

Gondwana University, Gadchiroli



Choice Based Credit System (CBCS)

Syllabus

M.Sc. (Geology)

Semester I& II

(Two Years Degree Course)

Prepared by

Dr.C. P. Dorlikar

Chairman, BOS Geology

2016-2017

SYLLABUS for M. Sc. GEOLOGY
Choice Based Credit System (Semester Pattern)
Gondwana University, Gadchiroli
Effective from 2016-2017

Scheme of teaching and examination under semester pattern Choice Based Credit System (CBCS) for M.Sc. Program in Geology

M.Sc. GEOLOGY Semester I

Core	Theory / Practical	Teaching Scheme (Hrs/ week)			Credits	Examination Scheme					
		Th	Pr.	Total		Duration (Hrs)	Max. Marks		Total Marks	Min. Passing Marks	
							External	Internal		Th	Pr.
PSCGEOT01	PSGET01 Mineralogy and Crystallography (3+1)	4		4	4	3	80	20	100	40	
PSCGEOT02	PSGET02 Igneous Petrology (4)	4		4	4	3	80	20	100	40	
PSCGEOT03	PSGET03 Metamorphic Petrology and Geological Mapping (3+1)	4		4	4	3	80	20	100	40	
PSCGEOT04	PSGET04 Stratigraphy and Indian Geology (2+2)	4		4	4	3	80	20	100	40	
Pract. – I PSCGEOP01	PSGEP01 Mineralogy, Crystallography, Igneous Petrology (Marks: 75 Pract. Exam. + 05 Viva-voce + 20 Internal Assessment and Class Record)		8	8	4	3	80	20	100		40
Pract. – II PSCBOTP02	PSGEP02 Metamorphic Petrology, Geological		8	8	4	3	80	20	100		40

	Mapping and Stratigraphy (Marks: 75 Pract. Exam. + 05 viva-voce + 20 Internal Assessment and Class Record)										
Seminar	Seminar 1	2		2	1	---		25	25	10	80

PSCGEOT01

Mineralogy and Crystallography

Unit I:

Isotropic and anisotropic substances; Reflection, refraction and refractive index; Relief, birefringence and Becke line effect; Optically uniaxial and biaxial minerals; Determination of optic sign of uniaxial and biaxial minerals; interference figures; Pleochroism and determination of pleochroic scheme in minerals; X-ray crystallography and Bragg's equation; Application of X-ray diffraction spectrometry in mineral characterization; Application of following techniques in mineralogy: Differential Thermal Analysis (DTA), Thermogravimetric Analysis (TGA), Scanning Electron Microscope (SEM), Transmission Electron Microscope (TEM), Electron Probe Micro Analyser (EPMA); Application of thermal, magnetic and radioactive properties of minerals.

Unit II:

Principle of crystal structure; Bonding in minerals; Coordination and co-ordination numbers; Silicate structures and structural formula; Isomorphism and solid solution; Types of ionic substitution; Polymorphism and types of polymorphic transformations; Pseudomorphism; Conversions of oxide and element weight percentages; Calculation of mineral formulae.

A detailed study of following mineral groups with reference to their general formulae, classification, atomic structure, chemistry, experimental work and paragenesis:

Non-silicates: Carbonates- Calcite Group, Aragonite Group, Dolomite Group; Phosphates- Apatite, Monazite; Sulphates- Gypsum, Anhydrite, Barite, Alunite Group; Halides- Halite, Sylvite, Fluorite; Nitrates- Trona, Soda niter; Oxides and Hydroxides- Spinel Group, Hematite Group, Rutile Group, Bauxite Group, Periclase.

Unit III:

A detailed study of following mineral groups with reference to their general formulae, classification, atomic structure, chemistry, experimental work and paragenesis:

Silicates: Nesosilicates- Olivine Group, Garnet Group and Aluminosilicate Group; Sorosilicates- Epidote Group, Scapolite Group; Cyclosilicates- Beryl, Tourmaline; Inosilicates- Pyroxene Group, Amphibole Group; Phyllosilicate- Mica Group, Chlorite Group, Serpentine Group, Pyrophyllite, Talc; Tectosilicates- Quartz, Feldspars, Feldspathoids and zeolite Group.

Unit IV:

Crystals, crystalline solids and their formation; Ordered patterns, nets and lattices; Symmetry in crystals; Axial ratio, indices, lettering and order of the crystallographic axes; Crystallographic

notation (Weiss and Miller indices and convention in notation); Classification of crystals-introduction to 32 classes of symmetry; The crystal systems and symmetry types; Stereographic representation of crystal symmetry and their uses; Imperfection of crystals and crystal defects; Twinning- causes, effects and genetic types.

Practicals:

Study of rock forming minerals in hand specimen and thin sections: Physical and optical properties of common rock forming minerals; Study of Becke line; Determination of refractive indices and birefringence; An-content of plagioclase; Pleochroism and Dichroism: pleochroic scheme of tourmaline, biotite, hornblende, actinolite, glaucophane, hypersthene, aegirine, andalusite and other silicate minerals; Use of Berek Compensator (and other Compensators), Quartz wedge and gypsum plate; Determination of length-fast and length-slow character of minerals; Study of Interference figures of uniaxial and biaxial minerals and determination of optic sign; Refractive Index determination by immersion method; Interpretation of X-ray diffractograms of common minerals and components of the bulk rocks; Stereographic projection of crystals.

