Course-Curriculum for
Master of Science
in
Applied Geology

Based on
National Education Policy (NEP-2020)

Effective from 2022-23

Department of Earth Science
Aryabhatta School of Earth Sciences
Assam University,
Silchar -788011

2023

Structure of PG Syllabus as per NEP-2020

[A] Composition of Course Curriculum

Sl	**Course Components**	**Nature**	**Total Credit**	**Nature of offering**
1	Core Course **(CC)**	Compulsory (Discipline specific)	32-36	To be offered by the parent Department
2	Elective Core Course **(ECC)**	Discipline Specific Elective Courses	8-12	To be opted from a list of courses offered by the parent Department
3	Dissertation (Research Project)	Compulsory (Discipline specific)	13	Research Project
4	Interdisciplinary Core Course **(IDC)**	Interdisciplinary Elective Courses	7	To be opted from the parent department/allied Departments approved by the parent Department
5	Apprenticeship/Laboratory /Internship/Field **(ALIF)**	Discipline Specific Courses	9	To be offered by the parent Department
6	Skill Enhancement Course **(SEC)**	Skill based course	3	Courses offered or identified by the parent Department as Skill Enhancement Course
7	Value Based Course **(VBC)**	Value Based Course	2	May be decided at school level
8	Compulsory Community Engagement Course **(CCEC)**	Compulsory	2	1 Credit for Classroom and Tutorials and 1 Credit for Field Engagement
	Total		**80**	

Note:

1) Students may be allowed to opt certain courses (approved by the parent Department) from SWAYAM (and other approved platforms) after implementation and deployment of necessary Academic Credit Transfer facility by the University.

2) Minimum number of credits earned by a student in (CC+ECC+ Dissertation+IDC) should not be less than 64 and the minimum credit earned in Core Course (CC) should not be less than 32.

[B] PG Course Curriculum

First Semester

Paper Code	*Description*	*Credit*	*Hours/Week*	*Marks*
500	Orientation	Nil		
501	Core (CC)	4	4	100
502	Core (CC)	4	4	100
503	Core (CC)	4	4	100
504	SEC	3	3	100
505	ALIF	3	6	100
506	CCEC	2	2	100
Total		**20**	**23**	**600**

Second Semester

Paper Code	*Description*	*Credit*	*Hours/Week*	*Marks*
551	Core (CC)	4	4	100
552	Core (CC)	4	4	100
553	Core (CC)	4	4	100
554	IDC	3	3	100
555	ALIF	3	6	100
556	VBC	2	2	100
Total		**20**	**23**	**600**

Third Semester

Paper Code	*Description*	*Credit*	*Hours/Week*	*Marks*
601	Core (CC)/ Elective (ECC)	4	4	100
602	IDC	4	4	100
603	Elective (ECC)	4	4	100
604	ALIF	3	6	100
605	Dissertation (Research Project Part I)	5	10	100
Total		**20**	**28**	**500**

Fourth Semester

Paper Code	*Description*	*Credit*	*Hours/Week*	*Marks*
651	Core (CC)	4	4	100
652	Core (CC)	4	4	100
653	Elective (ECC)	4	4	100
654	Dissertation (Research Project Part II)	8	16	200
Total		**20**	**28**	**500**

[C] Percentage distribution of Course Components

Sl	**Course Components**	**Total Credit**	**Grouped Credit**	**%age of Credit**	**Remarks**
1	Core Course **(CC)**	36	57 (71% of 80 and 89% of 64)	64 (80% of 80)	
2	Elective Core Course **(ECC)**	8			
3	Dissertation (Research Project)	13			
4	Interdisciplinary Core Course **(IDC)**	7	7 (11% of 64)		
5	**ALIF**	9		9 (11% of 80)	
6	Skill Enhancement Course **(SEC)**	3		3 (3.75% of 80)	
7	Value Based Course **(VBC)**	2		2 (2.5% of 80)	
8	Compulsory Community Engagement Course **(CCEC)**	2		2 (2.5% of 80)	
	Total	**80**		**100%**	

Course Structure of M.Sc. in Applied Geology

First Semester

Course Type	Paper Code	Title of the paper	Credit	Mark distribution		
				Sem End	Sessional	Total
Orientation	ESC-500	Orientation	Nil			
CC	ESC-501	Mineralogy and Igneous Petrology	4	70	30	100
	ESC-502	Palaeontology and Remote Sensing	4	70	30	100
	ESC-503	Geomorphology and Sedimentology	4	70	30	100
SEC	ESC-504	Structural Geology (I) and Stratigraphy of NE India	3	70	30	100
ALIF	ESC-505	Practical and Basics of Field Work	3	70	30	100
CCEC	ESC-506	Community Engagement	2	70	30	100
		Total Credit	**20**	**Total Marks**		**600**

Second Semester

Course Type	Paper Code	Title of the paper	Credit	Mark distribution		
				Sem End	Sessional	Total
CC	ESC-551	Metamorphic Petrology and Geochemistry	4	70	30	100
	ESC-552	Principles of Stratigraphy and Applied Palaeontology	4	70	30	100
	ESC-553	Hydrogeology and Advanced Sedimentology	4	70	30	100
IDC	ESC-554	Essentials of Earth System Sciences	3	70	30	100
ALIF	ESC-555	Practical	3	70	30	100
VBC	ESC-556	Fuel Geology (Coal, Petroleum and Atomic Minerals)	2	70	30	100
		Total Credit	**20**	**Total Marks**		**600**

Third Semester

Course Type	Paper Code	Title of the paper	Credit	Mark distribution		
				Sem End	Sessional	Total
CC	ESC-601	Optical mineralogy and Advanced Igneous Petrology	4	70	30	100
IDC	ESC-602	Environmental Geology	4	70	30	100
ECC	ESC-603	(i) Instrumentation techniques in Earth Science (ii) Geophysics and Geoinformatics	4	70	30	100
ALIF	ESC-604	Practical and Field work	3	70	30	100
Dissertation (Research Project)	ESC-605	Project Oriented Dissertation (Part I)	5	70	30	100
		Total Credit	**20**	**Total Marks**		**500**

Fourth Semester

Course Type	Paper Code	Name of the paper	Credit	Mark distribution		
				Sem End	Sessional	Total
CC	ESC-651	Structural Geology (II) and Indian Stratigraphy	4	70	30	100
CC	ESC-652	Ore Geology and Mining Geology	4	70	30	100
ECC	ESC-653	(i) Seismology and Exploration Geology (ii) Engineering Geology and Geo-hazards	4	70	30	100
Dissertation (Research Project)	ESC-654	Project Oriented Dissertation (Part II)	8	140	60	200
		Total Credit	**20**	**Total Marks**		**500**

PROGRAMME OUTCOMES (POs)

- Enabling the students to understand the age, origin, evolution, nature, composition, structure and processes (endogenic and exogenic) of the Earth.

- Enabling the students to identify minerals, rocks, and fossils which provide insights into the composition, structure, and paleoenvironment of the Earth, and life that thrived on it through the geological ages.

- Enabling the students to explore and locate various Earth resources including minerals/metals, fossil fuel and natural gas, coal and atomic minerals etc. and judiciously exploit and manage the resources.

- To impart knowledge to the students on optimum harnessing of the earth resources without adversely affecting the geo-environment, and also to analyse the vulnerability of any terrain to various types of geo-hazards.

- To make students understand the suitability of any terrain for various civil engineering constructions such as dams, reservoirs, bridges, tunnels, roads, railway lines and buildings etc.

- To instil in them the quest for better understanding of the subject through continued pursuance and research and motivating them to take up and address the geo-scientific problems affecting the society.

First Semester

ESC-500: **Orientation Course**

(Credits Nil; one- two weeks; Marks: Nil)

Attendance: minimum 70% of the classes to pass the course

Course Objectives:

1. To make aware the students about the academic and research environment of the University, along with the departmental facilities, resources and activities.
2. To guide the students for a purposeful learning during their complete tenure of programme.
3. To make the students aware about their curriculum, evaluation process, academic flexibility and extracurricular activities
4. To enlighten the students about quality of education, feedback mechanisms, grievance redressal, discipline and their rights and duties.

Course Learning Outcomes:

The course will enable the students to be aware of their overall learning procedure, resources, and methods for their optimum use.

Evaluation:

This will be a non-credit course, with contact duration spread over minimum one week, and maximum of two weeks. The student must attend 70% of the classes to pass the course, and there shall be No test or Exam. Classes for orientation course will run along with the normal classes.

Mode of teaching: Interaction with experts/faculty members, discussions through physical/online mode, exchange of materials - digital lectures, documents, guidelines.

