Physiochemical characteristics and chemistry of sea water: temperature, salinity, density, light transmission, sound transmission in sea water. Gases in sea water. Role of carbon dioxide in keeping the pH of sea water. Formation of sea ice- Gas hydrates.

Instruments used in the study of sea water. Offshore exploration techniques: Instruments and measurements. Ocean floor drilling--JOIDES. Law of the Seas-UNCLOS, EEZ—coastal zone environment and its protection—CRZ Act and CZM plans. Factors of marine pollution and its

controls- Satellite Oceanography- instruments used-properties studied- Oceansat Series.

(25 hours)

MODULE 2

Classification of the marine environment and marine organisms. Physio-chemical factors affecting marine life – light, temperature, salinity, pressure, nutrients, dissolved gases; adaptation and biological processes.

Primary and secondary production; factors controlling phytoplankton and zooplankton abundance and diversity; nekton and fisheries oceanography; benthic organisms; coastal marine communities and community ecology – estuaries, coral reefs and mangrove communities, deep-sea ecology including hydrothermal vent communities. **(20 hours)**

MODULE 3

Marine sediments: Factors controlling deposition and distribution of marine sediments; geochronology of marine sediments. Carbonate Compensation Depth (CCD). Turbidity currents and turbidites. Opening and closing of ocean gateways and their effect on circulation and climate during the Cenozoic. Sea level processes and Sea level changes. Eustatic changes of sea level and its effects.

World ocean circulation patterns— Coriolis effect and Ekman spiral, convergence, divergence and upwelling, El Nino. Thermohaline circulation and oceanic conveyor belt, formation of Bottom waters; major water masses of the world's oceans. Role of ocean in deciding global climate.

(25 hours)

MODULE 4

Origin and Age of ocean basins and plate tectonics- East African rift valley system- Origin of Indian Ocean, Arabian Sea and Bengal Sea-Closure of Ocean basin- Tethys Sea and Rise of Himalayas. Sea water and basalt interaction- hydrothermal vents—vent biota and chemosynthesis.

Palaeooceanography - Approaches to paleoceanographic reconstructions; various proxy indicators for paleoceanographic interpretation. Marine Mineral resources. **(20 hours)**

REFERENCE

Balkema, A.A., 2001, Descriptive Physical Oceanography, Balkema Publishers, Tokyo.

Beer, T, 1997, Environmental Oceanography, CRC Press, New York.

Dickinson, W.R. & Yarborough, H., Plate Tectonics and Hydrocarbon Accumulation

Emery K O & B J Skinner, B.J., Mineral Deposits of the Deep Ocean Floor.

Friedman, G.M. & Sanders, J.E., 1978, Principles of Sedimentology, John Wiley & Sons.

Ghosh, A.K. & Mukhopadhyay, R., 1999, Mineral Wealth of the Ocean, Oxford & IBH Pub. Co., New Delhi.

Gross, G.M., 1967, Oceanography, Merril Physical Science Series.

Gross, G.M., 1995, Principles of Oceanography, VII edn., Prentice Hall.

King, C.A.M., 1979, Introduction to Physical and Biological Oceanography, Edward Arnold.

Pinet, P.R., 2000, Invitation to Oceanography, II edn., Jones & Bartlett.

Prothero, D.R. & Schwab, F, 1996, Sedimentary Geology, W.H.

Freeman & Co. Qasim, S.Z., 1998, Glimpses of Indian Ocean, University Press.

Qasim, S.Z.,1999, The Indian Ocean, Oxford & IBH Pub. Co., New Delhi.

Shepard, F.P, 1963, Submarine Geology, II edn., Harper & Row.

Sverdrup, H.V. et al., 1961, The Oceans, Asia Publishing House.

Weisberg, J. & Parish, H., 1974, Introduction to Oceanography, McGraw Hill.

Edward J. Tarbuck ,Frederick. K Lutgens,1994, Earth Science VII edn,Macmillan college Publishing Company.

FUEL GEOLGY

SEMESTER	COURSE CODE	CONTACT/ WEEK	COTACT/ SEMESTER	CREDIT	EXTERNAL MARKS	INTERNAL MARKS
IV	MSGEO04E05	3	54	3	48	12

COURSE OUTCOME

At the end of the semester students will be able to: -

CO1: Understand the composition, characteristics, and migration of petroleum and gas, as well as the transformation of organic matter into kerogen.

CO2: Recognize the different types of reservoir rocks and traps, and understand the techniques used in prospecting for oil and gas, including drilling and logging procedures.