Books Recommended:

Mineralogy and Mineral Optics:

- Batthey, M.H. (1981) Mineralogy for students 2nd Edn. Longmans.
- Berry, L.G. and Mason, B. and Dietrich, R.V. (1983) Mineralogy, 2nd Edn, Freeman.
- Bunn, C.W. (1961) Chemical Crystallography, Clarendon.
- Donald Bloss (1971) Crystallography and Crystal chemistry, Holt, Rinehart and Winston.
- Deer, W.A., Howie, R.A., and Zussman, J. (1992) An Introduction to the rock forming minerals, Longman.
- Hutchinson, C.S. (1974) Laboratory Handbook of Petrographic Techniques, John Wiley.
- Klein, C. and Hurlbut, Jr., C.S. (1993) Manual of Mineralogy, John Wiley.
- Kerr, P.F. (1977) Optical Mineralogy 4th Edn., McGraw-Hill
- Phillips, Wm, R. and Griffen, D.T. (1986) Optical Mineralogy, CBS Edition.
- Putnis, Andrew (1992) Introduction to Mineral Sciences, Cambridge University Press.
- Santosh, M. (1988) Fluid Inclusions, Geological Society of India, Bangalore.
- Spear, F.S. (1993) Mineralogical Phase Equilibria and Pressure -Temperature-Time Paths, Mineralogical Society of America Publication.
- Winchell, A.N. (1962) Elements of Optical Mineralogy, John Wiley.
- Slemmons, D.B. (1962). Determination of Volcanic and Plutonic Plagioclases using a three- or Four-Axis Universal Stage, Geological Society of America.

Szymanski, A. (1988). Technical Mineralogy and Petrography, Elsevier.

Hota, R.N. (2011) Practical Approach to Crystallography and Mineralogy, CBS Publisher and Distributors Pvt Ltd., New Delhi.

PSCGEOT02
Igneous Petrology

Unit I:

Magma- its nature and composition. Factors controlling evolution of magma; Introduction to mantle petrology mantle metasomatism and mantle heterogeneities; Magmatism in relation to plate tectonics; Chemical characteristics of igneous rocks in the following tectonic setting: Mid Oceanic Ridge, Island Arcs, Oceanic plateaus, Continental Margins, Continental Rifts and Continental intraplates; Plume magmatism and hot spots; Large igneous provinces, mafic dyke swarms and layered complexes.

Unit II:

Mantle melting: Partial melting (batch and fractional melting); Crystal fractionation (equilibrium and fractional (Rayleigh) crystallization); Contamination (AFC process) and dynamic melting. Crystallisation of magma, fractional crystallization and differentiation, liquid immiscibility and assimilation. Influence of volatiles and role of oxygen fugacity in magmatic crystallizations; Phase equilibrium studies - binary systems, ternary systems and their relations to magma genesis and crystallization in the light of modern experimental works.

Unit III:

Textures and structures of igneous rocks; Petrography and Interpretation of igneous textures in terms of rate of nucleation and crystal growth; Major, Trace and Rare Earth Element systematics in igneous rocks; Silica/alumina saturation, variation diagrams (Harker, AFM and TAS diagrams) their applications and limitations; Mg Number, Alteration Index, Saturation Index and other geochemical parameters; Fractional crystallization, liquid lines of descent and lever rule.

Unit IV:

IUGS classification of igneous rocks (QAPF diagram); weight norm, cation norm; Petrology and petrogenesis of major igneous rock types with Indian examples of ultramafic, komatiite, basalt, granite, pegmatite, alkaline rocks, anorthosite, spilite, boninite, carbonatite, kimberlite, lamproite, lamphrophyre and charnockite.

Practicals:

Megascope and microscopic study of different igneous rocks; Calculation of CIPW norms; Modal analysis; Exercises on Crystal Fractionation of Igneous Rock Suites. Exercises on Partial Melting of Igneous Rock Suites. Preparation and description of variation diagrams. Exercises on the construction and interpretation of Spider diagrams of N-type MORBs, E-type MORBs, OIBs, etc.

Books Recommended:

Best, M. G. (2003) *Igneous and Metamorphic Petrology*, 2nd Edn., Blackwell. Bose, M.K. (1997) *Igneous Petrology*, World Press, Kolkata.

Cox, K. G., Bell, J. D. and Pankhurst, R. J. (1979) *The Interpretation of Igneous Rocks*, Unwin Hyman. Faure, G. (2001) *Origin of Igneous Rocks*, Springer.