Topics for interaction:

1: About the University and Department, mutual expectations of students and department to achieve Mission of Department / University. Student behaviour and discipline, anti-ragging campus, Placements

2: Curricular aspects and evaluation process, online registration processes, Scholarships and Awards, safety / lab-safety/ biosafety at workplace.

3: Feedback mechanisms, Quality framework and role of students, Mentor and mentee system, Green campus initiatives, Waste management and Zero-plastic use in the campus.

4: Library activities, extracurricular activities, University facilities for students and its maintenance, Student Union, Rights and Duties of the students.

5: Grievance redressal system, Gender issues and sensitization, Ethics in education, Protocols for emergencies like natural disasters and fire at workplace.

ESC-501: **Mineralogy and Igneous Petrology**

(Credits 4; 60 Hrs; Max. Marks: 100 = 70 End Sem. + 30 sessional)

Course Objectives:

1. To introduce the fundamentals of crystal chemistry.
2. To enlighten the principles governing the arrangement of atoms to form crystal structures.
3. To provide detail understanding on Silicate minerals.
4. To provide understandings on the nature of magma, generation of magma and processes of magma differentiation.
5. To make students familiar with different types of igneous rocks.

Course Learning Outcomes:

1. Students will learn the crystal chemistry, rules for development of atomic structures in silicate minerals.
2. Students will be able identify mineral phases based on physical and optical properties.
3. Students will obtain sound knowledge on magma generation processes, crystallization mechanisms and diverse types of igneous rocks.
4. The course content will help students to prepare themselves for various competitive examinations.

UNIT I: Introduction to crystal chemistry: bonding in minerals, solid solution, exsolution, polymorphism, isomorphism, pseudomorphism, polytypism, polysomatism; Atomic and Ionic radii, Pauling's rules governing the ionic structures; Spheres in closest packing: Cubic closest packing, Hexagonal closest packing, Body centred cubic packing. Physical properties of mineral.

UNIT II: Structure & Classification of Silicate minerals. Detailed study of following mineral groups with reference to their general formulae, classification, atomic structure, chemistry, diagnostic physical and optical properties, PT stability, alteration and occurrences: a. Nesosilicates: Olivine Group, Garnet Group, Aluminosilicate Group (Kyanite, Andalusite, and Sillimanite).

UNIT III: Detailed study of following mineral groups with reference to their general formulae, classification, atomic structure, chemistry, diagnostic physical and optical properties, P-T stability, alteration and occurrences: a. Inosilicates: Pyroxene Group; Amphibole Group, b. Phyllosilicates: Kaolinite Group; Serpentine Group; Mica Group; Chlorite Group, c. Tectosilicates: Feldspar Group.

UNIT IV: Heat flow, geothermal gradient; source, origin and nature of Magma; Physical properties of magma: Factors influencing physical properties of magma, ascent and emplacement of magma; Magmatic differentiation processes: Partial melting, fractional crystallization, magma mixing, assimilation, liquid immiscibility. Forms, Textures and structures of igneous rocks.

UNIT V: IUGS mineralogical and chemical classification schemes of igneous rocks; Petrogenesis of Felsic and Mafic igneous rocks: Granitoids, Basaltic rocks, Alkaline rocks, peridotites and kimberlites.

Books Recommended:

L.G. Berry, B. Mason, and R.V.Dietrich, Mineralogy, CBS Publishers.
E.S. Dana, and W.E. Ford, A textbook of Mineralogy. Wiley Eastern Limited.
W.A., Deer, R.A. Howie, & J.Zussman: An Introduction to the rock forming minerals, Longman
Myron G. Best, 2002: Igneous and Metamorphic Petrology, Blackwell Science.
M. K. Bose, 1997: Igneous Petrology, World Press, Kolkata.
John D. Winter, 2009: Principles of Igneous and Metamorphic Petrology (2nd Edition).

ESC-502: **Palaeontology and Remote Sensing**

(Credits 4; 60 Hrs; Max. Marks: 100 = 70 End Sem. + 30 sessional)

Course Objectives:

1. To carry out critical analysis of different mega and micro-invertebrates.
2. To know distribution of plant fossil through time and space.
3. To know the evolutionary trend and change of vertebrates.
4. To apply the functional morphological techniques to fossil groups.
5. To understand the principles & applications of remote sensing, its capabilities and limitations.
6. To understand the basic techniques of areal photography.

Course Learning Outcomes:

1. Students will have the working knowledge for every group of fossils.
2. They will be able to identify all groups of fossils.
3. They can carry out analysis on evolution, functional morphology etc.
4. Students will learn the fundamentals of remote sensing techniques.
5. They will have the knowledge of different laboratory techniques to interpret the images and extract information by visual interpretation and by making measurements.
6. Students will learn the applications of remote sensing in different fields and especially in geology.

UNIT I: Functional morphology and evolutionary history of Brachiopods, Molluscs and Echinoids. Variations in pedicle opening in brachiopods; variation in occulogenital system and ambulacral plates in echinoids.

UNIT II: Introduction to Micropalaeontology, Foraminifera: brief morphology and classification. Morphology and classification of Ostracoda, Radiolaria, Introduction to dinoflaggellates and its significance. Palynology including spore/pollen morphology and their applications.

UNIT III: Plant diversity through time, significance of Gondwana Flora. Vertebrate body plan, major evolutionary events of vertebrates; evolution of Horses, Elephant, Hominid.

UINT IV: Electromagnetic spectrum; electromagnetic bands in remote sensing; spectral signatures of soil, rock, water and vegetation; thermal, near infrared and microwave remote sensing; digital image processing; LANDSAT, IRS and SPOT characteristics and use.

UNIT V: Aerial photography: Planning and Execution, types of aerial photography; Aerial photos: classification, scale, resolution, stereoscopic parallax, image displacement; Elements of image and photo interpretations, Interpretations keys.

Books Recommended:

A. R. Loeblich, Jr. and Helen Tappan, 1998: Foraminiferal Genera and their classification: Van Nostrand Reinhold Company, New York

Arnold, 2002: Quaternary Environmental Micropaleontology (Ed. S. K. Haslett), Oxford Univ. Press, NY

M.J. Benton, 1990: Vertebrate Paleontology. Unwin Hyman, London

Bignot, G., Grahm and Trottman, 1985: Elements of Micropaleontology, London

R.S., Boardman, A.M. Cheethan, and A.J. Rowell, 1988: Fossil Invertebrates, Blackwell

E.N.K. Clarksons, 1998: Invertebrate Paleontology and Evolution, Allen and Unwin

E.H. Colbert, 1984: Evolution of Vertebrates. Willey Eastern Ltd

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

D.R. Prothero, 2004: Bringing Fossil to Life- An Introduction to Paleontology (2nd Ed.), McGraw Hill

D.M. Raup, and S.M Stanley, 2008: Earth System History, Blackwell Publ.

Jim Ellis and Floyd Sabins, 2020: Remote Sensing Principles and Applications; (4th Ed.) Waveland Press.

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

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

D.P. Paine, 1981: Aerial Photography and Image Interpretation for Resource Management, Wiley.

ESC-503: **Geomorphology and Sedimentology**

(Credits 4; 60 Hrs; Max. Marks: 100 = 70 End Sem. + 30 sessional)

Course Objectives:

1. To understand the mechanism of geomorphic processes and the relationships between properties of earth materials and the forces applied to them by gravity, wind, ice, and water.
2. To introduce geomorphological processes responsible for development and modification of different landforms.
3. To introduce the fundamentals of fluid flow, fluid- sediment interaction and resultant bedforms and texture and structure of clastic sedimentary rocks.
4. To know the development and sedimentation history of basins in conjunction with different tectonic regimes.
5. To understand the petrogenetic evolution of siliciclastic and carbonate rocks and associated paleoclimatic indicators.

Course Learning Outcomes:

1. Students will be able to identify the major and minor landforms on the Earth's surface and interpret the processes responsible for their formation.
2. Students will understand the evolution of hillslopes and associated processes.
3. Students will understand the role of fluid-sediment interaction processes to develop bedforms.
4. Students will learn sedimentation history of siliciclastic and carbonate rocks and their importance in paleoclimatic studies.

UNIT I: Introduction to Geomorphology; Control of geomorphological features by geological structure, lithology and climate. Physical, chemical, and biological processes in weathering; Soil profiles and nomenclature of horizons. Classification of soils, Role of soil in geomorphology.

UNIT II: Geomorphic processes; Fluvial, Glacial, Coastal landforms; Models of Landform evolution, Davis' Model, Penck's Model, King's Model; Tectonic Geomorphology; geomorphic markers.

UNIT III: Mass movement and hillslope evolution, Classification of mass movements. Morphometric analysis of basins. Concept of basin morphometry. Laws of drainage composition. Linear aspects, aerial aspects and relief aspects.

