Syllabus of

Four-SemesterPost-Graduate Course

In

APPLIED GEOLOGY

To be offered by

The Department of Geology,

Presidency University, Kolkata.

w.e.f. the Academic Session 2021-2022.

This revision succeeds the ongoing syllabus, in effect from the academic session 2017-2018

Preamble:

This new syllabus comes in response to the completion of the First batch of UG CBCS Curriculum, and primarily aims to remove the redundancy of topics from the ongoing PG Applied Geology Syllabus and allows incorporating more pertinent topics into this new draft.

This new syllabus categorises the various topics into Core Geology courses and Applied Geology Courses; each of which was subdivided to either as a Compulsory module or as an Elective Module. The Core Geology courses will be taught in the first two semesters and the Applied Courses in the last two semesters.

The electives are placed in Second and Third Semesters [Elective 1 (A&B) and Elective 2(A&B)]. These electives will be treated as sessional papers and the pedagogy will be designed by the instructor(s) accordingly. Students have to choose two electives; one from Category A and the other from Category B.

In the taught course there shall be a theoretical end Semester examination of 35 marks and the 15 marks will have the component of Internal Assessment as continuous evaluation of student's class performance. In the Sessional Paper (Full Marks 50) students will be evaluated through their performance in Laboratory work, Project & Assignment, Field work and Seminar.

COURSE-STRUCTURE

Applied Geology-M. Sc.

PG Semester I (Total Marks: 250)

Paper	Group	Subject	Marks [Taught Course (35+15)] / Sessional [Lab/Field/Project (50)	Credits
GEOL0701		IGNEOUS PETROLOGY	50 (35+15)	4
GEOL0702		METAMORPHIC PETROLOGY	50 (35+15)	4
GEOL0703		STRUCTURAL GEOLOGY AND CRUSTAL DEFORMATION	50 (35+15)	4
GEOL0791		ISOTOPE GEOLOGY AND GEOCHRONOLOGY	50	4
GEOL0792		GEOSTATISTICS	50	4

PG Semester II (Total Marks: 250)

Theory

Paper	Group	Subject	Marks [Taught Course (35+15)] / Sessional [Lab/Field/Project (50)	Credits
GEOL0801		SEDIMENTOLOGY	50 (35+15)	4
GEOL0802		PALAEONTOLOGY	50 (35+15)	4
GEOL0803		HYDROGEOLOGY	50 (35+15)	4
GEOL0891	A	ELECTIVE 1A	50	4
	B	ELECTIVE 1B		
GEOL0892		FIELD WORK*	50	4

Subjects under elective 1A: LARGE IGNEOUS PROVINCE (LIP)/ TECTONIC PROCESSES THROUGH TIME/ GEOARCHEOLOGY/ PRECAMBRIAN STRATIGRAPHY OF INDIA IN A GLOBAL PERSPECTIVE

Subjects under elective 1B: GEOMATHEMATICS AND COMPUTER APPLICATIONS/PHANEROZOIC STRATIGRAPHY OF INDIA IN GLOBAL PERSPECTIVE/ MICROSTRUCTURE AND FABRIC DEVELOPMENT/ FUNDAMENTALS OF OCEANOGRAPHY

***Field Work of two (02) weeks duration (Compulsory)**

PG Semester III (Total Marks: 250)

Paper	Group	Subject	Marks [Taught Course (35+15)] / Sessional [Lab/Field/Project (50)	Credits
GEOL0901		REMOTE SENSING AND GIS	50 (35+15)	4
GEOL0902		GEOPHYSICS	50 (35+15)	4
GEOL0903		ORE GEOLOGY	50 (35+15)	4
GEOL0991	A	ELECTIVE 2A	50	4
	B	ELECTIVE 2B		
GEOL0992		INDUSTRIAL TRAINING AND OPEN SEMINAR	50	4

Subjects under elective 2A: ORGANIC BIOGEOCHEMISTRY/APPLIED HYDROLOGY / APPLIED MICROPALAEONTOLOGY
Subjects under elective 2B: ADVANCED REMOTE SENSING/ ORE DEPOSITS IN LAYERED INGEOUS COMPLEX / BASIN ANALYSIS/ APPLIED GEOPHYSICS

Industrial Training/Summer Project of two/three (02/03) weeks duration

PG Semester IV (Total Marks: 250)

Paper	Group	Subject	Marks [Taught Course (35+15)] / Sessional [Lab/Field/Project (50)	Credits
GEOL1001		COAL, NUCLEAR FUEL AND ENGINEERING GEOLOGY	50 (35+15)	4
GEOL1002		PETROLEUM GEOLOGY	50 (35+15)	4
GEOL1003		MINERAL EXPLORATION, MINING AND ORE BODY MODELING	50 (35+15)	4
GEOL1091		EVALUATION OF DISSERTATION	50	4
GEOL1092		SEMINAR-VIVA-VOCÊ ON DISSERTATION	50	4

FIRST SEMESTER

GEOL0701 IGNEOUS PETROLOGY Full Marks: (35+15=50)

Programme highlights/Objectives:

To understand the nature of diverse types of magma/magma series evolved in different tectonic settings, processes of magma generation under high pressure condition in lower crustal and upper mantle depths and their correlation with Earth's heat release system through space and time.

Learning outcome:

After successful completion of different modules of the course students will get to know and able to apply following issues-

i) Characteristics of magmatic rocks from different tectonic setting using rock association, mineralogy, geochemistry, magma generation and diversification process in those tectonic setting with respect to parameters like source rock composition, Temperature, Pressure, role of volatiles,

ii) Nature of elevation and depression of melting/freezing point of minerals with changing dry and wet pressure condition, change in nature of liquidus and solidus surfaces and enlargement and reduction of stability fields of minerals under high dry and wet pressure and their petrogenetic implication.

iii) Behavior (compatibility and incompatibility) of trace elements in high temperature magmatic system of varying chemical environment, quantify trace element distribution during different petrogenetic processes like partial melting, fractional crystallization, assimilation, magma mixing using trace element modeling.

iv) Tectonic classification of granitoid rocks using mineralogical and chemical composition, evolution of granitoid rocks through space and time and their role in crustal evolution.

v) Mantle heterogeneity from study of mantle xenoliths, ophiolite, causes of mantle heterogeneity through space and time, types of fluid phases present in the upper mantle and possible changes in mineralogy and geochemistry of upper mantle rock through fluid-rock interactions.

Syllabus:

Theory:

1. **Magmatism in the following plate tectonic settings-**
   - i) Mid Oceanic Ridge setting
   - ii) Subduction Zone setting
   - iii) Continental and oceanic rift zone

Types of magmatic rocks/series/suite in all these tectonic setting, petrography-mineralogy of magmatic rocks, major and trace element geochemistry, Sr-Nd-Pb isotopic abundances to characterize petrogenetic processes (nature of source rock, processes of magma generation, role of volatiles in magmatic system), magma emplacement in relation to tectonic activity.

2. **Study of phase diagram under high pressure dry and also wet conditions, petrogenetic implications-**

Elevation and depression of melting/freezing point of mineral phases under high dry and wet pressure conditions, changes in the nature of liquidus and solidus surfaces under high dry and wet pressure with respect to their nature under low pressure (1 atmosphere), changes in crystallization and melting behavior of minerals under elevated pressure, petrogenetic implication of phase diagram under high pressure (lower crust and upper mantle) condition.

3. **Trace elements as important indicator of petrogenetic process and tectonic setting-**

Behavior of trace element during equilibrium and fractional crystallization, equilibrium and fractional melting, trace element modelling and quantification of petrogenetic process.

Trace element abundance of magmatic rocks (especially basalt and granite) from different tectonic setting, trace element discrimination diagrams and identification of tectonic setting.

4. **Classification, characterization and petrogenesis of granitoid rocks and their tectonic implication-**

Petrographic-mineralogical and geochemical classification, characterization of I-, S-, M-, and A-type granites, petrogenetic processes involved in origin and evolution of different types of granitoid rocks, Tectonic discrimination of granitoids on the basis of trace elements and isotopic abundances, brief idea about importance of granite in crust building process through time.

5. **Petrology & geochemistry of upper mantle, mantle heterogeneity, magma diversification-**

Mineralogy of upper mantle, phase transition in upper mantle, broad geochemical composition of upper mantle, variation in composition (mineralogical and geochemical) of upper mantle through space and time- mantle heterogeneity and its causes. Fluid phases in upper mantle.

Practical:

1. Study of the following thin sections of igneous rock under microscope
a. Lamprophyre and lamproite
b. Pyroclastic rock and ignimbrite
c. Alkaline rocks
2. Numerical problems related to petrogenetic processes like fractional crystallization, partial melting, assimilation, magma mixing
3. Numerical/graphical problems on solid-liquid equilibrium system, magma viscosity, magma ascent rate

Suggested Reading:

1. Philpotts, A. and Auge, J., 2009. Principles of Igneous and Metamorphic Petrology. Cambridge University Press.
2. Winter, J.D., 2001. An Introduction to Igneous and Metamorphic Petrology, Prentice Hall.
3. Wilson, M., 1989. Igneous Petrogenesis: a global tectonic approach, Cambridge University Press.
4. Bose, M.K. 1997. Igneous Petrology, The World Press Pvt. Ltd. Kolkata
5. Cox, K.G., Bell, J.D., and Pankthrust, R.J.1979. The Interpretation of Igneous Rocks. Springer
6. Pitcher, W.S. 1997.The Nature and Origin of Granitic Rock. Springer.

GEOL0702 METAMORPHIC PETROLOGY Full Marks: (35+15=50)

Programme Highlights/ objective: To introduce metamorphism as a process of crustal evolution that can be quantified and correlated with other geological processes.

Learning Outcome: The students will have a holistic idea about metamorphism and how it is related to deformation, magmatism and tectonics. At the same time, they will be able to quantify the process.