- Hall, A. (1996) *Igneous Petrology*, 2nd Edn., Longman.
- LeMaitre R.W. (2002) *Igneous Rocks: A Classification and Glossary of Terms*, Cambridge Uni. Press.
- McBirney, A.R. (2006) *Igneous Petrology*, 3rd Edn., Jones & Bartlett.
- Middlemost, E.A.K. (1985) *Magmas and Magmatic Rocks*, Longman.
- Parfitt, E. and Wilson, L. (2008) *Fundamentals of Physical Volcanology*, Wiley-Blackwell.
- Phillipotts, A.R. (1994) *Principles of Igneous and Metamorphic Petrology*, Prentice Hall of India.
- Sood, M.K. (1982) *Modern Igneous Petrology*, Wiley-Interscience Publ., New York.
- Srivastava, R.K. and Chandra, R. (1995) *Magmatism in Relation to Diverse Tectonic Settings*, A.A. Balkema, Rotterdam.
- Wilson, M. (1993) *Igneous Petrogenesis*, Chapman and Hall, London.
- Winter, J.D. (2001) *Introduction to Igneous and Metamorphic Petrology*, Prentice-Hall.
- Bell, Keith (Ed.) (1989) *Carbonatites: Genesis and Evolution*, Unwin Hyman, London.
- Bell, K., Kjarsgaard, B.A. and Simonetti, A. (1998) Carbonatites – Into the twenty-first Century, *Journal of Petrology*, Spl. Vol.39 (11 & 12).
- Carmichael, J., Turner and Verhoogen (1974) *Igneous Petrology*, McGraw Hill.
- Fitton, J.G. Upton, B.J.G. (Eds) (1987) *Alkaline Igneous Rocks*, Geological Society, London.
- LeBas, M.J. (1977) *Carbonatite-nephelinite Volcanism*, Wiley.
- Rock, N.M.S., (1991) *Lamprophyres*, Blackie, Glasgow.
- Perchuk, L.L. and Kushiro, I. (Eds.) (1991) *Physical Chemistry of Magmas*, Springer Verlag.
- Gupta, Alok (1998) *Igneous Rocks*, Allied Publishers Limited.
- Allegre, C.J. and Hart, S.R. (1979) *Trace elements in Igneous Petrology*, Elsevier.
- Hughes, C.J. (1982) *Igneous Petrology*, Elsevier.
- Hota, R.N. (2011) *Practical Approach to Petrology*, CBS Publisher & Distributors Pvt Ltd., New Delhi.

Unit I:

Metamorphism: Nature and scope; Factors controlling metamorphism (T, P and fluids); Types of metamorphism: Regional, contact, dynamic, hydrothermal, impact, retrograde and ocean floor metamorphism; Transient geotherm, and pressure-temperature regimes; Protolith types and characteristic metamorphic minerals; metamorphic textures.

Unit II:

Metamorphic facies and sub-facies series; metamorphic zones; regional metamorphism of pelitic, carbonate and mafic rocks; high grade metamorphism of granulite and eclogite; Metamorphic differentiation, metasomatism and granitization, anatexis and origin of migmatites, granites, charnokites, amphibolites in the light of experimental studies; Ultra high temperature and ultra high pressure (blue schist) metamorphism; Pressure – temperature – time paths and metamorphic terrains in relation to plate tectonics; Regional metamorphism and Paired metamorphic belts; Relationship of metamorphic rocks and associated mineral deposits; Tectonic controls of metamorphism.

Unit III:

Thermodynamic principles of metamorphic reactions, Mineralogical phase rule for closed and open systems; Gibb's free energy, entropy, enthalpy, activity and fugacity of metamorphic reactions (solid-solid and dehydration reactions); Clausius – Clapeyron equation; Isograds and reaction isograds; Role of fluids, Nucleation and growth in solids kinetics of metamorphic reactions, Arrhenius relations, diffusion and interface controlled reactions; Experimental studies on metamorphic reactions; Concepts of geothermometry and geobarometry; Metamorphic projections in positive and negative space; ACF, AKF and AFM diagrams; Schrienermakers rule and construction of petrogenetic grids.

Unit IV:

Objectives of Geological mapping, precision required in geological mapping; Topographic maps and base maps for geological mapping, topographic maps and their numbering by Survey of India; Types of geological maps and sections; Geological symbols in maps; General principles of geological mapping; Mapping methods in sedimentary, igneous and metamorphic terrains.

Practicals:

Metamorphic Petrology:

Study of metamorphic rocks of different metamorphic facies in hand specimens; Detailed study of textures in thin sections with reference to time relations between the phases of deformation and recrystallization of minerals; Calculation of ACF, AKF and AFM values from chemical and structural formulation of minerals and their graphical representation; Construction of petrogenetic grid;

Estimation of pressure and temperature from important models of geothermobarometry.

Geological Mapping:

Study of topographical survey sheets of Survey of India.

Books Recommended:

Metamorphic Petrology:

Harker, Alfred (1964) Metamorphism, Methuen, London.

Turner, F.J. (1980) Metamorphic Petrology, McGraw Hill, New York.

Yardley, B.W.D. (1989) An introduction to Metamorphic Petrology, Longman Scientific and Technical, New York.

Philopotts, A.R. (1994) Principles of Igneous and Metamorphic Petrology, Prentice Hall. Bhaskar Rao, B. (1986) Metamorphic Petrology, IBH & Oxford.

Kretz, R. (1994) Metamorphic Crystallization, John Wiley.

Blatt, H. and Tracy, R.J. (1996) Petrology (Igneous, Sedimentary, Metamorphic), W.H. Freeman and Co., New York.

Bucher, K. and Frey, M. (2002) Petrogenesis of Metamorphic Rocks (7th Rev. Ed.), Springer-Verlag.

Powell, R. (1978) Equilibrium thermodynamics in Petrology: An Introduction, Harper and Row Publ., London.

