Geothermal Education in Europe and other Continents

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ABSTRACT

The paper presents oriented or related geothermal education programs offered in different countries, at graduate and postgraduate levels, with as many details as available, such as curricula and course content. This will allow for a comparison between what is currently offered in Europe and on other continents, and a basis for further recommendations on what should be changed in the European countries in the near future in order to have well trained specialists needed for the expected development of the geothermal energy utilization.

1. STANFORD UNIVERSITY

Bachelor Program: Energy Resources Engineering (Petroleum Engineering)

ENERGY 101. Energy and the Environment—(Same as EARTHSYS 101.) Energy use in modern society and the consequences of current and future energy use patterns. Case studies illustrate resource estimation, engineering analysis of energy systems, and options for managing carbon emissions. Focus is on energy definitions, use patterns, resource estimation, pollution. Recommended: MATH 21 or 42, ENGR 30. GER:DB-EngrAppSci

ENERGY 102. Renewable Energy Sources and Greener Energy Processes—(Same as EARTHSYS 102.) The energy sources that power society are rooted in fossil energy although energy from the core of the Earth and the sun is almost inexhaustible; but the rate at which energy can be drawn from them with today's technology is limited. The renewable energy resource base, its conversion to useful forms, and practical methods of energy storage. Geothermal, wind, solar, biomass, and tidal energies; resource extraction and its consequences. Recommended: 101,
MATH 21 or 42. GER:DB-EngrAppSci

ENERGY 104. Technology in the Greenhouse—Technologies that might be employed to reduce emissions of greenhouse materials, such as carbon dioxide, methane, nitrous oxide, and black soot, produced by the generation and use of energy. Sources of greenhouse materials in the current energy mix and evidence for global geochemical and climate changes. Advantages and limitations of technologies to reduce emissions. Examples include renewable sources such as wind and solar energy, more efficient use of energy, hydrogen, capture and storage of carbon dioxide, and nuclear power.

ENERGY 120. Fundamentals of Petroleum Engineering—(Same as ENGR 120.) Lectures, problems, field trip. Engineering topics in petroleum recovery; origin, discovery, and development of oil and gas. Chemical, physical, and thermodynamic properties of oil and natural gas. Material balance equations and reserve estimates using volumetric calculations. Gas laws. Single phase and multiphase flow through porous media. GER:DB-EngrAppSci

ENERGY 121. Fundamentals of Multiphase Flow—(Same as 221.) Multiphase flow in porous media. Wettability, capillary pressure, imbibition and drainage, Leverett J-function, transition zone,

vertical equilibrium. Relative permeabilities, Darcy's law for multiphase flow, fractional flow equation, effects of gravity, Buckley-Leverett theory, recovery predictions, volumetric linear scaling, JBN and Jones-Rozelle determination of relative permeability. Frontal advance equation, Buckley-Leverett equation as frontal advance solution, tracers in multiphase flow, adsorption, three-phase relative permeabilities. GER:DB-EngrAppSci

ENERGY 130. Well Log Analysis I—For earth scientists and engineers. Interdisciplinary, providing a practical understanding of the interpretation of well logs. Lectures, problem sets using real field examples: methods for evaluating the presence of hydrocarbons in rock formations penetrated by exploratory and development drilling. The fundamentals of all types of logs, including electric and non-electric logs.

ENERGY 155. Undergraduate Report on Energy Industry Training—On-the-job practical training under the guidance of experienced, on-site supervisors. Required report detailing work activities, problems, assignments and key results. Prerequisite: written consent of instructor.

ENERGY 161. Statistical Methods for the Earth and Environmental Sciences: Geostatistics—(Same as GES 161.) Statistical analysis and graphical display of data, common distribution models, sampling, and regression. The variogram as a tool for modeling spatial correlation; variogram estimation and modeling; introduction to spatial mapping and prediction with kriging; integration of remote sensing and other ancillary information using co-kriging models; spatial uncertainty; introduction to geostatistical software applied to large environmental, climatological, and reservoir engineering databases; emphasis is on practical use of geostatistical tools. GER:DB-NatSci

ENERGY 167. Engineering Valuation and Appraisal of Oil and Gas Wells, Facilities, and Properties—(Same as 267.) Appraisal of development and remedial work on oil and gas wells; appraisal of producing properties; estimation of productive capacity, reserves; operating costs, depletion, and depreciation; value of future profits, taxation, fair market value; original or guided research problems on economic topics with report. Prerequisite: consent of instructor. GER:DB-EngrAppSci

ENERGY 175. Well Test Analysis—Lectures, problems. Application of solutions of unsteady flow in porous media to transient pressure analysis of oil, gas, water, and geothermal wells. Pressure buildup analysis and drawdown. Design of well tests. Computer-aided interpretation.

