Program Structure and Syllabus

for

2-Year M. Tech.

in

GEO-EXPLORATION

Department of Applied Geology and
Department of Applied Geophysics
Indian Institute of Technology
(Indian School of Mines)
Dhanbad-826004

(Recommended to be effective from Academic Session 2019-20 onwards)

A. About the M. Tech. Geo-exploration Programme

Exploration forms the backbone of resource development and evaluation. Natural resources like Petroleum, Coal, Mineral deposits, and Groundwater are all geologically controlled and their formation, dimensions, extent, mode of occurrence and spatial variation are affected by characteristic geological settings with the interplay of several factors that contribute to the economic viability of the deposit.

The 2-year M. Tech. program in Geo-exploration is multidisciplinary and is designed to educate and train the students to take up the challenges of exploration of the hydrocarbon and mineral deposits. The course is equipped with the state-of-the art topics on exploration by geological, geochemical and geophysical techniques including both surface and the subsurface methods applying field, laboratory and computer simulation techniques. Students will be encouraged to take up dissertation topics based on active and future exploration challenges of mineral and hydrocarbon deposits. At the end of the course students can find opportunity in the service sectors of mineral and hydrocarbon industries and may also proceed towards research and development.

The M. Tech. program shall be jointly operated by Department of Applied Geology and Department of Applied Geophysics, IIT (ISM) Dhanbad.

B. Eligibility Criteria:

Any of the following:

- M.Sc./M. Sc. Tech. degree in Geology/Applied Geology/Geoscience/ Exploration Geology/Marine Geology with 3-year B. Sc (Honours/Major/Main) in Geology
- M.Sc./M. Sc. Tech. degree in Geophysics/Applied Geophysics/ Exploration Geophysics/ Marine Geophysics with any two subjects out of Mathematics/ Physics/ Chemistry at B.Sc. level.
- 5-year integrated M.Sc./M. Sc. Tech./M. Tech in Applied Geology/5-year integrated M.Tech. in Geological Technology/Geoexploration/Geoexploration Technology/Exploration Geology
- 5-year integrated M.Sc./M. Sc. Tech. in Applied Geophysics/5-year integrated M. Tech. in Geophysical Engineering/Geophysical Technology.
- B.S-M.S. Earth Sciences/Geosciences
- B.E./B. Tech. in Mining/Opencast Mining Engineering.
- B.E./B. Tech. in Mineral/ Mining/ Metallurgy Engineering.

- B.E. / B. Tech. in Petroleum Engineering/ Applied Petroleum Engineering/ Petroleum Studies/ Petroleum Technology/ Petroleum Science/Petroleum Science and Engineering.

Note:
Candidates with colour blindness/uniocularity are not permissible.
GATE Paper Codes for GATE candidates: GG, MN, PE, MT

C. Proposed Seat Distribution:

Total seats = 15.
Seats reserved for various categories, as per rules of the Institute.

D. Other

Other items, as listed below, shall be as per M.Tech. Brochure and rules of the Institute.

- General Eligibility
- Selection Procedure
- Admission Procedure
- Scholarship
- Reservation

Annexure -V

PG Course Template for
2-Year M. Tech. Programme in GEO-EXPLORATION

Semester I

Course No.	Course Name	L	T	P	C
	Theory				
GLC 556	Geological and Geophysical Exploration for Mineral Deposits	3	0	0	9
GLC 557	Tectonics and Structural Geological Methods for Exploration	3	0	0	9
GPC 551	Petroleum Geophysics	3	0	0	9
GLC 592	Programming in MATLAB	3	0	0	9
GLC 559	Resource Evaluation and Geostatistics	3	0	0	9
	Practical				
GLC 560	Geological and Geophysical Exploration for Mineral Deposits Practical	0	0	3	3
GLC 561	Tectonics and Structural Geological Methods for Exploration Practical	0	0	3	3
	Total	**15**	**0**	**6**	**51**

Semester II

Course No.	Course Name	L	T	P	C
	Theory				
GLD 569/570/571	Department Elective 1	3	0	0	9
GPD 550/GLD 572/573/574	Department Elective 2	3	0	0	9
GPD 523/GLD 575	Department Elective 3	3	0	0	9
	Open Elective 1 (Table-7)	3	0	0	9
	Open Elective 2 (Table-7)	3	0	0	9
	Practical				
GPC 553	Petroleum Geophysics Practical	0	0	2	2
GLC 562	Resource Evaluation and Geostatistics Practical	0	0	3	3
	Total	**15**	**0**	**5**	**50**

Semester – III

Course No.	Course Name	L	T	P	C
GLC 563	Thesis Unit 1	0	0	0	9
GLC 564	Thesis Unit 2	0	0	0	9
GLC 565	Thesis Unit 3	0	0	0	9
GLC 566	Thesis Unit 4	0	0	0	9
	Total	**0**	**0**	**0**	**36**

Semester – IV

Course No.	Course Name	L	T	P	C
GPD 551/GLD 576/577	• **Department Elective 4** **or** **Open Elective 3** (Table-7)	3	0	0	9
GPD 552/GLO 596	• **Department Elective 5** **or** **Open Elective 4** (Table-7)	3	0	0	9
GLC 567	Thesis Unit 5	0	0	0	9
GLC 568	Thesis Unit 6	0	0	0	9
	Total	**6**	**0**	**0**	**36**

Table 1. List of Department Elective-1 (DE-1)

Course No.	Course Name	L	T	P	C	S#
GLD 569	Exploration of Coal, Coal Bed Methane, Shale Gas and Gas Hydrate	3	0	0	9	W
GLD 570	Hyperspectral Remote Sensing	3	0	0	9	W
GLD 571	Petroleum Exploration and Micropalaeontology	3	0	0	9	W

Table 2. List of Department Elective-2 (DE-2)

Course No.	Course Name	L	T	P	C	S#
GLD 572	Advanced Geostatistics and Exploration Economics* (*Prerequisite: Course on “Resource Evaluation and Geostatistics”)	3	0	0	9	W
GLD 573	Sedimentary Environment, Sequence stratigraphy and Basin Analysis	3	0	0	9	W
GLD 574	Geospatial Analysis	3	0	0	9	W
GPD 550	Geophysical Methods for Coal Exploration	3	0	0	9	W

Table 3. List of Department Elective-3 (DE-3)

Course No.	Course Name	L	T	P	C	S#
GLD 578	Rock Deformation Kinematics for Engineering Geology	3	0	0	9	W
GLD 575	Modern Instrumental Methods in Exploration Geosciences	3	0	0	9	W

Table 4. List of Department Elective-4 (DE-4/OE-3)

Course No.	Course Name	L	T	P	C	S#
GLD 576	Nanotechnology in Mineral and Hydrocarbon Exploration	3	0	0	9	W
GPD 551	Engineering Geophysics	3	0	0	9	W
GLD 577	Digital Image processing	3	0	0	9	W

Table 5. List of Department Elective-5 (DE-5/OE-4)

Course No.	Course Name	L	T	P	C	S#
GLD 540	Geomorphology	3	0	0	9	W
GPD 552	Geophysical Methods for Groundwater Exploration	3	0	0	9	W

Table 6. List of Department Core Practical Courses

Course No.	Course Name	L	T	P	C	S#
GPC 553	Petroleum Geophysics Practical	0	0	2	2	W
GLC 562	Resource Evaluation and Geostatistics Practical	0	0	2	2	W

Note: Where S# = Semester in which course may be offered.
M = Monsoon Semester; W = Winter Semester.

Table 7. Table of Open Electives (any one or from Department Electives or Other Department) (OE-1 & OE-2)

Course No.	Course Name	L	T	P	C	S#
GPO 515	Well Logging and Seismic Reservoir Characterization	3	0	0	9	W
GPD 521	Time Series Analysis in Geosciences	3	0	0	9	W
GLD 594	Geotechniques of Dams, Tunnels and Underground Space	3	0	0	9	W
GLD 592	Environmental Geotechnology	3	0	0	9	W
GPO 503	Artificial Intelligence and Machine Learning in Geosciences	3	0	0	9	W

A. Syllabus of Department Core (DC): Theory Courses

1. Course Name: Geological and Geophysical Exploration for Mineral Deposits#

Course Code: GLC 556
L-T-P = 3-0-0
Credit = 9
Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Concepts and methods in mineral exploration: Different concepts used in mineral targeting, remote sensing application in mineral exploration, geological methods of prospecting and exploration.	6
2.	Different stages of exploration: Objectives and tasks involved; preliminary studies and reconnaissance surveys, sampling, borehole planning and methods of reserve estimation.	7
3.	Exploration Geochemistry: Geochemical mobility and association of elements. Geochemical anomalies – primary and surficial dispersion patterns. Reconnaissance and detailed geochemical exploration, Geochemical soil surveys, drainage and hydrogeochemical surveys, geobotanical and biogeochemical prospecting	7
4.	Environmental planning for exploration and mining: Environmental baseline data acquisition and documentation, nature and extent of environmental problems due to surface and underground mining – Air pollution, water pollution, visual impact, noise pollution. Reclamation and Mine waste management.	6
5.	Introduction to geophysics: Geophysical methods used in mineral exploration, Geophysical anomalies and their sources, Ambiguity, Geophysical exploration practice	2
6.	Data enhancement: Wavelength-based enhancement, Gradient-based enhancements, Amplitude-based enhancements	3
7.	Petrophysics: Bulk-grain-texture, Importance of proper sampling, Rock and mineral density and magnetism, Physical properties and common geological processes, Importance of analysing the data in a geochemical/petrological/geological framework, Workflow for petrophysical data in a mineral systems context: analysis in context of lithology, stratigraphy, metamorphism/alteration, location	5
8.	Geophysics of metamorphic orogenic deposits	4

Total Classes =	**39**

 # Units 5-8 will be contributed and covered by faculty from Department of Applied Geophysics

Recommended Text Books

1. Gandhi, S. M., & Sarkar, B. C. (2016). Essentials of Mineral Exploration and Evaluation. Elsevier.
2. Michael , D., and Mudge, S. T., 2014, Geophysics for the Mineral Exploration Geoscientist, Cambridge University Press

Other references

3. McCuaig, T.C. and Hronsky, J.M.A., 2014. The Mineral System Concept: The Key to Exploration Targeting Society of Economic Geologists Special Publication 18, pp. 153–175.

Course Goal / Learning Outcome:

The primary objective of the course is to introduce the different approaches and methods of mineral exploration, execution of the exploration project and simultaneously evaluation of the environmental impacts and possible remedial measures.

Unit wise Learning Objectives

Upon completion of the course, students will be able to:

1. Understand how the mineral exploration is initiated in different terrains from a thorough geological and geochemical overview of the area.
2. Planning of the exploration programme including subsurface exploration and sampling.
3. Geochemical tools (conventional and non-conventional methods) in mineral exploration.
4. Environmental issues related to exploration and mining and different rules pertaining to these issues.
5. Understand the mineral system concept and its implications for geophysical exploration, especially when exploring for blind targets.
6. Know how to recognise responses from components of mineral system in their geophysical datasets.
7. Understand data enhancement in geophysical data sets
8. Be familiar with the geophysical characteristics of metamorphic orogenic deposits.

