# St. Xavier's College
# Mumbai

# Syllabus
# for I$^{st}$ Semester Courses in
# M.Sc. Geology
# (June 2017 onwards)

Courses:

- M.S.Geo.1.01 – Stratigraphy and Geology of India
- M.S.Geo.1.02 - Geochemistry
- M.S.Geo.1.03 – Structural Geology
- M.S.Geo.1.04 – Advanced Gemmology
- Practical Course:
- M.S.Geo.1.01. PR, M.S.Geo.1.02. PR, M.S.Geo.1.03. PR and M.S.Geo.1.04. PR. (Pertinent to the above mentioned theory courses)

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ST. XAVIER'S COLLEGE-AUTONOMOUS
MUMBAI-400 001

**M.Sc-I Geology** **Course: M.S.Geo.1.01**
**Title: Stratigraphy and geology of India**

**Learning Objective:** To understand the tectonics and geological formations in different basins through geological ages from studying the rock strata which will in turn, help in building the geological history of Indian subcontinent.

**Number of lectures: 60**
**Unit 1:** **(15 lectures)**
**Precambrian Stratigraphy**
Precambrian geochronology, Precambrian Stratigraphy of:
Dharwar Supergroup
Aravalli and Delhi fold belts
Singhbhum shear zone
Sausar Belt
Vindhyan Supergroup
Cuddapah Supergroup
Precambrian-Cambrian boundary

**Unit 2:** **(15 lectures)**
**Palaeozoic and Gondwana Stratigraphy**
Palaeozoic of Kashmir
Palaeozoic of Spiti
Gondwana Supergroup
Permian-Triassic Boundary

**Unit 3:** **(15 lectures)**
**Mesozoic Stratigraphy**
Triassic of Spiti
Jurassic of Kutch
Cretaceous of Trichinopalli
Deccan Volcanics
Cretaceous- Tertiary Boundary

**Unit 4:** **(15 lectures)**
**Cenozoic Stratigraphy**
Palaeogene Systems of India
Neogene Systems of India
Evolution of Himalaya
-Pleistocene-Holocene Boundary

**Practical Courses**
**Stratigraphy and geology of India**
Study of Geological Maps to establish the geological sequence of the area in the Chronological order

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**List of Recommended Reference Books**

1) K. S. Valdiya (2010), The Making of India-Geodynamic Evolution; Macmillan Publishers India Ltd.
2) M. Ramakrishnan and R. Vaidyanadhan (2008), Vol. I and II, Geology of India; Geological Society of India, Bangalore.
3) Roy, R. Lemon (1990), Principles of Stratigraphy; Merrill Publishing Company, Ohio
4) Harold L. Lewis (1987), Earth through Time; 3rd Edition. Saunders College Publishing, New York
5) D. N. Wadia (1984), Geology of India; 4th edition. Tata McGraw-Hill Publishing Co. Ltd., New Delhi.
6) M. S. Krishnan (1982), Geology of India and Burma; 6th Ed. CBS Publishers and Distributors (India).

**M.Sc-I Geology** **Course: M.S.Geo.1.02**
**Title: Geochemistry**

**Course Objectives:** To learn basic concepts, applications, and scope of geochemistry. Studying Importance of geochemistry in Precambrian stratigraphy, and current status of numerous chemical analysis techniques. Studying importance in Climate Change, petrological and Paleoceanographic problems.

**Number of lectures: 60**

**Unit 1:** **(15 lectures)**

**Introduction**

Basic principles of geochemistry.
Elements: Atomic Structure, Formation, Abundance, Distribution in Earth and Solar System.
Periodic Table with special reference to transitional and trace elements.
Geochemical Classification of Elements.
Trace element – Definition and Types.

**Thermodynamics**

Basic Concepts and terms, Fugacity and Activity.
Oxidation and Reduction reactions
Kinematics.

**Unit 2:** **(15 lectures)**

**Isotope Geochemistry**

Introduction to Techniques used in geochemical analysis(ICPMS, AMS, EPMA)
Stable Isotopes of Carbon and Oxygen and its application in Geological Studies.
Radioactive Isotopes: Radioactivity, Decay scheme.
Introduction to Isotopic Systems of Carbon-14, Rb/Sr, Sm/Nd, Lu/Hf, U-Th-Pb, K/Ar, $^{40}Ar/^{39}Ar$.
Petrogenetic implications of Sm-Nd, Rb-Sr.
Trace Element Geochemistry

**Unit 3:** **(15 lectures)**

**Application of Geochemistry**

Sedimentary Rocks (weathering, Diagenesis)
Igneous Rocks (Partial Melting and Fractional Crystallization)
Metamorphic Rocks( P-T-t Path)

**Unit 4:** **(15 lectures)**

**Ocean Geochemistry**

Ocean $CaCO_3$ Cycles
Geochronometry of Marine Deposits
Geochemical evidence of quaternary sea-level changes.
Elemental and isotopic proxies for past ocean temperature estimations
Tracers of past ocean circulation
Geochemical Indicators of Ice sheet dynamics during Glacial and Interglacial periods
Past Global Climate Change and tectonics indicated by marine microfossil Geochemical analysis.



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**Practical Course:**
**Geochemistry**
Mineral Calculations
Normalization and End Member Calculations
Feldspar Group
Pyroxene Group
Olivine Group
Amphibole Group
NORM Calculations
Geochemical analysis of Marine Core data and interpreting past Ocean Circulation patterns, Past Global Climate change, Regional Climate Change.

**List of Recommended Reference Books**

1. Geochemistry, 2nd edition, 1996, by Arthur Brownlow, Prenctice Hall.
2. Principles and Application of Geochemistry, 2nd edition, 1998, by Gunter Faure, Prentice Hall.
3. Principles of Geochemistry, 4th edition, 1985, by Brian Mason and Carleton B. Moore, Wiley Eastern Limited.
4. The Oceans and the Marine Geochemistry, First Edition,2006, by Henry Elderfield, Elsevier.

**M.Sc-I Geology** **Course: M.S.Geo.1.03**
**Title: Structural Geology**

**Learning Objectives:** To understand the concept of stress and strain and how rock behaves under different stress regimes. To learn the methods of structural analysis in complicated terrains and relationship between tectonics and crustal deformation. Detailed study of tectonites, rock fabric and its relation with deformation.