CO3: Gain knowledge about the oil-bearing basins in India, the geology of productive oil fields, and the position of oil and natural gas resources in the country. Analyze future prospects and the economic scenario of the oil and gas industry.

CO4: Comprehend the definition and origin of coal, sedimentology of coal-bearing strata, and the rank, grade, and types of coal. Understand Indian and international classifications of coal and the macroscopic and microscopic constituents of coal.

CO5: Apply coal petrology in solving industrial and geological problems, and understand the processes of coal carbonization, gasification, and hydrogenation. Explore the potential of coal bed methane as a new energy resource.

CO6: Gain knowledge about atomic fuel, including its mode of occurrence, prospecting methods, and productive geological horizons in India.

CO7: Understand the concept of nuclear power stations and future prospects.

CO8: Familiarize with the formation, occurrence, and potential of gas hydrates and other geologically important fuels.

MODULE I

Petroleum: Composition, fractions, and characteristics-Origin, nature, and migration of oil and gas.-Transformation of organic matter into kerosene.

Surface and subsurface occurrence of petroleum and gas.-Reservoir rocks and traps: Structural, stratigraphic, and correlation characteristics-Prospecting for oil and gas-Drilling and logging procedures. **(15 hours)**

MODULE II

Oil-bearing basins of India-Geology of productive oil fields in India - Position of oil and natural gas in India. Future prospects and economic scenario of oil and gas.

Gas hydrates: Formation, occurrence, and potential as a geologically important fuel- Methane hydrates in marine sediments-Other geologically important fuels: Oil shale, tar sands, and bitumen-Exploration and extraction techniques for gas hydrates and other unconventional fuels.

(15 hours)

MODULE III

Coal: Definition, origin of kerogen and coal-Sedimentology of coal-bearing strata-Rank, grade, and types of coal-Indian and international classifications of coal-Macroscopic ingredients and microscopic constituents of coal-Concepts of macerals and microlitho types.

Chemical characterization: Proximate and ultimate analysis of coal-Coal petrology and its applications-Preparation of coal for industrial purposes-Coal carbonization, gasification, and hydrogenation. **(10 hours)**

MODULE IV

Coal carbonization, gasification, and hydrogenation-Coal bed methane (CBM): A new energy resource-Other geologically important fuels: Shale gas, tight gas, and unconventional oil. Hydrocarbon evaluation

Atomic fuel: Mode of occurrence and prospecting methods in India-Productive geological horizons in India for atomic fuel-Nuclear power stations in the country and future prospects-Mud engineering and drilling fluid-Gas sampling, mud logging, sample catching, and interpretation. **(14 hours)**

REFERENCE

Sharma,N.L. and Ram,K.S.V. (1966), Introduction to the geology of Coal and Indian Coal fields, Oriental Publishers, Jaipur, 148p.

Sharma,N.L. and Ram,K.S.V. (1964), Introduction to India's economic Minerals, Dhanbad Publications, 258p.

Thomas,L. (1984), Hand book of Practical Coal geology, John Wiley& Sons, USA, 338p.

Despande, B.G., 1992, The World of Petroleum, Wiley Eastern Ltd.

Tisso, B.P. & Welta, D.H., 1978, Petroleum Formation and Occurrence, Springer-Verlag.

Van Krogalen, D., 1964, Coal, Elsevier.

MINING AND ENGINEERING GEOLOGY

SEMESTER	COURSE CODE	CONTACT/ WEEK	COTACT/ SEMESTER	CREDIT	EXTERNAL MARKS	INTERNAL MARKS
IV	MSGEO04E06	3	54	3	48	12

COURSE OUTCOME

At the end of the semester students will be able to: -

CO1: Understand the basic mining terminology and the classification of mining methods, including alluvial mining.

CO2: Comprehend the principles of mineral and ore beneficiation, specifically focusing on the principles of ore dressing. This includes knowledge of crushing and grinding (comminution units and practices), sizing, and screening units.

CO3: Gain knowledge of various mining methods, such as open-cast mining, underground mining (including coal mining), deep-sea bed mining, and petroleum mining methods.

CO4: Gain an understanding of the role of geology in civil engineering, including the characteristics and engineering properties of different types of rocks used in construction.

CO5: Develop knowledge and skills in geotechnical investigation for river valley projects, including the selection of dam sites, assessment of foundation rocks, and addressing issues related to grouting, abutment, reservoir problems, and environmental impacts.