Spear, F.S. (1993) Mineralogical Phase Equilibria and pressure – temperature – time Paths, Mineralogical Society of America.

Wood, B.J. and Fraser, D.G. (1976) Elementary Thermodynamics for Geologists, Oxford University Press, London.

Stuwe, K. (2007) Geodynamics of the Lithosphere. Springer-

Verlag. Spry, A. (1976) Metamorphic Textures, Pergamon Press.

Winter, J.D. (2001) An introduction to Igneous and Metamorphic Petrology, Prentice Hall.

Yardley, B.W.D., Mackenzie, W.S. and Guilford, C. (1995) Atlas of Metamorphic Rocks and their textures, Longman Scientific and Technical, England.

Geological Mapping:

Mathur, S.M. (2001) Guide to Field Geology, Prentice-Hall, New Delhi

Compton, R.R. (1962) Manual of Field Geology. John Wiley and Sons,

Inc. Lahi, F.H. (1987) Field Geology, CBS Publishers.

Forrester, J.D. (1957) Principles of Field Geology and Mining Geology. John Wiley.

PSCGEOT04
Stratigraphy and Indian Geology

Unit I:

Approaches to measurement of geological time; Stratigraphic Principles and concept of Litho, Bio and Chrono Stratigraphy, brief idea about sequence, magneto- seismic- chemo- and event stratigraphy; Stratigraphic correlations; Precambrian chronostratigraphy of Aravalli craton, Dharwar craton, Eastern Ghats mobile belt, Bastar Craton, Southern Granulite belt and Singhbhum craton.

Unit II:

Proterozoic stratigraphy of Cuddapah, Vindhyan, Godavari Supergroup and their equivalents; Precambrian/Cambrian boundary. Concept, classification, fauna, flora and age limits of Gondwana Supergroup and related paleogeography, paleoclimate, depositional characteristics and igneous activities.

Unit III:

Classification, depositional characteristics, fauna, and flora of Triassic, Jurassic and Cretaceous systems in major basins of India; Stratigraphy of Deccan Trap, Permian/Triassic boundary.

Unit IV:

Classification, depositional characteristics, fauna, and flora of the Palaeogene, Neogene and Quaternary systems and their equivalents in India; Epoch boundaries of the Cenozoic in India. Cretaceous/Tertiary boundary. Paleogene/ Neogene boundary.

Practicals:

Study of rocks in hand specimens from known Indian stratigraphic horizons; Exercises on stratigraphic classification and correlation, sequence, magneto and seismic stratigraphic interpretations; Study and understanding of plate-movements through important periods during Phanerozoic eon; Evolution of ocean systems during Phanerozoic.

Books Recommended:

Boggs, S. (2001) Principles of Sedimentology and Stratigraphy, Prentice Hall.

Danbar, C.O. and Rodgers, J. (1957) Principles of Stratigraphy, John Wiley and Sons.

Doyle, P. and Bennett. M.R. (1996) Unlocking the Stratigraphic Record, John Wiley and Sons.

Krishnan, M.S. (1982) Geology of India and Burma, C.B.S. Publ. and Distributors, Delhi.

Naqvi, S.M. and Rogers, J.J.W. (1987) Precambrian Geology of India, Oxford University Press.

Pascoe, E.H. (1968) A Manual of the Geology of India and Burma (Vols.I-IV), Govt. of India Press, Delhi.

Pomerol, C. (1982) The Cenozoic Era: Tertiary and Quaternary, Ellis Harwood Ltd., Halsted Press.

Schoch, Robert, M. (1989) Stratigraphy: Principles and Methods, Van Nostrand Reinhold, New York.

Ramakrishnan, M. and Vaidyanadhan, R. (2008) Geology of India, Vol.1, Geological Society of India, Bangalore.

Vaidyanadhan, R. and Ramakrishnan, M. (2008) Geology of India, Vol.2, Geological Society of India, Bangalore.

M.Sc. GEOLOGY

Semester II

Core	Theory / Practical	Teaching Scheme (Hrs/ week)			Credits	Examination Scheme					
		Th	Pr.	Total		Duration (Hrs)	Max. Marks		Total Marks	Min. Passing Marks	
							External	Internal		Th	Pr.
PSCGEO T05	PSGET05 Sedimentology, Geostatistics and Computer Application in Geology (3+1)	4		4	4	3	80	20	100	40	
PSCGEO T06	PSGET06 Paleontology and Applied Paleobiology (3+1)	4		4	4	3	80	20	100	40	
PSCGEO T07	PSGET07 Geochemistry & Instrumentation Techniques (3+1)	4		4	4	3	80	20	100	40	
PSCGEO T08	PSGET06 Structural Geology, Geodynamics & Tectonics (3+1)	4		4	4	3	80	20	100	40	
Pract. – III PSCGEO OP03	PSGEP03 Sedimentology, Geostatistics, Computer Application in Geology, Paleontology and Applied Paleobiology (SGCPAP) (Marks: 75 Pract. Exam. + 05 viva-voce + 20 Internal Assessment and Class Record)		8	8	4	3	80	20	100		40
Pract.- IV PSCGEO OP04	PSGEP04 Geochemistry, Structural		8	8	4	3	80	20	100		40

	Geology and Geological Field Work and Mapping (Marks: 55 Pract. Exam + 05 Viva-voce + 20 Field Work & Mapping + 20 Internal Assessment and Class Records)										
Seminar	Seminar 2	2		2	1	---		25	25	10	
	Total	18	16	34	25		480	145	625	170	80

FIELD WORK:

Each candidate must carry out field work of 10 to 20 days duration in igneous / sedimentary / metamorphic (including structurally deformed) terrain. The field report should be based on the mapping as well as laboratory work on the rock samples collected during the field work. The field work should be treated as a part of practical II examination of semester II and the field report shall be assessed by field excursion In-charge.