Theory:

1. Application of Geochemical thermodynamics, G-P-T surface, Schreinemakers' analysis, phase equilibria modeling
2. Quantification of P,T and fluid variables; Geothermobarometry; fluid inclusions study
3. Geochronology of metamorphic rocks; time scale of metamorphic process
4. Tectonics and metamorphic styles through ages
5. Ultrahigh temperature (UHT) and ultrahigh pressure (UHP) metamorphism
6. Crustal anatexis and metamorphism
7. Heat flow and thermal modeling of orogenic belts

Practical:

1. Analysis of reaction textures from thin section study.
2. Estimation of pressure and temperature of metamorphism from mineral equilibria.
3. Construction of petrogenetic grid, P-T paths and phase diagram modeling

Suggested Readings:

1. Ganguly, J. 2008. Thermodynamics in Earth and Planetary Sciences. Springer
2. Bucher, K. and Grapes, R., 2010. Petrogenesis of Metamorphic Rocks, Springer.
3. Philpotts, A. and Auge, J., 2009. Principles of Igneous and Metamorphic Petrology. Cambridge University Press.
4. Vernon, R. H., and Clarke G.L. 2008. Principles of Metamorphic Petrology, Cambridge University Press.
5. Winter, J.D., 2001. An Introduction to Igneous and Metamorphic Petrology, Prentice Hall.
6. Spear, F.S., 1995. Metamorphic Phase Equilibria and Pressure-Temperature-Time paths, Mineralogical Society of America Monograph.

GEOL0703STRUCTURAL GEOLOGY AND CRUSTAL DEFORMATION

Full Marks: (35+15=50)

Programme Highlights/ objective

The course outlines the geometry, principles and kinematics of the deformation of the earth's crust and lithosphere. The overall aim is to give the students a better understanding of the deformation of rocks (from brittle to ductile) at different scales (from macroscopic to microscopic). Deformation processes and structures that develop at different tectonic settings have also been included into this course.

Learning Outcome

The course is designed to enable the students

a) to have a comprehensive idea of the geometries of the natural structures that result out of deformation
b) to develop the skills of analysing natural structural data and maps of poly-deformed terranes.
c) to understand the rheology and mechanism of rock deformation at different scales.
d) To form an overall idea of the varieties of tectonics operative within the crustal domain.

Theory:

1. Principles of rock deformation – Stress and Strain Analyses
2. Rheological properties of rocks – Deformation mechanism, microstructure and fabric development
3. Mechanics of folding and fracturing
4. Shear zone and its kinematics
5. Superposition of deformation sequences: geometry and analytical techniques
6. Large scale deformation of the crust: Tectonic features of extensional-, compressional-, and strike-slip-terrains and relevance to plate boundaries

Practical:

1. Application of Borehole and Rotational Problems in Structural analyses

2. Problems on Stress and Strain analyses

3. Balanced Cross-section Construction

4. Structural analyses of ploy deformed terrains: map and data analyses

Suggested Readings:

1. Davis, GH. and Reynolds, S.J., 1996. Structural Geology of rocks and regions, John Wiley. and Sons.
2. Ghosh, S.K., 1993. Structural Geology: Fundamentals, and modern developments, Pergamon Press.
3. Passhier, C. and Trouw, RAJ, 2005. Microtectonics. Springer, Berlin.
4. Pollard, D.D. and Fletcher, R.C., 2005. Fundamentals of structural geology, Cambridge University Press.
5. Ramsay, J.G and Huber, M.I., 1983. Techniques of Modern Structural Geology: Vol.I & 11. Academic Press
6. Ramsay, J. G, 1967. Folding and Fracturing of Rocks, McGraw-Hill Book Company, New York .

7. Rowland, S.M., Duebendorfer, E. and Schiefelbein, I.M., 2007. Structural analysis and synthesis: a laboratory course in structural geology, Blackwell Pub.
8. Twiss,R.J. and Moores, E.M., 2007. Structural Geology. Freeman.
9. Van der Pluijm, B.A. and Marshak, S., 2004. Earth structure: an introduction to structural 12 geology and tectonics, W.W. Norton & Company Ltd.

GEOL0791 ISOTOPE GEOLOGY AND GEOCHRONOLOGY Full Marks :50

Programme Highlights/ objective: The course aims to allow the student to use stable and radiogenic isotopes to track different processes in the different reservoirs of the earth. The course also aims to allow the student to understand and apply the most used techniques for the geochronology of rock and minerals along with the use of different state of the art analytical techniques in geochemistry.

Learning Outcome: On successful completion of the course the student will be able to understand the principal isotope systematics used in the geosciences and how they are applied to track planet evolution and the evolution of the environment. The student will also acquire the basic knowledge of radiometric dating and the tools to choose between the different dating techniques as a function of the study case.

Theory:

Unit 1: Nucleosynthesis and chart of nuclides. General introduction to isotopes, cosmogenic nuclides and extinct radionuclides.

Unit 2: Importance of instrumentation in Geology. Quality, Precision, Accuracy, calibration and standards. Introduction to instrumental techniques in Geochemistry (XRF, EPMA, ICPMS, AMS, TIMS).

Unit 3: Stable isotope geochemistry (C, O, S) and its application in geology. Application of non-traditional stable isotopes (Mo, Ca, Fe, Sr)

Unit 4: Introduction to radioactivity and geochronology; Decay scheme of different radio-isotope systems (Rb-Sr, Sm-Nd, U-Pb, K-Ar, Lu-Hf).

Unit 5: Geochronology – Importance, Methods, and limitations, basic principles of Radioactive dating Methods: K-Ar, U-Series dating, Rb-Sr, Sm-Nd and C-14.

Suggested Readings:

1. Faure, G., Mensing. T.M. 2005. Isotopes. Principles and Applications,
2. Dickin, A. P., Radiogenic Isotope Geology. Cambridge University Press, 2018
3. White, M. William (2014). Isotope Geochemistry. Wiley – Blackwell

GEOL0792 GEOSTATISTICS Full Marks: 50

Programme Highlights/ objective:

This course provides the learners to have an idea about the nature and variabilities of Earth Science Data sets. The course aims to introduce the different statistical operations done on such data enabling estimation, prediction, simulation and modeling. Knowledge of statistical procedures is inherent in data analysis and management.

Learning Outcome:

This course will help the students in the skill of data handling and data management. At the end of the course the students will be able to correlate between variables and use statistical procedures as estimators. Students have expertise developed in Data processing, data interpretation, statistical testing and modeling needed for a professional career in Geosciences.

Theory:

1. Basic Statistics – Classification and presentation of statistical data, Characteristics of Normal distribution, measures of central tendency and dispersion, correlation, Least square method and regression analysis, probability and probability distributions, concept of population and sample, Sampling and sample distributions.
2. Central limit theorem; Concept and methodology of Hypotheses Testing and its application in geology - student's t test, F test, $\chi 2$ test, ANOVA(one way),
3. Concept of regionalized variable- semi variance & semivariogram, kriging
4. Analysis of sequences of data: Markov chains, auto correlation and cross correlation.
5. Analysis of multivariate data, Map analysis
6. Fractals in geology.

Suggested Readings:

1. Schabenberger, O. and Gotway, C. (2005) Statistical Methods for Spatial Data Analysis Chapman & Hall/CRC.
2. Peter J. Diggle, Paulo J. Ribeiro, Jr (2007) Model-based geostatistics, Springer.
3. Cressie, N. (1993). Statistics for Spatial Data (Revised Ed.). John Wiley & Sons, Inc.
4. Chiles, J. P. and Delfiner, P. (1999) Geostatistics: Modeling Spatial Uncertainty. Wiley.
5. Davis, J.C., Statistics and Data Analysis in Geology, 3rd Edition, John Wiley & Sons, Inc.

SECOND SEMESTER

GEOL0801 SEDIMENTOLOGY FullMarks: (35+15=50)

Programme Highlights/ objective:

Postgraduate students of Geology are acquainted with basic principles of sedimentation and sedimentary rock composition. The PG course in Sedimentology aims to provide the students with advanced knowledge in sedimentology based on critical and in-depth study of basic and applied aspects of sedimentary geology.

Learning Outcome:

Upon successful completion of the course the students will develop skills on

a) Interpretation of the mechanism of sedimentation from primary sedimentary structure.
b) Interpretation of sedimentary environment from facies analysis
c) Interpretation provenance and tectonics of sedimentation from compositional data
d) Interpretation of carbonate platform and stable isotope compositions from carbonate rocks
e) Interpretation of tectonic and eustatic controls on sequence development from surface and subsurface data from sedimentary successions

Theory

1. Outline of mechanism of sediment transport and deposition;
2. Petrogenetic significance of Sandstone (Classification and factors controlling sandstone types)
3. Facies models for fluvial, deltaic, siliciclastic shelf, deep-sea fan;
4. Petrology of carbonate rocks (classifications and factor controlling different types of carbonate rocks), dolomites and dolomitization
5. Carbonate Platforms: types and general facies model
6. Role of stable isotopes in understanding carbonate sedimentation and diagenesis
7. Siliceous sediments and iron formations
8. Tectonic classification of sedimentary basins
9. Principles of Sequence Stratigraphy

Practical

1. Exercises related to determination of source area and tectonics from composition of sandstones,
2. Exercises related to environmental reconstruction and sequence stratigraphy of siliciclastic and carbonate successions.

Suggested Readings:

1. Allen, P.A., 1997. Earth Surface Processes, Blackwell publishing.
2. Catuneanu, O., 2006. Principles of Sequence Stratigraphy. Elsevier, Amsterdam, 375 pp.
3. Collinson, J.D. and Thompson, D.B., 1988. Sedimentary Structures, Unwin- Hyman, London.
4. Leeder, M.R., 1982. Sedimentology: Process and Product. George Alien &Unwin, London, 344p.
5. Lindholm, R.C., 1987. A Practical Approach to Sedimentology, Allcn and Unwin, London.
6. Pettijohn, F.J., 1975. Sedimentary Rocks, Harper and Row Publ. New Delhi.
7. Miall, A.D., 1999. Principles of Sedimentary Basin Analysis 3rd Fd Springer Verlag, New York.
8. Nichols, G., 1999. Sedimentology and Stratigraphy, Blackwell publishing.
9. Reading, H. G., 1996. Sedimentary Environments: Processes, Facies and Stratigraphy, Blackwell Publishers
10. Boggs, S., 1995. Principles of Sedimentology and Stratigraphy, Prentice Hall, New Jersey.
11. Tucker, M.E., 2006. Sedimentary Petrology. Blackwell Publishing.
12. Tucker, M.E. and Wright, V.P., 1990. Carbonate Sedimentology, Blackwell.
13. Walker, R.G., Facies model 1976. Geoscience Canada

GEOL0802 PALAEONTOLOGY FullMarks: (35+15=50)

Programme Highlights/ objective: The programme intends to outline the evolution of life through geological time. It seeks to establish the relationships of evolving life with other geological events like climatic and tectonic changes. The programme also introduces some major groups of macro- and microfossils.