2. Course Name: Tectonics and Structural Geological Methods for Exploration

Course Code: GLC 557
L-T-P = 3-0-0
Credit = 9
Syllabus & Lecture Plan:

Unit	Description	No. of classes
1.	Introduction to stress and strain in rocks	3
2.	Mapping of surface exposures of folded areas: Projection of fold geometry; Concentric-arc method; Kink-style construction; Down-plunge projection method. Analysis of superposed terrains.	6
3.	Mapping of subsurface structural geometry: Structural contour maps, isopach and isochore maps. Stratigraphic sections and Fence diagrams.	3
4.	Analysis of areas with brittle deformation of rocks: Faults, Fractures and fracture types. Relationship with stress / strain. Concept of fault interactions and thrust belt geometry. Balanced cross-section.	6
5.	Analysis of areas with ductile deformation of rocks: Development of ductile shear zones. Shear zone rocks. Shear sense criteria. Mechanisms of deformation.	3
6.	Plate Tectonics: Concepts of plate tectonics and kinematics of plate motion	6
7.	Evolution of different plate boundaries: Divergent / convergent / strike-slip boundaries and their petro-tectonic assemblages.	9
8.	Plate Tectonic Settings and Mineral / Hydrocarbon accumulation.	3
	Total Classes =	**39**

Recommended Text Books:

1. Fossen, H 2016 Structural Geology, 2nd edition, Cambridge University Press.

Other references:

2. Davis, GH and Reynolds, SJ (1996) Structural Geology of Rocks and Regions (2nd Ed.). John Wiley & Sons.
3. Ghosh, SK (1993) Structural Geology. Pergamon Press.
4. Marshak, S and Mitra, G (1988) Basic Methods of Structural Geology. Prentice Hall.
5. Ramsay, JG and Huber, MI (1987) The Techniques of Modern Structural Geology. Academic Press.
6. Roberts, J.L. (1982) Introduction to Geological Maps and Structures. Pergamon Press.

7. Tearpock and Bischke, R.E. (2003). Applied Subsurface Geological Mapping with Structural Methods (Second Edition). Prentice Hall PTR, New Jersey, 822p.
8. Turcotte, D.L. and Schubert, G. (2002). Geodynamics (2nd Edition). Cambridge University Press
9. Twiss, RJ and Moores, EM (1992) Structural Geology. W. H. Freeman & Company.
10. Woodward, NB, Boyer, SE and Suppe, J (1989) Balanced Geological Cross-sections. Amer. Geophys. Union.

Course Goal / Learning Outcome:

The primary objective of the course is to provide theoretical background for different structural techniques and tectonic analyses used in industry / exploration organisations.

Learning Objectives:

Upon completion of the course, students will be able to:
1. Apply different methods to determine structural geometry.
2. Determine strain in rocks.
3. Understand the tectonic environments of rocks formation.

Unit wise learning objectives

1. Knowledge of mapping techniques and section preparation in complexly folded terrains
2. Gain insights of subsurface structural geometry
3. Knowledge on fracturing of rocks and their analysis.
4. Understand shear zones, their development and role in mineralization
5. Knowledge on how plate motion occurs and why.
6. Knowledge on interaction of plate boundaries , their types and associated rock and structures
7. Application of Plate Tectonics on occurrences of Mineral /Hydrocarbon exploration.

3. Course Name: Petroleum Geophysics

Course Code: GPC 551
L-T-P = 3-0-0
Credit = 9
Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Introduction and theory of potential field: Inverse square law and concept of potential; Poisson's and Laplace's equations; Earth's gravity and magnetic field; Susceptibilities and densities	5

	of various rocks and minerals; factors affecting density and susceptibilities, density and susceptibility determination.	
2.	Instruments for potential field data acquisition: Gravity and Magnetic instruments for exploration; Land, shipborne and airborne gravity and magnetic surveys; Gravity data reduction- Drift, Latitude, Elevation, Free-air and Bouguer corrections. Free-air, Bouguer anomalies and Isostatic anomalies; various corrections applied to magnetic data-Diurnal, IGRF and Reduction to Pole transformation.	5
3.	Data analysis and interpretation of potential field: Analytic methods for separation of regional and residuals; ambiguity in potential field interpretation and conditions for unique interpretation; wavelength filtering; upward and downward continuation; calculation of second vertical derivatives; gravity and magnetic anomalies due to simple and irregular shaped 2-D and 3-D bodies; Source-depth estimation techniques-Half width rules, Wenner and Euler deconvolution; Gravity and magnetic anomalies- salt domes and stratigraphic traps. Application of gravity and magnetic in hydrocarbon exploration- Structural identification, Basement depth mapping and reservoir monitoring.	5
4.	Introduction of oil and gas cycle and seismic theory: Introduction of Hydrocarbon Exploration and its classification; Oil and Gas life cycle. Different terminology for hydrocarbon exploration, Understand seismic fundamentals and the advantages of seismic data in their hydrocarbon exploration and exploitation practice, Wave physics and fundamentals of seismic theory.	4
5.	Seismic data acquisition technique: Methodology for 2D seismic reflection survey, Different kinds of shooting techniques & geometry, 3D survey designing for conventional & unconventional reservoir in hydrocarbon exploration, Advanced source and receiver system, Marine seismic data acquisition technique.	5
6.	Introduction passive seismic data: Introduction of passive seismic survey and usefulness of this survey in hydrocarbon exploration, Case study for passive seismic in hydrocarbon exploration	2
7.	Seismic data processing technique: Introduction of seismic data processing technique, workflow of standard seismic data processing for 2D and 3D seismic survey. Velocity gradients and turning waves, Aliasing & frequency-shifting in migration, Reverse-time migration.	5
8.	Seismic data interpretation: Standard work flow for seismic	4

	interpretation, Study of seismic section and other geological aspects of prospecting, structural interpretation, Construction of isochron and isopach maps & seismic stratigraphic interpretation. Velocity model building & depth conversion, Incorporation of anisotropy factor in velocity model, Seismic attribute analysis.	
9.	Well logging method for exploration: Introduction well logging technology in hydrocarbon exploration, conventional and special tools, Using of well log data in challenged reservoir such as detection of overpressure zone from well logs, detection of fractures from FMS/FMI, and Dipmeter and interpretation of Dipmeter logs etc.	4
	Total Classes =	**39**

Recommended Text Books

1. Dobrin, M. B. and Savit, C., 1988, Introduction to Geophysical Prospecting, 4th Edition. McGraw Hill College Publishers.

Other References:

2. Parasnis, D. S., Applied Geophysics
3. Rao, B. S. R. and Murthy, I. V. R., Gravity and Magnetic Methods of Prospecting
4. Nettleton, L. L., Gravity and Magnetics in Oil prospecting
5. Telford, W. M., Geldart, L. P., Sheriff N D & Keys, D. A., 1976 Applied Geophysics.
6. Lowrie W. 2006. Fundamental of Geophysics. Cambridge University Press.
7. Published Paper in different International and National peer reviewed Journals.

Course Goal / Learning Outcome:

The primary objective of the course is to introduce fundamental and advanced aspects of geophysical study based on data acquisition, processing and interpretation for hydrocarbon exploration.

Learning Objectives:

Upon completion of the course, students will be able to:

1. Knowledge on fundamentals of geophysical methods for hydrocarbon exploration
2. Knowledge on geophysical instrument, data acquisition, processing and interpretation towards hydrocarbon exploration
3. Application of geophysical tools for hydrocarbon exploration

Unit wise learning objectives

1. Knowledge on potential theory and it requirement for characterization of sub-surface geology.
2. Knowledge on instrumentation part towards acquiring potential field data; fundamental knowledge on various correction of field data.
3. Characterization of data variability; clustering and interpretation of potential field data for different types of geological features towards exploration.
4. Fundamental study oil and gas cycle and various geoscientific data required for hydrocarbon exploration; wave physics.
5. 2D and 3D seismic data acquisition technique and process.
6. Knowledge on passive seismic data and requirement of passive seismic for hydrocarbon exploration.
7. Knowledge on seismic data processing technique/workflow for 2D and 3D seismic field acquired data.
8. Fundamental knowledge on seismic interpretation technique; various workflow for seismic data interpretation in different geological setup; knowledge on anisotropy factors for seismic data interpretation.
9. Requirement of well log data; classification of well log; fundamental knowledge on tool physics; working principle.

4. Course Name: Programming in MATLAB

a. **Course Code: GLC 592**
b. **L-T-P = 3-0-0**
c. **Credit = 9**
d. **Syllabus & Lecture Plan:**

Unit	Description	No. of Classes
10.	Introduction: Why MATLAB?, History, Its strengths and Weaknesses, Competitors, Starting MATLAB, Using MATLAB as a calculator, Quitting MATLAB	3
2.	Basics: Familiar with MATLAB windows, Basic Operations, MATLAB-Data types, Rules about variable names, Predefined variables,	5
3.	Programming-I. Vector, Matrix, Array Addressing, Built-in functions, Mathematical, Operations, Dealing with strings (Array of characters). Array of array (cell) concept.	7
4.	Programming-II: Script file, Input commands, Output commands, Structure of function file, Inline functions, Comparison between script file and, Function file.	6
5.	Conditional statements and Loop: Relational and Logical Operators, If-else statements. Switch- case statements, For loop, While loop, Special commands (Break and continue).	5
6.	Creating a database, Import data from large database, Modifying table content, Export data to own file or database, 2D Plotting: In-built functions for plotting. Multiple plotting with special graphics, Curve fitting. Interpolation, Basic fitting interface, 3D Plotting: Use of meshgrid function. Mesh plot, Surface plot, Plots with special	6

	graphics.	
7.	GUI: Creating menu window for providing input, Creating graphical user interface.	4
8.	Applications in Geoscience	3
	Total Classes =	**39**

e. Recommended Text Book

1. Mikhailov, E. E. (2018). *Programming with MATLAB for Scientists: A Beginner's Introduction*. CRC Press.

Other References:

1. Trauth, M., Gebbers, R., Sillmann, E., & Marwan, N. (2007). *MATLAB®Recipes for Earth Sciences*. Springer Berlin Heidelberg.
2. Attaway, S. (2013). *Matlab: A Practical Introduction to Programming and Problem Solving*. Elsevier Science.

f. Course Goal / Learning Outcome:

The primary objective of the course is to introduce programming, data analysis and plotting in MATLAB and its applications in earth sciences.

g. Learning Objectives:

Upon completion of the course, students will be able to:

- Write and read MATLAB programs
- Work with other MATLAB programs and its applications especially in the field of geosciences.

h. Unitwise learning objectives

Upon completion of this course, the student will able to understand:

- Unit 1: What is MATLAB programming language and its strength and weakness
- Unit 2: Basic operations in MATLAB; rules and type of variables
- Unit 3: Vector, Matrix function in MATLAB
- Unit 4: How to input commands in MATLAB and what is its output, structure of function file
- Unit 5: Relational and logical operators; If-else commands
- Unit 6: Various type of plotting options using MATLAB
- Unit 7: Basic knowledge on Graphical User Interface (GUI)
- Unit 8: How MATLAB programming can be used in solving geosciences problems

5. Course Name: Resource Evaluation and Geostatistics

Course Code: GLC 559
L-T-P = 3-0-0
Credit = 9
Syllabus & Lecture Plan:

Unit	Description	No. of Classes
	(A) Theory Classes (L-T-P=3-0-0)	
1.	**Sampling:** Theory, Methods, Sample optimisation, Errors, drill core logging and Core sampling.	3
2.	**Resources and Reserves:** Terminology, Classification Schemes, viz. USGS, UNFC, AAPG Schemes.	3
3.	**Plans and Sections for Ore Evaluation:** Structure Contour Plans, Isopach & Isochore Maps, Isograd Plan, Assay Plan, Ore Distribution Plan, Transverse and Longitudinal Vertical Sections, Slice Plan and Isometric Projection.	2
4.	**Conventional Methods of Ore Evaluation:** Polygonal, Triangular, Sectional, Random Stratified Grid, Contouring, and Distance weighting.	3
5.	**Scales of Measurements in Geology; Basic concepts of Exploration Statistics:** Universe, Population, and Sample; Random Variables; Probability distributions, viz. discrete and continuous; Characterization of Continuous Frequency distribution; Exploratory Data Analysis.	6
6.	**Classical Statistics:** Probability distributions: Theoretical models, Characteristics and Properties of Normal (Gausian), Lognormal, Binomial, Negative Binomial, Poisson and Exponential; Graphical and Numerical Techniques of Model Fit to Normal and Lognormal distributions, and their applications in Mineral Exploration. Tests of Hypotheses (Statistical Tests, viz. t, F and chi-squared goodness of fit); Trend Surface analysis and application in Mineral Exploration.	7
7.	**Geostatistical Concepts and Theories:** Random Function; What, When and Why of Geostatistics; Regionalized Variable Theory;. Geostatistical Schools of thought; Stationarity assumptions in geostatitics.	6
8.	**Semi-variogram Analysis:** Definition, Characteristics, Properties; Relation with Co-variogram; computation of experimental Semi-variograms in One, Two and Three-Dimensions.	7
9.	**Theoretical Models of Semi-variogram:** Models with Sill and without Sill; Trend Models.	2
	Total Classes =	**39**

Recommended Text Books

1. Gandhi, S.M. and Sarkar, B.C. (2016) Essentials of Mineral Exploration and Evaluation, Elsevier, USA, 410 p.
2. Sinclair, A.J. and Blackwell, G.H. (2002) Applied Mineral Inventory Estimation, Cambridge Univ. Press, 378 p.