CO6:Understand the concepts of seismicity and post-construction challenges such as leakage, seepage, and waterlogging.

CO7: Acquire expertise in geotechnical investigation for infrastructure projects, shoreline engineering structures, encompassing foundation investigations for bridges and multi-storey structures, geotechnical investigations for road and rail alignments in hilly terrains, and tunneling considerations in different geological terrains.

MODULE I

Mining Geology: Basic mining terminology. Classification of mining methods: Alluvial mining. Mineral and Ore Beneficiation: Principles of Ore Dressing: Crushing and Grinding—Comminution units and Comminution practices—Sizing—Screening units.

Open cast mining and Underground mining methods-Coal mining, Deep Sea bed mining and Petroleum mining methods. **(12 hours)**

MODULE II

Methods of Stoping, Shaft sinking, Mine supports, Mine Ventilation. Mine hazards and principles of mine evaluation. Role of geologist at operative mines.

Classifying techniques---Filtering and Drying. Hydrocyclones: Classifiers and Gravity concentration units-- Concentration by Washing, Scrubbing, Jigging, Tabling, Floatation—Froth floatation: Floatation reagents and practices. Magnetic and Electrostatic separation methods. Miscellaneous processes. **(12 hours)**

MODULE III

Geology in Civil Engineering-Rock as a construction material: Igneous, sedimentary, and metamorphic rock-Engineering properties of construction material-Influence of geological factors on engineering properties-Structural discontinuities and their nature of fillings-Rock-water interaction

Stages of geotechnical investigation for river valley projects-Types of dams and general criteria for selecting dam sites-Foundation rocks, topography, and availability of construction materials for dams-Grouting, abutment and reservoir problems-Environmental impact of dams-Seismicity and reservoir-induced seismicity-Post-construction problems: leakage, seepage, and waterlogging **(15 hours)**

MODULE IV

Geotechnical Investigation for Infrastructure Projects:Foundation investigations for bridges-multi-storey structures-Geotechnical investigations for route locations in hilly terrains for road and rail alignments-Classification and terminology of tunnels-Geological factors in tunneling in igneous, sedimentary, and metamorphic terrains

Geotechnical Engineering for Slope Stability-Engineering classification of landslides-Graphical analysis of slope stability- calculation of factor of safety-Causes and prevention of landslides-Hazard zonation mapping and utilization of remote sensing data-Basic engineering and geological principles in shoreline engineering structures-Tsunami-resistant structures-Terrain modeling- lineament, and tectonics. **(15 hours)**

REFERENCE

Arogyaswamy, R.N.P., Courses in Mining Geology, Oxford & I.B.H. Publishing Co.

McKinstry, H.E., 1960, Mining Geology, Asia Publishing House.

Nininger, R.D., 1956, Minerals for Atomic Energy, Von Nostrand.

Peters, W.C., Exploration and Mining Geology, John Wiley

Ball, G.G., 1993, Fundamental of Engineering Geology, Butterworths Pub., London.

Billings, M.P., 1974, Structural Geology, II Edn., Prentice Hall.

Davis, G.H., 1984, Structural Geology of Rocks and Regions, John Wiley & Sons.

Garg, S.K., 1999, Physical and Engineering Geology, Khanna Publishers, New Delhi.

Hills, E.S., 1965, Elements of Structural Geology. I Edn., Asia Publishing House.

Hobbs, B.E., Means, W.D. & William, P.F., 1976, An Outline of Structural Geology, John Wiley.

Kesavulu, N.C., 1993, A Text Book of Engineering Geology, Macmillan India Ltd., New Delhi.

Krynine, D.P. & Judd, W.R., 1957, Principles of Engineering Geology and Geotechniques, McGraw Hill.

Lahee, F.H., 1987, Field Geology, VI edn, McGraw Hill.

Parbin Singh, Engineering and General Geology, Katson Pub. House, Ludhiana, India.

OPEN ELECTIVE/MULTI DISCIPLINARY COURSE

MSGEO03O01	**Climatology**
MSGEO03O02	**Geostatistics**
MSGEO03O03	**Water resource management**

CLIMATOLOGY

SEMESTER	COURSE CODE	CONTACT/ WEEK	COTACT/ SEMESTER	CREDIT	EXTERNAL MARKS	INTERNAL MARKS
III	MSGEO03O01	5	90	5	48	12

COURSE OUTCOME:

At the end of the semester students will be able to: -

CO 1: Understand earth's atmosphere, solar energy, insolation, heat budget, and radiation balance and Earth-Sun relationships.