**Number of lectures: 60**
**Unit 1:** **(15 lectures)**
**Tectonites and microfabric**
Concept of scale and homogeneity of geological body
Types of tectonites
Tectonite fabric and fabric domains
Fabric symmetry
Penetrative and non-penetrative discontinuities
Basic concepts of geometrical analysis
Interpretation of structure and fabric
**Microfabric**
Introduction
Deformation mechanisms
Crystal defects
Principles and types of microstructure development
Recovery, meta-dynamic recrystallisation & static grain growth
Grain shape & crystallographic fabric development
Deformation by transfer of dissolved material and structures in veins
Crystallographic preferred orientations in deformed rocks

**Unit 2:** **(15 lectures)**
**Foliation and lineation**
**Foliation**
Axial plane foliation- fracture cleavage, crenulation cleavage, slaty cleavage, schistosity and metamorphic layering
Origin of axial plane foliations
Transposed foliation
Cleavage bedding relationship
Structural association of gently dipping schistosity
Field study of high grade gneissic terrain
Recognition of shear zones
Kinematic classification of shear zones
Fabric distribution in shear zones
Mylonites
**Lineation**
Description- Slickensides, fold axes, intersection lineation, mineral lineation, deformed pebbles, rods, mullions and boudinage
Origin of lineation

Lineation and kinematics
Problem of lineations indicating extension parallel to fold axes
Determining shear sense with lineation and in absence of lineation

**Unit 3:** **(15 lectures)**

**Structural associations and analysis**

Strain measurement, stress-strain relationship
Mathematical expression of deformation
Cross section and data projection
Structure contouring
Slate belts and flat lying sediments
Fold geometry and outcrop patterns
Complex folds, Dome and basins
Analysis of area with complex structure
Extensional deformation regime- Study of Indian examples
Fold and thrust belts- Study of Indian examples
Recognition of faults on geological maps, seismic profiles and structure contour maps
Tectonic melanges
Wrench faults and associated structures
Multiply deformed belts of low and medium metamorphic grade- Indian examples
Restoration and balancing of geological section

**Unit 4:** **(15 lectures)**

**Tectonics and crustal deformation**

Plate tectonics- Ridges, trenches, transform faults, geometry of plate motion, stress and strain within plates
Extensional, compressional and strike slip tectonic regimes
Tectonic settings- Ophiolites, cratons, active and passive margins, arc systems, orogens
Evolution of the crust-mantle system
Seismic structure of the crust
Plate tectonics and mountain belts
Changes in tectonic settings with time
Crustal deformation

**Practical Course:**

**Structural geology**

Profiles and cross sections of geological maps with showing various structural features: folds, faults, dykes, two series of dipping beds.
Geometrical construction of folds
Completion of outcrop and construction of geological map
Structure contour maps
Interpretation and cross sections of geological maps of complex structural areas
Equal-area net
a. Locating fold axis- $\beta$ and $\pi$ diagram
b. Point diagrams and contouring for various fabric elements

**List of Recommended Reference Books**

1. Hobbs D.W., Means W.D. And Williams P.F. (1976), An Outline of Structural Geology, John Wiley.
2. Groshong, R.H (2006), 3-D Structural Geology, Springer-Berlin-Hydelberg-New York
3. Fossen, H. (2010), Structural Geology, Cambridge University Press
4. Passicher C.W, Myers J.S and Kroner A. (1990), Field geology of high grade gneiss terraines; Narosa Publishing house, Springer Verlag and IUGS
5. Hatcher Jr. R.D. (1990), Structural Geology, Merrill Publishing Company.
6. Leyshon, P. R. And Lisle, R.J (2004), Stereographic projection techniques for geologists and civil engineers, Cambridge University Press
7. Condie, K (1976), Plate tectonics and crustal evolution, Butterworth Heinemann Publication
8. Ragan D.M. (1968), Structural Geology- An Introduction to Geometrical Techniques, 2nd ed., John Wiley and Sons.
9. Badgley P.C. (1959), Structural Methods for the Exploration Geologist, Oxford Book Company.
10. Ramsay J.G. and Huber M.I. (2002), The Techniques of modern structural geology, 2nd ed., Vol. 2, Elsevier Science Ltd.
11. Ghosh S.K. (1993), Structural Geology, Pergamon Press.

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**M.Sc. Geology** **Course S.Geo 1.04**
**Title: Advanced Gemmology**

**Learning Objectives:**
**To develop means and ways to study and detect gem minerals and identify gemstones from the new synthetics and enhancement treatments as they are introduced.**

**Number of lectures: 60**

**Unit 1** **(15 hours)**

**Introduction**

The geological sources of gems
Laboratory equipment and methods
Polariscope, Dichroscope, Refractometer, Spectroscope, Chelsea Filter, UV & X-ray equipment
Gem Microscope
Electron microprobe, scanning electron microscope, spectrophotometers, Raman spectroscopy, Quantitative cathodoluminescence.

**Fashioning of gemstones**

Cutting styles, critical angle, composite stones, gemstone polishing, lapidary techniques and gemstone carving.
Diamonds: Diamond cutting and polishing methods, diamond grading including cut, colour, clarity and carat weight.

**Unit 2** **(15 hours)**

**Internal features**

Growth lines and colour zoning, twinning, types of inclusions. Identification features of natural gemstones, synthetic gemstones and simulants based on localities and process
Gemstone enhancements
Methods of staining, heat treatment, diffusion treatment, fracture filling, cavity filling, coatings, dyeing, laser drilling, atomic irradiation and their detection

**Synthesis of gemstones**

Methods of manufacture: flame-fusion (Vernueil), flux-melt, hydrothermal, crystal-pulling (Czochralski), skull-crucible method, zone melting, diamond synthesis, thin diamond films, chemical vapour deposition (CVD), ceramic techniques.
Gemstone simulants: Glass, plastics, diamond simulants, assembled or composite stones (includes doublets and triplets)

**Unit 3** **(15 hours)**

**Descriptive gemology of important gem minerals/gemstones excluding organic gemstones (Gems)**

Includes crystallography, chemical composition, physical and optical properties, inclusions, enhancements and diagnostic features.

Important gemstones including beryl group, chrysoberyl, corundum group, diamond, felspar group, garnet group, jadeite, marble, opal, peridot, spinel, topaz, tourmaline, zircon, zoisite.

**Unit 4** **(15 hours)**

**Descriptive gemology of less common species of gem minerals/gemstones including organic gemstones**

Includes crystallography, chemical composition, physical and optical properties, inclusions, enhancements and diagnostic features.

andalusite, apatite, calcite, diopside, epidote, fluorite, gypsum, hematite, idocrase, iolite, kyanite, lapis lazuli, malachite, nephrite, peridot, quartz, rhodochrosite, rhodonite, scapolite, serpentine, sodalite, spodumene, talc, turquoise.

**Biological Gem Materials**

*Animal origin*:

*Terrestrial*; Ivory & teeth, bone & antler, horn, hoofs, claws, hair,skin & leather exoskeletons

*Avian*; Hornbill casque, claws and beaks, feathers

*Marine*; Pearl, shells, mother of pearl, operculum, calcific coral:- precious & reef building, tortoise shell, ivory and teeth, chitinous claws, skin

*Plant origin*:

*Terrestrial*; Amber, copal,resin & other solid plant resins, vegetable ivory, seeds, nuts,fruit skin, gourds, wood,jet/coal

*Marine*; Vegetable coral:-black & golden.

**List of recommended Reference Books:**


1. Berry L.G., Mason B.H. and Dietrich R.V. (1983), Mineralogy, concepts, descriptions, determinations, W.F. Freeman and Co.
2. Cornelius K. and Hurlbut Jr. S. (1994), Manual of Mineralogy, Twenty first Edition and Minerals and Rocks Exercises in Crystallography, J. Wiley & Sons.
3. Dana J.D. and Ford W.E. (rev. ed.) (2010), Dana's Manual of Mineralogy, J. Wiley & Sons.
4. Deer W.A., Howie A.H. and Zussman J. (1992), An introduction to rock forming minerals, Longman Scientific and Technical.
5. Nesse W.D. and Schulze D.J. (2004), Introduction to Optical Mineralogy" (Third Edition) and An Atlas of Minerals in Thin Section, Oxford University Press.
6. Perkins Dexter (2011), Mineralogy (International Edition), Pearson Education.
7. Read H.H. (Rev. ed. C.D. Gribble) (1988), Rutley's Elements of Mineralogy" (27$^{TH}$ Edition), CBS Publications.
8. Rogers A.F. and Kerr P.F. (1942), Optical Mineralogy (2$^{nd}$ Edition), McGraw- Hill Co. Inc., New York.
9. Shelly David (1985), Optical Mineralogy (2$^{nd}$ Edition), Elsevier.
10. Wenk H.R. and Bulakh A. (2004), Minerals: their constitution and origin, Cambridge University Press.