ENERGY 180. Oil and Gas Production Engineering—(Same as 280.) Design and analysis of production systems for oil and gas reservoirs. Topics: well completion, single-phase and multi-phase flow in wells and gathering systems, artificial lift and field processing, well stimulation, inflow performance. Prerequisite: 120. Recommended: 130. GER:DB-EngrAppSci, WIM

ENERGY 192. Undergraduate Teaching Experience—Leading field trips, preparing lecture notes, quizzes under supervision of the instructor. May be repeated for credit.

ENERGY 193. Undergraduate Research Problems—Original and guided research problems with comprehensive report. May be repeated for credit.

ENERGY 194. Special Topics in Energy and Mineral Fluids—May be repeated for credit.

ENERGY 211. Computer Programming in C++ for Earth Scientists and Engineers—(Same as CME 211.) Computer programming methodology emphasizing modern software engineering

principles: object-oriented design, decomposition, encapsulation, abstraction, and modularity. Fundamental data structures. Time and space complexity analysis. The basic facilities of the programming language C++. Numerical problems from various science and engineering applications.

ENERGY 221. Fundamentals of Multiphase Flow—(For graduate students; see 121.)

ENERGY 222. Advanced Reservoir Engineering—Lectures, problems. General flow equations, tensor permeabilities, steady state radial flow, skin, and succession of steady states. Injectivity during fill-up of a depleted reservoir, injectivity for liquid-filled reservoirs. Flow potential and gravity forces, coning. Displacements in layered reservoirs. Transient radial flow equation, primary drainage of a cylindrical reservoir, line source solution, pseudo-steady state. Prerequisite: 221. May be repeated for credit.

Master Program: Energy Resources Engineering

ENERGY 223. Reservoir Simulation—Fundamentals of petroleum reservoir simulation. Equations for multicomponent, multiphase flow between gridblocks comprising a petroleum reservoir. Relationships between black-oil and compositional models. Techniques for developing black-oil, compositional, thermal, and dual-porosity models. Practical considerations in the use of simulators for predicting reservoir performance. Class project. Prerequisite: 221 and 246, or consent of instructor. Recommended: CME 206 (formerly ME 300C).

ENERGY 224. Advanced Reservoir Simulation—Topics include modeling of complex wells, coupling of surface facilities, compositional modeling, dual porosity models, treatment of full tensor permeability and grid nonorthogonality, local grid refinement, higher order methods, streamline simulation, upscaling, algebraic multigrid solvers, unstructured grid solvers, history matching, other selected topics. Prerequisite: 223 or consent of instructor. May be repeated for credit.

ENERGY 225. Theory of Gas Injection Processes—Lectures, problems. Theory of multicomponent, multiphase flow in porous media. Miscible displacement: diffusion and dispersion, convection-dispersion equations and its solutions. Method of characteristic calculations of chromatographic transport of multicomponent mixtures. Development of miscibility and interaction of phase behavior with heterogeneity. May be repeated for credit. Prerequisite: CME 200 (formerly ME 300A).

ENERGY 226. Thermal Recovery Methods—Theory and practice of thermal recovery methods: steam drive, cyclic steam injections, and in situ combustion. Models of combined mass and energy transport. Estimates of heated reservoir volume and oil recovery performance. Wellbore heat losses, recovery production, and field examples.

ENERGY 227. Enhanced Oil Recovery—The physics, theories, and methods of evaluating chemical, miscible, and thermal enhanced oil recovery projects. Existing methods and screening techniques, and analytical and simulation based means of evaluating project effectiveness. Dispersion-onvection-adsorption equations, coupled heat, and mass balances and phase behavior provide requisite building blocks for evaluation.

ENERGY 230. Advanced Topics in Well Logging—(Same as GEOPHYS 230.) State of the art tools and analyses; the technology, rock physical basis, and applications of each measurement.

Hands-on computer-based analyses illustrate instructional material. Guest speakers on formation evaluation topics. Prerequisites: 130 or equivalent; basic well logging; and standard practice and application of electric well logs.