Other References:

3. Armstrong, M. (1998) Basic Linear Geostatistics, Springer, Berlin, 154 p.
4. Barnes, M.P. (1980) Computer-assisted Mineral Appraisal and Feasibility, SME, New York, 167 p.
5. Caers, Jeff (2005) Petroleum Geostatistics; SPE, 88 p.
6. Chiles, J.P. and Definer, P. (1999) Geostatistics - Modelling Spatial Uncertainty, John Wiley and Sons, New York, 695 p.
7. Clark, I. (1979) Practical Geostatistics, Elsevier Applied Science Publ. London, 151 p.
8. David, M. (1977). Geostatistical Ore Reserve Estimation, Elsevier Scientific Publ. Co. Amsterdam, 364p.
9. Deutsch, Clayton V. (2002) Geostatistical Reservoir Modelling; Oxford University Press, 376p.
10. Dubrule, Oliver (1998) Geostatitics in Petroleum Geology; AAPG Continuing Education Course Note Series #38.
11. Gandhi, S.M. and Sarkar, B.C. (2016) Essentials of Mineral Exploration and Evaluation, Elsevier, USA, 410 p.
12. Goovaerts, P. (1997) Geostatistics for Natural Resources Evaluation, Oxford Univ. Press, Oxford, 483p.
13. Isaaks, E.H. and Srivastava, R. M. (1989) An Introduction to Applied Geostatistics, Oxford University Press, 561 p.
14. Journel, A. G. and Huijbregts, C. J. (1978) Mining Geostatistics, Academic Press, London, 600 p.
15. Kelkar, Mohan and Perez, Godofredo (2002) Applied Geostatistics for Reservoir Characterization; SPE, 263 p.
16. Marjoribanks, Roger W. (1997) Geological Methods in Mineral Exploration and Mining. Springer-Science+Business Media, Dordrecht, 115 p.
17. Moon, C., Whateley, M. K.G., and Evans, A.M. (2006) Introduction to Mineral Exploration. Blackwell Publ., Oxford, 481 p.
18. Peters, W. C. (1978) Mining and Exploration Geology. John Wiley and Sons, Chichester and New York, 696 p.
19. Popoff, C. (1966) Computing Reserves of Mineral Deposits–Principles and Conventional Methods, USBM Inf. Circular, 8283.
20. Rendu, J.M. (1981) An Introduction to Geostatistical Methods of Mineral Evaluation, SAIMM Monograph, Johannesburg, 84p.
21. Sinclair, A.J. and Blackwell, G.H. (2002) Applied Mineral Inventory Estimation, Cambridge Univ. Press, 378 p.

22. Wellmer, F. W. (1998) Statistical Evaluation in Exploration for Mineral Deposits, Springer, Hannover, 379 p.

Course Goal / Learning Outcome:

The key objective of the course is to introduce the students with the techniques of resource evaluation and principles of Geostatistics for mineral and petroleum exploration and evaluation. Tutorial covers techniques of sampling, reserve estimation and problem solving for mineral and petroleum geostatistics.

Learning Objectives:

Upon completion of the course, students will be able to:

1. Conceptualise sampling and resource estimation of mineral deposits and petroleum reservoirs;
2. Understand the utilisation of classical statistical tools and tests as applicable in exploration;
3. Apply concepts and principles of geostatistics for characterisation of mineral deposits and petroleum reservoirs.
4. Carry out Spatial data analysis.
5. Solve geostatistical problems related to characterisation of mineral deposits and petroleum reservoirs.

Overall Learning Outcome*:*

To introduce the students with the techniques of mineral sampling, resource evaluation and principles of Geostatistics for mineral, petroleum and engineering geological applications.

Unit wise learning objectives

1. Theory and procedures of mineral sampling;
2. Resources and Reserves – terminologies and classification schemes;
3. Plans and Sections for Ore Evaluation;
4. Conventional Methods of Ore Evaluation;
5. Basic concepts of Exploration Statistics;
6. Mineral Deposit Statistics;
7. Geostatistical Concepts and Theories;
8. Semi-variogram Analysis;
9. Mathematical models of Semi-variogram.

Prerequisite: This is a pre-requisite course for course on "Advanced Geostatistics and Exploration Economics".

B. Syllabus of Department Core (DC): Practical Courses

6. Course Name: Geological and Geophysical Exploration for Mineral Deposits Practical

Course Code: GLC 560
L-T-P = 0-0-2
Credit = 2
Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Megascopic identification of ore minerals: Identification of different ore and associated gangue minerals based on their physical properties.	2
2.	Microscopic studies of major ore mineral assemblages.	2
3.	Borehole planning and resource estimation methodology: Planning of borehole based on the geological and geochemical signatures.	1
4.	Reserve estimation using the borehole data.	1
5.	Data enhancement, Analysis of petrophysical data.	1
6.	Interpretation of gravity maps for exploration targeting.	1
7.	Interpretation of magnetic maps for exploration targeting.	1
8.	Interpreting electrical data for exploration targeting.	1
9.	Interpreting electromagnetic data for exploration targeting.	1
10.	Integrated interpretation of data set over metamorphic orogenic deposits.	1
11.	Practical Examination.	1
	Total Classes =	**13**

Recommended Book

1. Reedman, J H. Techniques in Mineral Exploration: 1979. Applied Science Publishers Ltd., London.
2. Peters, W.C. Exploration and Mining Geology (2nd Ed.); 1987. John Wiley & Sons, New York.

Other References:

3. Gandhi, S. M., & Sarkar, B. C. (2016). Essentials of Mineral Exploration and Evaluation. Elsevier.

Course Goal / Learning Outcome:

The primary objective of the course is to identify different ore minerals and associated host rocks occurring as different modes. Planning of the borehole based on integrated data sets and resource estimation.

Learning Objectives:

Upon completion of the course, students will be able to:

1. To acquaint the students to identify the different ore minerals and their mode of occurrences associated with various litho units.
2. How to plan the drill holes to understand the subsurface geology and calculate the reserve based on the subsurface data.

Unit wise learning objectives

1. Hand specimen identification of ore minerals and their physical properties
2. Study of ore minerals under the microscope
3. Borehole planning based on geological and geochemical signatures
4. Reserve estimation using Borehole data
5. Analysis of Petrophysical data
6. Interpretation of Gravity maps for exploration targeting
7. Interpretation of magnetic maps for exploration targeting
8. Interpreting electrical data for exploration targeting
9. Interpreting electromagnetic data for exploration targeting
10. Study and interpretation from integrated data sources of metamorphic deposits

Course Name: Tectonics and Structural Geological Methods for Exploration Practical

Course Code: GLC 561

L-T-P = 0-0-2

Credit = 2

Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Stereographic projections: Planes, lines and angles.	1
2.	Stereographic projections: Tilt, rotation and bore-hole data	1
3.	Subsurface Mapping: Preparation and interpretation of fence diagram.	1
4.	Subsurface Mapping: Preparation and interpretation of structure contour.	1
5.	Subsurface Mapping: Preparation and interpretation of isopach / isochore maps.	1
6.	Structural analysis: Construction of profiles of cylindrical folds.	1
7.	Structural analysis: Analysis of areas of superposed folding.	2
8.	Analysis of areas with faults: Depth to detachment, Balanced cross-section.	1
9.	Analysis of areas with faults: Restoration of section	1
10.	Analysis of shear zones and strain in rocks	2

11.	Practical Examination	1
	Total Classes =	**13**

Recommended Text Books

1. Roland, S.M., Duebendorfer, E.M. and Schiefelbein, I.M. (2007) Structural Analysis and Synthesis. Blackwell Publishing, Oxford

Other References:

2. Marshak, S and Mitra, G (1988) Basic Methods of Structural Geology. Prentice Hall.
3. Richard H. Groshong, Jr. (2006). 3-D Structural Geology: A Practical Guide to Quantitative Surface and Subsurface Map Interpretation. Springer-Verlag, Berlin.

Course Goal / Learning Outcome:

The primary objective of the course is to provide practical tools for different structural techniques and tectonic analyses used in industry / exploration organisations.

Learning Objectives:

Upon completion of the course, students will be able to:

1. Determine structural geometry and interpret the geometry.
2. Determine strain in rocks
3. Identify the suitable sites for detailed exploration

Unit wise learning objectives

1. To learn analysis of orientation data of lines and planes
2. To use analysis of orientation data of bore foles to determine tilt and rotation.
3. To learn the use of fence diagrams
4. To construct structure contour maps and interpret them
5. To learn the use of isochore and isopach maps
6. To learn how to construct profile section of plunging flds
7. To understand and interpret superposed fold geometry from map patterns
8. Fault analysis with depth to detachment
9. Fault analysis with section restoration
10. Analysis of shear zones and strain

Course Name: Petroleum Geophysics Practical

Course Code: GPC 553
L-T-P = 0-0-2
Credit = 2
Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1	Field planning and acquisition of gravity data	1
2	Reduction of field gravity data and preparation of anomaly maps	1
3	Acquisition of magnetic data and preparation of anomaly maps	1
4	Computation Regional-Residual separation by Graphical and Grid methods	1
5	Qualitative interpretation aeromagnetic anomaly map of sedimentary basin	1
6	Computation of basement depth from magnetic data using Peters half slope method	1
7	Plotting of time distance curve for reflection, refraction and diffraction data.	1
8	Acquisition and processing of refraction data using signal enhancement seismographs.	2
9	Acquisition of reflection / refraction data using accelerated weight drop seismic energy source.	1
10	Study of velocity spectrum plots and calculation of interval velocity using DIX's relation. Drawing of velocity profiles on the spectrum plots.	2
11	Practical Examination	1
	Total Classes =	**13**

Recommended Books

i. Dobrin, M. B. and Savit, C., 1988, Introduction to Geophysical Prospecting, 4th Edition. McGraw Hill College Publishers.

Other References:

3. Parasnis, D.S., 1997. Principles of Applied Geophysics. Fifth edition, Chapman & Hall, 2-6 Boundary Row, London SE1 8 HN,
4. Rao, B. S. R. and Murthy, I. V. R., Gravity and Magnetic Methods of Prospecting
5. Nettleton, L. L. (1976), Gravity and Magnetics in Oil prospecting
6. Telford, W. M., Geldart, L. P., Sheriff N D & Keys, D. A., 1976 Applied Geophysics.
7. Lowrie W. 2006. Fundamental of Geophysics. Cambridge University Press.
8. Published Paper in different International and National peer reviewed Journals.

Course Goal / Learning Outcome:

The primary objective of the course is to introduce fundamental and advanced aspects of geophysical methods for hydrocarbon exploration.

Learning Objectives:

Upon completion of the course, students will be able to:

1. Understand fundamentals of geophysical methods for hydrocarbon exploration.
2. Work with geophysical data for processing and interpretation.
3. Apply geophysical tools for hydrocarbon exploration.