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**Practical Course:**

**Gem Properties and Characteristics**

1. Procedures of distinguishing, different gemstones using a dichroscope, polariscope and a loupe, on the basis of their various physical and optical characters.
2. Study of growth features and inclusions of the gemstones.
3. Drawings of various types of composite gemstones
4. Identification of natural, cultured, and imitation pearls on the basis of structural data.
5. Appraising gemstones

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**Evaluation and Assessment: MS.Geo. 1.01, 1.02, 1.03 and 1.04 courses**

**Evaluation (Theory): Total marks per course - 100.**

**Continuous Internal Assessment (CIA) - 40 marks**

CIA 1: Written test -20 marks

CIA 2: Assignment /MCQ/ One day Geological Field work around Mumbai with field report and viva on the fieldwork. -20 marks

**End Semester Examination – 60 marks**

One question from each unit for 20 marks, with internal choice. Total marks per question with choice -28 to 30.

**Evaluation of S.Geo.1.PR (Practicals) Total marks for Practical course - 100.**

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**Template for S.Geo courses End Semester examination in Semester 1**

| UNITS | KNOWLEDGE | UNDERSTANDING | APPLICATION and ANALYSES | TOTAL MARKS- Per unit |
|---|---|---|---|---|
| 1 | 08 | 04 | 03 | 15 |
| 2 | 08 | 04 | 03 | 15 |
| 3 | 08 | 04 | 03 | 15 |
| 4 | 08 | 04 | 03 | 15 |
| -TOTAL - Per objective | 32 | 16 | 12 | **60** |
| % WEIGHTAGE | 53 | 27 | 20 | **100%** |

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**St. Xavier's College, Mumbai** | **Course: S.GEO.1.01/1.02/1.03/1.04**

**Department of Geology**

**Roll Number: ________**

**UID Number:________**

**MARKS:____/20**

**Date:____________**

**Assessment Grid for Course: MS.GEO.1.01/1.02/1.03/1.04 CIA 2 (Field Work)**

| Parameters Category | Details of Assessment | 80 – 100 % Excellent | 60 – 80 % Good | 40 – 60 % Satisfactory | 20 –40 % Poor | 0 - 20 % Very Poor |
|---|---|---|---|---|---|---|
| **Field Work** (30 %) | 1. Equipment – field diary, hammer, chisel, hand lens, map, Field discipline.(02) | | | | | |
| | 2. Sample Collection and Instrument handling (01) | | | | | |
| | 3. Prior Preparation (03) | | | | | |
| **Field Report** (60 %) | 1. Field Diary (04) | | | | | |
| | 2. Content, Presentation and Technical correctness (08) | | | | | |
| **Viva Voce** (10 %) | 1. Ability to answer questions. (02) | | | | | |
| **Total Marks/20** | | | | | | |

**Name, Signature of Course Instructor**

**Date:**

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St. Xavier's College
Mumbai

Syllabus
for II$^{nd}$ Semester Courses in

(November 2017 onwards)

Courses:
M.S.Geo.2.01 – Remote Sensing and Digital Image Processing
M.S.Geo.2.02 - Igneous Petrology
M.S.Geo.2.03 – Metamorphic Petrology
M.S.Geo.2.04 – Sedimentary Petrology
Practical Course:
M.S.Geo.2.01. PR, M.S.Geo.2.02. PR, M.S.Geo.2.03. PR and M.S.Geo.2.04. PR. (Pertinent to the above mentioned theory courses)

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**M.Sc-I Geology Course: M.S.Geo.2.01**
**Title: Remote Sensing and Digital Image Processing**

**Learning Objectives:**
Understand the analytical aspects of image processing with special emphasis on processing remotely sensed imagery for geological data interpretation, field mapping.

**Number of lectures: 60**

**UNIT 1** **(15 lectures)**
**Concepts of Remote Sensing**
Satellite imaging technology - Definitions of: Resolution, Classification of sensors, Accuracy and precision, Geolocation , georeferencing and geocoding., Orthoimages, Image products.
Principles: Satellite Orbits, Geometry of a single image, Acquisition of stereoscopic data, Height from stereoscopic data, Ground control, Accuracy.
History of optical sensors in space

**UNIT 2** **(15 lectures)**
**Principles of High Resolution Optical Sensors**
Across track stereo, Along track stereo,
Spatial and radiometric aspects,
Sensor optics,
Data recording and transmission,
Sensors with GSD 1m to 16m and 1m or less.

**UNIT 3** **(15 lectures)**
**Introduction to Digital Image Processing**
Introduction.
Image Rectification and Restoration.
Image Enhancement.
Contrast Manipulation.
Spatial Feature Manipulation.
Multi-Image Manipulation.

**UNIT 4** **(15 lectures)**
**Digital Imaging classification**
Image Classification: Supervised Classification.
The Classification Stage: Minimum-Distance to Means Classifier, Parallelepiped Classifier, Gaussian Maximum Likelihood Classifier.
The Training Stage.
Unsupervised Classification.
Subpixel classification,
Hyperspectral Image Analysis
Classification Accuracy Assessment.

## List Of Recommended Reference Books


1. Dowman Ian., Karsten Jacobsen., Gottfried Konecny and Rainer Sandau (2012), High Resolution Optical Satellite Imagery., Whittles Publishing.
2. Schowengerdt Robert A., (2007), Remote Sensing – Models and Methods for Image Processing, 3rd ed., Elsevier (Academic Press).
3. Lillisand T. M., Ralph W. Kiefer and Jonathan W. Chipman (2007), Remote Sensing and Image Interpretation, 6th ed, Wiley.
4. Jensen John R. (2000), Remote Sensing of the Environment – An Earth Resource perspective, Pearson Education Series, Low Price Edition.
5. Drury S.A., (1993), Image Interpretation in Geology, 2nd ed., Chapman and Hall, London.
6. Ramasamy S.M., (2005), Remote Sensing in Geomorphology, New India Publishing Agency.
7. Mather Paul M., (2004), Computer Processing of Remotely Sensed Images- An Introduction, 3rd ed., John Wiley.


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**Practical Course:**

**Remote Sensing and Image Processing**

- Interpretation of Satellite imagery for : Landuse/Landcover, Geomorphology, Geology.
- Digital Image Processing (using number matrix): enhancement, manipulation and classification.
- Digital image processing on Computer
  - Display of various types of image formats
  - Pallets and Display elements
  - Georeferencing
  - Image enhancement
  - Image classification

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**M.Sc-I Geology Course: M.S.Geo.2.02**
**Title: Igneous Petrology**

**Course Objectives:** To understand the principles and processes involved in the evolution and formation of Igneous rocks and provinces, and their significance in deciphering the Earths evolution.