Sedimentology, Geostatistics and Computer Application in Geology

Unit I:

Liberation and flux of sediments, rock cycle; Texture of sedimentary rocks and their significance; Processes of sediment transport; Classification and composition of conglomerate, sandstones, shale and carbonate rocks; Sedimentary structures.

Unit II:

Paleocurrent, heavy mineral study and provenance; Diagenesis - physical and chemical, processes and evidences of diagenesis in sandstones, mud rocks and carbonate rocks; Study of evaporites such as gypsum, anhydrite and halite; Detailed study of siliceous, phosphatic and ferruginous rocks.

Unit III:

Facies analysis; Sedimentary environments and facies: Continental – Alluvial, lacustrine, desert-aeolian and glacial; Transitional and Marine; Sedimentary basins of India- Precambrian-Proterozoic, Gondwana, post-Gondwana and Quaternary sedimentation.

Unit IV:

Arithmetic mean, Mode, Median, Range, Variance, Frequency, Skewness, Kurtosis, Standard deviation, Probability. Distributions: Binomial, Poisson, Normal, Gamma, Exponential, Hypergeometric, Multinomial, Chi-square. Application of geostatistical techniques to earth sciences. Use of computers and software as tools in the areas of geological problem-solving, report-writing, and presentations; Brief idea about computer software used in earth sciences such as Archinfo, ArcGIS, Elvis, Mapinfo, Autocad, GCD-kit, Rockware, Rockworks, Igpct, Petrograf, Surfer, Aquachem, Statpack, Tilia, Past etc.

Practicals:

Sedimentology:

Detailed study of clastic and non-clastic rocks in hand specimens; Study of assemblages of sedimentary structures in context of their paleoenvironmental significance; Microscopic examination of important rock-types; Heavy mineral analyses; Grain-size analyses; Plotting of size-distribution data as frequency and cumulative curves, computation of statistical parameters and interpretation; Staining test.

Geostatistics and Computer Application in Geology:

Computation of various statistical parameters for a given data; student test, chi-square test; least square method; Statistical models; Practical training in data analysis using different computer softwares available in the department.

Books Recommended:**Sedimentary petrology:**

- Blatt, H., Middleton, G.V. and Murray, R.C. (1980) *Origin of Sedimentary Rocks*, Prentice-Hall Inc.
- Collins, J.D. and Thompson, D.B. (1982) *Sedimentary Structures*, George Allen and Unwin, London.
- Lindholm, R.C. (1987) *A Practical Approach to Sedimentology*, Allen and Unwin, London.
- Miall, A.D. (2000) *Principles of Basin Analysis*, Springer-Verlag.
- Pettijohn, F.J. (1975) *Sedimentary Rocks* (3rd Ed.), Harper and Row Publ., New Delhi.
- Reading, H.G. (1997) *Sedimentary Environments and facies*, Blackwell Scientific Publication.
- Reineck, H.E. and Singh, I.B. (1973) *Depositional Sedimentary Environments*, Springer-Verlag.
- Selley, R.C. (2000) *Applied Sedimentology*, Academic Press.
- Tucker, M.E. (1981) *Sedimentary Petrology: An Introduction*, Wiley and Sons, New York.
- Tucker, M.E. (1990) *Carbonate Sedimentology*, Blackwell Scientific Publication.
- Hota, R.N. (2011) *Practical Approach to Petrology*, CBS Publisher and Distributors Pvt Ltd., New Delhi

Geostatistics/ Statistical Methods in Geology:

- Pitman, J. (1993) *Probability*, Springer Verlag, (also Narosa Publishers).
- Creighton, J.H.G. (1994) *First course in probability models and statistical inference*, Springer Verlag.
- Davis, J.G. (1986) *Statistics and data analysis in geology*, John Wiley.
- Walpole, R.E. and Myers, R.H. (1989) *Probability and statistics for engineers and scientists*, Macmillan Publ. Co.
- Johnson, R.A. and Wichern, D.W. (1982) *Applied multivariate statistical analysis*, Prentice Hall Inc., New Jersey.
- Cooley, W.W. and Lohnes, P.R. (1971) *Multivariate data analysis*, John Wiley and Sons.
- Morrison, D.F. (1967) *Multivariate statistical methods*, McGraw-Hill.
- Pandalai, H.S. and Saraswati, P.K. (Eds.) (2000) *Geological data analysis: Statistical Methods*. Hindusthan Publishing Corporation (India), New Delhi.
- Spiegel, M.R. (1982) *Probability and Statistics*, Schaums Outline Series, McGraw-Hill Int., Singapore, Asian Student Edn.
- Kubackova, L., Kubacek, L. and Kukuca, J. (1987) *Probability and Statistics in Geodesy and Geophysics*, Elsevier.
- Journel, A.G. and Huijbregts, Ch. (1978) *Mining Geostatistics*, Academic Press.
- Armstrong, M. (1998) *Basic linear geostatistics*, Springer Verlag, Berlin.
- Isaaks, E.A. and Srivastava, R.M. (1990) *An Introduction to Geostatistics*, Oxford University Press.
- Journel, A.G. and Huijbregts, C. (1978) *Mining Geostatistics*, Academic Press, London.
- Chiles, J.P. and Delfiner, P. (1999) *Geostatistics: Modeling Spatial Uncertainty*, John Wiley & Sons, New York.