Unit wise learning objectives:

1. Method of gravity data acquisition
2. Preparation of gravity anomaly maps
3. Preparation of magnetic anomaly maps
4. Computation of Regional-residual separation
5. Analysis of aeromagnetic maps
6. Computation of basement depths of sedimentary basin
7. Time distance curve for reflection refraction and diffraction data
8. Acquisition of refraction data using signal enhancement seismographs
9. Use of accelerated weight drop in data processing
10. Study of velocity spectrum plots and velocity profiles

Course Name: Resource Evaluation and Geostatistics Practical

Course Code: GLC 562
L-T-P = 0-0-2
Credit = 2
Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Sample Value Compositing and Reserve Estimation Exercise	**1**
2.	Mineral Deposit Statistics	**1**
3.	Normal Distribution Modelling	**1**
4.	Lognormal Distribution Modelling	**1**
5.	Construction of 1-D & 2-D Experimental Semi-variogram and spatial variability characterization	**2**
6.	Manual Computation of Estimation Variance	**1**
7.	Block Kriging Manual Exercise	**1**
8.	Computer based modelling for Univariate and Bivariate data	**1**
9.	Computer based semi-variography	**2**
10.	Computer based Block Kriging	**1**
11.	Practical Examination	**1**
	Total Classes	**13**

Recommended Books:

1. Sinclair, A.J. and Blackwell, G.H. (2002) Applied Mineral Inventory Estimation, Cambridge Univ. Press, 378 p.
2. Wellmer, F. W. (1998) Statistical Evaluation in Exploration for Mineral Deposits, Springer, 365 p.

Other References:

3. Clark, I. (1979) Practical Geostatistics, Elsevier Applied Science Publ. London, 151 p.
4. David, M. (1977) Geostatistical Ore Reserve Estimation, Elsevier Scientific Publ. Co. Amsterdam, 364p.
5. Gandhi, S.M. and Sarkar, B.C. (2016) Essentials of Mineral Exploration and Evaluation, Elsevier, USA, 410 p.

6. Rendu, J.M. (1981) An Introduction to Geostatistical Methods of Mineral Evaluation, SAIMM Monograph, Johannesburg, 84 p.

Course Goal / Learning Outcome:

The primary objective of the course is to introduce fundamental and advanced aspects of geophysical methods for hydrocarbon exploration.

Learning Objectives:

Upon completion of the course, students will be able to:

j. Understand fundamentals of geophysical methods for hydrocarbon exploration.
9. Work with geophysical data for processing and interpretation.
10. Apply geophysical tools for hydrocarbon exploration.

Overall Learning Outcome*:*

To solve various practical exercises of mineral sampling, mineral deposit statistics, semi-variography and kriging.

Learning outcome of each unit*:*

1. Sample Value Compositing and Reserve Estimation;
2. Mineral Deposit Statistics;
3. Normal Distribution Modelling;
4. Lognormal Distribution Modelling;
5. Construction of 1-D & 2-D Experimental Semi-variogram and spatial variability characterization;
6. Manual Computation of Estimation Variance;
7. Block Kriging Manual Exercise;
8. Computer based modelling for Univariate and Bivariate data;
9. Computer based semi-variography;
10. Computer based Block Kriging.

C. Syllabus of Department Elective (DE): Theory Courses

Course Name: Exploration of Coal, Coal Bed Methane, Shale Gas and Gas Hydrate

Course Code: GLD 569
L-T-P = 3-0-0
Credit = 9
Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Coal exploration: Varieties of coal, Analyses of coal; Different methods of coal exploration: Photogeological and remote seam sensing, Geological, Sedimentological, Coal Petrological, Geophysical methods	4
2.	Coal bed methane and shale gas: generation and accumulation; Micropore, Mesopore and macropore, cleat system	5
3.	Sorption: principles, sorption isotherms – types and interpretation. CO2, CH4 and N2 adsorption – desorption, hysterisis, langmuir isotherm,Swelling and shrinkage of coal matrix, isotherm construction	5
4.	CBM Reservoir analysis: CH4 content determination in coal seams; , comparison between conventional gas reservoir and coal bed methane reservoir, Permeability Klinkenberg, shrinkage, stress and depth effects on permeability, Darcy flow in cleats, sorption time, CBM reservoir characterization method, enhanced recovery.	5
5.	CBM Water: CBM Water production and disposal, injection wells, carbon dioxide sequestration	3
6.	Coalbed Methane Basins: Potential Indian coalbed methane basins and production, hydraulic fracturing of coal seams; CBM exploration	3
7.	UCG:In-situ gasification	2
8.	Gas hydrate: Gas hydrate, occurrence and origin; structure of gas hydrate, Types of gas hydrate	3
9.	Geological setting: Geological setting of Hydrate; Stability of gas hydrates; Gas hydrate reservoir; Volume of gas in hydrate; inhibitors	5
10	Gas Hydrate Exploration: Geological exploration of gas hydrate; Prospect and potentialities of gas hydrate in India	4
	Total Classes =	**39**

Recommended Books:

1. Coalbed Methane and Coal Geology-Eds. R.Gayer and I. Harris, Geological Society, London 1996.
2. Shale Gas: Exploration and Environmental and Economic Impacts,2017 AM Dayal and D.Mani (eds) Elsevier.

Other References:

3. Natural Gas Hydrates- Sloan, E.D., J. Happel, and M.A. Hnatow (eds.), New York Academy of Science- New York, NY, (1994).

Course Goal / Learning Outcome:

The primary objective of the course is to introduce fundamental aspects of coal, coal bed methane, shale gas and gas hydrate such as origin, types, reservoir analysis and production to the students.

Learning Objectives:

Upon completion of the course, students will be able to Understand the origin, types, reservoir analysis and production of coal, coal bed methane, shale gas and gas hydrate.

Unit wise Learning outcome :

1. Exploration methods for coal
2. Origin of CBM and coal gas
3. Sorption types
4. CBM reservoir analysis for production
5. CBM water production and disposal
6. Hydraulic fracturing of coal and various CBM basins
7. Geological and petrophysical aspects of underground coal gasification
8. Gas hydrate types and their origin
9. Gas hydrate reserve and depletion of gas hydrate deposits
10. Geological exploration of gas hydrates

Course Name: Rock Deformation Kinematics for Engineering Geology

Course Code: GLO 596

L-T-P = 3-0-0

Credit = 9

Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Stress: Definition, units, classification, stress ellipsoid, stresses at a point, stress on a plane, Mohr circle construction and stress trajectory. Applications for slope stability studies and foundation analysis.	7
2.	Strain: Definition, strain parameters, classification, strain	5

	ellipsoid and theory of deformation in two and three dimensions.	
3.	Strain Analysis: Measurement of deformation in nature, graphical representation by Flinn, Ramsay, Hossack and Mohr diagrams, progressive deformation, deformation paths and significance of geological structures, Strain measurement in engineering geology.	6
4.	Experimental Deformation and Rheology: Behaviour of rocks under experimental conditions. Effects of confining pressure, pore fluid pressure, anisotropy, temperature and scale on rock deformation.	8
5.	Development of Structures - I: Mechanisms of folding, and strain variations around folds. Development of secondary cleavage and lineations.	6
6.	Development of Structures - II: Development of rock fractures. Conditions of fault development. Deformation mechanisms.	7
	Total Classes =	**39**

Recommended Textbooks:

11. Ghosh, S.K. (1993) Structural Geology. Pergamon Press.
12. Means, W.D. (1976) Stress and Strain. Springer-Verlag.

Other References:

1 Passchier, C.W., and Trouw, R.A.J. (1996). Microtectonics, Springer.

2 Ramsay, J.G. (1967) Folding and Fracturing of Rocks. McGraw-Hill.

3 Ramsay, J.G. & Huber, M.I. (1983). The Techniques of Modern Structural Geology. Vol. 1. Academic Press.

4 Ramsay, J.G. & Huber, M.I. (1987). The Techniques of Modern Structural Geology. Vol. 2. Academic Press.

5 Twiss, R.J. & Moores, E.M. (1992) Structural Geology. W.H. Freeman & Company.

6 Turcotte, D.L. & Schubert, G. (2002). Geodynamics (2nd Edition). Cambridge University Press.

7 Van der Pluijm, B.A. & Marshak, S. (2004). Earth Structure: An Introduction to Structural Geology and Tectonics (2nd Edition). WW Norton & Company.

Course Goal / Learning Outcome:

The primary objective of the course is to provide theoretical background for techniques of stress and strain analysis in rocks and its application in engineering geology.

Learning Objectives:

Upon completion of the course, students will be able to:

1. Measure rock deformation in nature.
2. Understand the evolution of different structures.
3. Evaluate engineering projects in deformed rocks.

Unit wise learning objectives

1. Stress fields and its geological domains
2. Theory of strain
3. Methods of strain analysis
4. Behavior of rocks under experimental deformation
5. Development of structues in the ductile field: folds, cleavage and lineations
6. Developments of structures in the brittle field: Rock fractures, faults and deformation mechanisms

Course Name: Geophysical Methods for Groundwater Exploration

Course Code: GPD 552

L-T-P = 3-0-0

Credit = 9

Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Introduction to Groundwater: Groundwater: Problems and definition. Definition of groundwater table. Definition of aquifers, classifications of aquifers; confined and un-confined, perched, aquiclude, aquitard, aquifuge etc. groundwater flow in unconfined aquifer.	7
2.	Hydraulic Properties: Hydraulic properties of soils, porosity, permeability, transmissibility, hydraulic conductivities, empirical relations among hydraulic parameters. Geophysical methods for groundwater exploration.	7
3.	Estimation of Hydraulic Properties: Geophysical methods and hydro-geochemical methods for aquifer parameter estimations and fracture characterization in various hydro-geological settings of India. Interpretation of hydro-geological sections.	7
4.	Hydro-geological cycles and sustainability: Hydro-geological cycles, linkage to other geo-cycles, their importance to groundwater exploration and sustainability.	4
5.	Geophysical Methods for Groundwater Management: Application of geo-physical methods (DC resistivity/Electromagnetic (EM), Well logging etc) and remote sensing (RS) and geographical information systems (GIS) for groundwater management.	7

6.	Groundwater Quality Assessment: Geophysical and hydro-geochemical methods for groundwater pollution assessment. Modelling of groundwater quality index, quantification of role of each geophysical/hydro-geochemical parameter for groundwater quality assessment.	7
	Total Classes =	**39**

Recommended Books

1. Kirsch, R., 2006. Groundwater Geophysics- A Tool for Hydrogeology, Springer-Verlag Berlin Heidelberg, pp. 500
2. Parasnis, D.S., 1997. Principles of Applied Geophysics. Fifth edition, Chapman & Hall, 2-6 Boundary Row, London SE1 8 HN, UK

Other References:

1. Schwartz, W.F., Zhang, H., 2004. Fundamentals of Groundwater, John Wiley & Sons, Inc. pp. 583
2. Telford, W.M., Geldart, L.P., Sheriff, R.E., 2004. Applied Geophysics, 2nd Edition, Cambridge University Press
3. Todd, D. K., 1959. Groundwater hydrology, John Wiley and Sons, New York, pp.535

Course Goal / Learning Outcome:

The key objective of the tutorial is to introduce the students with the techniques of sampling, reserve estimation and problem solving for mineral and petroleum geostatistics.

Learning Objectives:

Upon completion of the course, students will be able to:

1. Carryout mineral and petroleum resource appraisal;
2. Solve geostatistical problems related to characterisation of mineral deposits and petroleum reservoirs.
3. Carry out Spatial data analysis.

Unit wise Learning Objectives:

1. Groundwater fundamentals : elements and parameters
2. Hydraulic analysis of groundwater
3. Geophysical methods of determining aquifer properties and hydraulics
4. Hydrogeological cycles
5. Geophysical metyhod of groundwater management
6. Groundwater quality and assesment

Course Name: Nanotechnology in Mineral and Hydrocarbon Exploration

Course Code: GLD 576
L-T-P = 3-0-0
Credit = 9
Syllabus & Lecture Plan:

Unit	Description	No. of Classes
	(A) Nanotechnology in Mineral Exploration	
1.	Nano- ores: High resolution techniques for studying ore samples at the nanoscale; Nanomaterials in Earth Science	4
2.	Trace elements systematics: Understanding nanoscale incorporation of trace metals in ore samples	3
3.	Ore mobility: Colloidal transport, precipitation and isotopic fractionation in supergene settings	3
4.	Ore depositional mechanism: The effects of atomic and nanoscale processes on ore stability	3
	(B) Nanotechnology in Hydrocarbon Exploration	
5.	Introduction: Introduction, New forms of matter, Nanopowders and nanomaterials, nanopores and their properties, Structure of nanomaterials, Fullerene structures, New forms of carbon, carbon nanotubes (CNT)	7
6.	Analytical methods: Analytical methods for studying nanomaterial: Scanning Tunneling Microscope, Atomic Force Microscope (AFM), Raman Spectroscopy	5
7.	Processes: Processes for CNT production; Utilization of coal for production of CNT; Application of CNT- vacuum microelectronics, energy storage,	4
8.	Applications: Dynamics of natural gas adsorption; Application of Nanotechnology: gas separation and storage; Removal of SO_x and NO_x, Coal Bed Methane, Petroleum exploration; CO_2 sequestration and CO_2 adsorption dynamics of nanopores; Molecular sieves; Nanoprobes and sensors.	10
	Total Classes =	**39**

Recommended Books:

1. Carbon Nanotubes Synthesis, Structure, Properties and Applications : Mildred S. Dresslhaus, Gene Dresslhaus and Phaedon Avouris (Eds), 2001 (Springer)

Course Goal / Learning Outcome:

The primary objective of the course is to introduce fundamental aspects of Nanotechnology in Mineral and Hydrocarbon Exploration to the students.

