

**Department of Earth Science
Aryabhata School of Earth Sciences
Assam University, Silchar**

Framework and Syllabus for
Master of Science

in

Applied Geology

Based on
National Education Policy (NEP-2020)



M.Sc.(Applied Geology) Course Curriculum
(Effective from the Academic Year 2022-23)

**Department of Earth Science
Assam University,
Silchar -788011**

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

<i>Paper Code</i>	<i>Description</i>	<i>Credit</i>	<i>Hours/Week</i>	<i>Marks</i>
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

<i>Paper Code</i>	<i>Description</i>	<i>Credit</i>	<i>Hours/Week</i>	<i>Marks</i>
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

<i>Paper Code</i>	<i>Description</i>	<i>Credit</i>	<i>Hours/Week</i>	<i>Marks</i>
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

<i>Paper Code</i>	<i>Description</i>	<i>Credit</i>	<i>Hours/Week</i>	<i>Marks</i>
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

SI	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. (Applied Geology)

First Semester

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

Second Semester

Paper Code	Title of the paper	Credit	Mark distribution		
			Sem End	Sessional	Total
ESCC-551	Metamorphic Petrology and Geochemistry	4	70	30	100
ESCC-552	Principles of Stratigraphy and Applied Palaeontology	4	70	30	100
ESCC-553	Hydrogeology and Advanced Sedimentology	4	70	30	100
ESIDC-554	(I): Essentials of Earth System Sciences (II): Meteorology and Oceanography	3	70	30	100
ESALIF-555	Laboratory	3	70	30	100
ESVBC-556	Fuel Geology (Coal, Petroleum and Atomic Minerals)	2	70	30	100
Total Credit		20	Total Marks		600

Third Semester

Paper Code	Title of the paper	Credit	Mark distribution		
			Sem End	Sessional	Total
ESCC-601	Optical mineralogy and Advanced Igneous Petrology	4	70	30	100
ESIDC-602	Environmental Geology	4	70	30	100
ESDSE-603	(i) Instrumentation techniques in Earth Science (ii) Geophysics and Geoinformatics	4	70	30	100
ESALIF-604	Laboratory and Field work	3	70	30	100
ESPOD(I)-605	Project Oriented Dissertation (Part I)	5	70	30	100
Total Credit		20	Total Marks		500

Fourth Semester

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

First Semester
Orientation: Compulsory
ESORC-500: Orientation Course
(Credits Nil; one- two weeks; Marks: Nil)
Attendance: minimum 70% of the classes to pass the course

Course Objectives:

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

Course Outcome:

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.

Discipline Specific: Core
ESCC-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 and rules for development of atomic structures in silicate minerals.
2. Students will be able to identify mineral phases based on physical and optical properties.
3. Students will obtain sound knowledge on magma generation processes, crystallization mechanisms and identify 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, P-T 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 Guillman: Art and Science of Crystal Growth.
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).

Discipline Specific: Core
ESCC-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 aerial photography.

Course Learning Outcomes:

1. Students will have the working knowledge for every group of fossils.
2. They will be able to identify various groups of fossils and 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 of 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 dinoflagellates 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.

UNIT 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, N.Y.
M.J. Benton, 1990: Vertebrate Paleontology. Unwin Hyman, London
Bignot, G., Grahm and Trotman, 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 Stanley, S.M. 2008: Earth System History, Blackwell Publ.
D.M. Raup, and S.M. Stanley, 1985: Principles of Paleontology, CBS Publ.
Jim E. and Floyd Sabbins 2020: Remote Sensing Principles and Applications; 4th Edn. 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.

Discipline Specific: Core
ESCC-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 role of fluid-sediment interaction processes to develop bedforms.
3. 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 Sedimentology, Blackwell Scientific Publication.

Discipline Specific: Skill Enhancement Course
ESSEC-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 gather 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. and Williams, P.F. (1976): An outline of Structural Geology, John Wiley and Sons, New York.
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. Ind
A.B. Dasgupta, and A.K. Biswas, 2000: Geology of Assam. Geol Soc. India, Bangalore.
D. N. Wadia, 1957: Geology of India (3rd ed). Mc Millan, London, 536p.
E. H. Pascoe, 1968. A manual of the Geology of India & Burma (Vols. 1 – 1v) Govt. of India Press, Delhi.
M.S. Krishnan, 1982. Geology of India and Burma (6th ed) CBS Publishers & Distributors, Delhi, 536p.
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 223p

Discipline Specific: Apprenticeship/Laboratory/Internship/Field (ALIF)
ESALIF-505: **Laboratory 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.

Compulsory Community Engagement Course (CCEC)
ESCCEC-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
Discipline Specific: Core
ESCC-551: Metamorphic Petrology and Geochemistry
(Credits 4; 60 Hrs; Max. Marks: 100 = 70 End Sem. + 30 sessional)

Course Objectives:

- 1) The course aims 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 develop knowledge and understanding of theoretical, and applied aspects of geochemistry in the near-surface as well as deep earth environment.
- 4) To develop 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 the quantitative as well as qualitative mineral and mineral assemblage data to interpret different metamorphic reactions.
- 3) Students will study the geochemical properties of major trace and rare earth elements. They will learn the principles and applications of Stable and Radiogenic isotopes in geological studies.
- 4) Students will learn about the classification, mineralogy, origin and significance of meteorites:
- 5) Students will be made ready for research work as well as preparing themselves for various competitive examinations.