UNIT IV: Earth Surface System: liberation of flux of sediments. Sedimentary texture and structures: classification, significance and field recording. Fluid flow mechanics and formation of sedimentary bedforms, Concept of Flow Regime.

UNIT V: Petrogenesis and classification of siliciclastic and carbonate rocks; plate tectonics and sandstones composition, Clastic and carbonate petrofacies, Palaeoclimate indicators.

Books recommended:

Thornbury, Principles of Geomorphology, 2nd Edition CBS

H.S. Sharma, 1991: Indian Geomorphology, Concept Publishing Co, New Delhi.

S. Singh, 2001: Geomorphology, Pustakalaya Bhawan, Allahabad.

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

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

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

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

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

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

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

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

S. Sengupta, 1997: Introduction to Sedimentology. Oxford - IBH.
H.E. Reineck, and I.B. Singh, 1980: Depositional Sedimentary Environments. Springer Verlag.
J.D. Collins, and D.B. Thompson, 1982: Sedimentary Structures, George Allen and Unwin, London.
R. C. Selley, 2000 Applied Sedimentology, Academic Press.
M.E. Tucker, 1981: Sedimentary Petrology: An Introduction, Wiley and Sons, New York.
M.E. Tucker, 1990: Carbonate Sedimentolgy, Blackwell Scientific Publication.

ESC-504: **Structural Geology (I) and Stratigraphy of NE India**

(Credits 3; 45 Hrs; Max. Marks: 100 = 70 End Sem. + 30 sessional)

Course Objectives:

1. To provide understandings on geometries and mechanisms of development of different geological structures.
2. To provide understandings on the geology of Meghalaya, Assam, and Cachar-Mizoram-Tripura in terms of stratigraphy, lithology, Structure and Tectonics, fossil contents and mineral resources.

Course Learning Outcomes:

1. Students will get sound knowledge on different geological structures and their significance.
2. Students will understand the geology of NE India.

UNIT I: Morphology of folds. Geometric and genetic classification of folds. Mechanics of folding: buckling, bending, flexural slip, and flow folding. Mechanics of single layer and multilayer buckling. Fold development and distribution of strain in folds. Superposed folding and interference patterns.

UNIT II: Causes and dynamics of faulting with special reference to stress and strain. Complex geometry of normal faults, strike slip faults and thrust faults with natural examples. Over thrust, nappe and their characteristics. Recognition of faults. Concept of fractures, joints and their tectonic importance.

UNIT III: Detailed Stratigraphic succession, Lithology, Structure and Tectonics and Mineral Resources of Meghalaya.

UNIT IV: Detailed Stratigraphic succession, Lithology, Structure and Tectonics, Fossil content and Mineral Resources of Assam.

UNIT V: Detailed Stratigraphic succession, Lithology, Structure and Tectonics, Fossil content and Mineral Resources of folded belts of Cachar-Mizoram-Tripura.

Books Recommended:

Ghosh, S.K. (1993): Structural Geology: Fundamental and Modern Developments. Pergamon Press.
Hobbs, B.E., Means, W.D. & Williams, P.F. (1976): An outline of Structural Geology, J. Wiley & Sons, NY.
Ramsay, J.G. (1967): Folding and fracturing of rocks, McGraw Hill.
G.H. Davies, (1996): Structural geology of rocks and regions, Wiley, New York
Twiss, R.J. and Moores E.M. (2007): Structural Geology, W.H. Freeman.
Van der Pluijm, B.A. and Marshak, S., 2004. Earth structure: an Introduction to Structural Geology and Tectonics, W.W. Norton & Company Ltd.
Karunakaran, C.1972: Geology and Mineral Resources of the states of India, Misc. Publ., Geol. Surv. India.
Dasgupta, A.B. and Biswas, A.K. 2000: Geology of Assam. Geol Soc. India, Bangalore.
M.S. Krishnan, 1982. Geology of India and Burma (6th Ed) CBS Publishers & Distributors, Delhi
S.M. Naqvi, 2005. Geology and Evolution of the Indian plate (from Hadean to Holocene-4 Ga to 4ka) Capital publishing Co., 450p.
S.M. Naqvi, and J.J.W. Roger, 1987. Precambrian Geology of India, Oxford Univ. Press

ESC-505: **Practical and Basics of Field Work**
(Credits 3; 90 Hrs; Max. Marks: 100 = 70 End Sem. + 30 sessional)

Section A: Hand specimen and Thin-section studies of minerals. Megascopic and microscopic studies of igneous rocks. Exercises on calculation of modal mineralogy.

Section B: Study of pollens, foraminifers, ostracods and Trace fossils of India. Study of coiling geometry in Gastropods and cephalopods. Application and interpretations in sedimentary depositional environment.

Section C: Morphometric analysis in different river basins. Interpretation of structures from contour maps. Study of nature of aerial photographs: resolution, mosaics, symbols, gully pattern, drainage analysis, and image parallax. Determination of scale, height, dip, slope, vertical exaggeration, and image distortion.

Section D: Megascopic study of clastic and non-clastic rocks. Studies of primary, secondary, and biogenic sedimentary structures in hand specimens, in photographic atlases. Exercises related to palaeocurrent analysis and interpretation of depositional sedimentary environments.

Section E: Preparation and interpretation of geological maps and sections. Recording and plotting of the field data; Study of deformed structures in hand specimens.

Section F: Students are compulsorily required to carry out a local fieldwork of 2 days duration. Each student is required to submit a report duly certified by the Teachers in-charge of the Field tour and the Head of Department and have to take a viva voce examination at the end of semester.

ESC-506: **Community Engagement**
(Credits 2; 30 Hrs; Max. Marks: 100 = 70 End Sem. + 30 sessional)

The students will be engaged to disseminate knowledge on the following aspects:

- Awareness on Geo-Environmental Risks
- Precautionary measures to be taken during and after earthquake
- Drinking water quality assessment and its effects on resident's health
- Knowledge on Rain Water Harvesting techniques and water resource management
- Disseminate knowledge to assess risks, mitigate and prevent geohazards
- Assessment of soil quality for agricultural purposes
- Societal importance of study on Earth Science

Note: *1 Credit for Classroom and Tutorials and 1 Credit for Field Engagement*

Second Semester

ESC-551: **Metamorphic Petrology and Geochemistry**

(Credits 4; 60 Hrs; Max. Marks: 100 = 70 End Sem. + 30 sessional)

Course Objectives:

1. To enable students to understand recrystallization, structural readjustment, metamorphic reactions, and metamorphic P-T conditions of rocks.
2. To enlighten metamorphism as a process of crustal evolution that can be correlated with tectonics.
3. To provide knowledge and understandings on theoretical, and applied aspects of geochemistry in the near-surface as well as of deep earth environment.
4. To provide a qualitative understanding of geochemical processes.

Course Learning Outcomes:

1. Students will have sound knowledge of identifying equilibrium mineral assemblages through textural and mineralogical observations.
2. The students will understand the metamorphic facies of different P-T conditions. They will be able to plot mineral and mineral assemblage data to interpret different metamorphic reactions.
3. Students will study the geochemical properties of major trace and rare earth elements.
4. They will learn the principles and applications of isotopes in geological studies.

UNIT I: Kinetics of metamorphism. Metamorphic textures and structures. Types of metamorphic equilibrium reactions. Graphical representation of mineral assemblages in composition diagrams (ACF AKF and AFM diagrams). Progressive metamorphism of pelites and basic rocks. Metamorphism in relation to plate tectonics.

UNIT II: Concept of Barrovian and Buchan type of metamorphism. Metamorphic facies; Classification of metamorphic facies. Description of each facies of regional metamorphism with special emphasis on characteristic minerals, mineral assemblages and PT conditions of metamorphism.

UNIT III: Concepts of geochemistry; Introduction to properties of elements. Geochemical classification of elements and distribution of elements within the earth. Element partitioning in mineral/ rock and concept of distribution coefficients. Principles of ionic substitution in minerals. Geochemical behaviour of major elements.

UNIT IV: Geochemical characteristics of trace elements and rare earth elements (REE) in minerals. Geochemical variability of magma, melting of the mantle and growth of continental crust. Planet formation and geochemical differentiation of the primordial earth. Meteorites: classification, mineralogy, origin, significance.

UNIT V: General characteristics of isotopes. Stable isotopes: fundamentals and principles; nature, abundance and fractionation of stable isotopes. Application of stable isotopes (O, H, C and S) in geological studies. Radiogenic isotopes: Radioactive decay mechanisms. Radioactive decay schemes, growth of daughter isotopes and radiometric dating. Geochronology: Rb-Sr, U-Pb and Sm-Nd isotope systematization.