**Number of lectures: 60**

**Unit 1:** **(15 lectures)**

**Role of Magma In Geological Processes**

Magma definition, its physical property- Geothermal gradient and heat source.
Magmatism and plate tectonics.
Igneous texture and structure and their genetic significance.
Classification of Igneous rocks - historic perspective and the IUGS systematic
Igneous activity at the present day

**Unit 2:** **(15 lectures)**

**Geochemical Tracers of Mantle Process**

Introduction
Continental and Oceanic mantle Lithosphere.
MORB and depleted mantle.
OIB and enriched mantle.
Island arc basalt.
Concept of Hot Spots
Mantle Plumes- theory and structure
Trace Elements in Igneous processes- Melting and crystallization models- Application of trace elements to petrogenesis

**Unit 3:** **(15 lectures)**

**Magma Evolution and Crystallisation**

Igneous processes and diversity in igneous rocks.
Compositional variation in magmas
Magmatic differentiation
Mixing of magma
Assimilation of magma
Phase relations of silicates and silicate melt.
Binary and ternary system.
Partial melting

**Unit 4:** **(15 lectures)**

**Petrogenetic Provinces**

Large Igneous Provinces: Basaltic associations of continental areas, Basaltic rocks of the Ocean Basins.
Ophiolites.



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Layered Gabbroic Intrusions.
Alkaline rocks, Nephelinites and Ijolites, Lamprophyres.
Carbonatites ,Anorthosites, Kimberlites, Lamproites : Geology and Distribution in India.
Granites and Granitic rocks

**Practical Course:**

1. Megascopic and Microscopic identification of igneous rocks.
2. CIPW normative calculation of igneous rocks.
3. Application of trace elements in igneous petrology.

**List of Recommended Reference Books :**


1. Bose M.K. (1997), Igneous Petrology. The World Press Pvt. Ltd. 568 p.
2. Bowen N.L. (1928), The evolution of Igneous Rocks. Princeton Univ. Press. N.J 332 p.
3. Hall A. (1987), Igneous Petrology. Longman. 573p.
4. Hatch F.H., Wells A.K and Wells M.K. (1984), Petrology of the igneous rocks. CBS Publishers, 551 p.
5. Philpotts A.R. (1994), Principles of igneous and metamorphic Petrology, Prentice Hall of India. 498p.
6. Turner F.J & Verhoogen J. (1951), Igneous and Metamorphic Rocks, McGraw Hill.
7. Williams H, Turner F.J & Gilbert C.M. (1955), Petrography. San Francisco: W.H. Freeman and company. 406p
8. Winter J. D. (2001), an Introduction to Igneous and Metamorphic Petrology, Prentice Hall, 697p.
9. Ehlers, E.G. and H. Blatt (1982), Petrology, Igneous, Sedimentary and Metamorphic, W.H Freeman, San Francisco.

**M.Sc-I Geology Course: M.S.Geo.2.03**
**Title: Metamorphic Petrology**

**Learning Objectives:** To understand the metamorphism and its controlling factors, to understand concept of metamorphic facies and significance of metamorphic mineral assemblages. To relate metamorphic textures with deformation conditions and to understand role of global tectonics in metamorphism.

**Number of lectures: 60**
**Unit 1: (15 lectures)**
**Metamorphism and its controlling factors**
Metamorphism and its limits
Metamorphic agents and changes: Role of temperature, pressure, stress and fluids
Types of metamorphism
Types of protolith
Classification of metamorphic rocks
Structures and textures of metamorphic rocks
Analysis of polydeformed and polymetamorphosed rocks
Analytical techniques

**Unit 2: (15 lectures)**
**Thermodynamics and metamorphism**
Phase rule and phase diagram
Chemographic diagrams: Basic concepts and common diagrams in metamorphic petrology
Projections in chemographic diagrams
Metamorphic facies and facies series
Types of metamorphic reactions
Petrogenetic grids
P-T-t paths
Calculation of equilibrium curve for metamorphic reactions
Examples of thermometry and barometry

**Unit 3: (15 lectures)**
**Types and products of metamorphism-1**
Metamorphism of pelitic rocks
Migmatites: Types and formation processes
Metamorphism of carbonate rocks
Metamorphism of mafic rocks

**Unit 4: (15 lectures)**
**Types and products of metamorphism-2**
Metamorphism of granitoids.
Charnockites
Metamorphic fluids, mass transport and metasomatism.
Impact metamorphism and Retrograde metamorphism.
Tectonics and metamorphism, Paired metamorphic belts

**Practical Course:**
**Metamorphic petrology**

· Plotting rock compositions on chemographic diagrams: ACF, AKF and AFM.

· Study of hand specimen of metamorphic rocks

Slate, Phyllites, Quartzite, Schists, Gneisses, Granulites, Khondalite, Leptynite, Charnockite, Eclogite, Amphibolite, Migmatite, Blueschist, Breccia, Mylonite,

· Study of thin sections of

a) Metapelitic rocks

b) Metabasic rocks

c) Granulites and eclogite

d) Marbles

**List of Recommended Reference Books**

1. Winter, John D. (2010): Principles of igneous and metamorphic petrology, PHI learning Pvt. Ltd.

2. Philpotts, A and Ague, J (2009): Principles of igneous and metamorphic petrology, Cambridge University Press

3. Williams H, Turner F.J & Gilbert C.M. (1955), Petrography, W.H. Freeman and company. San Francisco, 406p.

4. Blatt H., Tracy R.J. and Owens B.E. (2006), Petrology – Igneous, sedimentary and Metamorphic (3rd Edition), W.H. Freeman and Company, New York.

5. Passicher C.W, Myers J.S and Kroner A. (1990), Field geology of high grade gneiss terraines; Narosa Publishing house, Springer Verlag and IUGS

6. Yardley Bruce W.D. (1989), An Introduction to Metamorphic Petrology, Longman Singapore Publishers (Pvt.) Ltd.

7. Miyashiro A. (1998), Metamorphism and Metamorphic Belts, George Allen & Unwin, New York.

8. Mason Roger (1984), Petrology of the Metamorphic Rocks, CBS Publishers and Distributors, New Delhi.

9. Winkler Helmut G.F. (1987), Petrogenesis of Metamorphic Rocks (Fifth Edition), Narosa Publishing House, New Delhi.

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**M.Sc. Geology Course: M.S.Geo.2.04**
**Title: Sedimentary Petrology**

**Course Objectives:**
Understanding different sedimentary processes, rocks and structures and their associated environment.
Application of Sedimentary petrology in understanding different geological processes.

**Number of lectures: 60**

Unit-1 (15 lectures)
Sediment transport and deposition, fundamentals of fluid dynamics
Sedimentary textures: grain size, sorting, shape, etc.
Sedimentary structures: lamination, ripples, cross-bedding etc.

Unit-2 (15 lectures)
Siliciclastic sedimentary rocks, classifications, Siliciclastic diagenesis
Siliciclastic marine environments
Fluvial depositional environments

Unit -3 (15 lectures)
Carbonate sedimentary rocks, classification and diagenesis
Carbonate marine environments
Biochemical and evaporitic rocks

Unit-4 (15 lectures)
Eolian and lacustrine environments
Glacial environment
Deltaic and beach barrier island environments
Estuarine, lagoonal and tidal environments

**Practical Course:**
Sedimentary petrology
Rock Specimens of different sedimentary rocks and structures
Thin section of sedimentary rocks
Grain Size analysis
Paleocurrent analysis

**List of Recommended Reference Books**
1. Miall, A.D. (2000): Principles of Basin Analysis, Springer-Verlag.
2. Pettijohn;, F.J. (1975): Sedimentary Rocks (3rd Ed.), Harper and Row Publ., New Delhi.
3. Reading, H.G. (1997): Sedimentary Environments and facies, Blackwell Scientific Publication.
4. Reineck, H.E. and Singh, I.B. (1973): Depositional Sedimentary Environments, Springer-Verlag.
5. Selley, R. C. (2000) Applied Sedimentology, Academic Press.