ENERGY 240. Geostatistics for Spatial Phenomena—(Same as GES 240.) Probabilistic modeling of spatial and/or time dependent phenomena. Kriging and cokriging for gridding and spatial interpolation. Integration of heterogeneous sources of information. Multiple-point geostatistics and training image-based stochastic imaging of reservoir/field heterogeneities. Introduction to GSLIB and SGEMS software. Case studies from the oil and mining industry and environmental sciences. Prerequisites: introductory calculus and linear algebra, STATS 116, GES 161, or equivalent.

ENERGY 241. Practice of Geostatistics and Seismic Data Integration—(Same as GEOPHYS 241A.) Students build a synthetic 3D fluvial channel reservoir model with layer depths, channel geometry, and facies-specific petrophysic and seismic properties, stressing the physical significance of geophysical data. Reference data set is sparsely sampled, providing the sample data typically available for an actual reservoir assessment. Geostatistical reservoir modeling uses well and seismic data, with results checked against the reference database. Software provided (GSLIB and SRBtools). Prerequisite: 240. Recommended: experience with Unix, Matlab/C++/Fortran programming.

ENERGY 242. Topics in Advanced Geostatistics—(Same as GES 242.) Conditional expectation theory and projections in Hilbert spaces; parametric versus non-parametric geostatistics; Boolean, Gaussian, fractal, indicator, and annealing approaches to stochastic imaging; multiple point statistics inference and reproduction; neural net geostatistics; Bayesian methods for data integration; techniques for upscaling hydrodynamic properties. May be repeated for credit. Prerequisites: 240, advanced calculus, C++/Fortran.

ENERGY 244. Modeling of 3D Geological Objects with Gocad—Accurate 3D modeling of subsurface structures as prerequisite for decision making. Concepts and methods for modeling the complex geometries and spatial distribution of geological objects. Building 3D models using the Gocad software. The definition and placement of discrete curves and surfaces. Integration of diverse types of data. Flexible volume modeling algorithms used to conform the volume objects to both the structural model and the data.

ENERGY 245. Probability Theory—(Same as GEOPHYS 245.) Probabilistic formulations and solutions to inverse problems. Monte Carlo methods for solving inverse problems. Metropolis algorithm. Deterministic solutions using maximum likelihood, gradient methods. Dealing with prior probability and data uncertainty. Gaussian and non-Gaussian model formulations. Application to Earth Science problems. Prerequisite: introduction to probability theory course.

ENERGY 246. Reservoir Characterization and Flow Modeling with Outcrop Data—(Same as GES 246.) Project addresses a reservoir management problem by studying an outcrop analog, constructing geostatistical reservoir models, and performing flow simulation. How to use outcrop observations in quantitative geological modeling and flow simulation. Relationships between disciplines. Weekend field trip.

ENERGY 247. Stochastic Simulation—Characterization and inference of statistical properties of spatial random function models; how they average over volumes, expected fluctuations, and implementation issues. Models include point processes (Cox, Poisson), random sets (Boolean, truncated Gaussian), and mixture of Gaussian random functions. Prerequisite: 240.

ENERGY 251. Thermodynamics of Equilibria—Lectures, problems. The volumetric behavior of fluids at high pressure. Equation of state representation of volumetric behavior. Thermodynamic functions and conditions of equilibrium, Gibbs and Helmholtz energy, chemical potential, fugacity. Phase diagrams for binary and multicomponent systems. Calculation of phase compositions from volumetric behavior for multicomponent mixtures. Experimental techniques for phase-equilibrium measurements. May be repeated for credit.

ENERGY 255. Master's Report on Energy Industry Training—On-the-job training for master's degree students under the guidance of on-site supervisors. Students submit a report detailing work activities, problems, assignments, and key results. May be repeated for credit. Prerequisite: consent of adviser.

ENERGY 259. Presentation Skills—For teaching assistants in Energy Resources Engineering. Five two-hour sessions in the first half of the quarter. Awareness of different learning styles, grading philosophies, fair and efficient grading, text design; presentation and teaching skills, PowerPoint slide design; presentation practice in small groups. Taught in collaboration with the Center for Teaching and Learning.

ENERGY 260. Groundwater Pollution and Oil Slicks: Environmental Problems in Petroleum Engineering—Sources and types of wastes in petroleum operations. Partitioning of hydrocarbons in soil. Review of single phase flow. Multiphase flow of oil, water, and air. Movement of hydrocarbons in the vadose zone and in the groundwater. Remediation and cleanup techniques: air stripping and sparging, bioremediation, steam flooding, and solvent and surfactant injection. Drilling wastes. The physical processes affecting the spread of oil slicks at sea. Methods for containing and removing the spill and cleaning polluted beaches.