Learning Outcome: After completion of the programme a student is expected to gain insights on (1) macroevolutionary patterns of life, (2) major evolutionary breakthroughs in the evolution of life, (3) major mass-extinction events and their significance in the shaping of evolution, (4) Precambrian life, (5) possible link between other geological phenomena and life's evolution, (6) principles and comparison between conventional and modern systematics, (7) major macro- and microfossil groups, (8) application of palaeontological information to make palaeobiological interpretation.

Theory

1. Key evolutionary events in Earth's history: Precambrian, Palaeozoic, Mesozoic and Cenozoic biota – brief idea, turnover pattern through time; controls of tectonics, geography and mass-extinction.
2. Major turning points in evolution of vertebrates – evolution of jaw, terrestrialization, amniote evolution, evolution of dinosaurs, evolution of flight, evolution of mammals.
3. Important invertebrate groups (e.g., Anthozoa, Brachiopoda, Echinoidea etc.) and their evolutionary palaeobiological significance.
4. Important microfossil groups (e.g., Calcareous nannofossil, Diatoms) and their biostratigraphic significance.
5. Evolutionary, numerical and phylogenetic systematics.
6. Brief idea about palynology.
7. Application of palaeontology to palaeo-environmental reconstruction.

Practical

1. Microscopic study of Microfossils.
2. Exercises on numerical and phylogenetic systematics.
3. Exercises on analytical methods employed in palaeontology.
4. Functional morphological study of molar teeth.

Suggested Readings:

- Benton, M. (2009). Vertebrate paleontology. John Wiley & Sons. 4th Edition.
- Armstrong, H.A., and Brasier, M.D. (2005) Microfossils. Blackwell Publishing.
- Saraswati, P.K., and Srinivasan, M.S. (2016) Micropaleontology Principles and Applications. Springer International Publishing.
- Clarkson, E.N.K. (2011). Invertebrate Palaeontology and Evolution. Wiley India. 4th edition.
- Stanley, S.M. and Luczaj, J.A. (2015). Earth System History. Freeman & Co. 4th edition.
- Foote, M. and Miller, I.A. (2007). Principles of Paleontology. Freeman & Co. 3rd edition.
- Skelton, P. (ed.) (1993). Evolution: A Biological and Paleontological Approach. Addison-Wesley. 1st edition.

GEOL0803 HYDROGEOLOGY FullMarks: (35+15=50)

Programme Highlights/ objective:

Hydrogeology is a subject that in principle deals with the relationship between geology and groundwater systems. Thus, the scope of this paper is to explore the fundamentals of this relationship by understanding the influence of geology on the occurrence and behaviour of groundwater in different setups. This would include understanding the physical and chemical nature of the groundwater system. Moreover, this paper would also examine the different aspects of human interaction with groundwater in the form of different management issues and strategies, legislations and policy making. The main objective of this paper is to introduce the fundamentals of groundwater science to the students and give them an insight into different hydrogeological environments.

Learning Outcome:

We expect students to learn about the following in the course of this paper:

- To understand the fundamental concepts of hydrogeology.
- To learn about the basics of groundwater systems, including aquifers and their properties.
- To understand the nature and issues related to groundwater chemistry
- To explore the status of groundwater resources at national and global levels
- To familiarize with groundwater management issues and strategies.

To explore groundwater legislations and policy frameworks at different levels of governance.

Syllabus:
Theory
1. Introduction to Hydrogeology

Meaning and significance of Hydrogeology; Role of groundwater in Hydrologic cycle; Geological structures favouring groundwater occurrence; Classification of groundwater; Subsurface profile of groundwater including detailed study of zones of aeration and saturation.

2. Aquifers and their properties

Classification of aquifer and aquifer systems; Introduction to hydrological properties of aquifers: porosity, void ratio, specific retention, storage coefficient, hydraulic conductivity, transmissivity; Darcy's law and its application.

3. Introduction to Well Hydraulics

Theory of groundwater flow including detail study of piezometric head of groundwater, flow of viscous fluid and Reynolds Number; Concept of hydraulic diffusivity; Bore hole exploration for delineating groundwater resources through geophysical methods and well logging; Concept of drilling and well development in hard rock and alluvial areas.

4. Groundwater Quality

Concept of groundwater contamination and pollution; Sampling protocols and tests of Groundwater quality parameters (Physical, Chemical and Biological); Factors influencing groundwater quality in different geological settings.

5. Groundwater in India and World

Status of groundwater resources across the globe with special emphasis on India; Detailed study of Groundwater provinces of India; Major groundwater issues and challenges in India and different parts of the world.

6. Groundwater Legislation and Management

Major groundwater legislation in India and West Bengal; National Water policy with special emphasis on groundwater; Groundwater Management strategies in different parts of the country; Protocols, treaties and frameworks related to groundwater conservation and management at global level.

Practical

1. Preparation and Interpretation of hydrogeological maps and flow nets
2. Numerical Problems on aquifer properties
3. Interpreting data from borehole exploration
4. Interpreting groundwater quality data through calculations and graphical plots

Suggested Readings:

• Karanth, K. R., Groundwater Assessment, Development and Management, Tata McGraw Hill
• Todd, D. K., Ground Water Hydrology, John Wiley and Sons Inc. New York.
• Davis, S. N. and De Weist, R. J. M. (1966). Hydrogeology. John Wiley and Sons Inc., New York.
• Raghunath H, M. (2007). Groundwater. 3rd Ed. New Age International Publishers, New

GEOL0891 **ELECTIVE 1A+ ELECTIVE 1B Full** Marks**: 25+25=50**

ELECTIVE 1A

1. LARGE IGNEOUS PROVINCE (LIP)

Programme highlights/Objectives: To understand the definition and scope of Large Igneous Province (LIP), Global distribution of LIPs through space and time characteristics of rocks of LIP and various ideas about origin.

Learning outcome: After successful completion of different modules of the course students will get to know and able to apply following issues-

i) Concept, modern definition of LIP, how the definition of LIP changes with time
ii) Distribution of LIP all over the world and through time which will give them idea about the heat release system of the dynamic earth through space and time
iii) Rock types in LIP, (mostly mafic with subordinate felsic rock), broad mineralogical and geochemical characters of different rocks of LIP.
iv) Tectonic setting of evolution, source of heat for generation of such voluminous melt, petrogenetic process.
v) Deccan trap-distribution and volume of Deccan Trap, flow stratigraphy, simple vs compound flows, mineralogical and geochemical character of rocks of Deccan Trap, age and petrogenetic process.

Syllabus:
Theory:

1. Definition and scope: Modern definition and scope, evolving ideas about LIP
2. Distribution of LIP all over the world through ages,
3. Rock types – petrography-mineralogy, geochemistry
4. Tectonic setting for emplacement of LIP: e.g. Within plate setting- rift, plate margin setting.
5. Petrogenetic theories for origin and evolution of LIP- e.g., mantle plume model, rift model.
6. Deccan Trap- a typical LIP from India, one of the most well studied LIPs all over the world- A case study.

Practical:

1. Petrographic study of tholeiitic basalt, alkali basalt, mantle xenoliths of Deccan Trap

Suggested Reading:

1. Coffin, M.F., and Eldholm, O. 2005. Large Igneous Province. Encyclopedia of Geology.
2. Ernst, R.E. 2021. Large Igneous Province. Encyclopedia of Geology, Second Edition, 2021.
3. Kent C. Condie, K.C. 2011. Tectonic setting of LIP. i Earth as an Evolving Planetary System (Second Edition), 2011.
4. Various articles on Deccan Traps.

2. TECTONIC PROCESSES THROUGH TIME

Programme Highlights/ objective

The course will be designed to address the enigmatic question of initiation of plate tectonics in Geological time. The course shall address this with the evidence that is put forward to establish when plate tectonics began, and how it has evolved through time. This course shall therefore be a trans –disciplinary course which will deal with different branches of Geology (like geochemistry, geodynamics, petrology, geophysics) and will help develop a comprehensive idea of tectonics in the students.

Learning Outcome:

This course will expose the students to the different views and opinions prevalent in the geodynamics of the earth through time. This is presently an active area of research, with branches of Geology like petrology and geochemistry in unravelling the history of terrestrial tectonics; and this course will thus facilitate the students to correlate between these branches and form a holistic idea of evolution of geodynamics through time. Students will have an idea of the different models of Archaean tectonics. Successful completion of the course will enhance critical thinking in this field in the view of the present research that is going on.

Syllabus

a) Models of Archaean Tectonics and crustal development
b) Geochemical constraints on the origin of Archaean magmatic rocks
c) Archaean orogens and modern analogues
d) Plate Tectonics and the geological record
e) Rheology of the lithosphere and crustal inheritance
f) Wilson cycle vs. Supercontinent cycle

Suggested Readings:

1. Moores, E. M. and Twiss, R. J., 1995. Tectonics. New York: WH Freeman.
2. Van Kranendonk, Martin J., Vickie Bennett, and Elis Hoffmann, 2018. eds. Earth's oldest rocks. Elsevier.
3. Stuwe, K., 2007. Geodynamics of the Lithosphere. Springer
4. Turcotte, D. L. and Schubert, G., 2002. Geodynamics. Cambridge university press.
5. Schubert, G., Turcotte, D. L., and Olson, P., 2001. Mantle convection in the Earth and planets. Cambridge University Press.