CO2: Analyse and interpret various atmospheric phenomena, such as latitudinal and seasonal variations in insolation, temperature, pressure, wind belts

CO3: Analyse and interpret atmospheric circulation patterns and various factors affecting atmospheric circulation.

CO4: Understand the process of cloud formation and classification, precipitation mechanism Monsoon system, cyclones and anticyclones, and the El Niño-Southern Oscillation (ENSO)

CO5: Analyse and interpret atmospheric phenomena related to cloud formation, precipitation, weather systems, and global climate patterns.

CO6: Understand about the concept of climate and climate change, consequences of climate change, the ozone layer, ozone depletion, global warming, the greenhouse effect.

CO:7 Analyse and interpret the complex interactions between atmospheric processes, human activities, and the Earth's climate system.

MODULE I

Atmosphere; Composition and its internal structure. Classification based on temperature and chemistry. Solar energy and radiation: Nature of radiation and basic Laws – Stefan Boltzman Law, Kirchhoff's Law, Plank's Law and Weins Displacement Law. Insolation: solar constant, distribution of insolation and factors affecting the distribution of insolation. Earth-Sun relationship. Atmospheric effect on solar radiation: scattering, diffusion, absorption and reflection (albedo). Heat budget and radiation balance: Latitudinal heat balance.

Temperature of the atmosphere: Heat flow mechanisms, heating and cooling of the atmosphere, controls of temperature. Distribution of temperature: Horizontal and vertical distribution of temperatures, temperature inversion and types. Isanomalous temperatures. **(25 hours)**

MODULE II

Atmospheric circulation--Atmospheric pressures and winds. Global pressure belts. Atmospheric motion / wind motion, Factors controlling atmospheric motion: Pressure gradient force, Coriolis force, frictional force, centrifugal action-geostrophic wind, gradient wind and Ekman Spiral.

General circulation of the atmosphere: Scales of atmospheric circulation. Primary, secondary and tertiary circulation. meridional circulation. Primary circulation or planetary wind systems: Inter Tropical Convergent Zone (ITCZ), doldrum, trade winds or tropical easterlies, prevailing westerlies, polar easterlies. Tricircular meridional circulation: Tropical cell/Hadley cell, polar front cell/ Ferrel cell, polar or subpolar cell. Jet streams: origin and types. Rossby waves. **(20 hours)**

MODULE III

Variations in Atmospheric circulation: Walker circulation, El Nino Southern oscillation (ENSO), Secondary circulation: cyclones, anticyclones and fronts. Monsoon system: Concepts of Origin of Monsoon, Indian Monsoon and theory of origin. Cyclones and anticyclones. Tertiary circulation: local and diurnal winds.

Atmospheric humidity, Condensation, forms of condensation: Dew, frost, drizzle, rime, mist, fog and clouds. Cloud classification. Precipitation: Precipitation mechanisms: Bergeron, Findeisen process, coalescence process. Forms of precipitation, types of precipitation. Artificial precipitation.

(25 hours)

MODULE IV Climate: Climate change through geological time. Indicators of past climate. Classification of climates – Koppen's and Thornthwaite's scheme of classification. Climate change: causes of climate change – Natural and anthropogenic causes.

Ozone layer: Ozone creation and destruction in the stratosphere. Chapman reaction. Ozone depletion. Ozone hole. Greenhouse gases. Global Warming and Green House Effect—its consequences.

(20 hours)

REFERENCE

Bradley, R.S., 1985, Quaternary Palaeoclimatology, Allen & Unwin, London
Edward J. Tarbuck ,Frederick. K Lutgens,1994, Earth Science VII edn,Macmillan college Publishing Company.
Herbert Riehl 1978, Introduction to the Atmosphere, III edn.
MacGraw Hill Howard,J Critchfield,2002, Genaral Climatology-Fourth Edition,Prentice Hall.
Savindra Singh, 2005,Climatology, Prayag Pustak Bhavan.
Siddartha.K, Climatology(Atmosphere, Weather and Climate) Kithab Mahal.
William James Burroughs, 2001, Climate change,A multidisciplinary Approach, Cambridge University Press.

GEOSTATISTICS

SEMESTER	COURSE CODE	CONTACT/ WEEK	COTACT/ SEMESTER	CREDIT	EXTERNAL MARKS	INTERNAL MARKS
III	MSGEO03O02	5	90	5	48	12

COURSE OUTCOME:

At the end of the semester students will be able to: -

CO1: Understand the fundamental concept of statistics.