Unit wise Learning objectives:

Upon completion of the course, students will be able to

1. Basic concept of nanogeosciences.
2. Learn trace element systematics of ore samples.
3. Ore mobility and its role in the formation of ore deposits
4. Understand the effects of atomic and nanoscale processes on ore depositional mechanism.
5. Nanomaterials and carbon nanotubes
6. Methods for studying nanomaterials
7. Various methods of producing CNT
8. Application of nano-studies in CBM, petroleum exploration, CO_2 sequestration.

Course Name: Advanced Geostatistics and Exploration Economics

Course Code: GLD 572

L-T-P = 3-0-0

Credit = 9

Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Problems and constraints of semi-variography associated with semi-variography, viz. anisotropy, non-stationarity, regularisation, presence of nugget effect and presence of trend. Extension, Estimation and Dispersion variances: definitions, methods of calculations.	6
2.	Ordinary Kriging: definition, point/block estimation procedu ~~Effect~~ Influence of Nugget variance on kriged weights, Effec Nugget variance on kriged weights, Screen Effect, Negative kri weights – causes, consequences and remedies; Practice of Semi-variogram model; Generalised geostatistical evaluation scheme.	7
3.	Non-linear and Non-parametric Geostatistics: Lognormal, Disjunctive and Multi-Gaussian, Indicator and Probability kriging.	3
4.	Geostatistical applications: optimisation of exploration drill	8

	calculation of mineral inventory, establishment of grade-tonnage relati calculation of planning cutoff grade; misclassified tonnages; geostatistical grade control plan.	
5.	Geostatistical Conditional Simulation - Theory, techniques and applications with special reference to Simulated Annealing.	2
6.	Geostatistical case studies of selected mineral deposits.	5
7.	Economic concepts for Exploration Strategy; Valuation of Mineral Properties: Valuation Techniques, Approaches and Methodology, viz. Cost approach: Appraised Value Method, Market approach, The Income Approach; Mineral Valuation Codes	8
	Total Classes =	**39**

Recommended Books:

1. Agnerian, H., 1996a: Valuation of Exploration Properties. CIM Bulletin, v. 89, no. 1004, pp. 69-72.
2. Armstrong, M. (1998) Basic Linear Geostatistics; Springer, Berlin.

Other References:

3. Baurens, S., 2010: Valuation of Metals and Mining Companies. Collaborative study of Univ. of Zurich, Swiss Banking Inst., and Dr.T. Hens., Nov. 2010, 81p.
4. Bhappu, R. R., and Jaime Guzman, J. 1995: Mineral Investment Decision Making: A Study of Mining Company Practices. E & MJ, July 1995, pp. 36-38.
5. Chiles, J.P. and Definer, P. (1999) Geostatistics - Modelling Spatial Uncertainty, John Wiley and Sons, New York, 695p.
6. Clark, I. (1979) Practical Geostatistics, Elsevier Applied Science Publ., London.
7. David, M. (1977) Geostatistical Ore Reserve Estimation, Elsevier Scientific Publ. Co., Amsterdam.
8. David, M. (1988). Handbook of Applied Advanced Geostatistical Ore Reserve Estimation, Elsevier Sc. Publ., Amsterdam.
9. Gandhi, S.M. and Sarkar, B.C. (2016) Essentials of Mineral Exploration and Evaluation, Elsevier, USA, 410 p.
10. Goovaerts, P. (1997) Geostatistics for Natural Resources Evaluation, Oxford Univ. Press, Oxford, 483p.
11. Isaaks, E.H. and Srivastava, R. M. (1989) An Introduction to Applied Geostatistics, Oxford University Press, Oxford.
12. Journel, A. G. and Huijbregts, C. J. (1978) Mining Geostatistics, Academic Press, London.
13. Kitanidis, P.K. (1997) Introduction to Geostatistics - Applications in Hydrogeology, Cambridge Univ. Press, 249p.

14. Mackenzie, B. and Woodall, R., 1987: Mineral Exploration Economics: The Search for Base Metals in Australia and Canada, Centre for Resources Studies Working Paper No. 40, pp 112.
15. Olea, R.A. (1999) Geostatistics for Engineers and Earth Scientists, Kluwer Academic Publ., Dordrecht, 303p.
16. Rendu, J.M. (1981) An Introduction to Geostatistical Methods of Mineral Evaluation, SAIMM Monograph, Johannesburg.
17. Sinclair, A.J. and Blackwell, G.H. (2002) Applied Mineral Inventory Estimation, Cambridge Univ. Press, 378 p.
18. Wackernagel, H. (1998) Multivariate Geostatistics - An Introduction with Applications. Second Revised Edn. Springer-Verlag, Berlin, 291 p.
19. Wellmer, F. W. (1998) Statistical Evaluations in Exploration for Mineral Deposits, Springer, Berlin, 379 p.
20. Chatterjee, K.K., 2008: Introduction to Mineral Economics. New Age International Pvt Ltd Publishers.406p.
21. Gocht, Werner R., Zantop, Half, Eggert, Roderick,1988:International Mineral Economics, Springer Publication

Course Goal / Learning Outcome:

The key objective of the course is to introduce the students with the techniques of Advanced Geostatistics for modelling of mineral and petroleum deposits.

Learning Objectives:

Upon completion of the course, students will be able to:

1. Apply the knowledge of advanced geostatistics for modelling and characterisation.
2. Evaluate mineral and petroleum deposits.
3. Understand the concepts of exploration economics.
4. Carry out valuation of mineral and petroleum deposits.

Learning objectives of each unit*:*

1. Problems and constraints of semi-variography associated with semi-variography;
2. Kriging and practice of semi-variography;
3. Non-linear and Non-parametric Geostatistics;
4. Geostatistical applications;
5. Geostatistical Conditional Simulation;
6. Geostatistical case studies;
7. Exploration Economics.

Overall Learning Outcome*:*

To introduce the students with the techniques of Advanced Geostatistics and Exploration Economics.

Prerequisite:

For taking this course, 1st semester course on "Resource Evaluation and Geostatistics" is a prerequisite course.

Course Name: Petroleum Exploration and Micropalaeontology

Course Code: GLD 571

L-T-P = 3-0-0

Credit = 9

Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Hydrocarbon-organic or inorganic, Surficial indication of subsurface hydrocarbons	4
2.	Molecular groups in hydrocarbons, Normal-, Iso- and Cycloparaffins, and NSO compounds, Specific gravity of hydrocarbon, Kerogen: classification and evolution of Kerogen, source and reservoir rocks	8
3.	Petroleum traps: concept and classification; different types of traps, their genesis	5
4.	Migration: Primary and secondary migrations	4
5.	Tectonics and sedimentation history and structures of the important petroliferous basins of India (Bombay offshore, Cambay, Assam oil field, Krishna-Godavari basin).	5
6.	Separation of foraminifera and their morphology	6
7.	Foraminifera: use as paleoproductivity, paleooxygen, depositional depth, sea level fluctuation, biostratigraphic marker	6
8.	Ostracod: Uses in hydrocarbon exploration	1
	Total Classes =	**39**

Recommended Books:

1. Tissot, B. P., and Welte, D. H. (1984), Petroleum Formation and Occurrence. Springer-Verlag, Germany.
2. North F. K. (1985), Petroleum Geology. Allen & Unwin Inc., London.

Other References:

3. Selley, R. C., Elements of Petroleum Geology. Academic Press, USA.
4. Selly, R. C. and Sonnenberg, S. A., Elements of Petroleum Geology, Elsiver-Academic Press

5. Slatt, R. M., Stratigraphic Reservoir Characterization for Petroleum Geologists, Geophysicists, and Engineers. Elsevier, Hungary

Course Goal / Learning Outcome:

The primary objective of the course is to introduce the students with the geochemical, origin and accumulation aspects of hydrocarbons including depositional environment of sediments, their stratigraphic positions, microfossils and their role in exploration.

Learning Objectives:

Upon completion of the course, students will be able to:

1. Brief idea about the hydrocarbon system.
2. Chemical and physical properties of hydrocarbons.
3. Hydrocarbon basins in India.
4. Support of microfossils for hydrocarbon exploration.

Unit wise learning objectives:

1) Knowledge about origin and indication of presence of subsurface hydrocarbon.
2) Knowledge about chemistry of hydrocarbon and kerogen
3) This part will deal with subsurface accumulation of hydrocarbons in different geological conditions
4) This part will impart knowledge about migration techniques of hydrocarbons.
5) This part will describe geologic settings of some petroliferous Indian basin so that student can understand about proved oil/gas fields.
6) This basic part is extremely required as it deals separation and identification of microfossils.
7) This part deals about the clues which we may infer from foraminiferal community including biostratigraphy.
8) This is another group of microfossils which also can give clues about depositional environment of the sediments in a petroliferous basin.

Course Name: Sedimentary Environment, Sequence Stratigraphy and Basin Analysis

Course Code: GLD 573

L-T-P = 3-0-0

Credit = 9

Syllabus & Lecture Plan:

Unit	Description	No. of

		classes
1.	Concept of sedimentary environments. Environmental parameters and their control. Classification of environments. Facies model and environmental reconstruction.	3
2.	Shallow and deep water sandstone reservoir geometry. Alluvial environments. Marginal marine and neritic environment; deltaic models, Barrier bar-lagoon, coastal (interdeltaic) model – barrier islands and lagoons, tidal channels and tidal deltas, Submarine fan.	12
3.	Carbonate sedimentation model, platform geometry.	2
4.	Concept of tectonics and sedimentation.	2
5.	Role of environmental analysis in petroleum exploration.	2
6.	Introduction to basin analysis. Tectonic classification of sedimentary basins.	6
7.	Definitions and key concepts, base level changes, ısgressions and regressions.	4
8.	Sequence stratigraphic surfaces. Unconformity and correlative conformity	3
9.	Systems Tracts: Lowstand, Transgressive, Highstand, Falling stage.	3
10.	Hierarchy of sequences and bounding surfaces`	2
	Total classes=	**39**

Recommended Books:

1. Gary Nichols – Sedimentology & Stratigraphy, 2009, Blackwell Publishing Company, Malden, USA
2. Richard C. Selley – Applied Sedimentology, 2000, Academic Press, California, USA.

Other References:

3. H.G. Reading – Sedimentary Environments: Processes, Facies and Stratigraphy, 1996, Blackwell Science Limited, Malden, USA.
4. Hans-Erich Reineck and Indra Bir Singh – Depositional sedimentary environments: with reference to terrigenous clastics, 1992, Springer-Verlag.
5. Winfried Zimmerle – Petroleum Sedimentology, 1995, Ferdinand Enke Verlag, Stuttgart, Germany.
6. B. Biju-Duval – Sedimentary Geology: Sedimentary Basins, Depositional Environments, Petroleum Formation, 2002, Editions Technip, Paris.
7. Andrew Miall – Principles of Sedimentary Basin Analysis. Springer, New York, 1990.

8. Magnus Wangen – Physical Principles of Sedimentary Basin Analysis. Cambridge University Press, New York, 2010

Course Goal / Learning Outcome:

In this course the students will study the fundamental concepts, principles and applications of sedimentology.