Books Recommended:

Bucher, K. and Grapes, R., 2010. Petrogenesis of Metamorphic Rocks, Springer
Best, M.G., 2003. Igneous and Metamorphic Petrology, Blackwell Science.
Winkler: Metamorphic Petrology
Turner, F. J., 1980: Metamorphic Petrology, Mc Graw Hill.
Yardley, B.W.D., 1997. An Introduction to Metamorphic Petrology, Longman Earth Science Series.
Winter, J.D., 2001. An Introduction to Igneous and Metamorphic Petrology, Prentice Hall.
Albarede, F., 2003. An introduction to geochemistry. Cambridge University Press.
Walther, 2009. Essentials of Geochemistry, Jones and Bartlett Publishers.
Rollinson, H., 2007. Using geochemical data: evaluation, presentation and interpretation. Longman
Faure, G. 1986: Principles of Isotope Geology
Hoefs, J. 2009. Stable Isotope Geochemistry. Springer.

ESC-552: **Principles of Stratigraphy and Applied Palaeontology**
(Credits 4; 60 Hrs; Max. Marks: 100 = 70 End Sem. + 30 sessional)

Course Objectives:

1. To make students familiar or equipped with the techniques to build up the stratigraphy or find out the time of deposition or formation of different rocks.
2. To make the students understand the principles to know how different bio-communities worked or works.
3. To make students understand the application of palaeontology in different industries.

Course Learning Outcomes:

1. After going through this course, the students are expected to be very much aware of different techniques for stratigraphy build-up, including qualitative and quantitative dating. They can use these techniques while carrying out any field trip.
2. Students can use different palaeontological principles to any group of fossils to understand their ecology, interaction, morphodynamics, biogeographical distributions etc.
3. Students will be able to use palaeontological technique for hydrocarbon and coal industry as well as to know the palaeoclimate and climate change through time and future.

UNIT I: Controls on the development of stratigraphic records. Completeness/incompleteness of stratigraphic records. Lithostratigraphy: correlation and stratigraphic code. Global Stratotype Section and Point (GSSP). Biostratigraphy: controlling factors, zonation, time significance, quantitative stratigraphy. Geochronology and chronostratigraphy.

UNIT II: Sequence stratigraphy and its correlation with sea level changes, controlling factors. Brief ideas of magneto seismic chemo and event stratigraphy; Stratigraphic correlations. Glacial-interglacial cycles, eustatic changes with a special reference to Quaternary. Quaternary dating methods, –radiocarbon, Luminescence and Amino acid.

UNIT III: Principles of palaeontology: Species concept and speciation, Species problem in palaeontology, bio, chrono, and morphospecies; Morphodynamics – growth and function; functional morphology; functional morphology and adaptation., Taphonomy, Paleobiogeography.

UNIT IV: Mechanism of evolution, History of Life: Origin and diversity of life, Precambrian life, Cambrian explosion and metazoan radiation, Phanerozoic diversification, Major mass extinction events of earth's history: causes and effects. Ecology and paleoecology.

UNIT V: Application of micropaleontology in hydrocarbon exploration. Oxygen and Carbon isotope studies of microfossils and their use in paleoceanographic and paleoclimatic interpretation, Climate Change.

Books recommended:

Miall, A.D., 1999. Principles of Sedimentary Basin Analysis 3rd Ed Springer Verlag, New York.
Nichols, G., 1999. Sedimentology and Stratigraphy, Blackwell publishing
Octavian Catuneanu, 2006. Principles of Sequence Stratigraphy, Elsevier.
Raup, D.M. and Stanley, S.M (2008): Earth System History, Blackwell Publ.
Faure, G. 1986: Principles of Isotope Geology
Hoefs, J. 2009. Stable Isotope Geochemistry. Springer.
Pankman Kirsty, 2023. Handbook of Archeological Sciences (2nd edition), Wiley.
Brookfield, M. E., 2003. Principles of stratigraphy. Wiley.
Saraswati, P.K. and Srinivasan, M.S., 2015. Micropalaeontology: Principles and applications, Springer.
Murray, J. W., 2006. Ecology and Applications of Benthic Foraminifera. UK: Cambridge University Press
Allen, A and Allen, J., 2005. Basin Analysis: Principles and applications. Blackwell
Jones, Robert Wynn. (1996): Micropaleontology in Petroleum Exploration, Clarendon Press

ESC-553: **Hydrogeology and Advanced Sedimentology**
(Credits 4; 60 Hrs; Max. Marks: 100 = 70 End Sem. + 30 sessional)

Course Objectives:

1. This course aims to introduce the fundamentals of groundwater science and different hydrogeological environments.
2. To know the different sedimentary environment of deposition, type of sediments, processes of deposition.
3. To know the diagenesis of sedimentary rocks, sedimentary mineral chemistry and their changes through diagenesis.

Course Learning Outcomes:

1. Students will learn about the occurrence and flow of groundwater, and the characteristic features of water-bearing horizons.
2. Students will be enlightened on the construction, design, and development of water wells.
3. Students will be equipped with a knowledge of different sedimentary environment of deposition so that they can interpret the palaeoenvironment, palaeoprocesses etc. Diagenetic changes, agents should be known to them so that they can differentiate syn-sedimentary deposition and the alteration sedimentary products.
4. Students will be very much aware of sedimentary chemistry after going through this course.

UNIT I: Hydrologic cycle, Groundwater in hydrological cycle, distribution of water in the Earth's crust, water balance studies. Darcy's law. Groundwater recharge; artificial and natural Factors controlling recharge, conjunctive and consumptive use of groundwater. Fluctuation of groundwater level, cone of depression.

UNIT II: Groundwater in arid and semiarid, coastal and alluvial regions. Intrusion of saline water in coastal rocks. Groundwater in hard rocks and limestone terrain with reference to Indian situation. Geologic structures favouring groundwater occurrence. Role of remote sensing and GIS in groundwater prospecting. Well types, drilling methods, construction, design, development and maintenance of wells.

UNIT III: Sedimentary Environments and Facies; Walther's law of facies succession, Processes and characteristics of fluvial, estuarine, deltaic, lagoonal, barrier beach, tidal flats and deep-sea environments.

UNIT IV: Diagenesis and fluid flow. Diagenesis of mudstones, sandstones and carbonate rocks: changes in mineralogy, fabric and chemistry. Heavy minerals and their uses in provenance studies.

Unit V: Continental and marine Evaporites. Shallow and deep marine carbonates, Volcanoclastic: onland and marine, Significance of ichnofossils in sedimentological studies, Cyclic sedimentation.

Books recommended:

McGraw Hill. Walton, W.C, 1988; Ground Water Resource Evaluation.
Fitts, C.R., 2006. Groundwater Science, Academic Press.
John Wiley. Freeze, R.A and Cherry,J.A, 1979; Groundwater, Prentice Hall Fetter.
Raghunath, H.M., 1987. Ground Water, Wiley Eastern Ltd., Calcutta.
Todd, D.K., 2004. Ground Water Hydrology, John Wiley & Sons, New York.
Nichols, G. 2009 : Sedimentology and Stratigraphy (2nd edition). Blackwell.
Miall, A.D. 2000: Principles of Sedimentary Basin Analysis. Springer Verlag
Tucker, M.E. (1990): Carbonate Sedimentolgy, Blackwell Scientific Publication.
Flügel, E., 2004. Microfacies of Carbonate Rocks: Analysis, Interpretation and Application. Springer-Verlag, Berlin, 976 p.
Boggs, Sam Jr. 1995: Principles of Sedimentology and Stratigraphy. Prentice Hall.

ESC-554: **Essentials of Earth System Sciences**
(Credits 3; 45 Hrs; Max. Marks: 100 = 70 End Sem. + 30 sessional)

Course Objectives:

1. To introduce the concept of solar system and earth's interior.
2. To provide the basic knowledge on plate tectonics, earthquakes, and Tsunamis.
3. To make students familiar with the evolution of life and fossils.
4. To make the students acquainted with igneous rock characteristics
5. To provide basic idea on plate tectonics and position of different continents in geological time.

Course Learning Outcomes:

1. Students will have sound knowledge on our solar system and fundamental of plate tectonics.
2. Students will be enlightened on types and causes of earthquakes and tsunamis.
3. Students will be able to understand origin and evolution of life, fossils, and their applications in earth science.
4. Students will get an elaborate knowledge on the various igneous rock types. They will understand the dynamics of magma generation.
5. The students will be able to understand how and what kind of magma is generated different tectonic settings and what can be the most probable rock type.

UNIT I: Solar system, origin of earth, Bing bang theory, Distribution of crust, mantle and core, Interior of the earth: density, heat budget, magnetism, gravity, isostasy. Geological Time Scale.