CO2: Understand the basic concept of probability and descriptive statistics.

CO3: Understand and analyse the basic statistical tests.

CO4: Apply variogram analysis, spatial estimation, and spatial relationship. krigging and uncertainty analysis of statistical data.

CO5: Expertise in data processing, interpretation, statistical testing and modelling in professional career in Geology.

MODULE I

Classification, tabulation, diagrammatic and graphical representation of data. Measures of location and dispersion: Measures of central tendency: Arithmetic Mean, Geometric Mean, Harmonic Mean, Median, Mode, Quartiles. Measures of dispersions: absolute and relative measures, Range, Mean Deviation, Standard Deviation, Variance, Coefficient of Variation. Measures of Skewness and Kurtosis.

Statistical surveys: Sampling and census. Important methods of sampling--simple, random, systematic, hierarchical and stratified sampling. Correlation: Karl Pearson correlation coefficient,

Spearman rank correlation coefficient. Multiple and partial correlations, Regression – simple linear regression. Principles of least square, fitting the polynomial and exponential curve. **(25 hours)**

MODULE II

Definition of Probability. Addition and multiplication theorem of probability. Conditional probability. Random variable. Probability mass function and probability density function. Distribution function. Mathematical expectation. Expectation of a random variable. Mean and variance of random variables. Standard distributions: Binomial, Poisson and Normal. Sampling distributions: t, F and Chi-square. **(15 hours)**

MODULE III

Point estimation of parameters. Maximum likelihood estimation. Interval estimation of parameters. Concept and methodology of hypothesis testing. t, F and Chi-square test. Tests of Significance: basic concepts of statistical inference and standard error.

Large sample tests and small sample tests: test for population mean(s), variance(s) (one and two samples) F-test. Testing the significance of a correlation coefficient. Contingency tables and testing the independence of attributes. Analysis of variance: One way and two way classification.

(25 hours)

MODULE IV

Need for statistical analysis. Type of spatial data. Geo statistical data, Lattice data, Point pattern. Auto correlation concept and elementary measurements. Localized indicators spatial auto correlation. Cross validation. Variogram analysis. Krigging and co krigging and uncertainty analysis. Calculation of drift. Spectral analysis and filters. Analysis of multivariate data – Multiple regression, discrimination function, Cluster analysis and R and Q mode of factor analysis.

Role of interpolation. Global and local deterministic method. Moving average, Inverse distance interpolation. Optimal interpolation using Geo statistics. Variogram interpolation. Krigging interpolation – Ordinary krigging, Block krigging, Non linear krigging, Stratified krigging, Co-krigging, Universal krigging and Probabilistic krigging. **(25 hours)**

REFERENCE

Krumbein, W.E. & Gray Hill, F.A., 1965, Introduction to Statistical Methods in Geology, McGraw Hill.

Miller, R.L & Khan, T.S., 1962, Statistical Analysis in the Geological Analysis, Wiley. Moroney, K.J., 1952, Facts from figures, Penguin.

Issac H Edward and Srivastava, Mohan (1989) Applied Geostatistics, Oxfrod University press, Newyork.

Anderson T W., Multivariate Statistical Analaysis., John Wiley and Sons Inc.

Johnson Richard A and Wichern Dean., Applied Multivariate Statistical Analysis., Prentice Hall, Pearson

Taneja., H C. Statistical Merhods for Engineering and Sciences. I K International Publishing House Pvt Ltd.

Lipshutz Seymour and Schiller John., Introduction to Probability and Statistics

WATER RESOURCE MANAGEMENT

SEMESTER	COURSE CODE	CONTACT/ WEEK	COTACT/ SEMESTER	CREDIT	EXTERNAL MARKS	INTERNAL MARKS
III	MSGEO03O03	5	90	5	48	12

COURSE OUTCOME

At the end of the semester students will be able to: -

CO1: Understand the hydrologic cycle, climate factors, drainage pattern and river Basins, data, tools and methods of hydrological analysis.

CO2: Understand the groundwater system, hydrogeological properties of water bearing rocks, subsurface water flow and well hydraulics.

CO3: Basic understanding of water reservoirs and management.

CO4: To study the flood management, hydrologic analysis and design.

CO5: Understand draught management and water harvesting.

CO6: Study the hydroelectric power and water resources planning and development.

CO7: Understand water resource development and management practices to conserve water.