3. GEOARCHEOLOGY

Programme Highlights/ objective: Geoarchaeology plays a vital role in archaeology by significantly enhancing the interpretation of human prehistory by refining its environmental and temporal context. Geoarchaeology applies the principles of geochemistry, sedimentology, stratigraphy and geochronology to interpret the occurrence, distribution and preservation of archaeological evidence and bridges between humans and the environment. This course teaches the theoretical and methodological aspects of geoarchaeology and typical cases of interdisciplinary research in different contexts and cultural groups (early hominids, hunter-gatherers, agriculturalists and urbanites). The course aims to introduce the concept of geoarchaeology and the role of earth scientists in geoarchaeology.

Learning Outcome:

By the end of the course, the students will be able to:

1. Understand the basic concept of Geoarchaeology.

2. Understand the basic principles of stratigraphy in archaeology.

3. Know the application of the basic tools of Earth Sciences in geoarchaeology.

4. Understand various dating techniques applied in archaeology.

5. Understand the role of stable isotopes and biomarkers in archaeological interpretations.

Syllabus:

1. Role of earth Scientists in archaeology.

2. Concept of stratigraphy in archaeology.

3. Quaternary dating techniques.

4. Application of stable isotopes and biomarkers in archaeological interpretations.

5. Basic application of sedimentology, mineralogy and geochemistry in geoarchaeology.

Suggested Readings:

1. Rapp G., Hill C.L., 2006.Geoarchaeology: The Earth-Science Approach to Archaeological Interpretation. Yale University Press.
2. Garrison E., 2016. Techniques in Archaeological Geology. Springer
3. Pappu R.S., 1995. The Contribution of Earth Science to the Development of Indian Archaeology, in Quaternary Environments and Geoarchaeology of India, Edited by S. Wadia, R. Korisettar, and V. S. Kale, pp. 414-434. Bangalore: Memoirs of the geological Society of India 32.

4. PRECAMBRIAN STRATIGRAPHY OF INDIA IN A GLOBAL PERSPECTIVE

Programme Highlights/ objective: It is an elective course in the Master's degree program in Geology. This is designed specifically for the students who seek to understand the practical application of sedimentological and geochemical knowledge in the evolution of earth as well as reconstructing its climatic history during Precambrian. This course will mostly deal with the tools to reconstruct Precambrian history and the major global events during Precambrian and their Indian records.

Learning outcome: Upon successful completion of this course the students should be able to understand the usage of various tools that can be used to reconstruct Precambrian history, and also develop the basic idea about the major global events and their signatures during this time. They will also be able to understand the problems associated with the Precambrian-Cambrian boundary and its Indian records.

Syllabus:

1. Classification of the Precambrian Time: Divisions, basis of classification; Geodynamics and origin of cratons, Granite-greenstone and granulite belts; Evolution of atmosphere, Evidences of global climate changes; Evolution of life and Precambrian oceans; Use of U-Pb, Lu-Hf, Sm-Nd isotope signatures in Precambrian crustal evolution.

2. Archaean stratigraphy of India: Summary of comparative stratigraphic development of the Archaean cratons in India; salient records of the Archaean geodynamic and sedimentation models from the Indian rock sequences.

3. Purana Basins of India: Distribution, general characteristics and a comparative study of stratigraphic development from these basins.

4. Precambrian Mobile belts of India in relation to geodynamic models and global supercontinent cycles.

Suggested readings:

1. Condie, K. C., 2015, Earth as an Evolving Planetary System, Elsevier.
2. Miall, A. D., 2015, Stratigraphy: A Modern Synthesis, Springer.
3. Rollinson, H, 2007, Early Earth Systems, Blackwell.
4. Dilek, Y. & Furnes, H, 2014, Evolution of Archean crust and early life, Springer.
5. Naqvi, S. M. & Rogers, J. W., 1987, Precambrian Geology of India, New York, Oxford University Press.
6. Ramakrishnan, M. & Vaidyanadhan, R., 2008, Geology of India: Vol. 1, 556p, ISBN No: 978-81-85867-98-4, Geological society of India.

ELECTIVE 1B

1. GEOMATHEMATICS AND COMPUTER APPLICATIONS

Course Objective:

The course has been designed to foster an overview of the following:

a) the characteristics of the natural database and its manipulation
b) the errors associated with such measurements and how it propagates with overriding calculations
c) mathematical and computations rigors in frequent usages in earth sciences

Learning Outcome

The pedagogy will be crafted in a manner as to foster a self learning in these topics and therefore classroom teaching will comprise half of the entire learning process. At the end of the program a student will be able to

a) comprehend the database: its variability, manageability and mathematical treatment
b) get an idea about the decision making systems
c) write short program routines for the data analysis procedures
d) Exposure to some selected software in Earth Sciences

Syllabus

1. The variability of Geological database; Concept of Regionalised variable
2. Concept and measurement of Error propagation in natural systems
3. Concept of Decision Support system, Neural network, Fuzzy logic and genetic algorithm.
4. Mathematical approaches in geology including Fractals
5. Programming in C / Python
6. Commonly used Softwares in Earth Science studies.

Suggested readings:

1. Fornasini, Paolo. "Physical Quantities." The Uncertainty in Physical Measurements: An Introduction to Data Analysis in the Physics Laboratory (2008): 2-11.
2. Kanetkar, Yashavant. Data Structures Through C: Learn the fundamentals of Data Structures through C. Bpb Publications, 2019.
3. Kanetkar, Yashavant P. Let us C. BPB publications, 2004.
4. Mano, M. Morris. Computer system architecture. Prentice-Hall of India, 2003.
5. Nagar, Sandeep. Introduction to Python for Engineers and Scientists: Open Source Solutions for Numerical Computation. Apress, 2017.

2. PHANEROZOIC STRATIGRAPHY OF INDIA IN GLOBAL PERSPECTIVE

Programme Highlights/ objective:

Study of Phanerozoic stratigraphy of India in global perspective is one of the main objectives in this course. Understanding about the evolution of depositional settings in different Phanerozoic basins through time is the major objective of this course. In this aspect, study of the boundary problems will also be discussed. Study of different palaeoclimatic conditions is essential for comprehensive understanding of the evolution of climatic conditions throughout the Phanerozoic time.

Learning Outcome:

The learners could be able to understand the imprints of the global phanerozoic events in the records in the Indian stratigraphy in different Phanerozoic basins in India. This could enable them to correlate the Indian Phanerozoic stratigraphy on a global scale in terms of overall depositional and climatic conditions.

Syllabus:

1. Wilson cycle through Supercontinent and tectonic rock cycle
2. Breakup of Gondwanaland and associated major palaeoclimatic events
3. Journey of India through Phanerozoic time and associated climatic and stratigraphic changes
4. Major stratigraphic boundaries during Phanerozoic time: a global synthesis.

Suggested Readings:

1. Miall, A.D. (2016) Stratigraphy: A Modern Synthesis. Springer.
2. Ramakrishnan, M. and Vaidyanadhan R. (2008, 2010) Geology of India (Vol. 1 & 2). Geological Society of India Publications.
3. Kumar, R. (1998) Fundamentals of Historical Geology & Stratigraphy of India. New Age International Publishers.
4. Krishnan, M.S. (2017) Geology of India and Burma. CBS Publishers & Distributors Pvt. Ltd.
5. Dasgupta, A. (2010) Phanerozoic Stratigraphy of India. World Press.
6. Roy, A.B. and Purohit, R. (2018) Indian Shield: Precambrian Evolution and Phanerozoic Reconstitution. Elsevier.

3. MICROSTRUCTURE AND FABRIC DEVELOPMENT

Programme Highlights/ objective

Rock responses to deformation is evidenced from its fabric development and grain scale microstructures. An in-depth analysis of these is beyond the scope of the core Structural geology curriculum. The course aims to introduce the fabric development in rocks deformed at different deformation regimes. The course binds together concepts of High T/P petrology with structural geology, thereby giving it a trans-disciplinary nature.

Learning Outcome:

Successful completion of the course will enable the students to understand the grain scale response of the rock to different degrees of nature of deformation. The course will enable the learners to have an in-depth knowledge of the analysis of microstructures to interpret the conditions of their formations, petrofabrics, deformation history etc. The students will be exposed to the newer advances in the research of microstructure and fabric development in structural geology.

Syllabus:

a) Defects in Crystals
b) Cataclasis
c) Diffusive mass transfer by solution
d) Crystal plastic slip/ Dislocation creep
e) Lattice-preferred orientation
f) AMS fabric
g) Solid state diffusion and phase transformations
h) Geological and geophysical applications of fabric studies

Suggested Readings

1. Poirier J.-P. (1985) Creep of Crystals. Cambridge University Press.
2. Poirier J.-P. (2000) Introduction to the Physics of Earth's Interior. Cambridge University Press.
3. Nicolas A. and Poirier J.-P. (1971) Crystalline Plasticity and Solid State Flow in Metamorphic Rocks. John Willey & Sons.
4. Karato S.-I. (2008) Deformation of Earth Materials. Cambridge University Press.
5. Philips R. (2004) Crystals, Defects and Microstructures. Cambridge University Press.
6. Blenkinsop T. (2000) Deformation Microstructures and Mechanisms in Minerals and Rocks. Kluwer Academic Publishers.
7. Passchier, Cees W., and Rudolph AJ Trouw. Microtectonics. Springer Science & Business Media, 2005.
8. Wenk H.-R. (1985) Preferred Orientation in Deformed Metals and Rocks: An Introduction to Modern Texture Analysis. Academic Press.
9. Hobbs, B. E., Means, W. D. and Williams, P. F., 1976, An outline of Structural Geology, John Wiley and Sons, New York.