Learning Objectives:

Upon completion of the course, students will be able to:

Study, document and interpret sedimentary facies, their depositional trends through time and depositional environment and apply these in the field of Hydrocarbon and mineral exploration.

Unit wise learning objectives

Sedimentary environments and sedimentary facies

1. Concepts of sedimentary environment and their classification
2. Reservoir geometry of shallow and deep water environment
3. Carbonate sediments and depositional models
4. Tectonics and sedimentation interplay
5. Depositional Environmental analysis for petroleum exploration
6. Tectonic classification of sedimentary basins
7. Concepts of transgressions and regressions
8. Understanding sequence stratigraphic surfaces
9. To understand system tracts and relate them with base level changes
10. To organize sequences as per hierarchy

Course Name: Artificial Intelligence and Machine Learning in Geosciences
Course Code: GPO 503
L-T-P = 3-0-0
Credit = 9
Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Artificial Intelligence (AI): Definition and application. Definition of Machine Learning (ML). The relation between AI and ML. ML classification algorithm: supervised, reinforcement and unsupervised learning: Principal component analysis (PCA), K-means, Decision Tree (DT), random forest (RF), Logistic regression (LR), Self-organizing map (SOM).	7
2.	Artificial neural networks: Introduction to artificial neural networks (ANNs). Pre-processing and dimension reduction techniques for time/space series modeling/classification.	4

3.	Transfer Function: Types of transfer function, training, validation and test data set selection. Over-fitting, role of regularization, Calibration of model, cross-validation, early stopping techniques, bias-variance dilemma.	7
4.	Optimization: ANNs optimization: local and global techniques. Adaptive neuro-fuzzy systems (ANFIS). Hybrid ML algorithm with ordinary kriging (OK), semi-variogram modeling, singular spectrum analysis (SSA) for de-noising, interpolation and missing value prediction techniques.	7
5.	Probabilistic methods: Probabilistic inference, Bayesian learning for artificial neural networks, evidence maximization (EA), hybrid Monte Carlo (HMC), Automatic relevance determination (ARD), Gaussian process (GP), Support vector machines (SVM).	7
6.	Deep learning and Big data: Introduction to deep learning. Convolutional neural network (CNN): theory and practices. Application of ML algorithm for earth parameter estimation, classification and prediction of rock-type/litho-logy/litho-facies/mineral boundary for analysis of space-time geoscience data. Application of deep learning to "Big Data" analysis of geoscience.	7
	Total Classes =	**39**

Recommended Books:

1. Bishop C M, (1995) Neural networks for pattern recognition. Oxford University Press.
2. Haykin, S. (1999). Neural networks – a comprehensive foundation (2nd Ed.). Upper Saddle River, NJ: Prentice Hall.

Other References:

3. MacKay, D.J.C., (1992). A practical Bayesian framework for back-propagation networks. Neural Comput, 4 (3), 448–472.
4. Poulton M, (2001) Computational Neural Networks for Geophysical Data Processing, Pergamon, Oxford, U.K.
5. Van der Baan M, and Jutten C, (2000) Neural networks in geophysical applications, Geophysics, 65: 1032–1047.
6. Wasserman, P.D. (1993) Advanced methods in neural computing. Van Nostrand Reinhold, New York, NY 10003

Course Goal / Learning Outcome:

The primary objective of the course is to introduce fundamental and advanced aspects of Artificial intelligence and machine learning for geo-record analysis and processing.

Learning Objectives:

Upon completion of the course, students will be able to:

1. Practical knowledge on AI and ML for time/space series data analysis.
2. Practical knowledge on automatic nonlinear classification, regression and prediction of geo-records.
3. Practical knowledge on application of AI and ML with deep network for big data processing.

Unit wise Learning objectives:

1. Fundamental concepts on Artificial Intelligence an dMachine learning
2. Artificial neural networks and their applications
3. Transfer functions, their types and use
4. Artificial Neural networks and Neuro Fuzzy systems
5. Probabilistic models for Artificial neural networks
6. Big data analysis

Course Name: Digital Image Processing

Course Code: GLD 577

L-T-P = 3-0-0

Credit = 9

Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Introduction to Digital image Processing. Human perception of color, image display, lookup tables, resampling techniques, data formats, color composites. Camera systems. SLR, DSLR, HD & HDR images.	5
2.	Image analysis techniques: software formats, raster and vector, color space, histograms & stretching, image math, masking, mosaicking,	5
3.	Pre-processing, calibration, image normalization, gain and offset, destriping, spatial and spectral subset. Band ratios, indexes, image sharpening, principal components.	5
4.	Image convolution, kernels and image filters, fourier filtering, morphological filters, texture filters, and user-defined filter kernels.	7
5.	Image fusion techniques. Spectral libraries, usage and interpretation. Spectral analysis tools.	7
6.	Image Classification: class statistics, supervised and unsupervised classifications.	7
7.	Near real-time Direct Satellite Broadcast System and near-real time data processing to derive major parameters related to earth's	3

atmosphere, land, ocean, and biosphere.

Total Classes = 39

Recommended Textbooks:

1. Liu, J.G., and Mason, P. (2013), Essential Image Processing and GIS for Remote Sensing, John Wiley & Sons.
2. Jensen, J.R. (1996), Introductory Digital Image Processing: A Remote Sensing Perspective, Prentice Hall.

Other References:

3. Gonzalez, R.C., and Woods, R.E. (2013), Digital Image Processing Using MATLAB, Tata McGraw-Hill Education.
4. Gonzalez, R.C., Woods, R.E., and Eddins, S.L. (2009), Digital Image Processing, Pearson Education India.
5. Richards, J.A. (2012), Remote Sensing Digital Image Analysis: An Introduction, Springer Science & Business Media.

Course Goal / Learning Outcome:

The primary objective of the course is to impart knowledge of image processing algorithms necessary for critical assessment and visualization.

Learning Objectives:

Upon completion of the course, students will be able to carry out:

1. Image Enhancement and Fusion operations
2. Image Math operations and its applications
3. Image Filtering in spatial and frequency domains
4. Image Classification and error calculations

Unit wise Learning Objectives

1. Basic knowledge related to images, colors, formats, and systems.
2. Learn fundamentals of basic image processing and methods.
3. Know about commonly used algorithms, indices and methods.
4. Know about image convolution, kernals, types, and its applications.
5. Spectral analysis tools and image fusion techniques.
6. Know supervised and unsupervised image classification methods.
7. Near real-time download and processing using Direct Satellite Broadcast System.

Course Name: Geospatial Analysis

Course Code: GLD 574
L-T-P = 3-0-0
Credit = 9
Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Basic GIS operations and mapping: elements of map creation, using basemaps, DEM/Terrain Data and online map/WMS data. Working with raster and vector data; attributes, styling, logical grouping and symbology, file storage formats (BIL, BIP, BSQ), composer, importing table (csv) data and spreadsheets, interpolation, sampling raster data, operations, digitizing map data, overlay GPS data and generating basic statistics. Common geospatial analysis tools.	8
2.	Georeferencing and map projections: projections and coordinate systems, registration, rectification, ground control points (GCPs), ortho-rectification, warping. Best practices in map projection, convert map projection, convert coordinates among projections. Georeferencing Topo Sheets, Scanned Maps, Aerial Imagery.	8
3.	Advanced GIS operations: using table joins, spatial joins, spatial queries and generating advanced statistics, polygon analysis, and heatmaps. DEM and 3D data models; interpolation and overlay of observations (vector and raster data) onto 3D surfaces and rasters.	6
4.	Classification operations: Classification; post classification tools, confusion matrix and accuracy assessment.	7
5.	Advanced Workflows and batch operations: Batch processing and automating complex workflows using Modelling Framework. Automating map creation. Web mapping.	6
6.	Lidar data and GIS: data sampling, cloud points processing and analysis, 2D and 3d modeling using LIDAR scanner and GPS.	4
	Total Classes =	**39**

Recommended Textbooks:

1. Demers, M. N. (2008). Fundamentals of Geographic Information Systems, 3RD ED. Wiley India Pvt. Limited.
2. Longley, P. A., Goodchild, M., Maguire, D. J., & Rhind, D. W. (2010). Geographic Information Systems and Science.

Other References:

3. Liu, J.G., and Mason, P. (2013), Essential Image Processing and GIS for Remote Sensing, John Wiley & Sons.

Course Goal / Learning Outcome:

The primary objective of the course is to impart knowledge of geospatial methods critical assessment, integration and presentation (visualization) of available data to carry out independent GIS-based research.

Learning Objectives:

Upon completion of the course, students will be able to:

1. Enhance, integrate and retrieve information from various sources
2. Handle elevation data and create 3-dimensional surfaces,
3. Basic and advanced GIS operations
4. Properly work with spatially referenced data
5. Develop a GIS Model and Workflow.

Learning Outcome (for each unit):

1. Basic GIS operations using various types of geospatial (raster and vector) data.
2. Understanding georeferencing, map projections, and its applications.
3. Working with tables and database in GIS.
4. Classification operations and accuracy assessment in GIS.
5. Creating basic and complex workflows, modelling framework and automation in GIS.
6. Working with Lidar data and cloud point analysis.

Course Goal / Learning Outcome:

The primary objective of the course is to impart knowledge of geospatial methods critical assessment, integration and presentation (visualization) of available data to carry out independent GIS-based research.

Course Name: Hyperspectral Remote Sensing

Course Code: GLD 570

L-T-P = 3-0-0

Credit = 9

Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Hyperspectral Remote Sensing (HRS) Sensors & Systems: Characteristics of multi-spectral, super-spectral and hyper-spectral sensor. Platforms: Airborne, Spaceborne, Laboratory and Hand-Held. Integration of Hyperspectral Data with LIDAR. HRS	3

	Instruments (Earth observation): AVIRIS, Hyperion, HyspIRI, PRISMA, PROBA, EnMAP, HIUSI, HYSI etc.	
2.	HRS Spectral libraries and corrections: Hughes phenomenon. Redundant and noisy bands, selective narrow bands. Spectral Libraries: USGS, ASTER, Field Campaigns. Correction of HRS data. Solar irradiance, Radiance, Reflectance, and Calibration. Reflectance Spectra: topographic and atmospheric effects. Methods of atmospheric correction. Equal Area Normalization, Flat Field Correction etc.	5
3.	Basic operations and Indices: Building 3D cube/hypercube, pixel/image spectra, target spectra, laboratory spectra, pure end member spectra. Position and shape of narrow absorption features. Operations over spectra such as finding Continuum, removing continuum, normalization, derivative, interpolation, smoothing, linear fit (slope and offset), parabolic fit etc. Common Hyperspectral Indices (for Vegetation, Soil, Mineral). Red-edge.	6
4.	Hyperspectral Data Processing: Data mining methods: Feature Selection Methods, and Information Extraction Methods. Extraction of image spectra by pixel and unique absorption features. Spectral mixture analysis (unmixing), pure spectral signatures (end members), numerical inversion and abundance fractions. Linear and Non-linear spectral unmixing techniques. PC Transform, MNF Transform, PPI etc. Supervised and unsupervised classification methods. Matched (Derivative, Locally Adaptive) Filtering, SAM, Cross-Correlation, Linear Unmixing, SoM Classifier etc. ML Classification, SVM-based approaches. Iterative optimization methods: Clustering, ISODATA, K-means etc. Accuracy assessment.	12
5.	Spectral indicators and their applications (Case Studies): HRS in mineral targeting and exploration, soil type, composition and characteristics, gemstone identification, acid mine drainage, environmental degradation/stress indicators, effect of metals/heavy metals on vegetation, biophysical and biochemical properties of vegetation (Forest, Wetland, Crops, species identification, pigment(s), nitrogen, water content, stress, pests and disease), Global Change Studies.	10
6.	HRS of Planets and Moons in Solar System: Hyperspectral Missions and Case Studies of Moon, Mercury, Mars, Jupiter, Saturn, Titan etc.	3
	Total Classes =	**39**

Recommended Textbooks:

1. Borengasser, M., Hungate, W. S., & Watkins, R. (2007). Hyperspectral Remote Sensing: Principles and Applications. CRC Press.
2. Chang, C. I. (2007). Hyperspectral Data Exploitation: Theory and Applications. Wiley.