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:

- Albarede, F., 2003. An introduction to geochemistry. Cambridge University Press.
Bucher, K. and Grapes, R., 2010. Petrogenesis of Metamorphic Rocks, Springer
Best, M.G., 2003. Igneous and Metamorphic Petrology, Blackwell Science.
Winkler, HGF, 1979: Petrogenesis of Metamorphic Rocks, Springer
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.

Mason, B. and Moore, C. B., 1991. Introduction to Geochemistry, Wiley New York
Walther, 2009. Essentials of Geochemistry, Jones and Bartlett Publishers.
Rollinson, H., 2007. Using Geochemical Data: Evaluation, Presentation and Interpretation. Longman
Marshall, C.P. and Fairbridge, R.W., 1999. Encyclopaedia of Geochemistry

Discipline Specific: Core
ESCC-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. They can use different palaeontological principles to any group of fossils to understand their ecology, interaction, morphodynamics, biogeographical distributions etc.
- 2) 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

Discipline Specific: Core
ESCC-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. It is mandatory to identify and characterise different sedimentary rocks through their chemical attributes.
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: on-land 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 (2nd edition): Sedimentology and Stratigraphy. Blackwell.

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

Tucker, M.E. (1990): Carbonate Sedimentology, 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.

Discipline Specific: Interdisciplinary Core Course
ESCC-554 (I): 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, Lon
- 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

Discipline Specific: Interdisciplinary Core Course
ESIDC-554 (II): **Meteorology and Oceanography**
Credits 3; 45 Hrs; Max. Marks: 100 = (70: End Sem. + 30: sessional)

Course Objectives:

1. To acquaint students with fundamental concepts related to the atmosphere and its associated phenomena.
2. To provide understandings of atmospheric stability, mechanisms of cloud formation, and the atmospheric heat budget.
3. To offer insight into the physical processes within the ocean and the interactions between the ocean and the atmosphere.
4. To provide knowledge on the ocean waves, tides, ocean water masses, and the Indian Monsoon system.

Course Learning Outcomes:

1. Students will understand fundamental concepts pertaining to the ocean, atmosphere, and climate.
2. Students will become familiar with wind systems, atmospheric air masses and associated phenomena.
3. Students will learn the ocean-atmosphere interaction processes and Indian Monsoon system.
4. Students will be able to understand ocean circulation system and water budget.

UNIT I: The atmosphere: composition and vertical thermal structure; concept of an air parcel, dry and saturated adiabatic lapse rate; Radiation: basic Laws - Rayleigh and Mie scattering, multiple scattering, radiation from the sun; Atmospheric stability, cloud development, cloud classification, precipitation processes and precipitation types; Surface and planetary albedo; Insolation and heat budget.

UNIT II: Scales of Atmospheric Motion, Local Wind Systems, Global Wind Patterns, Air Masses and their classification, Fronts, formation of cyclones and anticyclones, tornadoes, hurricanes and typhoons. General weather systems of India, Cyclone and jet stream, Western disturbances, Classification of climates – Koppen's and Thornthwaite's scheme of classification.

UNIT III: Physiography of ocean floors; Physical and chemical properties of sea water and their spatial variations. Processes controlling composition of seawater, Residence times of elements in sea water. Thermohaline circulation. Ocean Laws and management; Mineral and hydrocarbon resources of the oceans.

UNIT IV: Ocean circulation: wind induced currents, Upwelling, sinking; equatorial current system, warm and cold currents of major world ocean, seasonal currents in North Indian Ocean, Waves: wave parameters, deep and shallow water waves, wave theories. Tides: Tide generation and propagation; characteristics of tides; Types of tides, tidal theories.

UNIT V: Water masses: T-S diagram, Characteristics of water masses, Deep circulation of water masses, Major water masses of the world oceans, Ocean – Atmosphere interaction in tropics, Southwest and Northeast monsoon in Indian subcontinent, El-nino and Southern Oscillation (ENSO), La-nina

Books Recommended:

- Holton JR: An Introduction to Dynamic Meteorology, Fourth Edn., Elsevier Press, 2004.
Lynch H, Cassano JJ: Atmospheric Dynamics, Wiley, 2006.
Gill A. Dynamics of Ocean and Atmosphere, Academic Press.
Pond and Pickard. Introductory Dynamical Oceanography, Butterworth-Heinemann, 1983
John A. Knauss. Introduction to physical oceanography, Waveland Pr Inc
Talley L D, Pickard G L, Emery, W J, Swift, J H. Descriptive Physical Oceanography: An Introduction Sixth Edition Elsevier Press, 2011
John Ralph Apel. Principles of Ocean Physics. Academic Press

Discipline Specific: Apprenticeship/Laboratory/Internship/Field
ESCC-555: Laboratory

(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 $^{235}\text{U}/^{207}\text{Pb}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ 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.