4. FUNDAMENTALS OF OCEANOGRAPHY

Programme Highlights/Objectives: It is an elective course in the Master's degree program in Geology. This is designed specifically for the students who seek to enrich their knowledge of physical and chemical aspects of oceanography and are ready to learn the application of geochemistry principles learned in the core course in marine science. The major objectives of this course are 1) to give an overview of the science of physical and chemical oceanography; 2) to demonstrate the practical application of the theoretical knowledge of geochemistry learned in the core module in various domains of marine science, and 3) to stimulate students' interest and curiosity in the varied sciences used in the study of the oceans.

Learning outcome: Upon successful completion of this course the students should be able

(i) to extend the geological and geochemical knowledge learned in previous courses to the marine realm; (ii) to interpret atmospheric and oceanic circulation systems as well as analyze their interconnections and driving forces on major Earth processes; (iii) to evaluate the relationship between climate change and ocean chemistry;

Syllabi:

Physical Properties of Water

Chemistry of Seawater

Air-Sea Interaction

Ocean Structure and Circulation

Sea floor and its sediments

Basics of elemental and isotopic proxies for paleo oceanographic reconstruction

Oceans in a warmer world

Suggested readings:

1. Hillaire-Marcel, C. and Vernal, A. D., 2007, Proxies in Late Cenozoic Paleoceanography, in Developments in Marine Geology, Elsevier.
2. Garrison, T., Ellis, R., 2016. Essentials of Oceanography by Tom Garrison, Cengage Learning.
3. Broecker, W. S., Peng, T. H., 1982. Tracers in the Sea, Lamont-Doherty Geological Observatory of Columbia University, Palisades, NY.

GEOL0892 **FIELD WORK** **Full Marks: 50**

Field Work Evaluation

Geological Account of Investigation of 15 days duration. Evaluation will be done on the basis of field-performance, field-report and a viva-voce examination.

THIRD SEMESTER

GEOL0901 REMOTE SENSING AND GIS Full Marks: (35+15=50)

Programme Highlights/ objective:

The course is aiming to cater the knowledge of studying satellite imagery and its interpretation in terms of geologic features on ground. The course enables the learners to bring about the information from satellite imagery by studying them both visually and digitally using image processing softwares. The course will also enrich the learners about the integration of remote sensing, GIS, GPS and GNSS in a single platform.

Learning Outcome:

The learners will be able to apply the understanding and knowledge of different aspects and information obtained from satellite imagery in the various fields of Earth Sciences. The course will enable the learners to apply the integrated knowledge of remote sensing, GIS, GPS and GNSS in different issues related to various branches of Earth Sciences.

Theory:

1. Fundamentals of remote sensing, Electromagnetic Radiation (EMR), Satellite, sensors and scanners, data formats; Remote sensing techniques: Optical, thermal and hyperspectral remote sensing.
2. Remote sensing application in lithological mapping, structural mapping, mineral exploration, groundwater exploration.
3. Digital Image Processing- rectification and restoration, image enhancement, image classification; Hyperspectral remote sensing - Basic concept, spectroscopy, use of spectroradiometer, spectral signature library, hyperspectral sensors and imagery.
4. Application of hyperspectral remote sensing in geological studies.
5. Active remote sensing: Synthetic Aperture Radar (SAR) and Side Looking Airborne Radar (SLAR) – principle and application in geological studies.
6. GIS: Spatial and non-spatial data analysis; applications in prospecting natural resources, risk assessment of natural hazards.
7. GNSS and GPS: Recent development; Applications in earth system sciences.

Practical:

1. Exercise on lithological, structural, mineral, groundwater potential zone mapping using multispectral imagery
2. Exercise in image classification and accuracy analysis.
3. Exercises on hyperspectral images and their interpretation
4. Analysis of SAR and SLAR data in geological studies
5. Introduction to GIS, GPS and GNSS softwares and their uses in geological studies.

Suggested Readings:

1. Prost, G.L. (2019) Remote Sensing for Geoscientists: Image Analysis and Integration. CRC Press.
2. Lillesand, T., Kiefer, R.W. and Chipman, J. (2015) Remote Sensing and Image Interpretation. Wiley.
3. Gupta, R.P. (2003) Remote Sensing Geology. Springer.
4. Richards, J.A., Jia, X. (2006) Remote Sensing Digital Image Analysis. Springer.
5. Eismann, M.T. (2012) Hyperspectral Remote Sensing. Spie Press.
6. Pu, R. (2017) Hyperspectral Remote Sensing: Fundamentals and Practices -. CRC Press.

GEOL0902 GEOPHYSICS Full Marks: (35+15=50)

Programme Highlights/ objective:

The programme is aiming to impart the knowledge on Geophysics, its basic principles, instrumental techniques, acquisition of data, data analysis and its interpretation in terms of geological materials present subsurface. The course has the objective to cover both Solid Earth Geophysics and Exploration Geophysics. The objective is also to select suitable combinations of geophysical methods which will enable the learners to resolve the issues in different allied subjects under Earth Sciences.

Learning outcome

Learners will be well versed with the advancement of geophysical methods in recent times. They will be able to exercise the various techniques of geophysics while addressing certain issues related to Earth Sciences. They can choose the proper combination of methods to solve specific problems in Geology. This will enable the learners to deal with both Solid Earth Geophysics and Exploration Geophysics after completion of the proposed course.

Theory:

1. Gravity Method: Gravity and its variation over the surface of the Earth. Principle of Gravimeters; Gravity field surveys. Interpretation of gravity anomaly curve in groundwater prospecting and mineral exploration, Gravity maps and their interpretation.

2. Magnetic Method: - Geomagnetic field, Principle of Magnetometers. Magnetic field survey, preparation of magnetic anomaly maps and their interpretation. Aeromagnetic survey. Earth's Magnetic Field: Internal and external fields, Measurements of horizontal, vertical, declination, inclination and total field, A brief introduction of the various theories of the main field and its secular variation, Rock magnetism and palaeomagnetism, Palaeopole determination, Application of palaeomagnetism in plate tectonics, Application of magnetic method in groundwater prospecting and mineral exploration.

3. Electrical and Electromagnetic Methods: - Electrical properties of rocks. Resistivity method, Induced Polarisation Method and Self potential method. Field procedure, interpretation of electrical profile and sounding curves. typical sounding curves, pseudo-sections; Electromagnetic field techniques, methods and interpretation. Principles and practices of Ground Penetrating Radar (GPR). Application of electrical and electromagnetic methods in groundwater prospecting, mineral exploration and engineering geology problems.

4. Seismic Method- Refraction and Reflection seismic surveys. Concept of seismic channel and multi-channel recording of seismic data. Seismic data acquisition and interpretation, Application of seismic method in petroleum and mineral exploration.

5. Petrophysics and well logging: - Principle of electrical logging and its application in petroleum, groundwater and mineral exploration. Open hole, cased hole and production logging; Electrical logs - lateral, latero, induction, temperature, S.P; porosity logs; sonic, density, neutron; natural gamma; Determination of formation factor, porosity, permeability, density, water saturation, lithology; Logging while drilling.

6. Seismology Elastic theory: Elements of earthquake seismology; seismic sources: faulting source, Focal mechanism and fault plane solutions; seismic gaps; seismotectonic and structure

of the earth; Himalayan and stable continental region earthquakes, reservoir induced seismicity; seismic hazards; earthquake prediction, travel time residuals, velocity anomalies, seismic tomography.

Practical:

1. Interpretation of gravity anomaly curve in terms of depth and shape of the object.
2. Determination of palaeopoles using palaeomagnetic data.
3. Interpretation of magnetic anomaly data.
4. Experiments with resistivity meter.
5. Plotting of VES curve & ERT data and its interpretation.
6. Interpretation of S.P. anomalies & I.P. data.
7. Interpretation of seismic velocity of the layer and depth of the body using seismic refraction data and Interpretation of seismic profile data.
8. Well log interpretation and correlation
9. Handing of different Geophysical tools and software's
10. Determination of the epicentral distance of an earthquake and interpretation of Travel -Time curves.

Suggested Readings:

1. Lowrie, W. (2007) Fundamental of geophysics (second edition). Cambridge University Press.
2. Robinson, E.S. and Coruh, C. (1988) Basic Exploration Geophysics. Wiley.
3. Telford, W.M., Geldart, L.P., Sheriff, R.E. (1990) Applied Geophysics. Cambridge University Press.
4. Musset, A.E. and Khan, M.A. (2000) Looking into the Earth, Cambridge University Press.
5. Dobrin, M.B. and Saviet, C.H. (1988) Introduction to Geophysical Prospecting. McGraw-Hill Education.
6. Keary, P., Brooks, M. and Hill, I. (2002) Introduction to Geophysical Exploration. Wiley-Blackwell.
7. Rider, M. and Kennedy, M. (2011) The geological Interpretation of Well Logs. Rider-French Consulting Limited.

GEOL0903 ORE GEOLOGY Full Marks: (35+15=50)

Programme Highlights/ objective: The objective of this course is to provide the students with advanced knowledge in ore geology based on critical study of various aspects of ore geology which includes (a) principles of mineral economics, (b) identification of common ore minerals at various scales of study, (c) the genetic controls exerted by physical and chemical processes on ore formation in various geologic settings, (d) relation between metallogeny and crustal evolution with geological time, and (e) case studies on important mineral deposits of India.

Learning Outcome:

On completion of this course, students should have developed skills in the following areas:

1. Identification of common ore minerals in hand samples and under microscope.
2. Develop understanding on basic concepts of mineral economics.
3. Knowledge about a wide range of ore deposits in terms of their mode of occurrences, structures, mineralogy, host rock associations and genesis.
4. Relation between metallogeny and crustal evolution with geological time.
4. Detailed knowledge about important mineral deposits of India.

Theory:

Unit I: Introduction to ore geology

Basic terminologies of economic geology: ore, ore bodies, industrial minerals, gangue, proto ore and grade; concepts of mineral resources and mineral reserves; distribution, morphology and disposition of ore bodies; classification of ore deposits; textures and structures of ore and gangue minerals; fluid inclusions; concepts of paragenetic sequence and zoning.

Unit II: Principles of mineral economics

Relative importance of ore and industrial minerals through time; factors related to the determination of commodity prices and marketing mechanisms; Important factors in the economic recovery of minerals; important factors in the evaluation of a potential ore body.