6. Tucker, M.E. (2001): Sedimentary Petrology: An Introduction, Wiley and Sons, New York.
7. Tucker, M.E. (1990): Carbonate Sedimentology, Blackwell Scientific Publication
8. Stow Dorrik A.V(2011): Sedimentary Rocks in the Field , A Colour guide. Manson Publishing House Ltd.
9. Nichols Gary (2009): Sedimentology and Stratigraphy., Wiley India.

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- **Evaluation and Assessment: S.Geo. 2.01, 2.02, 2.03 and 2.04 courses**

**Evaluation (Theory): Total marks per course - 100.**

**Continuous Internal Assessment (CIA) - 40 marks**

CIA 1: Written test -20 marks

CIA 2: 12 days Geological Field work with field report and viva on the fieldwork. -20 marks per course (20 X 4 courses = 80 marks)

**End Semester Examination – 60 marks**

One question from each unit for 20 marks, with internal choice. Total marks per question with choice -28 to 30.

**Evaluation of S.Geo.2.PR (Practicals) Total marks for Per Practical course - 50.**
**Total marks for four practical courses : 200**

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**Template for MS.Geo courses End Semester examination in Semester 1**

| UNITS | KNOWLEDGE | UNDERSTANDING | APPLICATION and ANALYSES | TOTAL MARKS- Per unit |
|---|---|---|---|---|
| 1 | 08 | 04 | 03 | 15 |
| 2 | 08 | 04 | 03 | 15 |
| 3 | 08 | 04 | 03 | 15 |
| 4 | 08 | 04 | 03 | 15 |
| **-TOTAL - Per objective** | 32 | 16 | 12 | **60** |
| **% WEIGHTAGE** | 53 | 27 | 20 | **100%** |

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**St. Xavier's College, Mumbai**

**Course: MS.GEO.2.01/2.02,2.03,2.04**

**Department of Geology**

**Roll Number: ______**

**UID Number:________**

**MARKS:____/20**

**Date:__________**

**Assessment Grid for Course: MS.GEO.2.01/2.02/2.03,2.04 CIA 2 (Field Work)**

| Parameters Category | Details of Assessment | 80 – 100 % Excellent | 60 – 80 % Good | 40 – 60 % Satisfactory | 20 –40 % Poor | 0 - 20 % Very Poor |
|---|---|---|---|---|---|---|
| Field Work (30 %) | 1. Equipment – field diary, hammer, chisel, hand lens, map, Field discipline.(02) | | | | | |
| | 2. Sample Collection and Instrument handling (01) | | | | | |
| | 3. Prior Preparation (03) | | | | | |
| Field Report (60 %) | 1. Field Diary (04) | | | | | |
| | 2. Content, Presentation and Technical correctness (08) | | | | | |
| Viva Voce (10 %) | 1. Ability to answer questions. (02) | | | | | |
| Total Marks/20 | | | | | | |

**Name, Signature of Course Instructor**

**Date:**

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ST. XAVIER'S COLLEGE-AUTONOMOUS ★ MUMBAI-400 001 ★

# St. Xavier's College
# Mumbai

# Syllabus
# for III$^{rd}$ Semester Courses in

# (June 2017 onwards)

Courses:
M.S.Geo.3.01 – General and Invertebrate Paleontology
M.S.Geo.3.02 – Hydrogeology
M.S.Geo.3.03 – Geophysical Prospecting
M.S.Geo.3.04 – Coal and Petroleum Geology
Practical Course:
M.S.Geo.3.01. PR, M.S.Geo.3.02. PR, M.S.Geo.3.03. PR and M.S.Geo.3.04. PR. (Pertinent to the above mentioned theory courses)

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MUMBAI-400 001

**M.Sc-II Geology Course: M.S.Geo.3.01**
**Title: General and Invertebrate paleontology**

**Learning Objectives:** To understand scope and applications of paleontology and to learn morphology and classification of invertebrate fossil fauna. To understand trace fossils and taphonomic record with Indian examples

**Unit -1:** **(15 lectures)**
**Introduction**
Paleontology, definition, subdivisions and scope, its relationship with other sub-disciplines of geology; Fossils, definition, characters, kinds (body and trace fossils); Conditions of fossilization; Incompleteness of fossils record; Bathymetric distribution of organisms. Modern systematics; Concept and kind of type specimens; Trans-specific evolution, speciation and radiation.

**Unit -2:** **(15 lectures)**
**Invertebrate paleontology-1**
Chief characteristics, Evolutionary trends and geological history of following groups:
Brachiopoda
Mollusca (Bivalvia, Gastropoda, Cephalopoda)
Echinoidea

**Unit -3:** **(15 lectures)**
**Invertebrate paleontology-2**
Chief characteristics, Evolutionary trends and geological history of following groups:
Trilobita, Cnidaria (Corals), Graptoloidea.
Ichnofossils, their modes of preservation, behavioral classification and ichnofacies.

**Unit -2:** **(15 lectures)**
**Paleoecology paleoenvironment**
Approaches to paleoecological and paleoenvironmental studies based on benthic communities, trace fossils and taphonomic record with Indian examples; Micro and macroevolution. Distribution, migration and dispersal of organisms applied to paleobiogeography and plate tectonics with Indian examples.

**Practical Course:**
**General and Invertebrate paleontology**
Study of the morphological characters of some important invertebrate fossils belonging to Brachiopoda, Bivalvia, Gastropoda, Ammonoidea, Trilobita, Echinoidea and corals; Study of ammonoid suture pattern.

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**List of Recommended Reference Books**

1) Clarksons, E.N.K. (1998): Invertebrate Paleontology and Evolution, Allen and Unwin, London.
2) Prothero, D.R. (2004): Bringing Fossil to Life – An Introduction to Paleontology (2nd Ed.), McGraw Hill.
3) Raup, D.M. and Stanley, S.M. (1985): Principles of Paleontology ,CBS Publ..
4) Smith, A.B.(1994): Systematics and Fossil Record – Documenting Evolutionary Patterns, Blackwell.
5) Strean, C.W. and Carroll, R.L. (1989): Paleontology – the record of life, John Wiley.
6) Shrock, Robert R. and Twenhofel, William H. (2002): Principles of Invertebrate Paleontology, (McGraw Hill) Dist. CBS Publishers.
7) Benton, Michael J. and Harper, David A.T. (2009): Introduction to Paleobiology and fossil record, John-Wiley & Sons.

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ST. XAVIER'S COLLEGE-AUTONOMOUS ★ MUMBAI-400 001 ★

**M.Sc-II Geology Course: M.S.Geo.3.02**
**Title: Hydrogeology**

**Learning Objectives:** To understand the functioning of groundwater systems and its interaction with surface water, climate change and landuse. To evaluate the quality parameters and its geological significance. To learn the techniques of groundwater exploration and management.