Other References:

3. Chang, C. I. (2013). Hyperspectral Data Processing: Algorithm Design and Analysis. Wiley.
4. Eismann, M. T. (2012). Hyperspectral Remote Sensing. SPIE.
5. Kalacska, M., & Sanchez-Azofeifa, G. A. (2008). Hyperspectral Remote Sensing of Tropical and Sub-Tropical Forests. CRC Press.
6. Sun, D. W. (2010). Hyperspectral Imaging for Food Quality Analysis and Control. Elsevier Science.
7. Thenkabail, P. S., & Lyon, J. G. (2016). Hyperspectral Remote Sensing of Vegetation. CRC Press.

Course Goal / Learning Outcome:

The primary objective of the course is to impart knowledge and applications of Hyperspectral remote sensing (HRS) in the field of geosciences.

Learning Objectives:

Upon completion of the course on hyperspectral remote sensing (HRS), students will be able to understand:

1. Importance of Spectral libraries.
2. Characteristics of HRS sensors & systems.
3. Basic and advanced methods employed in HRS data analysis.
4. Current and future applications of HRS.

Unit wise Learning Objectives:

1. Know hyperspectral sensors, systems and data.
2. Learn about hyperspectral libraries and typical corrections.
3. Commonly used basic operations used in the processing of hyperspectral data.
4. Know about hyperspectral data processing, algorithms, and classification methods.
5. Case studies showing applications of spectral indicators.
6. Case studied involving hyperspectral remote sensing of planets and moons in solar system.

Course Name: Modern Instrumental Methods in Exploration Geosciences

Course Code: GLD 575
L-T-P = 3-0-0
Credit = 9
Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Analytical Methods in Geochemistry: Classical and rapid methods of analysis, sample digestion techniques, fusion techniques, gravimetry, determination of concentration of major cations by photometry, chromatography	9
2.	Mineral Studies: X-Ray Diffractometry, Secondary Electron Microscopy, Electron Probe Micro Analysis, Cathodoluminescence, Thermoluminescence, Optically Stimulated Luminescence	8
3.	Optical and X-Ray Spectrometry: Atomic Absorption Spectrometry (AAS), Inductively Coupled Plasma – Atomic (Optical) Emission Spectrometry (ICP-AES/OES), X-Ray Fluorescence Spectrometry, Energy Dispersive and Wavelength Dispersive Techniques	9
4.	Mass Spectrometry: Inductively Coupled Plasma – Mass Spectrometry (ICP-MS), Thermal Ionization Mass Spectrometry (TIMS), Isotope Ratio (Gas Source) Mass Spectrometry (IRMS/GSMS), Secondary Ion Mass Spectrometry (SIMS/SHRIMP), Laser Ablation techniques	13
	Total Classes =	**39**

Recommended Books:

1. Potts. P.J., 1996, A Handbook of Silicate Rock Analysis, Chapman and Hall, London, 622 pp.
2. Rollinson, H.R., 1993, Using Geochemical Data: Evaluation, Presentation, Interpretation, Pearson Education Limited, Harlow, 352 pp.

Course Goal / Learning Outcome:

The course will introduce the students to both the classical methods and the advanced techniques in vogue for the geochemical analysis of elemental and isotopic concentration in samples of minerals, ores and rocks.

Learning Objectives:

Upon completion of the course, students will be able to:

1. Know the different geochemical analytical techniques applied in the field of mineral and rock studies.
2. Understand the fundamental principles involved in various geochemical methods.

3. Choose the right technique or method for the type of sample in question.

Unit wise learning objectives:

1. Overview of methods of sample preparation techniques and analysis
2. Instrumental methods for analysis of mineral chemistry and characterization
3. Optical and X-Ray spectrometry and its applications
4. Mass Spectrometry and its applications

Course Name: Engineering Geophysics

Course Code: GPD 551

L-T-P = 3-0-0

Credit = 9

Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Seismic method: Huygens' Principle, Elastic constants, effect of depth and age, Snell's law, Seismic waves, Seismic reflection and refraction, Analysis of time and distance graphs, Non-parallel interface, multilayered models, Velocity inversion, data correction. Application of seismic method to engineering technology and mineral exploration.	13
2.	Gravity method: Fundamentals of gravity method, Gravity instruments, gravity data acquisition, Gravity data processing, Correction/reduction, Free-air and Bouguer anomalies, Rock densities of rocks and minerals, gravity response of simple shapes and interpretation of gravity anomaly. Application of gravity method to engineering technology and mineral exploration.	7
3.	Magnetic method: Fundamentals concepts of Magnetic method, geomagnetic field, Remanent Magnetism, Magnetic susceptibilities of rocks and minerals, Magnetic instruments, Magnetic data acquisition, Magnetic data processing and Correction/reduction, Magnetic anomaly and interpretation of magnetic anomaly. Application of magnetic method to engineering technology and mineral exploration.	6
4.	Geoelectrical method: Fundamental concepts of geoelectrical method, Archie's law point current electrode on homogeneous Earth, Heterogeneous medium, Resistivity profiling and	7

	sounding, Resistivity data acquisition, Processing and its interpretation. Two/Three layered structures, Interpretation techniques of Electrical data, quantitative interpretation. Application of geoelectrical method to engineering technology and mineral exploration	
5.	Fundamental concepts of electromagnetic method, electromagnetic data acquisition, processing and interpretation. Application of electromagnetic method to engineering technology and mineral exploration.	6
	Total Classes =	**39**

Recommended Books:

1. William Lowrie (2007), Fundamental of Geophysics
2. Telford W. M. (1990) Applied Geophysics, Cambridge University Press.

Other References:

3. Dobrin, M. and Savit, C. (1988), Introduction to Geophysical Prospecting, McGraw-Hill Book Co.
4. Heiskanen, and Veining Meinsez (1958), Gravity Field of the Earth

Course Goal / Learning Outcome:

The primary objective of the course is to introduce geophysical methods and their application for engineering prospect such as identification of fault, fracture, joints, syncline/anticline etc. and classification of rocks, mineral, non-minerals etc.

Learning Objectives:

Upon completion of the course, students will be able to:

1. Understand the application of Geophysical method.
2. Distinguish between different types rocks, minerals, non-minerals and other geological signature based on physical properties.

Unit wise learning objectives

1. Seismic reflection and refraction methods and their applications
2. Gravity methods of exploration and their applications
3. Magnetic methods and applications
4. Geo-electrical methods and applications
5. Electro-magnetic methods and applications

Course Name: Geophysical Methods for Coal Exploration

Course Code: GPD 550
L-T-P = 3-0-0
Credit = 9
Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Introduction to geophysics: Fundamental concepts of Geophysical methods used in coal exploration exploitation and mitigation: (i) microgravity method, magnetic method including gradiometer and total magnetic field observation (ii) Shallow Seismic method, (iii) Electrical resistivity Tomography method (iv) Controlled Source Audio-Magneto-Telluric method, and (iv) Well logging method.	7
2.	Techniques for data processing and data Enhancement: Techniques to resolve geophysical anomalies and their sources location, amplitudes, wavelengths; ambiguity and sensitivity study in geophysical data interpretation and geological model interpretation.	6
3.	Coal basin mapping and analysis: Description of the concept and implications for coal exploration; Coal system classification schemes. Basin Analysis, geophysical techniques for coal basin mapping including source, coal reservoir, geological structure and isopach map. Lithofacies identification using geophysical methods.	6
4.	CBM and Gas hydrate potential zone mapping and analysis: Geophysical methods used in Coal bed methane and gas hydrate reservoir mapping analysis, Coal bed methane and gas hydrate exploration, potential zone of coal bed methane and gas hydrate, hydraulic fracturing of coal seams and techniques to find the hydro-fractured zone. CBM and gas hydrate exploration and potentialities of gas hydrate in India.	7
5.	Coal fire mapping and monitoring: Geophysical methods and some new techniques used for detection, delineation and monitoring of coal fires source, mapping and understanding of hidden subsurface coal fire zone. Techniques to resolve geophysical related anomalies and their sources location, amplitudes, wavelengths and data sensitivity study. Potential zone of Coal fire map.	6
6.	Microgravity and shallow geological inhomogeneity: Microgravity survey and some other new strategy used in detection, forecasting and monitoring the imaging of local geological inhomogeneity such as collapse of small subterranean karst cavities, waterlogs, barrier, fractures, galleries, collapsed/ unconsolidated material etc. Techniques to	7

resolve geophysical related anomalies and their sources location, amplitudes, wavelengths and data sensitivity study.		
	Total Classes =	**39**

Recommended Books:

1. William Lowrie (2007), Fundamental of Geophysics
2. Telford W. M. (1990) Applied Geophysics, Cambridge University Press.

Other References:

3. Dobrin, M. and Savit, C. (1988), Introduction to Geophysical Prospecting, McGraw-Hill Book Co.
4. Heiskanen, and Veining Meinsez (1958), Gravity Field of the Earth
5. Parasnis, D. S. (1996), Applied Geophysics, Springer.
6. Rao, B. S. R. and Murthy, I. V. R., Gravity and Magnetic Methods of Prospecting
7. Nettleton, L. L., Gravity and Magnetics in Oil prospecting

Course Goal / Learning Outcome:

The primary objective of the course is to introduce fundamental and advanced aspects of geophysical study based on data acquisition, processing and interpretation for coal exploration, understanding the problems coal field area and solve the problems.

Learning Objectives:

Upon completion of the course, students will be able to:

1. Knowledge on fundamentals of geophysical methods for coal exploration and other serious problems.
2. Knowledge on geophysical data interpretation for coal exploration and other serious problems
3. Geophysical methods for coal exploration and other serious problems

Unit wise learning objectives

1. Fundamentals on Geophysical methods of coal exploration
2. Techniques for data processing and data Enhancement
3. Coal basin mapping techniques and coal classification
4. CBM and Gas hydrate potential zone mapping and analysis
5. Coal fire mapping and monitoring
6. Use of Micro-gravity survey

D. Syllabus of Open Elective (OE): Theory Courses

Course Name: Well Logging and Seismic Reservoir Characterization

Course Code: GPO 515
L-T-P = 3-0-0
Credit = 9
Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Introduction to oil and gas life cycle: Brief overview on field development, Difference between oil and gas field development and strategies. Brief idea about geophysical data acquisition, processing and interpretation technique towards identification of reservoir in development phase of hydrocarbon exploration.	2
2.	Well logging method: Well logging Technique and its role in Hydrocarbon exploration. Borehole environment. Open Hole Logging Tools: a) Latero (Resistivity measurement), SP, Conductivity method (Induction); b) Porosity measurement tools: Density-Porosity, Neutron Porosity, Sonic Porosity; c) Caliper and Correlation log (Gamma ray); d) Electrofacies analysis techniques to identify various sedimentary features (regressive, transgressive, sandbars, channels, delta deposits) and environment using various correlation techniques; e) Formation evaluation from open hole logs	5
3.	Introduction to reservoir engineering method: Fundamentals of Reservoir Engineering, Basic rock and fluid properties (e.g. porosity, saturation, gas-oil ratio (GoR), gas solubility (Rs), formation volume factor (FVF), etc.), Volumetric analysis, reserves, reservoir drive mechanisms, recovery factor and static fluid distribution in hydrocarbon reservoirs.	5
4.	Advanced seismic method for reservoir characterization: Usefulness of pre and post stack seismic data, Multi resolution analysis for computational seismic study, Different type of seismic inversion for reservoir characterization and its benefits, Reservoir characterization for thin bed reservoir., AVO/AVA principles, Well data and seismic data preconditioning for seismic characterization, AVO modelling, AVO interpretation, Case study on AVO - onshore & offshore, Quantitative reservoir property prediction: lithologies and fluids, Lithology/fluid classification, Stratigraphic analysis of 2D and 3D seismic data for clastic and carbonate rocks, Seismic model for 3D salt and overthrust.	10
5.	Modelling for conventional and unconventional reservoir: Introduction of Reservoir Modelling, Conceptual Development of	10

	Geo-cellular Model – Static & Dynamic Model & case study, Sedimentary Model development for Deep Water reservoir, Current technology development for Gas Hydrate and Deep Water reservoir production, Introduction of geo-cellular model for CBM production	
6.	Introduction to 4D seismic: Introduction of 4D/time lapse seismic for field development strategy 4D seismic monitoring of reservoir production through characterization.	4
7.	CCS: Introduction of CCS, Scope, Objective and Requirement for Oil and Gas reservoir.	
8.	Case study: a) Reservoir characterization of sub-salt in deep water clastics channel system; b) Prediction of reservoir parameters from seismic for carbonate rock	3
	Total Classes =	**39**

Recommended Books:

1. Cosse, R. (1993), Basics of Reservoir Engineering, Editions Technip.
2. Craft, B. C and Hawkins, M. (1991), Applied Petroleum Reservoir Engineering, Prentice Hall.