MODULE I

Introduction, Hydrologic cycle, Climate and water availability, Water balances, Precipitation: Forms, Classification, Variability, Measurement, Data analysis, Evaporation and its measurement, Evapotranspiration and its measurement, Penman Monteith method. Infiltration: Factors affection infiltration, Horton's equation and Green Ampt method.

Hyetograph and Hydrograph Analysis: Hyetograph, Runoff: drainage basin characteristics, Hydrograph concepts assumptions and limitations of unit hydrograph, Derivation of unit hydrograph S hydrograph, Flow duration curve. **(20 hours)**

MODULE II

Groundwater and Well Hydraulics: Occurrence and movement of groundwater, Darcy's law, governing ground water flow equations, Factors governing ground water flow, Types of aquifers, porosity, specific yield, specific retention, storage coefficient, permeability, hydraulic conductivity, hydraulic transmissibility, Conjunctive use and its necessity.

Reservoir: Types, Investigations, Site selection, Zones of storage, Safe yield, Reservoir capacity, Reservoir sedimentation and control. **(20 hours)**

MODULE III

Flood Management: Indian rivers and floods, Causes of flooding, Alleviation, Levees and floodwalls Flood ways, Channel improvement, Flood damage analysis.

Hydrologic Analysis and Design: Design flood, Flood estimation, Frequency analysis, Flood routing through reservoirs and open channels, Storm drainage design. **(25 hours)**

MODULE IV

Drought Management and Water Harvesting: Definition of drought, Causes of drought, measures for water conservation an augmentation, drought contingency planning. Water harvesting: rainwater collection, small dams, runoff enhancement, runoff collection, ponds, tanks, natural and artificial ground water recharge methods.

Hydroelectric Power and Water Resources Planning and Development: Introduction, Components of Hydroelectric Power Plant, Levels in planning, Functional requirements of water resources projects, steps in water resources planning, Environmental aspects in water resources planning. **(25 hours)**

REFERENCE

Cech Thomas V. (2003). Principles of water resources: History, development, management and policy. John Wiley& Sons.

Todd, D.K. (2004) Ground Water Hydrology, John Wiley & Sons, 636p.

Karanth, K.R. (1987) Groundwater Assessment, Development and Management. Tata McGraw Hill, New Delhi, 720p. • Mays, L.W. Water resource engineering, John Wiley& Sons

Linsley R.K and Franzini J.B (1979) Water resource engineering, McGraw-Hill

Mays L.W. (1996) Water resources hand book, McGraw-Hill.

Jain S.K. and SnghV.P.,Water resources system planning and Management Elsevier

Walton, W.C. Ground Water Resources evaluation, McGraw-Hill.

ANNEXURE I

1. Guidelines for the preparation of dissertation on project:

Two copies of the thesis has to be submitted to the department. One the copies will be sent to the institution library for the reference of future students.

- **Arrangement of contents shall be as follows:**
  1. Cover page and title page
  2. Bonafide certificate
  3. Declaration by the student
  4. Acknowledgement
  5. Abstract
  6. Table of contents
  7. List of tables
  8. List of figures
  9. List of symbols, Abbreviations and Nomenclature
  10. Chapters
  11. Appendices (if any)
  12. References

- **Page dimension and typing instruction:**

The dimension of the dissertation on project should be in A4 size. The dissertation should be typed in bond paper and bound using flexible cover of the thick white art paper or hard binding. The general text shall be typed in the font style **'Times New Roman'** and font size 12. Portrait orientation shall be there on left and right of the page.The content of the report shall be around 40-100pages.

- **Margins**

A margin of 35 mm is to be provided on left and right sides, whereas top and bottom margins should be 30 mm. No print matter should appear in the margin except the page numbers. All page numbers should be centered inside the bottom margin, 20mm from the bottom edge of the paper.

- **Font**

Times New Roman (TNR) 12 point font has to be used throughout the running text. The captions for tables and figures should have font size of 11 and foot notes should be set at font size 10. Font sizes for various levels of headings are given in section.

- **Line Spacing**

The line spacing in the main text should be 1.5. Single line spacing should be given for quotations, abstract, figure captions, table captions, figure legends, footnotes, and references. The equations, tables, figures, and quotations should be set off from the main text both before and after with spacing of 1.5. Two consecutive paragraphs should be separated by triple line spacing.