Unit III: Magmatic Ore deposits

Magmas and metallogeny, major theories of magmatic ore genesis; general characteristics and genesis of magmatic ore deposits - chromite deposits, anorthosite hosted Fe-Ti oxide deposits, base-metal Ni-Cu sulfide deposits, PGE sulfide deposits, diamond deposits associated with kimberlites and lamproites, the carbonatite-alkaline igneous ore environment.

Unit IV: Hydrothermal and Magmatic-hydrothermal Ore deposits

Major theories of hydrothermal and magmatic-hydrothermal ore genesis; general characteristics and genesis of hydrothermal and magmatic-hydrothermal ore deposits- porphyry deposits, epithermal deposits, volcanic-hosted massive sulfide deposits, orogenic gold deposits, carlin-type gold deposits, iron oxide-copper-gold (IOCG) deposits, kiruna type iron oxide apatite deposits, Mississippi Valley-type (MVT) Pb-Zn deposits, SEDEX Pb-Zn-Ag deposits, Kuperschiefer or red-bed copper deposits and uranium deposits in sedimentary basins.

Unit V: Ore deposits Formed by Sedimentary or Surficial Processes:
General characteristics and genesis of ore deposits formed by sedimentary processes: banded iron formations (BIF), sedimentary-rock-hosted Mn and P deposits, coastal heavy mineral sand deposits, and fluvial placer (and paleoplacer) deposits. Ore deposits formed by surficial and supergene processes - lateritic bauxite and Ni-Co deposits; supergene gold and copper ores.

Unit VI: Crustal evolution and metallogeny:
Relationship between crustal evolution, plate tectonics and metallogeny; concepts of metallogenic epochs and provinces

Unit VII: Ore geology in Indian context:
Metallogenic provinces and epoch in Indian subcontinent; distribution of various types of ore deposits and industrial minerals in India.

Practical:

1. Identification of metallic and non-metallic (industrial) ores in hand specimens.
2. Microscopic identification of major oxide ore minerals such as- magnetite, hematite, ilmenite, wolframite, goethite, pyrolusite, psilomelane, cryptomelane, braunite, bixbyite, jacobsite, hollandite, chromite and bauxite.
3. Microscopic identification of major sulphide ore minerals such as- chalcopyrite, pyrite, galena, sphalerite, chalcocite, covellite, bornite, pyrrhotite, stibnite and molybdenite.
4. Microscopic study of textural relationships and mineral paragenesis in the assemblage of gangue and ore minerals.

Suggested Readings:

1. Evans, A.M. (1993) Ore Geology and Industrial minerals. Wiley
2. Laurence Robb. (2005) Introduction to ore forming processes. Wiley.
3. Ridley, J. (2013) Ore Deposit Geology. Cambridge University Press, UK. P398.
4. Sarkar, S.C. and Gupta, A. (2014) Crustal Evolution and Metallogeny in India. Cambridge Publications.
5. Deb, M. and Sarkar, S.C. (2017) Minerals and Allied Natural Resources and their Sustainable Development Springer.
6. Mukherjee, A. (1999): Ore Genesis – A Holistic Approach. Allied Publishers Ltd., New Delhi, India. P657.

GEOL0991 **ELECTIVE 2A+ ELECTIVE 2B Full** Marks**: 25+25=50**

ELECTIVE 2A

1. ORGANIC BIOGEOCHEMISTRY

Programme Highlights/ objective:

Organic biogeochemistry is the study of impacts and processes that organisms (both living and dead) have on the earth. Natural organic matter is a key component in the interplay between the biosphere, hydrosphere, and geosphere. Knowledge of the geochemical cycling of organic matter in terrestrial and aquatic (marine and freshwater) systems is essential for understanding the biogeochemistry of a variety of elements and the global carbon cycle, and thus climate and environmental changes. The course will introduce organic biogeochemical processes in aquatic and sedimentary environments and its application in paleoclimate and palaeoecological reconstructions.

Learning Outcome:

By the end of the course, the students will understand:
1. Basic concept of organic biogeochemistry.
2. Sampling and analytical techniques.
3. Application of stable isotopes of organic carbon and nitrogen.
4. Concept of lipid biomarkers and biomarker applications.
Knowledge and skills, which the student will gain from the organic biogeochemistry class, will add a broad range of approaches to their industrial and/or academic career.

Topics:

1. Tools of organic biogeochemistry.
2. Sample collection, handling, storage and preparation for organic biogeochemical analyses.
3. Analytical techniques.
4. Application of stable isotopes of organic carbon and nitrogen in organic matter source identification.
5. Concept of lipid biomarkers, and biomarker application in paleoclimate and palaeoecological reconstructions.

Suggested Readings:

1. Killops S.D., Killops V.J. 2005. An introduction to organic geochemistry. 2nd ed. Blackwell Publishing, Malaysia.

2. APPLIED HYDROLOGY

Programme Highlights/ objective:

The influence of hydrological studies on understanding earth processes and human societies goes beyond the conventional groundwater science. In this context, the scope of this paper is to explore the multidisciplinary nature of hydrology through studying the occurrence and behaviour of different sources of water in nature. Further, it would also deal with the applied nature of water sciences and how they could be linked with different disciplines of earth sciences and social studies. The objective of this paper is to familiarize students with various branches of water sciences and inculcate the practical knowledge of handling and analysing hydrological data.

Learning Outcome:

We expect students who opt this paper to have a basic understanding of the following:

- To understand the fundamental concepts of hydrology.
- To introduce basic features of different sources of freshwater including river, lakes and glaciers.
- To examine the relation between hydrosphere and climate and role of physical factors on occurrence and behaviour of various freshwater sources.
- To explore the fundamental concepts of groundwater hydraulics and their application
- To familiarize with some common methods for hydrological data analysis including modelling techniques.
- To familiarize with the application of hydrological data for multidisciplinary studies

Topics:

1. Basics of Hydrology Significance of Hydrology as a multidisciplinary subject; Detailed study of phases of hydrologic cycle; types and measurement of precipitation, evapo-transpiration, runoff and infiltration.
2. Water and Climate Role of climatic conditions in global distribution of water resources; Wind systems and precipitation-Mechanism of Monsoon and tropical cyclones; Concepts of humidity and aridity significance and measurements
3. River, Lakes and Glaciers Introduction to major river systems across the globe; Development, morphology and catchment processes in lakes; Concepts of surface water-groundwater interaction and base-flow separation; Introduction to Glacial hydrology.
4. Understanding Groundwater Geomorphic and geological controls on groundwater; Concept of hydro-stratigraphy and its significance in groundwater assessment and management; Groundwater Pumping in terrestrial and coastal environments.
5. Analysing Hydrological Data Concept of Water budgeting and water balance calculations, surface water and groundwater monitoring; Processing of groundwater flow data and recharge estimation; Flood frequency analysis and drought assessment studies; Groundwater Modelling-Introduction to conceptual and analytical models; Introduction to snowmelt modelling
6. Application of Hydrological Data Case studies on using hydrological data for environmental impact assessment; civil engineering structures; agricultural and industrial activities; mining and resource exploration; Water quality and Human health.

Tutorial:

• Analysing data from Aquifer performance tests and Step drawdown test.
• Determination of permeability, conductivity and yield in field and laboratory set ups.

Suggested Readings:

• Karanth, K. R., (1987) Groundwater Assessment, Development and Management, Tata McGraw Hill
• Davis, S. N. and De Weist, R. J. M. (1966). Hydrogeology. John Wiley and Sons Inc., New York.
• Raghunath H, M. (2007). Groundwater. 3rd Ed. New Age International Publishers.
• Lal, D.S., (2010). Climatology. Sharda Pustak Bhawan, Allahabad
• Evans, W. L. (1966) Lake Hydrology: An Introduction to Lake Mass Balance. Johns Hopkins University Press.
• Singh, P. (2001). Snow and glacier hydrology (Vol. 37). Springer Science & Business Media.

3. APPLIED MICROPALAEONTOLOGY

Programme Highlights/ objective:
The course aims to provide the students with knowledge on modern techniques, methods used for Micropalaeontological study. The course is designed to cover the applied aspect of Micropalaeontology.

Learning Outcome:
The students will have an idea about the different Ocean drilling program. The students will develop the skills on modern techniques, methods employed in Micropalaeontology. The students will have an advanced knowledge on applications of microfossils.

Syllabus:

1. Scope of Applied Micropalaeontology

2. Modern field and laboratory techniques employed in Micropalaeontology (collection, preparation, processing and slide study techniques)

3. Data analytical methods employed in Micropalaeontology

4. General overview on Deep Sea Drilling Project (DSDP), Ocean Drilling Program (ODP), Integrated Ocean Drilling Program (IODP), National Gas Hydrate Program (NGHP) and their accomplishments in Micropalaeontology

5. Oxygen and Carbon isotope studies of microfossils and their applications in paleoceanographic and paleoclimatic interpretation

6. Importance of microfossils in environmental monitoring.

Suggested Readings:

- Armstrong, H.A., and Brasier, M.D. (2005) Microfossils. Blackwell Publishing.
- Kathal, P.K., Nigam, R., and Talib, A. (2007) Micropaleontology and its Applications. Scientific Publishers.
- Kathal, P.K. (2012) Applied Geological Micropalaeontology. Scientific Publishers.
- Saraswati, P.K., and Srinivasan, M.S. (2016) Micropaleontology Principles and Applications. Springer International Publishing.

ELECTIVE 2B

1. ADVANCED REMOTE SENSING

Programme Highlights/ objective:

The course is designed to introduce the students to the frameworks of advanced techniques of remote sensing in earth sciences. Both Thermal and Microwave remote sensing finds their application in various professional and academic exercises in earth sciences. The targets vary from our earth to all planets in our universe.

Learning Outcome:

The essentials of the practice of Thermal and Microwave remote sensing helps the students to learn how to investigate areas remotely, which are otherwise not approachable by optical remote sensing techniques. Therefore, the course promotes the applications of further studies and practices in this field to our graduates in their pursuit towards their careers as Remote sensing scientists.