ENERGY 267. Engineering Valuation and Appraisal of Oil and Gas Wells, Facilities, and Properties—(For graduate students; see 167.)

ENERGY 269. Geothermal Reservoir Engineering—Conceptual models of heat and mass flows within geothermal reservoirs. The fundamentals of fluid/heat flow in porous media; convective/conductive regimes, dis persion of solutes, reactions in porous media, stability of fluid interfaces, liquid and vapor flows. Interpretation of geochemical, geological, and well data to determine reservoir properties/characteristics. Geothermal
plants and the integrated geothermal system.

ENERGY 273. Special Topics in Petroleum Engineering

ENERGY 280. Oil and Gas Production Engineering—(For graduate students; see 180.)

ENERGY 281. Applied Mathematics in Reservoir Engineering—The philosophy of the solution of engineering problems. Methods of solution of partial differential equations: Laplace transforms, Fourier transforms, wavelet transforms, Green's functions, and boundary element methods.
Prerequisites: CME 204 or MATH 131, and consent of instructor.

ENERGY 284. Optimization: Deterministic and Stochastic Approaches— Deterministic and stochastic methods for optimization in earth sciences and engineering. Linear and nonlinear regression, classification and pattern recognition using neural networks, simulated annealing and genetic algorithms. Deterministic optimization using non-gradient-based methods (simplex) and

gradient-based methods (conjugated gradient, steepest descent, Levenberg-Marquardt, Gauss-Newton), eigenvalue and singular value decomposition. Applications in petroleum engineering, geostatistics, and geophysics. Prerequisite: CME 200 or consent of instructor.

ENERGY 285. Research Seminars—Focused study in research areas within the department. Graduate students may participate in advanced work in areas of particular interest prior to making a final decision on a thesis subject. May be repeated for credit. Prerequisite: consent of instructor.

ENERGY 285A. SUPRI-A Research Seminar: Enhanced Oil Recovery

ENERGY 285B. SUPRI-B Research Seminar: Reservoir Simulation

ENERGY 285C. SUPRI-C Research Seminar: Gas Injection Processes

ENERGY 285D. SUPRI-D Research Seminar: Well Test Analysis

ENERGY 285F. SCRF Research Seminar: Geostatistics and Reservoir Forecasting—Stanford Center for Reservoir Forecasting.

ENERGY 285G. Geothermal Reservoir Engineering Research Seminar

ENERGY 285H. SUPRI-HW Research Seminar: Horizontal Well Technology

ENERGY 290. Numerical Modeling of Fluid Flow in Heterogeneous Porous Media—How to mathematically model and solve elliptic partial differential equations with variable and discontinuous coefficients describing flow in highly heterogeneous porous media. Topics include finite difference and finite volume approaches on structured grids, efficient solvers for the resulting system of equations, Krylov space methods, preconditioning, multi-grid solvers, grid adaptivity and adaptivity criteria, multiscale approaches, and effects of anistropy on solver efficiency and accuracy. MATLAB programming and application of commercial or public domain simulation packages. Prerequisite: CME 200, 201, and 202, or equivalents with consent of instructor.

ENERGY 300. Earth Sciences Seminar—(Same as EARTHSYS 300, GES 300, GEOPHYS 300, IPER 300.) Required for incoming graduate students except coterms. Research questions, tools, and approaches of faculty members from all departments in the School of Earth Sciences. Goals are: to inform new graduate students about the school's range of scientific interests and expertise; and introduce them to each other across departments and research groups. Two faculty members present work at each meeting. May be repeated for credit.

ENERGY 355. Doctoral Report on Energy Industry Training—On-the-job training for doctoral students under the guidance of on-site supervisors. Students submit a report on work activities, problems, assignments,and results. May be repeated for credit. Prerequisite: consent of adviser.

ENERGY 359. Teaching Experience in Energy Resources Engineering—For TAs in Energy Resources Engineering. Course and lecture design and preparation; lecturing practice in small groups. Classroom teaching practice in na Energy Resources Engineering course for which the participant is the TA (may be in a later quarter). Taught in collaboration with the Center for Teaching and Learning.

ENERGY 360. Advanced Research Work in Petroleum Engineering—Graduate-level work in experimental, computational, or theoretical research. Special research not included in graduate degree program. May be repeated for credit.

ENERGY 361. Master's Degree Research in Petroleum Engineering—Experimental, computational, or theoretical research. Advanced technical report writing. Limited to 6 units total.