- **Chapter title**

Chapter title should be -CENTERED TNR 17-POINT BOLD ALL CAPS

- **Section Heading**

Left aligned with number, TNR 17 points, bold and leading caps
(First section heading in chapter 2 numbered 2.1)

- **Second level section heading**

Left aligned with number, TNR 14 points, bold and sentence case.
(First secondlevel section heading in chapter 2 numbered 2.1.1)

- **Third level section heading**

Left aligned with number, TNR 12 points, bold and sentence case.
(First third leval section heading in chapter 2 numbered 2.1.1.1)

- **Fourth-level section heading**

Numbered subsections beyond third level are not recommended. However, fourth-level subsection headings may be included without numbering, TNR 12-point font, left aligned and italicized.
Running text should be set in 12-point TNR and fully justified. First line of paragraph should have indentation of 15 mm.

2. Bonafide certificate shall be in the following format

CERTIFICATE

This is to certify that the project entitled .....(title) submitted to the Kannur University in partial fulfilment of the requirements of Post Graduate Degree in .....(subject), is a bonafide record of studies and work carried out by .....(Name of the student) under my supervision and guidance.

Office seal

Signature,
Name, designation and official address of the Supervisor.

Date

3. Declaration by the student shall be in the following format:

DECLARATION

I.....(Name of the candidate) hereby declare that this project titled .....(title) is a bonafide record of studies and work carried out by me under the supervision of .....(Name, designation and official address of the supervisor) , and that no part of this project , except the materials gathered from scholarly writings, has been presented earlier for the award of any degree or diploma or other similar title or recognition.

Date:

Signature and name of the student

ANNEXURE II

QUESTION PAPER PATTERN

Part	No of questions to be answered		Marks	Percentage
A	No of Questions in the QP	6	6	13%
	No of Questions to be answered	6		
	Marks of each question	1		
B	No of Questions in the QP	5	15	31%
	No of Questions to be answered	3		
	Marks of each question	5		
C	No of Questions in the QP	5	27	56%
	No of Questions to be answered	3		
	Marks of each question	9		
Total mark			**48 mark**	**100 %**

Total Number of questions	= 6 + 5 + 5	= **16**
Number of questions to be answered	= 6 + 3 + 3	= **12**
Total Marks in the question paper	= 6×1 + 5×5+ 5×9	= **76**
Difference in marks	= 76 - 48	= **28**

COGNITIVE LEVEL OF QUESTIONS AS PER REVISED BLOOM'S TAXONOMY

PART	REVISED BLOOMS TAXONOMY LEVEL	COGNITIVE LEVEL
A	1 and 2	Remembering Understanding
B	6	Creating
C	3, 4 and 5	Applying Analysing Evaluating

ANNEXURE III

MODEL QUESTION PAPERS

KANNUR UNIVERSITY

I SEMESTER MSc PROGRAMME IN GEOLOGY

MINERALOGY AND GEOCHEMISTRY

Time: 3 Hours **Total marks: 48**

Part – A (Answer all the questions)

1. What is pleochroism, and how does it help in mineral identification?
2. Classify dispersion in minerals.
3. What are distinguishing features Kaoline group of clay minerals?
4. What is the Oddo-Harkin Law
5. Explain the geochemical classification of elements.
6. Describe the principles behind X-ray fluorescence spectroscopy.

(6*1 mark = 6 mark)

Part – B (Answer any three)

7. X-ray diffraction and how it is used in crystallographic analysis.
8. Elaborate the concept of interference colors in minerals and their relationship to thickness and birefringence.
9. Assess the concept of optic axes and how they are related to the optical indicatrix of biaxial minerals.
10. Create an Eh-PH diagram illustrating the mobility of elements in different environments.
11. Design a research project that integrates various analytical techniques to investigate a specific geochemical problem.

(3*5 mark = 15 mark)

Part – C (Answer any three)

12. Discuss the occurrence, formation, and geological significance of amphibole group of minerals
13. Discuss the principles and instrumentation involved in conoscopic observation of minerals.
14. Compare and contrast the geochemistry of the Earth's crust, mantle, and core, highlighting their major elemental compositions and processes.
15. Discuss the concept of the geochemical cycle and its role in the cycling of elements in the Earth's systems.
16. Evaluate the significance of radiogenic isotopes in understanding the origin and evolution of magma

(3*9 mark = 27 mark)

KANNUR UNIVERSITY

I SEMESTER MSc PROGRAMME IN GEOLOGY

STRATIGRAPHY AND MICRO PALAENTOLOGY

Time: 3 Hours **Total marks: 48**

Part – A (Answer all the questions)

1. Define GSSP and describe its importance?
2. Write a short note the petrography of Closepet granite?
3. Differentiate between geochronology and chronostratigraphy?
4. Identify the criteria for the first hand division of microfossils?
5. Differentiate Formanifers and Radiolaria?
6. Illustrate the external morphologic characters of Ostracode through figure?