Computer Application in Geology:

No Textbook - only handouts and web pages

PSCGEOT06
Paleontology and Applied Paleobiology

Unit I:

Types of fossils and taphonomy; Origin of life; Modern Concept of systematic of fossils; Biostratigraphy; Concept of species and type specimens; speciation and radiation; Types of growth; Brief morphology and evolutionary trends in Bivalves, Gastropods, Cephalopods, Brachiopods, Echinoids, Crinoids, Graptolites, Corals and Trilobites; Ichnofossils, their modes of preservation and significance.

Unit II:

Vertebrate life through ages; Evolution and Extinction of dinosaurs, Indian dinosaurs; Mammalia-Origin and evolution of the mammals, mammalian characters; Siwalik mammals; Evolutionary changes in Equidae; Evolution of Homo; Major extinction and origination through ages.

Unit III:

Approach to paleobotany; Classification of fossil plants; Evolutionary trend in angiosperms plants; A brief idea about Indian pre-Gondwana; Gondwana and Paleogene flora; Application of paleobotany in assessing paleoclimate and paleoenvironment; Dendrochronology and its application; Introduction to important animal and plant microfossils.

Unit IV:

Concept of evolution and extinction; Micro and macro-evolution, evolutionary lineages and their application to biochronology; Phylogenetic analysis; Molecular biology and its application Distribution, migration and dispersal of organisms applied to paleobiogeography and plate-tectonics; Fossil record applied to sequence stratigraphy and depositional environment; Paleoecological and paleoclimatological significance of fossils. Stable isotope studies in paleoclimatology; Applications of important mega and micro fossils in the exploration of coal and petroleum.

Practicals:

Study of modes of preservation of fossils; Study of the morphological characters of some important invertebrate fossils belonging to Brachiopoda, Bivalvia, Gastropoda, Nautiloidea, Ammonoidea, Trilobita, Echinoidea and Corals; Study of important vertebrate fossils; Study of important trace fossils and microfossils; Study of important Indian Gondwana and Paleogene flora; Shell petrography of bivalves and brachiopods; Measurements of dimensional parameters and preparation of elementary bivariate growth curves and scatter plots. Paleogeographic maps.

Books Recommended:

General Paleontology

- Boardman, R.S., Cheethan, A.M. and Rowell, A.J. (1988) Fossil Invertebrates, Blackwell.
Clarkson, E.N.K. (1998) Invertebrate Paleontology and Evolution, Allen and Unwin, London.
Dobzhansky, Ayala, Stebbins and Valentine (1977) Evolution, Freeman.
Horowitz, A.S. and Potter, E.D. (1971) Introductory Petrography of Fossils, Springer Verlag.

Mayr, E. (1971) Population, Species and Evolution, Harvard.

Prothero, D.R. (2004) Bringing Fossil to Life – An Introduction to Paleontology (2nd Ed.), McGraw Hill.
Raup, D.M. and Stanley, S.M. (1985) Principles of Paleontology, CBS Publishers, New Delhi.

Smith, A.B. (1994) Systematics and Fossil Record – Documenting Evolutionary Patterns, Blackwell.

Stearns, C.W. and Carroll, R.L. (1989) Paleontology – the record of life, John Wiley.

Applicative Paleobiology

Allison, P.A. and Briggs, D.E.G. (1991) Taphonomy. Releasing the data locked in the fossils record, Plenum Press.

Dodd, J.R. and Stanta, R.J. (1981) Palaeoecology concepts and applications, John Wiley and Sons.

Patnaik, R. (2003) Reconstruction of Upper Siwalik palaeoecology and palaeoclimatology using microfossil palaeocommunities, Palaeogeography, Palaeoclimatology, Palaeoecology, Vol. 197.

Bergland, B.E. (1986) Handbook of Holocene paleoecology & paleohydrology, John Wiley, New York.

Jones, T.P. and Rowe, T.P. (1999) Fossil Plants and Spores Modern Techniques, Geological Society of London.

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

Seaward, A.C. (1991) Plant fossils, Today's and Tomorrow, New Delhi.

Agashe, Shipad N. (1995) Paleobotany, Oxford and IBH Publ., New Delhi.

Stewart, Wilson N. and Rothwell, Gar W. (1993) Paleobotany and the Evolution of Plants, Cambridge University Press.

Dodd, J. Robert and Stanton, Robert. J. Jr. (2012) Paleocology: Concepts and Applications. Second Edition (Reprint), Wiley India Pvt. Ltd., New Delhi

PSCGEOT07
Geochemistry and Instrumentation Techniques

Unit I:

Principles of geochemistry; Origin and abundance of elements in the solar system and Earth; Chemical composition and properties of atmosphere, hydrosphere and lithosphere; Geochemical cycles; Atomic structures and properties of elements in the periodic table with special reference to major, minor and trace elements (transition, LILE, HFSE) including rare earth elements; Geochemical classification of elements.