UNIT II: Basic idea of Magma: physics of magma generation in mantle, nature of magma. factors affecting magma composition and evolution of magma. Magma crystallization; Bowen's reaction series. Mode of occurrence, texture & structure of the igneous rocks. Classification of igneous Rocks. Petrographic study of common igneous rocks of continental regions.

UNIT III: Seismicity. Different types of seismic wave, Earthquake and Tsunami: theory evidences and results. Major Earthquakes and Tsunami of India: causes and results.

UNIT IV: Origin of life, Evolution of life: mechanism and major trend, Fossil: basic and application, Major Mass extinction Events of Earth s history.

UNIT V: Basic idea of plate tectonic: different types of plates and plate boundaries, evidences and results. Positions of different continents in geological time. Journey of India and origin of Himalaya.

Books Recommended:

Bose M. K., 1997. Igneous Petrology. World Press
Bott, M.H.P., 1982: The interior of the earth its structure, constitution and evaluation.
Condie, K. C.: Plate tectonics and crustal evolution
Cox, K.G., Bel, J. D. and Pankthrust, R. J., 2002. The interpretation of Igneous rocks. Allen and Unwin, London
Kearey, P. & Brooks, M., 1991: Introduction to Geophysical Prospecting, Osney Mead, Oxford.
Udías, A., &Buforn, E., 2017: Principles of Seismology (2nd ed.). Cambridge: Cambridge University Press.
Raup, D.M. and Stanley, S.M., 2008: Earth System History, Blackwell Publ.
Raup, D.M. and Stanley, S.M.,1985: Principles of Paleontology, CBS Publ.
Raymond L. A., 2002. Petrology: The study of Igneous, Sedimentary and Metamorphic rocks. Mc Graw Hill. New York

ESC-555: **Practical**
(Credits 3; 90 Hrs; Max. Marks: 100 = 70 End Sem. + 30 sessional)

Section A: Megascopic and microscopic study of metamorphic rocks of different facies. Graphic construction of ACF, AKF and AFM diagrams.

Section B: Plotting and interpretation of major elemental characteristics of igneous rocks. The uses and applications of major and trace element composition of igneous rocks as a means to understand the petrogenesis of the rocks. Exercise on isotopes: Stable; Radiogenic; Dating of earth samples using $^{235}U/^{207}Pb$ and $^{87}Sr/^{86}Sr$ ratio.

Section C: Application and interpretation in sedimentary depositional environment. Techniques of separation of microfossils from matrix; SEM applications in micropaleontology, Exercises on stratigraphic classification and correlation, Litho-, Bio- sequence-, magneto- and seismic stratigraphic interpretations.

Section D: Delineation of hydrological boundaries on water table contour maps and estimation of permeability; Hydrogeomorphic mapping. Analysis of hydrochemical facies and its evolution on Trilinear and Durov diagrams. Pumping test: time drawdown and time recovery tests and evaluation of aquifer parameters. Vertical electrical resistivity.

Section E: Exercises related to palaeocurrent analysis and interpretation of depositional sedimentary environments. Microscopic examination of important rock types. Heavy mineral separation and microscopic examination. Grain-size analysis by sieving method; plotting of size distribution data as frequency and cumulative curves, computation of statistical parameters and interpretation.

ESC-556: **Fuel Geology (Coal, Petroleum, and Atomic Minerals)**
(Credits 2; 30 Hrs; Max. Marks: 100 = 70 End Sem. + 30 sessional)

Course Objectives:

1. To provide knowledge on various aspects of coal petrology, formation, origin and grading of coal.
2. To provide knowledge on various aspects of petroleum geology and prospecting for oil and gas deposits in current scenario.
3. To provide concepts of drilling and logging procedures.
4. To make students understand about atomic minerals, their geology, mode of occurrence, genesis and utilization.

Course Learning Outcomes:

1. Students will develop a wholesome knowledge on coal chemistry, its chemical analysis and distribution of the coal deposits in various parts of India especially NE India.
2. The students will know about the petroleum, oil and gas bearing basins of India. Geology of the productive oil-fields of India and future prospects and the economic scenario.
3. The students will develop understanding on the concepts and applications uranium, thorium and REE bearing mineral deposits in India and their prospects
4. Further, knowledge gained from this course will help to seek jobs in the coal, oil & gas, atomic mineral exploration sectors.

UNIT I: Coal forming epochs in the geological past. Geological and geographical distribution of coal deposits in India. Detail geology for some important coal- fields of India with special reference to Northeast India. Coal bed methane: a new energy resource. Maturation of coal and generation of methane in coal beds.

UNIT II: Coal-formation and origin. Rank, grade, and type of coal; coal chemistry and classifications. Chemical characterization: Proximate and ultimate analysis. Petrography: macroscopic and microscopic constituents of coal, concepts of lithotypes, maceral and micro-lithotypes.

UNIT III: Petroleum: Its composition and different fractions. Origin, nature and migration (Primary and secondary) of oil and gas. Transformation of organic matter into kerogen, organic maturation, thermal cracking of kerogen. Characteristics of reservoir rocks and traps (structural, stratigraphic and combination).

UNIT IV: Prospecting for oil and gas, drilling and logging procedures. Oil bearing basins of India. Geology of the productive oil-fields of India, future prospects and the economic scenario.

UNIT V: Classification of atomic minerals. Geology, mode of occurrence, genesis and utilization of atomic minerals. Indian distribution of important atomic mineral deposits with special reference to Northeast India. Nuclear power stations of the country and future prospects. Atomic fuels and environments.

Books Recommended:

Boyle, R.W. 1982: Geochemical Prospecting for Thorium and Uranium Deposits. Elsevier.
Chandra, D, Singh, R.M. & Singh, M.P. 2000: Textbook of Coal (Indian Context). Tata Book Agency. Varanasi.
Dahlkamp, F.J. 1993: Uranium Ore Deposits. Springer Verlag.
Durrance, E.M. 1986: Radioactivity in Geology-Principle and Application. Ellis Hoorwool.
Holson, G./D. and Tiratsoo, E.N. 1985: Introduction to Petroleum Geology. Gulf Publ. Houston, Texas.
Selley, R.C. 1998: Elements of Petroleum Geology. Academic Press.
Stach, E., et al., 1982: Textbook of Coal Petrology. GebruderBorntraeger, Stuttgart.
Tissot, B.T. & Welte, T.S. 1984: Petroleum Formation and Occurrence. Springer Verlag.

Third Semester

ESC-601: **Optical mineralogy and Advanced Igneous Petrology**

(Credits 4; 60 Hrs; Max. Marks: 100 = 70 End Sem. + 30 sessional)

Course Objectives:

1. This course is designed to understand the behaviour of minerals under transmitted polarized light.
2. To introduce the concept of crystal field theory with emphasis on application of liquid crystals.
3. To explain the the behaviour of chemical solid solution series in various pressure temperature conditions using phase rule and phase diagrams
4. To provide knowledge on mantle chemistry, partial melting processes in the mantle along with hot spots and plume related magmatism.
5. To make student understand the relation of magmatism with global tectonic processes.

Course Learning Outcomes:

1. At the end of this course, students will understand the distinction between light velocity, vibration direction, propagation direction and wavelength and interaction of light with isotropic and anisotropic minerals.
2. Students will understand the optical characteristics of various minerals which will aid in identifying specific minerals in different rock thin sections thus identifying the rocks at the end.
3. Students will understand the solid solution phase diagram which explains the behaviour of chemical solid solution series.
4. Students will understand the mantle melting processes and the geochemical features of ocean island basalt (OIB), continental flood basalts (CFB) and Ophiolites.

UNIT I: Twinning and twin laws; common types of twins and their examples in minerals. Concept of Crystal Field Theory and mineralogical spectroscopy; Liquid crystals and their applications

UNIT II: Light – mineral interactions, Refractive index determinations; Pleochroism; Isotropism vs. Anisotropism, Interference color; Birefringence; Extinction types and determination. Optical Indicatrix Uniaxial and Biaxial Interference Figures and Optic sign determination, 2V and 2E.

UNIT III: Phase rule and phase diagrams. Phase relations in Binary and Ternary systems, Application of phase rule in the study of silicate systems Binary: Diopside-Anorthite; Albite-Anorthite; Leucite-Quartz and Ternary: Diopside-Albite-Anorthite; Diopside-Forsterite-Anorthite; Forsterite-Anorthite-Silica.

UNIT IV: Upper mantle mineral assemblages and Mantle heterogeneities. Partial melting processes in the upper mantle. Basaltic magma spectrum in relation to partial melting processes. Concept of Enriched and Depleted mantle (EM and DM); Hot spots, Hot spots and plume related magmatism: ocean island basalt (OIB) and continental flood basalts (CFB). Ophiolites

UNIT V: Magmatism in relation to global tectonic processes. Characteristic magma series associated with specific tectonic settings. Magmatism at constructive plate margins: Mid-oceanic ridges. Magmatism at destructive plate margins: island arcs, active continental margins.