**Unit -1: Origin, occurrence and distribution of water.** **(15 lectures)**

Water on earth; Types of water — meteoric, juvenile, magmatic and sea water;
Hydrological Cycle and its components; Water balance;
Water-bearing properties of rocks — porosity, permeability, specific yield and specific retention; Vertical distribution of water; Zone of aeration and zone of saturation; Classification of rocks according to their water-bearing properties; Aquifers; Classification of aquifers; Concepts of drainage basins and groundwater basins;
Aquifer parameters- transmissivity and storage coefficient; Water table and piezometric surface; Fluctuations of water table and piezometric surface; Barometric and tidal efficiencies; Water table contour maps; Hydrographs; Springs; Geologic and geomorphic controls on groundwater; Groundwater provinces of India.

**Unit -2:** **(15 lectures)**
**Groundwater Hydraulics**

Theory of groundwater flow; Darcy's law and its applications; Determination of Permeability in laboratory and in field;
Flow through aquifers; steady, unsteady and radial flow conditions;
Evaluation of aquifer parameters of confined, semi-confined and unconfined aquifers -Thiem, Thies, Jacob and Walton's methods; Groundwater modelling

**Groundwater management**

Groundwater problems related to foundation work, mining, canals and tunnels; Over-exploitation of groundwater and groundwater mining; Groundwater problems in urban areas; Ground water management in arid and semi-arid areas; Concept of sustainable development of groundwater resources; Groundwater management —supply side and demand side management; Rainwater harvesting and managed aquifer recharge; Conjunctive use of surface and groundwater; Groundwater legislation. Artificial Recharge of Groundwater

**Unit -3: Groundwater management and Quality** **(15 lectures)**
**Groundwater management**

Over-exploitation of groundwater and groundwater mining; Groundwater problems in urban areas; Ground water management in arid and semi-arid areas; Concept of sustainable development of groundwater resources; Groundwater management —supply side and demand side management; Rainwater harvesting and managed aquifer recharge; Conjunctive use of surface and groundwater; Groundwater legislation. Artificial Recharge of Groundwater

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**Groundwater quality**

Physical and chemical properties of water; Quality criteria for different uses; Graphical presentation of groundwater quality data; Water-Quality Standards and collection of Water Samples. Groundwater contamination; natural (geogenic) and anthropogenic contaminants; Saline water intrusion in Aquifers- Ghyben-Herzberg relation between Fresh and Saline water

**Unit-4** **(15 lectures)**

**Groundwater Exploration and Water Well Construction**

Geologic and hydrogeologic methods of exploration; Role of remote sensing in groundwater exploration; Hydrogeomorphic and lineament mapping;

Surface and subsurface methods for investigation of groundwater:

Surface investigation of groundwater- seismic, gravity, geo-electrical and magnetic

Sub-surface geophysical methods – resistivity logging and SP

Yield characteristics of wells; Pumping tests- methods, data analysis and interpretation

Types of water wells and methods of construction; Design, development, maintenance and revitalization of wells.

**List of Recommended Reference Books**

1. Appelo, C. A. J., & Postma, D. (2005). Geochemistry, Groundwater and Pollution (2nd ed.). Rotterdam: A. A. Balkema.
2. Assad, F.A., LaMoreaux, P.E., & Hughes,T. H., (2004) Field methods for Geologists and Hydrogeologists. Springer-Verlag, Berlin.
3. Brassington, R., (2006) Field Hydrogeology (3rd ed). John Wiley & Sons, Chichester
4. Fetter, C. W. (1988). Applied Hydrogeology (Second). USA: Merril Publishing Company.
5. Ingebritsen, S.E., Stanford, W.E & Neuzil, C.E. (2006) Groundwater in geologic processes. 2nd ed., Cambridge
6. Karanth, K. R. (1987). Ground Water assessment, development and Management. New Delhi: Tata McGraw-Hill.
7. Nath, S.K, Patra, H.P, Shahid. S. (2000) Geophysical Prospecting for Groundwater. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi
8. Ragunath, H.M., (1992) Groundwater .Wiley Eastern Ltd. New Delhi
9. Sen, Z. (2015). Practical and Applied Hydrogeology. Amsterdam: Elsevier Inc.
10. Todd, D. K. (2008). Groundwater Hydrology (3rd ed.). John Wiley& Sons (Asia) Pte. Ltd

**Practical Course:**

**Hydrogeology**

Groundwater contour maps and flow nets

Analysis of rainfall data,

Groundwater quality analysis and graphical representation

Application of remote sensing and GIS in groundwater exploration and management.

Resistivity data interpretation

Groundwater flow problems

**M.Sc-II Geology Course: M.S.Geo.3.03**
**Title: Geophysical Prospecting**

**Learning Objectives:** To understand basic concepts, scope and applications of geophysical prospecting. To learn methods of logging and log interpretation.

**Unit-1** **(15 Lectures)**

**Introduction**
Introduction to Geophysical Prospecting and historical background
Overview of Geophysical Prospecting methods

**Seismic Methods**
Fundamentals of Seismic prospecting
Seismic instruments, measurements and field operations
Seismic refraction method
Seismic reflection method
Geological interpretation of refraction and reflection data

**Unit-2** **(15 Lectures)**

**Gravity Methods**
Fundamentals of Gravity prospecting
Instruments, measurements and field operations
Geological interpretation of Gravity Data

**Magnetic Methods**
Fundamentals of Magnetic prospecting
Instruments, measurements and field operations
Geological interpretation of Magnetic Data

**Unit-3** **(15 Lectures)**

**Electrical Methods**
Electrical properties of rocks and minerals
Methods employing Natural Electrical sources:
(a)Self-potential (b) Telluric and Magnetotelluric
Resistivity method
Induced Polarization method
Geological interpretation of Electrical Data

**Electromagnetic Methods**
Fundamentals of electromagnetic surveys
Instruments and field settings
Geological interpretation of EM Data



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**Unit-4** **(15 Lectures)**

**Radioactivity methods**
Fundamentals of radioactivity surveys
Instruments and field settings
Geological interpretation of Radioactivity Data
**Geophysical Well Logging**
Introduction to well logging
General aspects well logging and historical background
Common logging methods:

(a) Resistivity log (b) Self-potential log (c) Sonic log
(d) Neutron log (e) Gamma-ray log (f) Density log
(g) Well bore seismic (h) Image logs

Well-log interpretation

**List of Recommended Reference Books:**

1. Dobrin, Milton B. (1960): Introduction to Geophysical Prospecting, McGraw-Hill Book Company, Inc.
2. Milsom, J. and Asger, E. (2011): Field Geophysics, 4th edition, Wiley and Sons Ltd.
3. Committee on Geodesy, National Research Council (1995): Airborne Geophysics and Precise Positioning: Scientific Issues and Future Directions, National Academics Press.
4. Gadallah, M. and Fisher, R. (2009): Exploration Geophysics, Springer-Verlag Berlin Heidelberg.
5. Kalyan Kumar Roy (2008): Potential Theory in Applied Geophysics, Springer-Verlag Berlin Heidelberg.
6. Kearey, Brooks and Hill (2002): An Introduction to Geophysical Exploration, Third Edition, Blackwell Science.
6. W. M. Telford, L. P. Geldart and R. E. Sheriff (2004): Applied Geophysics, Second Edition, Cambridge University Press.