(6*1 mark = 6 mark)

Part – B (Answer any three)

7. Create logically your own model for evolution of Geologic Time Scale?
8. Generate a tabular chronological sequence for evolution of early crust?
9. Hypothesize the different possibility of mass extinction of Earth in near future?
10. Integrate the idea of application of microfossils in petroleum exploration along with sequence stratigraphy?
11. Specify the stratigraphic importance of Dinoflagellates?

(3*5 mark = 15 mark)

Part – C (Answer any three)

12. Demonstrate how the physical property of rocks helps in establishing the seismic stratigraphy? Also give an idea of principles of seismic stratigraphy?
13. Justify the arguments relating the mass K T boundary mass extinction by meteorite impact?
14. Illustrate the idea of mobile belt evolution with special reference to Pandian MB?
15. Review the scope of pollens and spores in petroleum exploration?
16. Distinguish Classification, morphology and stratigraphic importance of Benthic and planktonic formanifera, **(3*9 mark = 27 mark)**

KANNUR UNIVERSITY

I SEMESTER MSc PROGRAMME IN GEOLOGY

STRUCTURAL GEOLOGY

Time: 3 Hours **Total marks: 48**

Part – A (Answer all the questions)

1. Define homogeneous strain.
2. What makes mullions and buckle folds similar?
3. What is stress ellipsoid?
4. What are conical folds?
5. Why do normal faults tend to be steeper than reverse faults?
6. What is the difference between angular shear and shear strain? **(6*1 mark = 6 mark)**

Part – B (Answer any three)

7. Plan geological mapping in a metamorphic terrain.
8. Discuss kinematic analysis. What happens to the principal strain axes during pure shearing?
9. Construct types of fold based on Ramsay classification.
10. Discuss strain indicators of shear zones.
11. Compare classic boudinage and foliation boudinage.

(3*5 mark = 15 mark)

Part – C (Answer any three)

12. Analyze the role of stress and strain in structural geology. Discuss the different types of stress and strain and their influence on the formation of geological structures.
13. Examine the kinematic and dynamic aspects of faulting and fracturing in structural geology. Discuss the factors influencing fault behaviour, the mechanics of fracture propagation, and the implications for earthquake studies.
14. Propose how are various lineations defined and how do they develope?
15. Appraise the main causes of foliation development in rocks? How does foliation relate to the deformation history of rocks? Justify the use of foliation patterns to determine the tectonic history of a region.
16. Discuss classification of faults based on their mechanism of origin. Elaborate methods used to study and analyze faults in the field?

(3*9 mark = 27 mark)

KANNUR UNIVERSITY

I SEMESTER MSc PROGRAMME IN GEOLOGY

IGNEOUS AND METAMORPHIC PETROLOGY

Time: 3 Hours **Total marks: 48**

Part – A (Answer all the questions)

1. Short note on types of magma?
2. Diagrammatic representation of Bowens reaction series?
3. Differentiate solid solution and ex solution?
4. List the different agents for causing metamorphism.
5. Define metasomatism
6. Define isograds and reaction isograds.

(6*1 mark = 6 mark)

Part – B (Answer any three)

7. Design a melting – crystallization experiment for An- 20 wt%, Wo- 35 wt% and Si- 45 wt%?
8. Explain the importance of different variation diagrams in establishing the genetic significance of igneous suits?
9. Investigate the granulite facies rocks with special reference to charnockites in the Southern Granulite Terrain. Discuss their petrogenesis, mineralogy, and tectonic implications within this specific geological context.
10. Design a flowchart that illustrates the step-by-step process of conducting geothermobarometry to determine the pressure and temperature conditions during metamorphism.

(3*5 mark = 15 mark)

Part – C (Answer any three)

12. Examine the textural and mineralogical changes encounter in both equilibrium and in equilibrium crystallization of Al- An- Di system?
13. Relate basaltic magmatism at MOR and OIC?
14. Analyse the various textures and structures of metamorphic rock and interpret the various metamorphic processes that have caused their formation.
15. Examine the role of fluids in metamorphism and their influence on metasomatism and skarn formation.
16. Examine the significance of phase rule in determining the stability and mineral assemblages in metamorphic rocks. **(3*9 mark = 27 mark)**