Books Recommended:

Berry, L.G., Mason, B. and Dietrich, R.V.: Mineralogy, CBS Publishers.
Best, Myron G., 2002. Igneous and Metamorphic Petrology, Blackwell Science.
Bose, M.K., 1997. Igneous Petrology, World Press, Kolkata.
Deer, W.A., Howie, R.A. & Zussman, J.: An Introduction to the rock forming minerals.
Longman Guillman: Art and Science of Crystal Growth.
Kerr,P.F. Optical Mineralogy. McGraw Hill Book Company.
Klein, C. and Huburt, Jr., C.S., 1993: Manual of Mineralogy. John Wiley.
Moorhouse, W.W.: Optical Mineralogy.
Nesse, D.W.: Introduction to Optical Mineralogy.
Philpotts, A.R. 1994. Principles of Igneous and Metamorphic Petrology, Prentice Hall.
Sood, M.K., 1982. Modern Igneous Petrology. Wiley-Interscience Publ., New York.
Wilson, M., 1993. Igneous Petrogenesis. Chapman & Hall, London.
Winter John D., 2009. Principles of Igneous and Metamorphic Petrology (2nd Edition)

ESC 602**: Environmental Geology**
(Credits 4; 60 Hrs; Max. Marks: 100 = 70 End Sem. + 30 sessional)

Course Objectives:

1. The main objective of the course is to study global climate processes such as impact of atmospheric circulation and oceanic currents on climate.
2. To study the various types of environmental pollution such as surface and groundwater pollution, pollution of marine water, Air Pollution, problems of waste disposal etc.
3. To understand environmental impact of mineral development exploration, extraction and processing,
4. To learn about soil profile and basic pedalogy.
5. To study the greenhouse effect and global warming
6. To study the various geological hazards

Course Learning Outcomes:

1. This course will help students to understand various global processes such as atmospheric circulation and oceanic currents. They will also learn about the Southwest and Northeast monsoon in Indian subcontinent.
2. The students will understand how various pollutions are arising due to anthropogenic activities and their effect.
3. They will know about the soil science, its various aspects and about the soil types in India.
4. The students will learn about the alternative energy resources – solar, wind, water, gas hydrates, bio mass and geothermal energies to mitigate the effect of global warming due to greenhouse gases.
5. Various geological hazards; their prediction, prevention and mitigation.

Unit I: Interaction between man and climate. Time scale of global changes in the ecosystem and climate. Impact of atmospheric circulation and oceanic currents on climate – Southwest and Northeast monsoon in Indian subcontinent, El-nino and Southern Oscillation (ENSO), La-nina.

Unit II: Pollution – Types of pollution, Sources of surface and groundwater pollution, pollution of marine water, Treatment of polluted water. Air Pollution and its effects. Problems of waste disposal - solid, liquid and toxic waste. Environmental impact of mineral development exploration, extraction and processing.

Unit III: Classification of soil, factors affecting soil forming processes, soil profile. Soil quality degradation due to irrigation, uses of fertilizers and pesticides. Soil erosion and its control. Soil types of India.

Unit IV: Greenhouse effect, Global warming and Ozone depletion. Source of Greenhouse gases and their controls on emission. Alternative energy resources – solar, wind, water, gas hydrates, bio mass and geothermal energies. Environmental Impact Assessment (EIA).

Unit V: Geological hazards: Earthquake, Floods, Volcanoes, Tsunamis: causes, distribution, magnitude, intensity and their impacts on environments. Prediction and prevention of the natural hazards, especially earthquake. Influence of neo-tectonism in seismic hazard assessment. Landslide – Types of landslide and its mitigation.

Books Recommended:

Valdiya, K.S. 1987: Environmental Geology- Indian context. Tata Mc Graw Hill.
Keller, E.A. 1978: Environmental Geology- Bell & Howell, USA.
Bryant, E. 1985: Natural hazards, Cambridge Univ. Press.
Patwardhan, A.M. 1999: The dynamic earth System. Prentice Hall.
Subramaniam, V. 2001: Textbook in environmental science. Narosa International.
Bell, F.G. 1999: Geological hazards. Routledge, London.
Smith, K. 1992: Environmental Hazards. Routledge, London.

ESC-603 (i): **Instrumentation techniques in Earth Science**
(Credits 4; 60 Hrs; Max. Marks: 100 = 70 End Sem. + 30 sessional)

Course Objectives:

1. To introduce students to the use of various sophisticated instruments helping in geological studies,
2. To learn about the working principle, data acquisition, instrumental error correction etc. Of the instruments and how they are employed in qualitative and quantitative analysis of the geological materials.

Course Outcomes:

1. This course for postgraduate students will equip them in understanding the various aspects of sophisticated analytical instruments employed in geological sciences for qualitative and quantitative analysis of geological specimen.
2. This knowledge will help them in handling sophisticated instruments in their future research endeavours.

UNIT I: Analytical techniques; Sensitivity and detection limits; Sample Preparation Techniques, analytical quality control and assurance. Data & Error Analysis

UNIT II: Principles, Instrumentation and Analytical Techniques involved in analysing the geological materials by Absorption Spectroscopic Methods: Atomic Absorption Spectrophotometry (AAS) (Flame-AAS, Graphite furnace-AAS, Hydride generation-AAS); Principles, Instrumentation and Analytical Techniques involved in Atomic Emission Spectroscopy

UNIT III: Principles, Instrumentation and Analytical Techniques involved in Scanning and Transmission Electron Microscopy (SEM and TEM); Electron Probe Microanalysis (EPMA)

UNIT IV: Principles, Instrumentation and Analytical Techniques involved in analysing the geological materials by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP AES) and Mass spectrometry (MS)

UNIT V: Principles involved in analysing the geological materials by X-Ray Analytical Methods: X-Ray powder Diffraction (XRD) and X-Ray Fluorescence (XRF);

Books Recommended:

Joseph I. Goldstein ... [et al.] 1981. Scanning electron microscopy and X-ray microanalysis: a text for biologists, materials scientists, and geologists, Plenum Press New York
Philip J. Potts, John F. W. Bowles, Stephen J. B. Reed and Mark R. Cave (Ed) 1995. Microprobe techniques in the earth sciences, 1st ed.; Chapman & Hall, London
Alex C. McLaren 1991. Transmission electron microscopy of minerals and rocks; Cambridge University Press, New York
R. Jenkins & R.L. Snyder 1996. X-Ray powder diffractometry; Wiley & Sons, New York
E.P. Bertin 1985. Introduction to X-ray spectrometric analysis; Plenum Press, New York

ESC-603(ii): **Geophysics and Geoinformatics**
Credits 4; 60 Hrs; Max. Marks: 100 = 70 End Sem. + 30 sessional)

Course Objectives:

Study of various physical propertiesof the earth and its interior,

1. Study of seismic wave velocities and its interaction with layers within earth
2. The study of earth's magnetic field, its components and paleomagnetism.
3. Study of principles, aspects, data attributes in Geographic Information systems and various operations involving the raster data type.

Course Learning Outcomes:

This course will equip students with a solid understanding on interaction and behaviour of various physical parameters like gravity, magnetism and current flow in earth vis a vis their measurement, data acquisition and interpretation involving various scientific methods.

UNIT- I: Density distribution, shape and mass of the earth, density vs. depth profile; Gravity and gravitational mechanics, gravity anomalies and isostatic equilibrium. The mantle: Seismological methods of investigating mantle structure; Electrical conductivity of mantle. Temperature-depth distribution composition of mantle. Density and elastic properties. Thermal properties of rocks. The earth s heat budget.

UNIT- II: Seismic waves and their velocities; The continental crust: Structure based on seismological data. Fundamentals of current flow in the earth. Electrode arrangements and field procedures. Instruments. Processing and interpretation of resistivity data. Field procedure, data acquisition and interpretation of self-potential, Induced polarization and electromagnetic methods

UNIT III: The earth as a magnet, earth s magnetic field, changes in magnetic field, origin of geomagnetic field, magnetic properties of rocks. Palaeomagnetism Paleomagnetic sampling. Measurement of NRM. Magnetic leaning techniques and field tests of Paleomagnetic stability.Palaeomagnatism and its applications.

UNIT IV: Principles of Geographic Information systems- Fundamentals of GIS, Spatial and Attribute Data Linkage, Components of GIS, Raster and Vector formats, Software modules of GIS- GIS as a set of Interrelated Subsystems- Data Processing, Data Analysis, Information Use and Management Subsystem

UNIT V: Raster GIS: The Data Model, Creating a Raster, Cell by cell entry, Digital data, Cell Values-Types of values, One value per cell, Map Layers-Resolution, Orientation, Zones, Value, Location. Raster GIS Capabilities- DISPLAYING LAYERS, Basic display, other types of display. Local operations-Recoding, Overlaying layers. Overview of different GIS packages.