Syllabus:

1. Concept of Thermal remote sensing, Thermal data processing,
2. RADAR: its environmental considerations and applications including InSAR
3. Concept of Microwave remote Sensing and data processing
4. Applications of Thermal and Microwave remote sensing in Earth sciences

Suggested Readings:

1. George, J. (2005) Fundamentals of Remote Sensing; University Press (India) Pvt. Ltd., Hyderabad, India,.
2. Woodhouse, I.H. (2017) Introduction to microwave remote sensing. CRC press..
3. Sabins, F.F. (1986) Remote sensing: Principles and interpretation. W.H.Freeman& Co. New York..
4. Kuenzer, C. and Stefan, D. (2013) Thermal infrared remote sensing: sensors, methods, applications. Vol. 17. Springer Science & Business Media

2. ORE DEPOSITS IN LAYERED IGNEOUS COMPLEX

Programme Highlights/ objective:

Post Graduate students are acquainted with the general characteristics of magmatic ore deposits. This elective course is specifically designed for those students who are interested to gather more detailed knowledge about Bushveld type layered magmatic deposit and ready to learn the systematics of research in layered magmatic deposits. The main purpose of this course is to give the students specific idea about the general characteristics of different bushveld type layered deposits in terms of their mode of occurrences, host rock lithologies, ore mineralogy, geochemistry across the layers and implications for their genesis.

Learning Outcome:

On completion of this course, students should have developed the following skills:
1. Detailed knowledge on Bushveld type layered magmatic deposits in terms of their mode of occurrences, host rock lithology, ore mineralogy, petrography and geochemistry across the layers.
2. Techniques of sampling and petrographic study in layered magmatic deposits.
3. Applications of major and trace element geochemistry and their interpretation to characterize the Bushveld type layered magmatic deposits.
4. Specific knowledge about the ore formation procedures in Bushveld type layered magmatic deposits and future scopes of study.

Syllabus:

1. General characteristics of bushveld type layered deposits, distribution in space and time with examples.

2. Variation in host rock types, their mode of occurrences, petrography and mineralogy.

3. Types of ores, their mode of occurrences, petrographic and mineralogy.

4. Trace element geochemistry of the ores and host rocks: implications for their genesis

5. Hypothesis on the source enrichment procedures indicated by such deposits and emplacement mechanisms; and future scopes of study.

Suggested Readings:

1. Von Gruenewaldt, G., Sharpe, M.R. and Hatton, C.J., 1985. The Bushveld Complex; introduction and review. Economic Geology, 80(4), pp.803-812.
2. Thy, P., Lesher, C.E. and Tegner, C., 2009. The Skaergaard liquid line of descent revisited. Contributions to Mineralogy and Petrology, 157(6), p.735.
3. VanTongeren, J.A. and Mathez, E.A., 2012. Large-scale liquid immiscibility at the top of the Bushveld Complex, South Africa. Geology, 40(6), pp.491-494.
4. Holness, M.B., Stripp, G., Humphreys, M.C.S., Veksler, I.V., Nielsen, T.F. and Tegner, C., 2011. Silicate liquid immiscibility within the crystal mush: late-stage magmatic microstructures in the Skaergaard intrusion, East Greenland. Journal of Petrology, 52(1), pp.175-222.
5. Lee, C.A., 1996. A review of mineralization in the Bushveld Complex and some other layered intrusions. Developments in Petrology, 15, pp.103-145.

3. BASIN ANALYSIS

Programme Highlights/ objective:

Postgraduate students of Applied Geology are acquainted with the major mechanisms involved in formation, subsidence, and filling of sedimentary basins. The PG course in Basin analysis aims to provide the students with advanced knowledge in stratigraphy, sedimentology, sequence stratigraphy and tectonics and their interrelationship.

Learning Outcome:

Upon successful completion of the course the students will develop skills to

a. apply the genetic mechanisms, history, and characteristic sedimentary fill of the main types of sedimentary basin,
b. apply first principles to create the key elements of a depositional sedimentary sequence; decipher the origin and significance of key bounding surfaces; discover the predictive power of the sequence stratigraphic model.
c. derive diffusion-based basin filling models that govern stratigraphic architecture of most basins,
d. acquire detailed insight into tectonic controls on sedimentary basin formation with particular reference to Indian stratigraphic successions

Syllabus:

1. Purpose and scope of basin analysis. Basin mapping methods: structure and isopach contouring, lithofacies maps, paleocurrent analysis, stratigraphic architecture analysis.
2. Tectonics and sedimentation: Sedimentary basins in different tectonic settings. Examples from India (Epeiric platforms, rift valleys, passive margins, foreland basins, active margins).
3. Principles and Methods of provenance analysis.
4. Application of well log analysis in sequence stratigraphy, sequence stratigraphy of carbonate platforms. Sedimentary ore deposits and hydrocarbon resources in relation to sequence stratigraphy
5. Subsidence and thermal history of sedimentary basins.

Suggested Readings:

1. Catuneanu, O., 2006. Principles of Sequence Stratigraphy. Elsevier, Amsterdam, 375 pp.
2. Leeder, M.R., 1982. Sedimentology: Process and Product. George Alien &Unwin, London, 344p.
3. Einsele, G., 2000. Sedimentary Basins, Springer.
4. Miall, A.D., 1999. Principles of Sedimentary Basin Analysis 3rd ed Springer Verlag, New York.
5. Nichols, G., 1999. Sedimentology and Stratigraphy, Blackwell publishing.
6. Reading, H. G., 1996. Sedimentary Environments: Processes, Facies and Stratigraphy, Blackwell Publishers
7. Sam Boggs, 1995. Principles of Sedimentology and Stratigraphy, Prentice Hall, New Jersey.
8. Tucker, M.E., 2006. Sedimentary Petrology. Blackwell Publishing.
9. Tucker, M.E. and Wright, V.P., 1990. Carbonate Sedimentology, Blackwell.
10. Walker, R.G., Facies model 1976. Geoscience Canada.
11. Posamentier, H.W., and Walker, R.G., 2006. Facies Models revisited, SEPM

4. APPLIED GEOPHYSICS

Programme Highlights/ objective:

The Course has the aim to cover the possible areas of Earth Sciences where geophysics may be successfully applied to solve any problems. The objective is to make the learners familiar with the prospective application of geophysics in different branches of Earth Sciences. Such programme will enable the learners to use geophysical methods in their respective interested areas of Geological Sciences.

Learning Outcome:

1. Students are able to know the concept and scope of work in the exploration and mapping of groundwater, important geological conditions in the formation of aquifer systems, physical properties and groundwater chemistry to determine its quality, groundwater exploration technique basics, water mapping and modelling methods soil
2. Students can understand the basics of exploration activities (concepts, models, principles, planning and stages of exploration of mineral deposits), capable of performing integrated analysis to the stage of reserve estimation. The concept and model of mineral deposits exploration. The concept includes several minerals of mineral deposits. The exploration model includes commonly used geological and geophysical models, for example: geological, geo-magnetic, geo-magnet, induced polarized, drilling, gravity (seismic) surveys.
3. Students are capable of analyzing geophysical statements in archaeology, paleo disaster, sedimentation and stratigraphy, radiocarbon dating, applying and utilizing geophysical methods to describe subsurface conditions in archaeological fields
4. Students are able to design and integrate various geophysical exploration acquisitions in accordance with the object of research. Students are able to interpret the geomorphology of the seafloor, anomalies or underwater objects from geophysical data
5. Students are able to master the concepts, principles and techniques of system design, process or application component of geophysical method for environmental problem and implement it procedurally starting from data retrieval, processing, analyzing the interpreters result with subsurface geology and modelling to solve the physical environment problems as well as to mitigate them deeply and be responsible for their own work and group work through scientific reports and presentations
6. Students are able to design and integrate geophysical exploration acquisitions related to mineral targets. Students are able to interpret field characteristics that affect sampling and interpret subsurface mineral conditions.
7. Students understand the basic property reservoir associated with the event of geology and the existence of economic fluid. Students are able to perform stratigraphic seismic analysis in interpreting seismic data Students are able to integrate all reservoir data for modelling.

Syllabus:

1. Exploration Geophysics: Application of geophysical methods for mineral exploration.
2. Engineering Geophysics- Concept of RMR, RQD, Q system, foundation rock, application of different and various geophysical methods for engineering purposes to detect the subsurface geological situation and to select the suitable foundation.

3. Archeological Geophysics: Application of geophysical methods in archaeological sites, interpretation of Geophysical Data in Archaeology.
4. Marine Geophysics: Application of geophysical methods to map the potential of marine resources by analysing the characteristics of marine geophysical data, ocean floor basin anomalies, sea gravity anomalies, ocean geophysical data interpretation.
5. Groundwater Geophysics: Application of geophysical methods in groundwater exploration and management; Selection of artificial recharge site.
6. Environmental Geophysics: Environmental geophysical techniques related to monitoring and mitigation of environmental pollution; Landfill characterization, selection of landfill site using geophysical tools, Application of geophysical techniques related to monitoring and mitigation of natural hazards.
7. Reservoir Geophysics: Reservoir's characteristics, Reservoir's rock, Reservoir properties, studying reservoir characterization methods using geophysical data.
8. Glacial geophysics- Application of geophysical tools in glaciology in various aspects.

Suggested Readings:

1. Lowrie, W. (2007) Fundamental of geophysics (second edition). Cambridge University Press..
2. Telford, W.M., Geldart, L.P., Sheriff, R.E. (1990) Applied Geophysics. Cambridge University Press.
3. Oswin, J. (2009) A Field Guide to Geophysics in Archaeology. Springer..
4. Vereecken, H., Binley, A., Cassiani, G., Revil, A., Titov, K. (2006) Applied Hydrogeophysics. Springer.
5. Foulger, G.R. and Pierce, C. (2007) Geophysical Methods in Geology. Teaching Handbook, University of Durham, UK
6. Idziak, A.F. and Dubiel, R. (2011) Geophysics in Mining and Environmental Protection. Springer.
7. Reynolds, J.M. (2011) An Introduction to Applied and Environmental Geophysics. Wiley Blackwell.