**Practical Courses:**

1. Calculations and interpretation based on Seismic Data
2. Calculations and interpretation based on Gravity Data
3. Calculations and interpretation based on Electrical Data
4. Exercises on Log interpretation
5. Exercises on Log correlation

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**M.Sc-II Geology Course: M.S.Geo.3.04**
**Title: Coal and petroleum geology**

**Learning Objectives:** To understand origin, properties, classification of coal and petroleum. Learning exploration methods, and coal/petroleum bearing rock formations in India.

**Unit-1** **(15 lectures)**
**Generation and migration of petroleum**
Physical and chemical properties of petroleum
i) Natural gases
ii) Gas hydrates
iii)Crude oil
Classification of petroleum
Generation and migration of petroleum
Origin of petroleum: Organic or Inorganic
Modern organic processes on the earth's surface
Formation of kerogen
Petroleum migration
Petroleum system

**Unit-2** **(15 lectures)**
**Reservoir and cap rocks**
The Reservoir
Porosity, Permeability, Capillary pressure, Relationship between Porosity, Permeability and Texture, Effects of diagenesis on reservoir quality
Reservoir continuity and characterization
Reserve calculations and Production methods
**Traps and Seals**
Nomenclature of a trap
Distribution of petroleum within a trap
Seals and cap rock
Classification of traps

**Unit-3** **(15 lectures)**
**Origin and distribution of coal**
The origin of coal
Sedimentation of coal and coal bearing sequences
Structural effects on coal
Age and occurrence of coal
Plate tectonics
Stratigraphy

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Coal as a substance
Physical description of coal
Coalification (Rank)
Coal quality
Classification of coals

**Unit-4**
**Sampling and analysis of coal** **(15 lectures)**
Coal sampling and analysis
*In situ* coal sampling
Non *in situ* coal sampling
Coal analysis
Geology and coal mining
Underground mining
Open cast or surface mining

**List of Recommended Reference Books**

1. Thomas L. (2012), Coal Geology, Wiley India Pvt. Ltd.
2. Francis W. (19640, Coal its formation and composition, Edward Arnold (Publishers) Ltd.
3. Deshpande B.G. (1992), The world of petroleum, Wiley Eastern Ltd. New Delhi.
4. Selley R.C. (1998), Elements of petroleum geology, Academic Press.
5. Ashcroft, W. (2011), A geologist's guide to seismic reflection, John Wiley and sons
6. Leverson, A.I (2006): Geology of Petroleum, CBS publications

**Practical course**
**Coal and petroleum geology**
Isopach and isolith maps
Outcrop completion, fault and borehole problems
Reserve estimation problems
Seismic profile interpretation
Borehole correlation

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ST. XAVIER'S COLLEGE-AUTONOMOUS MUMBAI-400 001

# St. Xavier's College
# Mumbai

# Syllabus
# for IV$^{th}$ Semester Courses in

# (November 2017 onwards)

Courses:

M.S.Geo.4.01 – Micropalaeontology and Oceanography
M.S.Geo.4.02– Engineering Geology
M.S.Geo.4.03 – Economic Geology
M.S.Geo.4.04* – Dissertation

Practical Course:

M.S.Geo.4.01. PR, M.S.Geo.4.02. PR, M.S.Geo.4.03. PR
(Pertinent to the above mentioned theory courses)

ST. XAVIER'S COLLEGE-AUTONOMOUS
MUMBAI-400 001

**M.Sc-II Geology Course: M.S.Geo.4.01**
**Title: Micropalaeontology and Oceanography**

**Learning Objectives:** To give an insight of the various microfossils with respect to their morphology, shell composition and their habitats. To emphasize on the applications of various microfossils in the field of paleoclimatology, paleoceanography and biostratigraphy.

**Number of lectures: 60**
**Unit 1:** **(15 lectures)**
**Definition and scope of the subject;** Relationship of micropaleontology with ocean sciences; Modern field and laboratory techniques in the study of microfossils (collection, sampling and processing techniques, scanning electron microscopy and mass spectrometry).

**Types of Microfossils**
Calcareous Microfossils:

(i) Foraminifera - planktic foraminifera, their modern biogeography, outline of morphology, significance in Cenozoic oceanic biostratigraphy and paleoceanographic, paleoclimatic interpretations.
Benthic foraminifera – outline of morphology; application in deep-water paleoceanography and paleobathymetric reconstructions.
Larger foraminifera- their outline of morphology and application in stratigraphy;
(ii) Calcareous nannofossils - outline of morphology, modern biogeography and their application in oceanic biostratigraphy and paleoceanographic, paleoclimatic reconstructions.
(iii) Pteropoda - a brief introduction, application of pteropods in reconstruction of the Quaternary oceanography and climate;
Organic Walled Microfossils:
Organic walled microfossils and their significance, significance of spores, pollen, in biostratigraphy, Concept of palynofacies and its application in paleoenvironment interpretation.

**Unit 2:** **(15 lectures)**
**Types of Microfossils**
Siliceous Microfossils:
Radiolaria and diatoms - outline of morphology, modern biogeography, their environmental significance and application in biostratigraphy.

Phosphatic Microfossils:
Conodonts - outline of morphology, paleoecology, geological significance and biological affinities; Stratigraphic significance of conodonts with special reference to India.
Micropaleontology in petroleum exploration; Environmental significance of microfossils; Geochemical study of microfossil tests (stable isotopes, radiocarbon isotopes and elemental composition) and its application in paleoceanography and paleoclimatology; Application of palynology in identifying ancient coast lines; Role of micropaleontology in marine geology and oceanography.



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**Unit 3:** **(15 lectures)**

**History of development of oceanography**; Sampling of modern ocean biogenic flux including sediment trap sampling; Methods of measuring properties of sea water; Temperature and salinity distribution (horizontal and vertical) in ocean waters; Dissolved gases in sea water, factors affecting the concentration of gases in sea water;
Carbon dioxide equilibria, precipitation and dissolution of carbonates; Biological - chemical - physical interactions in the oceans; Oxygen minimum layer in the ocean.
Scientific ocean drilling and its major accomplishments

**Unit 4:** **(15 lectures)**
Concept of mixed layer, thermocline, pycnocline halocline, and pycnocline, Coriolis force and Ekman spiral, upwelling, El Niño and La Nina, Ocean circulation- surface circulation; deep ocean circulation (concept of thermohaline circulation, formation of bottom waters, water masses of the world oceans, oceanic sediments).

**Practical Course**
Micropaleontology
Types of microfossils - calcareous, siliceous, and organic walled microfossils; Microscopic study of important planktic and benthic foraminifera; Study of larger benthic foraminifera.
Oceanography
Depth biotopes; Identification of planktic foraminifera characteristic of warm and mixed layer, thermocline and deep surface water of the modern oceans;
Quantitative study of planktic foraminifera and their interpretation in relation to paleoclimatology.