Other References:

3. Muskat, Flow of Homogeneous Fluids
4. Nettleton, L. L., Gravity and Magnetics in Oil prospecting
5. Parasnis, D. S., Applied Geophysics
6. Published Paper in different International and National peer reviewed Journals
7. Rao, B. S. R. and Murthy, I. V. R., Gravity and Magnetic Methods of Prospecting
8. Sheriff, R.E., Reservoir Geophysics
9. Telford, W. M., Geldart, L. P., Sheriff ND keys, D. A., Applied Geophysics
10. William Lowrie, Fundamental of Geophysics. Cambridge University Press.
11. William, D., McCain, Jr., The Properties of Petroleum Fluids.
12. Published Paper in different International and National peer reviewed Journals

Course Goal / Learning Outcome:

The primary objective of the course is to introduce fundamental and advanced aspects of full-scale reservoir understanding through advanced geophysical study.

Unit wise Learning Objectives:

Upon completion of the course, students will be able to gain knowledge on:

1. Oil and gas field development strategies and geophysical data acquisition techniques in development phases.
2. Methods and tools of Well logging

3. Reservoir engineering properties
4. Characterization of reservoirs by seismic methods
5. Conventional and unconventional reservoir modelling
6. 4D-seismic characterization of reservoirs
7. Carbon capture and Storage
8. Challenging Case studies

Course Name: Time Series Analysis in Geosciences

Course Code: GPO 515
L-T-P = 3-0-0
Credit = 9
Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Signal Processing: Basic Theory and Introduction, types of signals; Properties of time signal (time invariance, causality, linearity).	7
2.	Data Analysis: Z- transform, sampling theorem, antialiasing filter, discrete Fourier Transform, Fast Fourier Transform; Inverse Transform.	7
3.	Digital Filters: Characterization of digital filters (non-recursive and recursive filters), properties of some commonly used analog filters for low pass, high pass and band pass operation.	7
4.	Realization of Filters: Transformation for realization of digital filters from transfer functions of analogue filters (matched Z-transform, bilinear transform etc.), some commonly used non recursive filter windows.	4
5.	Convolution: Convolution theorem, unit impulse response and transfer function, convolution in time domain and in frequency domain; Interpolation and decimation of digital data; Correlation and Power Spectrum Estimation; Application in processing of geo-records.	7
6.	Processing and Applications: Interpolation and decimation, Correlation and Power spectral estimation, processing procedure of geophysical data.	7
	Total Classes =	**39**

Recommended Books:

1. Baskakov, S.. 1986, Signals and Circuits, Mir Publishers
2. Bath, M., 1974. Spectral Analysis in Geophysics. Elsevier, Amsterdam, Netherlands.

Other References:

3. Beauchamp, K.G., 1975. Walsh Functions and their Applications. Academic Press, New York, NY 236pp.
4. Blakeiy, Richard J., 1995, Potential Theory in Gravity and Magnetic Applications, Cambridge University Press.
5. Dimri, V. P., 1992, Deconvolution and Inverse Theory: Applications to Geophysical Problems, Elsevier Science.
6. Kanasewich, E. R., 1975,1'ime Sequence Analysis in Geophysics, The University of Alberta Press
7. Naidu, P. S., and Mathur, M. P., Analysis of Geophysical Potential Field: ADigital Signal Processing Approach: Elsevier
8. Robinson, E. A., 1967, Statistical communication detection with special reference to digital data processing of radar and seismic signal: GriffIn
9. Robinson, E. A., 1981, 'Time Series Analysis and Application: D. Reidel Yilmaz, Seismic Data Processing, Society of Exploration Geophysicists.

Course Goal / Learning Outcome:

The primary objective of the course is to introduce fundamental and advanced aspects of time series analysis techniques for geo-record analysis and processing.

Unit wise Learning Objectives:

Upon completion of the course, students will be able to:

1. Knowledge on geophysical/geological time/space series data analysis.
2. Knowledge on periodicity, how to design a filter, algorithm for signal enhancement and noise removal.
3. Knowledge on signal processing techniques for exploration of science.
4. Transformation of Analogue to digital filters
5. Application of Convolution theory in digital data processing
6. Techniques of Processing of geophysical data

Course Name: Geotechniques of Dams, Tunnels and Underground Space

Course Code: GLD 594

L-T-P = 3-0-0

Credit = 9

Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Types of dams and Geological Site Characterization of Dams	3
2.	Dam Foundation problems	4
3.	Treatment of Foundations of Concrete, Rock-Fill and earth dams	4
4.	Treatment of Foundation seepage	2
5.	Reservoir induced seismicity-case studies	2

6.	Types of Tunnelling and Tunnelling methods	3
7.	Conditions of Tunnelling Ground and controlling techniques	4
8.	Geohydrological hazards in tunnelling and underground space	4
9.	Geotechnical problems associated with tunnels (including stand-up time,Bridging capacity of rocks, overbreaks, arching action)	8
10	Stability in tunnels and underground space: Support requirements	5
	Total Classes =	**39**

Recommended Textbooks:

1. Fell R. McGregor, P., Stapledon, D. Bell, G., Foster, M (2015). Geotechnical Engineering of Dams, 2nd Edition, CRC Press.
2. Lunardi. P (2008). Design and construction of tunnels. Springer.

Other References:

1. Guglielmetti, V., Grasso,P. Mahtab, A., Xu, S. (2008). Mechanized tunneling in Urban areas. Methodology and Construction Control.

Course Goal / Learning Outcome:

The primary objective of the course is to introduce fundamental aspects of geological controls on the construction of Dams, Tunnels and underground space to the students.

Unit wise Learning Objectives:

Upon completion of the course, students will be able to

1 Plan and design a dam, tunnel or an underground space based on the geological controls.
2 Understand ground conditions and dam foundations
3 Treatment of soft and damaged foundations
4 Treatment of leaking foundations
5 Reservoir induced seismicity and effects on tunnel
6 Tunnelling methods based on types of tunnelling
7 Ground conditions of Tunneling
8 Hazards of groundwater in tunnels
9 Safety and stability in tunnels
10 Support requirements and remediation in tunnels

Course Name: Environmental Geotechnology

Course Code: GLD 592
L-T-P = 3-0-0
Credit = 9
Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Introduction to Environmental Geotechnology	2
2.	Scope of Environmental Geology, Changes in the environment caused by geological and anthropogenic activities	3
3.	Engineering geological studies for environmental evaluation and development	4
4.	Environment issues related to Environmental aspects of opencast mining projects with emphasis on impact of mine dumps, environmental impact of engineering projects.	6
5.	Environmental aspects of water, Impact of unplanned urbanization on groundwater regimes.	6
6.	Nuclear waste and disposal: Radiation and dangerous radioactive products and half-life, natural and anthropogenic sources; site selection for nuclear waste disposal.	4
7.	Land reclamation and restoration	3
8.	Mass movements	6
9.	Environmental planning, management and economics (EMP and EIA) and Preparation of Project Feasibility Report	5
	Total Classes =	**39**

Recommended Textbooks:

1. Reedman, JH.(1979) Techniques in Mineral Exploration, Applied Science Publishers Ltd., UK.
2. Peters, W.C.(1987) Exploration and Mining Geology (2nd Ed.); John Wiley & Sons, new York.

Other References:

1. D R Caotes. (1981) Environmental Geology.
2. L Lindgren. (1986) Environmental Geology, Prentice Hall Publ.
3. K S Valdiya. (1987) Environmental Geology: Indian Context. Tata McGraw Hill Publ.
4. Carla W Montgomery (1989) Environmental Geology (II Edn.), Wm C Brown Publ.
5. Saxena M. M.(1996) Environmental analyses of water soil and air.
6. Reply, E. A. (1996) Environmental effects of mining.
7. D Merrits, Dewet, A and Menking K.(1998) Environmental Geology, Freeman Publ.

8. Canter L. W. (1998) Environmental Impact Assessment, McGraw Hill Publ.

Course Goal / Learning Outcome:

The key objective of the course is to introduce the students with the implications of environmental impacts of geotechnical projects.

Overall Learning Outcome:

To introduce the basic tenants of environmental geology, sources of pollutants from natural as well as anthropogenic sources and their adverse impacts on the environments. The role of geologist in the remedial measures for environmental contaminants and its safe disposal.

Unit wise Learning Objectives:

Upon completion of the course, students will be able to:

1. Acquaint themselves with evaluation of environmental impact.
2. Environmental management.
3. Waste disposal.
4. Remediation.
5. Groundwater pollution
6. Radioactive pollution
7. How to restore and reclaim lands
8. Landslides and hazards
9. Environmental impact assessment

Course Name: Geomorphology

Course Code: GLD 540

L-T-P = 3-0-0

Credit = 9

Syllabus & Lecture Plan:

Unit	Description	No. of Classes
1.	Introduction to Geomorphology	2
2.	Methods of Geomorphic investigations	2
3.	Physical, Chemical and Biological processes in weathering	5
4.	Structural and lithological controls on landforms and drainage patterns	4
5.	Depositional and Erosional landforms: Fluvial, Aeolian, Glacial and Marine	11
6.	Morphometric analysis of landforms	6
7.	Impact of climate on geomorphology	3
8.	Applications of Geomorphology in environmental and engineering problems	3
9.	Neotectonics and geomorphology	3

Total Classes = 39

Recommended Textbooks:

1. Principles of Geomorphology– W.D. Thornbury, Wiley Eastern Limited.
2. Geomorphology – Arthur H. Bloom, Prentice hall of India

Other References:

1. Structural Geomorphology – J. Tricart , Longman Publishers
2. Geomorphology from the Earth – Karl W. Butzer, Harper International.
3. Glacial and Fluvioglacial Landforms – R.J. Price, Longman Publishers

Course Goal / Learning Outcome:

The primary objective of the course is to introduce fundamental and applied aspects of Geomorphology such as origin, evolution, maintenance and destruction of landforms, their link with tectonics and climate and their applications in flood control, landslides, transport engineering and others.

Overall Learning Outcome:

Upon completion of the course, students will be able to gain insights in:

1. Geomorphology as an important earth process that links landform development with climate, tectonics, sedimentary deposits, igneous activity and extra-terrestrial events.
2. Quantitatively analyse landforms and landscapes.
3. Application of geomorphology in Engineering and environmental problems.

How the program is different from earlier program

The entire program is new, mutli-disciplinary and compact and had not existed before.

The course has a balanced mix of mineral exploration and hydrocarbon exploration subjects.

Inclusion of several new state-of-the art topics like:

Programming in MATLAB (DC)
Geophysical methods for groundwater exploration (DE)
Artificial Intelligence and Machine learning in Geosciences (DE)
Geospatial Analysis (DE)
Digital Image Processing (DE)
Advanced Geostatistics and Mineral Economics (DE)
Time series analysis in Geosciences (OE)
Hyperspectral Remote Sensing (DE)

Summary

Total credits in 2 years: **173.00**
Average credit per semester: **43.25**
Average contact hours/week (1st year) (Theory +Practical Classes) = **20.50**
Average contact hours/week (2nd year) (Theory +Practical Classes) = **3.00**