GEOL0992 INDUSTRIAL TRAINING AND OPEN SEMINAR Full Marks:**50**

Visit to an industry of geologic interest for two/ three weeks duration or Summer Project of similar duration. Evaluation will be done upon Submission of a certificate from the concerned industry/project supervisor.

FOURTH SEMESTER

GEOL1001COAL, NUCLEAR FUEL AND ENGINEERING GEOLOGY

Full Marks: (35+15=50)

Programme Highlights/ objective: The course introduces peat formation from plant organic matter and explains the transformation of the peat into lignite and higher ranks of coal through coalification. Coal petrography and coal geochemistry are also taught. Age and occurrences of coal in India are covered. The students are introduced to the type and occurrences of radioactive minerals in India.

This course is basically about applying the concepts of geological sciences to engineering projects. Thus, the scope of this course extends to providing students with fundamental ideas of geological processes governing mass movement and slope stability. Further, it also introduces the concept of geotechnical studies that are essential for planning, design and implementation of major engineering structures like dams, tunnels, bridges.

Learning Outcome: The course aims to equip the students with advanced knowledge in coal geology and nuclear fuel for academic and industrial careers.
We expect students to learn about the following in the course of this paper:

1. To understand the fundamentals of engineering geology and geotechnical studies.
2. To explore the concept of soil investigation and the nature of different natural materials for building purposes.
3. To understand the natural process such as mass movement and its impact of slope stability
4. To examine the impact of geological processes on functioning and stability of civil structures such as Dams, Bridges and Tunnels.

Syllabus:

Theory:

Coal

Depositional environments of peat swamps.
Coalification and coal classification.
Minerals and elements in coal as indicators of peat depositional environments.
Maceral composition.
Coal facies concept.
Coal and the environment.
Geological and geographical distribution of coal and lignite deposits in India.

Nuclear Fuel

1. Important minerals.
2. Types of U and Th deposits.
3. U and Th deposits in India.

Engineering Geology

1. Role of Engineering geology in civil construction and mining industry. Engineering properties of rocks and their measurements. Methods of soil investigation.
2. Slope stability and mass movements, classifications, detailed study of landslides, factors influencing different mass movements in nature and their remedial measures.
3. Properties of Building materials and road metals and their occurrences in India.
4. Dams and Reservoirs, different types, criteria for selecting sites for their construction, remedial measures for failure of dams and reservoirs.
5. Tunnels and Bridges, different types, stability of tunnels, criteria for selecting sites for tunnel construction, failure of tunnels and their remedial measures.

Practical:

Coal

1. Proximate analysis.
2. Identification of coal macerals.
3. Paleoenvironmental reconstruction using coal macerals and petrographic indices.

Engineering Geology

1. Problems on rock mechanics and slope stability.
2. Problems related to dam site selection and failure assessment (calculating outflow hydrographs and breach formation factor).

Suggested Readings:

1. Thomas L., 2013. Coal geology. Second Edition. John Wiley & Sons, 2013.
2. Sen S., Naskar S., Das S., 2016. Discussion on the concepts in paleoenvironmental reconstruction from coal macerals and petrographic indices. Marine and Petroleum Geology 73, 371-391.
3. Dai S., Bechtel A., Eble C.F., Flores R. M., French D., Graham I.T., Hood, M.M., Hower, J.C., Korasidis, V.A., Moore, T.A. and Puettmann, W., 2020. Recognition of peat depositional environments in coal: A review. International Journal of Coal Geology 219, 103383.
4. Reddy D. R., 2017. Introduction to Energy Resources - Part I: Atomic Minerals and Part II: Fossil Fuels (Coal, Oil and Natural Gas).

GEOL1002 PETROLEUM GEOLOGY Full Marks: (35+15=50)

Programme Highlights/objective:
Petroleum geology is essentially an applied geological field of study. The course will address the source of organic matter to petroleum source rocks, kerogen type, the transformation of kerogen into petroleum, the processes of oil and gas generation, migration and trapping, and applications of organic geochemistry to reservoir assessment and production. The processes and the conditions that supported certain periods in the earth's history for petroleum source rock formation will also be discussed. Unconventional hydrocarbon resources will be covered.

Learning Outcome:
The course will provide a concise overview of the most common sedimentary environments of petroleum occurrences. After completion of the course, students will have an understanding of
(a) the elements and processes necessary for the formation of a hydrocarbon accumulation,
(b) basic concepts of generation, migration, accumulation of petroleum and petroleum composition, and
(c) the role of petroleum geochemistry in petroleum exploration.

The course will equip students with advanced knowledge and understanding appropriate for a career in the upstream petroleum industry.

Syllabus:
Theory
1. Origin of petroleum
2. Post depositional processes affecting the formation of petroleum.
3. Kerogen formation, composition and classification.
4. Basic components of petroleum system: Trap, reservoir and charge including source rock, generation, migration, seal and preservation of hydrocarbon; migration mechanisms, expulsion rate and expulsion efficiency.
5. Petrophysical study of reservoir rocks.
5. Relationship between eustatic sea level and major depositional periods of source rocks.
6. Implication of plate tectonics in petroleum occurrences.
7. Sequence stratigraphy and its implications in petroleum exploration.
8. Unconventional hydrocarbon resources: shale gas, biogenic natural gas and gas hydrate.
9. Petroliferous basins of India.
10. Composition of hydrocarbon and analytical techniques.
11. Basic of well logging.

Practical
Source rock analysis based on kerogen composition.
Sequence stratigraphic applications to identify the petroleum plays.

Suggested Readings:
1. Hunt J.M., 1996. Petroleum Geochemistry and geology, 2nd Edition. Freeman and Co. San Francisco.
2. Peters K.E., Moldowan J.M., 1993. The biomarker guide. Prentice Hall.
3. Tissot B.P., Welte D.H., 1984. Petroleum formation and occurrence. Springer-Verlag, New York.
4. Bjørlykke K., 2015. Petroleum Geoscience: From Sedimentary Environments to Rock Physics, Second Edition, Springer, Heidelberg, Germany.
5. Pohl W.L., 2011. Economic geology: principles and practice: metals, minerals, coal and hydrocarbon—introduction to formation and sustainable exploitation of mineral deposits. Wiley-Blackwell, Chichester.
6. Aminzadeh F., Dasgupta S.N., 2013. Fundamentals of Petroleum Geology. In: Developments in Petroleum Science 60, 15-36.

GEOL1003 MINERAL EXPLORATION, MINING AND ORE BODY MODELING

Full Marks: (35+15=50)

Programme Highlights/ objective:
The objective of this course is to provide the students with advanced knowledge in mineral exploration, mining and ore body modelling based on critical study of (a) different type of geophysical exploration method, (b) different type of geochemical exploration method, (c) different type of sampling method, (d) advanced mining and drilling process and (e) reserve estimation of mineral deposit.

Learning Outcome:
On completion of this course, students should have developed skills in the following areas:
1. Detailed knowledge on the ore deposits and the sample collecting technique.
2. Develop understanding on basic concepts of geochemical and geophysical exploration processes.
3. Knowledge about drilling and mining of ore deposits.
4. Able to estimate the ore reserve.
5. Detailed knowledge about exploration risks and management.

Syllabus:

Theory:

Unit I: Introduction
Classification of mineral deposits for prospecting. Mineral deposits and their possible host rocks, geological prospecting, Stages of exploration: RP, LAP, Pl, ML, Diamond drilling, bore hole survey, logging.

Unit II: Sampling
Pitting, Trenching, Channel, Chip, drill core, bulk/ Muck/ Grab/ Car /Stack sampling, sample reduction, accuracy in sampling, QC and QA analysis.

Unit III: Geochemical Prospecting
Pedogeochemical Prospecting, Lithogeochemical Prospecting, Hydrogeochemical Prospecting, Biogeochemical Prospecting, Geobotanical Prospecting, Atmogeochemical Prospecting.

Unit IV:Geophysical prospecting
Magnetic method, Gravimetric method, Geo-electrical method, Seismic method, Electromagnetic method, Radioactive method, Telluric and Magnetotelluric method.

Unit V:Reserves and reserve estimation of mineral deposit
Volume and tonnage, cut-off grade, ROM grade, Classification of ore reserves (Conventional, USGS, JORC and UNFC).

Unit VI:Exploration Risks and Management
Exploration Risks and Management and Parameters for success.

Unit VII: Ore beneficiation
General techniques of ore beneficiation, beneficiation of sulfide ores Pb-Zn and Cu and Iron ores.

Unit VIII:Mining and drilling

Mining terminologies- shaft sinking, drifting, cross-cutting, stoping, mine subsidence, mine support, top slicing, caving, bench mapping, underground mapping, preparation of plans & sections; Drilling methods- Percussion drills & Rotary drills (Jack Hammer, DTH). Mining methods- Alluvial mining, Open cast & Underground mining. Shrinkage, Cut and Fill (C & F), Sublevel stoping and Vertical Retreat Mining (VRM)); Mine hazards.

Practical:

1. Calculation of average grade, mean, variance, standard deviation, correlation coefficients of ores from bore hole sample data.
2. Ore reserve estimation and modelling: Graphical presentation of ore deposits and calculations of ore reserves and average grades.

Suggested Readings:

1. Clark, G.B. (1967). Elements of Mining. 3rd Ed. John Wiley and Sons.
2. Arogyaswami, R.P.N. (1996). Courses in Mining Geology. 4th Ed. Oxford-IBH.
3. Moon, C.J., Whateley, M.K.G. and Evans, A.M. (2006). Introduction to Mineral Exploration, Blackwell Publishing.
4. Haldar, S.K., 2013. Mineral Exploration – Principles and Applications. Elsevier Publication.

GEOL1091 **EVALUATION OF DISSERTATION** **Full Marks: 50**

GEOL1092 **SEMINAR-VIVA-VOCE ON DISSERTATION** **3Full Marks: 50**