Discipline Specific: Value Based Course (VBC)

ESCC-556: Fuel Geology (Coal, Petroleum, and Atomic Minerals)

(Credits 2; 30 Hrs; Max. Marks: 100 = 70 End Sem. + 30 sessional)

Course Objectives

1. To introduce coal geology which involve various aspects of coal petrology, formation, origin and grading of coal.
2. To cover various aspects of petroleum geology and prospecting for oil and gas deposits in current scenario.
3. To study the drilling and logging procedures.
4. To classify atomic minerals and study 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.
4. Students will learn about the distribution of important atomic mineral deposits in India. Nuclear power stations and their prospects
5. Further, knowledge gained from this course will help to seek jobs in the coal, oil & gas, atomic mineral exploration sectors in the country and abroad.

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.
Singh, M.P. (Ed). 1982: Coal and Organic Petrology. Hindustan Publ. Corp. New Delhi.
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
Discipline Specific: Core
ESCC-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 an elaborate knowledge on mantle chemistry, partial melting processes in the mantle along with hot spots and plume related magmatism.
5. To relate magmatism with global tectonic processes and characterize the nature of the magma associated with specific tectonic settings.

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.
5. This will also open paths toward research in the field of advance mantle geochemistry.

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 Hubert, 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)

Discipline Specific: Interdisciplinary Core Course (IDC) ESIDC 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 pedology.
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.

Discipline Specific: Elective Core Course **ESECC-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. 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.

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:

Azaraoff: Elements of X-ray Crystallography

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

Discipline Specific: Elective Core Course
ESECC-603(ii): Geophysics and Geoinformatics
Credits 4; 60 Hrs; Max. Marks: 100 = 70 End Sem. + 30 sessional)

Course Objectives: This course broadly focusses on the following objectives:

1. Study of various physical properties of the earth and its interior,
2. Study of seismic wave velocities and its interaction with layers within earth
3. The study of earth's magnetic field, its components and paleomagnetism.
4. 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. Palaeomagnetism 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: Palaeomagnetism, 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.

**Discipline Specific: Apprenticeship/Laboratory/Internship/Field
ESCC-604: Laboratory 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.

**Discipline Specific: Research Project Part-I
ESCC-605: Dissertation (Research Project Part I)**

(Credits 5; 150 Hrs; Max. Marks: 100 = 70 End Sem. + 30 sessional)

Candidates admitted to the M.Sc. Programme in 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) jointly by External and Internal Examiners : 70 Marks
- ii. Seminar/Viva-Voce : 20 Marks

Fourth Semester
Discipline Specific: Core
ESCC-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 spatial and temporal distribution of different sedimentary, igneous and sedimentary rocks of India.
5. To know the interrelationship of different lithounits of different basins, cratons, mobile belts etc.
6. To know about the lithological, palaeontological, geochemical variation of different rock units in India along with their palaeoenvironment, palaeoclimate, palaeogeographical position, economic value etc.

Course Learning Outcomes:

1. At the end, the students will have sound knowledge on structural geology. Students will obtain comprehensive knowledge 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, which is very much needed to carry on any economic exploration, climatic/ environmental condition, ground water problem, earthquake related problem etc. They will have the knowledge of all the rock strata of India.

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 Singhbhum, 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 Trichinopoly. Deccan Volcanism. Classification, lithology, correlation and fossils of Cenozoic rocks of India with particular reference Assam-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.

Passier, 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.

Discipline Specific: Core
ESCC-652: Ore Geology and Mining Geology
 (Credits 4; 60 Hrs; Max. Marks: 100 = 70 End Sem. + 30 sessional)

Course Objectives:

1. To study the role of magmas in formation of ores in space and time, nature and morphology of ore deposits etc.
2. To understand the Interaction of ore bearing magmatic/ hydrothermal fluids with the country rock and their implications.
3. To study the mineralogical association of the various ore minerals in various rock types controlled by the various geological processes viz. igneous, sedimentary and metamorphic.
4. To learn about the mineralogy and genesis of various metalliferous ores and their distribution in India.
5. To develop knowledge on various stages of mining and mineral exploration methods.

Course Learning Outcomes:

1. This course will provide a solid 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 economic ore deposits will supplement their understanding.
4. Further, knowledge gained from this course will also 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:

- Arrogayaswami, 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.

**Discipline Specific: Elective Core Course
ESCC-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 relation to 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
Halder 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.

Discipline Specific: Elective Core Course
ESCC-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 processes 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 knowledge on engineering geology will help students to understand 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 how geology is sometimes catalysing natural disasters and seismicity.
4. The students will develop a brief knowledge on which are the safe 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.

Discipline Specific: Research Project Part-II
ESCC-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) jointly by External and Internal Examiners : 140 Marks
- ii. Seminar/Viva-Voce : 40 Marks