Unit II:

Radiogenic isotopes: Basic principles, decay scheme and radiometric dating methods of K-Ar, Ar – Ar, U-Pb, Rb–Sr and Sm-Nd in rocks; Petrogenetic implications of isotope study eg. Sm-Nd and Rb-Sr; Radiometric dating of single minerals and whole rocks; Stable isotope geochemistry of carbon, oxygen, hydrogen and sulphur and their applications to geology; Geochemistry of U and Th in rocks, minerals and sediments.

Unit III:

Laws of thermodynamics; concept of internal energy, heat capacity, enthalpy and entropy; Gibbs free energy and chemical potential; fugacity and activity; Raoult's law and Henry's law; Principles of geothermobarometry; Principles of ionic substitution in minerals; Element partitioning between minerals and melts, in mineral assemblages /rock formation and their use in pressure-temperature estimation; Geochemistry of natural waters and sedimentary rocks; Mineral stability in Eh-pH diagram; Elemental mobility in surface environment; Geochemical processes involved in rock weathering and soil formation; Metamorphism as a geochemical phenomenon.

Unit IV:

Thin section and polished section making. Sample etching, staining and model count techniques. Principle and geological application of Cathodoluminescence, Thermoluminescence, Spectrophotometry, Flame photometry, Atomic absorption spectrophotometry; Inductively coupled plasma – Atomic emission spectrometry, Optical emission spectrometry and Mass spectrometry; X ray Fluorescence spectrometry; Scanning and Transmission electron microscopy; Instrumental Neutron Activation Analysis (INAA); Isotope dilution technique; Electron Probe Microanalysis (EPMA), X ray diffractometry; Thermal Ionisation and gas source mass spectrometry.

Practicals:

Rock analyses (rapid method of silicate analysis) and FeO determination by titration method; Determination of loss on ignition (LOI) of rock samples; Presentation of analytical data; Preparation of classificatory and variation diagrams and their interpretation; Plotting of REE data and their interpretation; Calculation of weathering indices in soil and sediments; Wet assay of Cu, Pb, Zn, Al, Cr, Fe, Mn, Ti, Na, K etc.

Books Recommended:

Geochemistry:

- Allegre, C.J. and Michard, G. (1974) Introduction to Geochemistry, Reidel, Holland.
- Anderson, G.M. (2005) Thermodynamics of Natural Systems, Cambridge University Press.
- Winter, J.D. (2001) Introduction to Igneous and Metamorphic Petrology. Prentice-Hall.
- Bloss, F.D. (1971) Crystallography and Crystal Chemistry, Holt, Rinehart, and Winston, New York.
- Drever, J.I. (1997) The Geochemistry of Natural Waters, 3rd Edn., Prentice Hall.
- Evans, R.C. (1964) Introduction to Crystal Chemistry, Cambridge Univ. Press.
- Faure, G. (1998) Principles and applications of geochemistry, 2nd Edn., Prentice Hall, New Jersey, 593p.
- Faure, G. (1986) Principles of Isotope Geology, 2nd Edn., John Wiley.
- Hoefs, J. (1980) Stable Isotope Geochemistry, Springer-Verlag.
- Klein, C. and Hurlbut, C.S. (1993) Manual of Mineralogy, John Wiley and Sons, New York.
- Krauskopf, K.B. (1967) Introduction to Geochemistry, McGraw Hill.
- Mason, B. and Moore, C.B. (1991) Introduction to Geochemistry, Wiley Eastern.
- Rollinson, H.R. (1993) Using geochemical data: Evaluation, Presentation, Interpretation, Longman U.K.
- Wood, B.J. and Fraser, D.G. (1977) Elementary Thermodynamics for Geologists, Oxford University Press, London.
- Rastogy, R.P. and Mishra, R.R. (1993) An Introduction to Chemical Thermodynamics, Vikash Pub. House.
- Anderson, G.M. and Crerar, D.A. (1993) Thermodynamics in Geochemistry- the equilibrium model, Oxford University Press, New York.
- Fletcher, P. (1993) Chemical thermodynamics for earth sciences. Longman Scientific and Technical, London.
- Glasstone, S. (1947) Thermodynamics for Chemists, East and West Pub.

Instrumentation Techniques:

- Shapiro, L. and Brannock, W.W. (1975) Rapid analysis and silicates, Carbonate and phosphate rocks, USGS Bulletin, 1144 A.
- Jeffrey, P.G. (1970) Chemical methods of rock analysis. Pergamon Press.
- Perry, D.L. (1990) Instrumental Surface Analysis of Geologic Materials, VCH Pub. Inc., New York.
- Hota, R.N. (2011) Geochemical Analysis, CBS Publisher and Distributors Pvt Ltd., New Delhi.

PSCGEOT08
Structural Geology, Geodynamics and Tectonics

Unit I:

Theories of rock failure; Mechanical principles, properties of rocks and their controlling factors; Concept of stress and strain: Classes of stress; stress ellipsoid; Mohr circle construction; Stress trajectory; Two-dimensional stress analyses; Stress-strain relationship; Strain parameters, Types of strain ellipses and ellipsoids and their properties; Theory of deformation in two and three dimensions; Strain Analysis: Graphical representations of strain (Flinn, Ramsay, and Nadai-Hossack plots), progressive deformation, significance of geological structures in relation to strain, methods of strain measurements in naturally deformed rocks.