**List of Recommended Reference Books**
1. Kennett, J.P. and Srinivasan, M.S. (1983): Neogene Planktonic Foraminifera- a phylogenetic atlas, Hutchinson Ross Publishing Company.
2. Bignot, G., Grahm and Trottman (1985): Elements of Micropaleontology, Micropaleontology Press, London.
3. Armstrong, H.A. and Brasier, M. (2005): Microfossils, Blackwell Publishing, Australia.
4. Pinet, Paul R. (2006): Invitation to Oceanography, Jones & Bartlett Learning.
5. Grant Gross, M. (1995): Oceanography; A view of the Earth (7th Ed.), Prentice Hall.
6. Garrison, T. (2007): Oceanography: an invitation to marine sciences, Cengage Learning.
7. Haq, Bilal and Boersma, Anne (Ed.) (1998): Introduction to Marine Micropaleontology, Elsevier.
8. Bradley, R.S. (Ed.) (1999): Paleoclimatology (2nd Ed.), Elsevier.
9. Marcel, C.H. and Vernal, A.D. (Ed.) (2007): Proxies in Late Cenozoic Palcoceanography, Elsevier.

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**M.Sc-II Geology Course: M. S.Geo.4.02**
**Title: Engineering Geology**
**Learning Objectives:** To understand the engineering properties of rocks. Detailed study of various geological and geotechnical investigations for various civil engineering projects.

**Number of lectures: 60**
**Unit 1:** **(15 lectures)**
**Rock and soil mechanics**
Techniques of determining properties of rocks and soil:
Specific Gravity
Porosity
Sorption
Compressive Strength
Tensile Strength
Elasticity of Rocks
Residual Stress and Shear Stress in Rocks.
Soil mechanics
Rocks as construction material

**Unit 2:** **(15 lectures)**
**Geological and Geotechnical investigations for Civil Engineering Projects:**
1. **Geotechnical investigations**- Sounding, Drilling equipment and methods, Wash borings, core samples, borehole logs.
2. **Building site exploration**- Types of foundations, load tests, groundwater problem. Commercial, residential and industrial building site investigation
3. **Tunnels:** Terminology, Geological conditions for tunnel sites, Tunnels in folded rocks and bedded rocks. Influence of divisional planes, Effects of faults, Crushed zones, Tunnels near slopes, Role of Groundwater in tunneling.
4. **Bridges and pavements**- Abutments and piers, foundations, cofferdams, Caissons, rigid and flexible pavement. Site exploration.

**Unit 3:** **(15 lectures)**
**Tunnels and shoreline engineering**
1. **Tunnels**- Terminology, technical classification, roof bolting, arching, effect of bedding orientation on tunnels. Gases and water in tunnels, geothermal gradient. Methods of tunnel excavation and site exploration
2. **Shoreline engineering**- Beach and shorelines, construction of shore cliffs and steep banks, Littoral barriers, harbour location, sedimentation in harbours and jetties.
3. **Earthquakes and Aseismic design of buildings**

**Unit 4:** **(15 lectures)**
**Dams, reservoirs and landslides**
1. **Dams and Reservoirs:** Geological conditions for the selection of dam and reservoir sites. Terminology associated with dams. Types of dams: Masonary Dams (Gravity Buttress and Arch types), Earthen dams. Types of spillways. Case studies of dam construction and failures.
2. **Landslides**- Causes, types and prevention of landslides.



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**Practical Course:**
**Engineering Geology**

- Correlation of borehole data
- determining uniaxial compressive strength of rock
- Equal-area net- Determining slope stability and rotation problems.

**List of Recommended Reference Books**

1. Waltham, T. (2009): Foundations of engineering geology, 3rd edition, CRC press
2. Vallejo, L.G, Mercedes, F., Freitas, M. (2011): Geological Engineering, 1st edition, CRC press
3. West, T.R (2010): Geology applied in Engineering, Waveland Pr Inc; 1 edition
4. Narayanswami S.B.S. (2000), Engineering Geology, Dhanpat Rai & Co, India.
5. Legget F. R and Hatheway A.W. (1988), Geology and Engineering., 3rd ed. McGraw-Hill.
6. Gupte R.B. (1992), A Textbook of Engineering Geology.2nd ed. Pune Vidyarthi Griha Prakashan.
7. Krynine D.P. And Judd W.R (2003), Principles of Engineering Geology and Geotechniques, CBS Publishers.
8. Wahlstrom E.E. (1974), Dams, Dam Foundations and Reservoir Sites. Elsevier Scientific.
9. Dunn I.S., Anderson L.R and Kiefer F.W. (1980), Fundamentals of Geotechnical Analysis, John Wiley.
10. Maslov N.N. (1987), Basic Engineering Geology and Soil Mechanics. Mir Publishers.
11. Gokhale K.V.G.K and Rao D.M. (1981), Experiments in Engineering Geology. Tata McGraw-Hill

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**M.Sc-II Geology Course: M.S.Geo.4.03**
**Title: Economic Geology**

**Learning Objectives:** To understand the various processes of ore formation, with special reference to the distribution in India.

**Number of lectures: 60**

**Unit 1:** **(15 lectures)**

Concept of ore bearing fluids, their origin and migration; Processes of formation of ore deposits-metasomatic, hydrothermal and supergene enrichment; Controls of ore localization; Ore deposits and plate tectonics.

**Unit 2:** **(15 lectures)**

Mineralogy, classification and genesis of ore deposits associated with mafic-ultramafic rocks; Ores of felsic-silicic rocks; Ores of sedimentary affiliation; Ores of metamorphic affiliation; Placer and residual concentration deposits.

**Unit 3:** **(15 lectures)**

Study of ore minerals related to the following metals with special reference to their mineralogy, genesis, specification, uses and distribution in India:
Iron, Manganese, Base Metals, Chromium, Gold, Tin and Tungsten.

**Unit 4:** **(15 lectures)**

Study of important Indian ore deposits with reference to their geology, stratigraphy and reserves; A few case studies of occurrence of economic mineral deposits from provinces other than Indian sub-continent.

**Practical Course:**

Identification of important ore minerals in hand specimens.
Ore microscopy- textures, microstructures, optical properties of ores.

**List of Recommended Reference Books**

1. Branes, H.L. (1979): Geochemistry of Hydrothermal Ore Deposits, John Wiley.
2. Cuilbert, J.M. (1986): The Geology of Ore Deposits, Freidman.
3. Evans, A.M. (1993): Ore Geology and Industrial Minerals, Blackwell.
4. Jensen M.R. and Bateman A.M. (1981), Economic mineral deposits, John Wiley & Sons.
5. Craig, J.R. and Vaughan, D.J. (1994): Ore Microscopy and Petrography.
6. Klemm, D.D. and Schnieder, H.J. (1977): Time and Strata Bound Ore Deposits, Springer-Verlag.
7. Wolf, K.H. (1976-1981): Handbook of Stratabound and Stratiform Ore deposits, Elsevier.
8. Mookherjee, A. (1999): Ore Genesis- A Holistic Approach., Allied Publishers.

**M.Sc.II Geology Course: M.S.Geo.4.04**
**DISSERTATION**
**(Topic for dissertation will be assigned during the 3rd semester.)**

**Evaluation of Dissertation: (CIA - 40%, Dissertation report and Viva - 60%)**
**CIA I: (30 marks):Reference work - pre-field / pre lab literature survey, preparation of field material (toposheet, satellite imagery etc)**

**CIA II: (30 marks): Field work , Lab work, Geological mapping, Sample collection, field diary.**

**End Semester Examination: Dissertation Report and Open Viva: (90 marks)**
**Dissertation report - 60 marks**
**Viva voce - 30 marks**

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