Books Recommended:

Kearey, P. & Brooks, M., 1991: Introduction to Geophysical Prospecting, Osney Mead, Oxford.
Nagata, T.: Rock Magnetism, Maruzen Co., Ltd., Tokyo
Parkinson, W.D., 1983: Introduction to Geomagnetism, Scottish Acad., Press, Edinburgh
Pick, M., Picha, J. &Vyskocil, V. 1973: Theory of the Earth s Gravity Field, Elsevier.
Tarling, D.H. 1983: Palaeomagnatism, Chapman and Hall, London
Muralikrishna 1999. Geographical information systems and digital image processing. Allied Publication
Burrough, P.A., 1986. Principles of GIS for land and resources assessment, Oxford.
Freeman and Pieroni, 1980. Map data processing, Academic Press.
Ian Heywood, Sarah Cornelius and Steve Carver. An introduction to Geographical information systems, Longman.

ESC-604: **Practical and Fieldwork**
(Credits 3; 90 Hrs; Max. Marks: 100 = 70 End Sem. + 30 sessional)

Section A: Identification of optical properties of rock forming minerals under petrological microscope. Determination of optic signs, order of interference color and pleochroic schemes of rock forming minerals. Determination of composition of Plagioclases by Michael Levey method. Megascopic and microscopic study of igneous rocks. Exercises on calculation of modal mineralogy and assigning name to rocks; Calculation of CIPW Norms; Exercises on Binary and Ternary Phase diagrams.

Section B: Structural problems concerning economic deposit based on orthographic and stereographic projections; Recording and plotting of the field data; Study of deformed structures in hand specimens; Strain estimation from the data collected from the field; Study of dip isogons from the fold profiles; Preparation of geotectonic maps.

Section C: Megascopic characterization of banded coals. Proximate analysis of coal. Completion of outcrops in the given maps and calculation of coal reserves. Microscopic examination of polished coal pellets (identification of minerals in coals). Study of geological maps and sections of important oil fields of India and world. Calculation of oil reserves. Megascopic study of some uranium and thorium bearing minerals and rocks.

Section D: Students are compulsorily required to carry out fieldwork of two weeks duration on various components of Field Geology. Each student is required to submit a report duly certified by the Teachers in-Charge of the Field tour and the Head of Department and have to take a viva voce examination at the end of semester.

ESC-605: **Dissertation (Research Project Part I)**
(Credits 5; 150 Hrs; Max. Marks: 100 = 70 End Sem. + 30 sessional)

Candidates admitted to the M.Sc. Applied Geology will be required to undergo a project-oriented dissertation on the problems assigned by the Department. The dissertation will be field/laboratory/data based and will be carried out under the guidance of a faculty member. The dissertation findings shall be compiled and submitted in the form of a thesis for evaluation. In addition, candidates are also required to present their dissertation findings in the form of seminar followed by viva-voce before a duly constituted committee.

A certificate duly signed by the candidate and the supervisor has to be enclosed stating the genuineness of the work and it has NOT been submitted elsewhere for any degree.

Examiners and scheme of evaluation shall be as follows:

1. Board of Examiners:
   i. Chairman: Head of Department
   ii. Expert: External Examiner
   iii. Member: Supervisor/ Internal Examiner

2. Evaluation Scheme:
   i. Evaluation (Thesis + Seminar/Viva-Voce) : 70 Marks
   (Jointly by External and Internal Examiners)

   ii. Seminar/Viva-Voce : 20 Marks

Fourth Semester

ESC-651: **Structural Geology (II) and Indian Stratigraphy**

(Credits 4; 60 Hrs; Max. Marks: 100 = 70 End Sem. + 30 sessional)

Course Objectives:

1. To understand the geometry, principles and kinematics of the deformation of the earth's crust and lithosphere.
2. To enlighten the students about the stress-strain behavior of rocks, through ductile to the brittle deformational regime at macroscopic to microscopic scale.
3. To know the deformation processes and structures that develop at different tectonic settings.
4. To know the spatio-temporal distribution of different sedimentary, igneous and sedimentary rocks of India.
5. To know the interrelationship of different litho-units of different basins, cratons, mobile belts etc.
6. To know about the lithological, palaeontological and geochemical variation of different rock units in India.

Course Learning Outcomes:

1. At the end, the students will have sound knowledge on structural geology along with understandings of the geometries of naturally deformed structures.
2. Students will understand the rheology and mechanism of rock deformation at different scales.
3. Students will be able to get an overall idea of the varieties of tectonics operative within the crustal domain.
4. Students will be able to know the distribution of different rocks of India through space and time,

UNIT I: Mechanical principles and properties of rocks and their controlling factors, Concept of stress; Theories of rock failure; Two dimensional stress analyses; Concept of strain, two dimensional strain analysis; Types of strain ellipses and ellipsoids, their properties and geological significance; Strain markers in naturally deformed rocks.

UNIT II: Brittle and ductile shear zones, geometry and products of shear zones; Mylonites and cataclasites; Planar and linear fabrics in deformed rocks, their origin and significance. Concept of petrofabrics, Planar and linear fabrics in deformed rocks, graphic treatment, Types of fabrics, fabric elements and interpretation of fabric data on microscopic and mesoscopic scale. Use of universal stage.

UNIT III: Plate Tectonics: recent advances, pros and cons. Dynamic evolution of continental and oceanic crust. Tectonic features of extensional, compressional, and strike slip terrains and relevance to plate boundaries. Tectonics of Precambrian Orogenic Belts of India. Formation of mountain roots. Anatomy of orogenic belt. Structure and origin of the Alpine-Himalayan belt, Plate tectonic evolution of India.

UNIT IV: Classification and correlation of Precambrian crystalline rocks of India with particular reference to Singbhum, Aravalli; Mobile belts: Eastern Ghats. Stratigraphic classification and correlation of Purana Basin with a special reference to Vindhyan and Cuddapah.

UNIT V: Phanerozoic Stratigraphy: Classification, lithology, correlation and fossils of Palaeozoic rocks of India with particular reference to Tethyan basins, Spiti, Kashmir and Peninsular India. Classification, lithology, correlation and fossils of Gondwana Super Group. Classification and correlation of Mesozoic rocks of India with particular reference to Triassic of Kashmir and Spiti, Jurassic of Kutch and Cretaceous of Trichinopally. Deccan Volcanism. Classification, lithology, correlation and fossils of Cenozoic rocks of India with particular reference Assam and Meghalaya; Quaternary stratigraphy of India.

Books Recommended:

Condie, Kent. C. (1982): Plate Tectonics and Crustal Evolution, Pergamon Press Inc.

Ramsay, J.G. and Huber, M.I. (1983): Techniques of Modern Structural Geology, Vol. I, Strain Analysis, Academic Press.

Ramsay, J.G. and Huber, M.I. (1987): Techniques of Modern Structural Geology, Vol. II, Folds and Fractures, Academic Press.
Ramsay, J.G. and Huber, M.I. (2000): Techniques of Modern Structural Geology, Vol. III (Application of continuum mechanics), Academic Press.
Twiss, R.J. and Moores, E.M., 2007. Structural Geology. Freeman.
Van der Pluijm, B.A. and Marshak, S., 2004. Earth structure: an introduction to structural geology and tectonics, W.W. Norton & Company Ltd.
Passhier, C. and Trouw, RAJ, 2005. Microtectonics. Springer, Berlin.
Twiss, R.J. and Moores E.M. (1992): Structural Geology, W.H. Freeman.
Vaidyanathan, R & Ramakrishnan, M. 2008. Geology of India, Geological Society of India
K.S. Valdiya, 2016. The Making of India: Geodynamic Evolution, Springer
Naqvi, S.M. and Rogers, J.J.W. 1987: Precambrian Geology of India. Oxford University Press
Naqvi, S.M. 2005. Geology and Evolution of the Indian Plate: From Hadean to Holocene-4 Ga to 4Ka. Capital Pub., New Delhi.
Banerjee, S. & Sarkar, S., 2021. Mesozoic Stratigraphy of India: A Multi-Proxy Approach (Society of Earth Scientists). Publisher: Springer.

ESC-652: **Ore Geology and Mining Geology**

(Credits 4; 60 Hrs; Max. Marks: 100 = 70 End Sem. + 30 sessional)

Course Objectives:

1. To study the nature and morphology of ore deposits and role of magma in formation of ores in space and time
2. To understand the interaction of ore bearing magmatic/ hydrothermal fluids with the country rock and their implications.
3. To learn about the mineralogy and genesis of various metalliferous ores and their distribution in India.
4. To develop knowledge on various stages of mining and mineral exploration methods.