Unit II:

Description of folds; Mechanisms of folding (buckling, bending and flow), fold development and distribution of strains in folds; Biot's law - strain within buckled layer, similar fold and shear fold, kink bands, chevron folds and conjugate fold; Decollement; Cleavage, lineation, boudinage; Deformation of linear structures and planar structures by flexural slip folding and shear folding; Superimposed folding, Type 1, 2, 3 fold interference patterns; Geometric and genetic classification of folds, Ramasay's classification of folds.

Concept of petrofabrics and symmetry; Types of fabric (planar and linear fabrics in deformed rocks), fabric element, and interpretation of fabric data on microscopic and megascopic scale; Field and laboratory techniques, graphical treatment.

Unit III:

Stereographic projections of linear and planar structures, π and β diagrams; Geometrical analysis of simple and complex structures on macroscopic scale; Thin-skinned deformation; Fractures and joints: their classification, nomenclature, relationships and significance; Mechanism of rock fracturing; Development of cleavage, lineation, foliation and schistosity in rocks and their mechanism; Faults: Causes, mechanism and dynamics of faulting, strike-slip faults, normal faults, thrust faults and nappe; Unconformities and their significance; Shear Zones: Brittle and ductile shear zones, geometry and products of shear zones; Mylonites and cataclasites: their origin and significance.

Unit IV:

Structure of the earth (crust, mantle and core), thermal structure of the earth; Concept of continental drift, supercontinents, sea-floor spreading, hot-spots and plumes, diapirs and salt-domes; Cratons and mobile belts; Plate tectonics- recent advances, pros and cons; Geology of plate boundaries, Wilson cycle, plate motions and driving forces; Precambrian tectonics; Phanerozoic

plate tectonics; Evolution of Indian subcontinent, Ur to Rodinia to Gondwanaland; Evolution of the Himalayas & Indian Ocean; Seismotectonics and earthquakes in India; Tectonics of the Indian plate.

Practicals:

Structural Geology

Preparation and interpretation of geological maps and cross sections; Structure contour maps, isopach maps and other facies maps, balanced cross-section, their importance in unraveling the geological history; Structural problems concerning economic deposit based on orthographic and stereographic projections; Recording and plotting of the field data; Study of deformed structures in hand specimens; Strain estimation from the data collected from the field; Study of dip-isogons from the fold profiles; Analysis of stress using Mohr Circle construction.

Books Recommended:

- Ghosh, S.K. (1993) Structural Geology: Fundamental and Modern Developments, Pergamon Press.
- Hobbs, B.E., Means, W.D. and Williams, P.F. (1976) An outline of Structural Geology, John Wiley and Sons, New York.
- Ramsay, J.G. (1967) Folding and fracturing of rocks, McGraw Hill.
- Ramsay, J.G. and Huber, M.I. (1983) Techniques of Modern Structural Geology, Vol. I, Strain Analysis, Academic Press.
- Ramsay, J.G. and Huber, M.I. (1987) Techniques of Modern Structural Geology, Vol. II, Folds and Fractures, Academic Press.
- Ramsay, J.G. and Huber, M.I. (2000) Techniques of Modern Structural Geology, Vol. III (Application of continuum mechanics), Academic Press.
- Turner, F.J. and Weiss, L.E. (1963) Structural analysis of Metamorphic Tectonites, McGraw Hill.
- Marshak, S. and Mitra, G. (1988) Basic methods of Structural Geology, Prentice-Hall, New Jersey.

Geodynamics and Tectonics:

- Condie, K.C. (1989) Plate Tectonics and Crustal Evolution, 3rd Ed., Pergamon, Oxford
- Press. Kearey Phillips and Vine, F.J. (1996) Global Tectonics, Blackwell Science, Oxford.
- Windley, B.F. (1977) The Evolving Continents, John Wiley and Sons, New York.
- Moore, E and Twiss, R.J. (1995) Tectonics. Freeman.
- Keary, P., Klepeis, K.A. and Vine, F.J. (2012) Global Tectonics. Third Edition (Reprint), Wiley-Blackwell, Wiley India Pvt. Ltd.
- Storetvedt, K.N. (1997) Our Evolving Planet: Earth's History in New Perspective. Bergen (Norway), Alma Mater Forlag.
- Summerfield, M.A. (2000) Geomorphology and Global Tectonics, Wiley.
- Patwardhan, A.M. (1999) The Dynamic Earth System, Prentice-Hall, New Delhi
- Gass, I.G. (1982) Understanding the Earth, Artemis Press (Pvt) Ltd. U.K.
- Moore, Eldridge M. and Twiss, Robert J. (1995) Tectonics, Freeman and Company.
- Valdiya, K.S. (1984) Aspects of Tectonics -Focus on south central Asia, Tata McGraw-Hill.
- Valdiya, K.S. (1998) Dynamic Himalaya. Universities Press, Hyderabad.
- Valdiya, K.S. (2010) The making of India Geodynamic Evolution, Macmillan Publishers India Ltd.