Course Learning Outcomes:

1. This course will provide a wholesome understanding to students regarding various concepts like ore genesis, their modes of formation and localization.
2. It will explain the phenomenon of interaction of ore bearing fluids with country rock, ore mineral association and paragenesis with their distribution over the country.
3. In addition, concepts of mineral exploration and various mining processes of ore deposits will supplement their understanding.
4. Knowledge gained from this course will help students to seek jobs in mineral exploration and mining sectors.

UNIT I: Concept of ore genesis; Spatial and temporal distribution of ore deposits; Metallogenic epochs and Metallogenic Provinces. Nature and morphology of principles types of ore deposits; Classification of ore deposits. Textures, paragenesis and zoning of ores and their significance

UNIT II: Concept of ore bearing fluids, their origin and migration. Wall rock alteration; Structural, physicochemical and stratigraphic controls of ore localization; Ore deposits in relation to Plate-tectonics; Fluid inclusions in ore – principles and applications.

UNIT III: Mineralogy, classification and genesis of ore deposits associated with orthomagmatic ores of ultramafic-mafic rocks; Ores of felsic-silicic igneous rocks; Ores of sedimentary affiliation -biochemical, chemical and clastic sedimentation, placers and residual concentration deposits; Ores of metamorphic affiliations.

UNIT IV: Study of ore minerals related to the following metals with special reference to their mineralogy, genesis, specification (if any), uses and distribution in India: Fe, Mn, Cr, Cu, Pb, Zn. Al, Sn, and W.

UNIT V: Classification and description of mining methods. Planning, exploration and exploratory mining of surface and underground mineral deposits. Exploration for placer deposits; Ocean bottom mining; Mining hazards: mine inundation, fire and rock burst.

Books Recommended:

Arrogyaswami, R.N.P. 1996: Courses in Mining Geology (IV ed). Oxford IBH.
Boyle, R.W. 1982: Geochemical Prospecting for Thorium and Uranium Deposits. Elsevier.
Craig, J.M. and Vaughan, D.J. 1981: Ore Petrography and Mineralogy. John Wiley.
Dahlkamp, F.J. 1993: Uranium Ore Deposits. Springer Verlag.
Evans, A.M. 1993: Ore Geology and Industrial Minerals. Blackwell.
Guilbert, J.M. and Park, C.F. Jr. 1986: The Geology of Ore Deposits. Freeman.
Klemm, D.D. and Schneider, H.J. 1977: Time and Strata Bound Ore Deposits. Springer Verlag.
Mookherjee, A. 2000: Ore Genesis A Holistic Approach. Allied Publishers.
Sawkins, F.J. 1984: Metal deposits in Relation to Plate Tectonics. Springer Verlag.
Torling, D.H. 1981: Economic Geology and Geotectonics. Blackwell.

ESC-653 (i): **Seismology and Exploration**

(Credits 4; 60 Hrs; Max. Marks: 100 = 70 End Sem. + 30 sessional)

Course Objectives:

1. To introduce the fundamentals of seismology, seismic waves, and seismotectonic aspect of India
2. To understand the principles and methods of geological and geochemical exploration.
3. To make students familiar with the geological and geochemical mapping and different data processing techniques.

Course Learning Outcomes:

1. Students will understand the concept of seismology and seismicity in Indian subcontinent.
2. Students will be able to analyse and interpret seismograms.
3. Students will obtain in-depth knowledge on the procedures of geological and geochemical mapping for mineral exploration.
4. Students will have sound knowledge on different geochemical environments and will be able to identify and interpret geochemical anomalies**.**

Unit I: Introduction to seismology; Types of Seismic waves and their characteristics, Earthquake and its effects; Elastic rebound theory; Classification of earthquakes; Seismicity and seismotectonics of India; Magnitude scales; Intensity scales.

UNIT II: Theory of elasticity; Generalized Hooke's law; Different types of elastic waves; Seismometers; Analysis of seismograms; Seismic networks and arrays; Earthquake prediction.

UNIT III: Mineral Stages and norms of exploration. Geological techniques and procedures of exploration. Geological criteria and guides to mineral search. Geological mapping phases and types. Sampling methods.

UNIT IV: Exploration of important economic mineral deposits. Exploration case histories. Study of geological maps and sections, stratigraphic columns, structure contour maps, isopach maps, facies maps.

UNIT V: Geochemistry in Mineral exploration. Geochemical dispersion, mobility and association of elements; various prospecting methods for geochemical rock sampling, soil, water, drainage, biogeochemical and geobotanical surveys and a brief description of geochemical anomalies developed in it.

Books recommended:

Thorne Lay & Terry C.: Wallace Modern Global Seismology, Academic Press
Peter M. Shearer: Introduction to Seismology, Cambridge University Press

Charles Moon, Charles J., Whatley Michael K.G. and Evans K.M. 2006; Introduction to mineral exploration, Blackwell publishing
Haldar S.K.; Mineral exploration, principle and exploration
Kuzbart M. and Bohmer M. 1978; Prospecting and exploration of mineral deposits. Elsevier Sci.
Levinson, A. A. 1974; Introduction to exploration geochemistry, Applied Pub.,
Calgary Peters, W.C. 1978; Exploration and mining geology. John Wiley & Sons, N.Y.

ESC-653 (ii): **Engineering Geology and Geo-hazards**

(Credits 4; 60 Hrs; Max. Marks: 100 = 70 End Sem. + 30 sessional)

Course Objectives:

1. This course is focussed to study the use of geological knowledge in civil constructions and mining industry
2. To learn about geological factors evaluated for dams and reservoir building
3. To understand the correlation between geology and environment
4. To study the mass wasting processed and basin morphometry
5. To study role of geology and broad applications of geological principles in the domains of geotechnical engineering, natural & man-made environment, natural disasters and seismicity.

Course Learning Outcomes:

1. The students will learn about the feasibility of rocks as construction material
2. The students will learn about the inter-relationship between geological processes and their direct and indirect impact on the associated domains of environmental geology.
3. The students will understand the potentials of natural processes causing natural disasters and seismicity.
4. The students will develop understandings on the safe/unsafe zones from earthquakes and landslides.
5. This will groom the students for jobs in construction domain.

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

UNIT II: Geological considerations for evaluation of dams and reservoir sites. Geotechnical evaluation of tunnel alignments, transportation routes and bridges.

Unit III: Environmental geologic mapping. Environmental change- natural and man-made; Prediction of environmental changes and areas of human concern and impact indicators. Environment impact analysis of dams, building, highways and tunnels. EIA methods.

UNIT IV: Mass movement with special emphasis on landslides and causes of hillslope instability. Identification of landslide prone areas; Flood hazard: Management. Zoning and risk assessment: Hazard Zonation maps.

UNIT V: Seismic hazards: Earthquake and seismicity, Causes and prediction; Seismic zones of India. Aseismic design of buildings. Influence of geological condition on foundation and design of buildings.

Books Recommended:

Arrogyaswami, R.N.P. 1996: Courses in Mining Geology (IV ed). Oxford IBH
Bell, F.G. 199: Geological Hazards. Routledge.
Bryant, E. 1985: Natural Hazards. Cambridge University Press.
Clark, G.B. 1967: Elements of Mining (3rd ed). John Wiley.
Keller, E.A. 1978: Environmental Geology. Bell and Howell.
McKinstry, H.E. 1962: Mining Geology (2nd ed). Asia Publishing House.
Peters, W.C. 1978: Exploration and Mining Geology. John Willey and Sons.

Smith, K. 1992: Environmental Hazards. Routledge.
Subramaniam, V. 2001: Textbook in Environmental Science. Narosa International.
Valdiya, K.S. 1987: Environmental Geology Indian Context. Tata McGraw Hill.

ESC-654: **Dissertation (Research Project Part II)**
(Credits 8; 240 Hrs; Max. Marks: 200 = 140 End Sem. + 60 sessional)

The dissertation will be field/laboratory/data based and will be carried out under the guidance of a faculty member. The dissertation findings shall be compiled and submitted in the form of a thesis for evaluation. The candidates are also required to present their dissertation findings in the form of seminar followed by viva-voce before a duly constituted committee.

A certificate duly signed by the candidate and the supervisor has to be enclosed stating the genuineness of the work.

Examiners and scheme of evaluation shall be as follows:

1. Board of Examiners:
   i. Chairman: Head of Department
   ii. Expert: External Examiner
   iii. Member: Supervisor/ Internal Examiner

2. Evaluation Scheme:
   i. Evaluation (Thesis + Seminar/Viva-voce) : 140 Marks
   (Jointly by External and Internal Examiners)

   ii. Seminar/Viva-Voce : 40 Marks