ENERGY 362. Engineer's Degree Research in Petroleum Engineering—Graduate-level work in experimental, computational, or theoretical research for Engineer students. Advanced technical report writing.Limited to 15 units total, or 9 units total if 6 units of 361 were previously credited.

ENERGY 363. Doctoral Degree Research in Petroleum Engineering—Graduate-level work in experimental, computational, or theoretical research for Ph.D. students. Advanced technical report writing.

ENERGY 365. Special Research Topics in Petroleum Engineering—Graduate-level research work not related to report, thesis, or dissertation. May be repeated for credit.

2. UNIVERSITY OF ALABAMA

Bachelor Program: Mechanical Engineering

ME 215 Thermodynamics I. (3-0) Three hours.

ME 283 Modern Manufacturing Laboratory. (0-4) One hour.
Operational experience with manual and computer-controlled machining operations. Interaction with machinist technology students in the design and fabrication of a machine part.

ME 305 Thermodynamics II. (3-0) Three hours.
Prerequisite: ME 215.
Corequisite: MATH 238.
Thermodynamic cycle analysis; Maxwell relations and development of thermodynamic properties; and thermodynamics of non-reacting and reacting mixtures and chemical equilibrium.

ME 308 Propulsion Systems. (3-0) Three hours.
Prerequisite: ME 305.
Basic propulsion dynamics, thermodynamics of fluid flow, combustion kinetics, air-breathing engines, rockets, design criteria, performance, and advanced propulsion systems.

ME 309 Heat Transfer. (3-0) Three hours.
Prerequisite: ME 215.
Corequisite: ESM 311.
Steady and unsteady conduction, convection, and radiation heat transfer.

ME 313 Theory and Design of Compressible Flow Systems. (3-0) Three hours.
Prerequisites: ME 215 and ESM 311.
Fundamentals of one-dimensional compressible flow including nozzles, friction and heating effects, shock waves, and expansion waves. Application of the basic theory in a design project.

ME 349 Engineering Analysis. (3-0) Three hours.
Prerequisites: GES 126 and MATH 238.
Elements of statistics, matrix algebra, numerical analysis, and partial differential equations applied to engineering problems; includes extensive computer applications.

ME 350 Static Machine Components. (3-0) Three hours.
Prerequisites: ESM 250, ESM 251, and DR 133.
Corequisite: MTE 271.
The analysis of stresses of machine elements and the topics of fatigue strength, wear, and failure criteria. Also includes the design of fasteners covering both bolted and welded joints.

ME 360 Control and Instrumentation Components. (2-3) Three hours.
Prerequisites: ECE 320 (or ECE 225), ESM 250, and ME 110.
Introduction to selection and use of electrical, pneumatic, and other components of mechanical system instrumentation and control. Specific components include modern electrical measurement devices, signal conditioning, force and torque measurement, proximity sensors, AC and DC motors, etc. Writing proficiency is required for a passing grade in this course.

ME 372 Dynamic Systems (also AE 372). (3-0) Three hours.
Prerequisites: MATH 238, ESM 264, and ECE 320 (or ECE 225).
Corequisite: ME 349.
An introduction to the modeling, analysis, and control of dynamic systems. The course takes the student from initial modeling through analysis of the system response and finally into the control of the system. Specific systems include mechanical devices, electrical circuits, and electromechanical systems.

ME 377 Noise Control. (3-0) Three hours.
Prerequisites: MATH 238, PH 106, and junior or senior standing in the College of Engineering.
Physical properties of noise; hearing and noise criteria measurement techniques; and noise-control fundamentals applied to practical problems.

ME 383 Modern Manufacturing Practices. (2-0) Two hours.
Prerequisite: DR 133.
Corequisites: ESM 250, MTE 271, and ME 283.
A survey of classical and modern manufacturing processes. Emphasis is on the selection of materials and manufacturing processes to meet design goals and for manufacturing ease. Students design and oversee the manufacturing of a part.

ME 406 Thermal Power Systems. (3-0) Three hours.
Prerequisite: ME 305.
Study of thermal systems emphasizing large power generation systems. Topics include Rankine and gas turbine cycles, fossil fuels combustion, boiler characteristics, cogeneration, combined cycle plants, environmental effects of power generation, and alternative energy concepts.

ME 407 Heating, Ventilating, and Air-Conditioning. (3-0) Three hours.
Prerequisite: ME 309.
Fundamentals and practice associated with heating, ventilating, and air conditioning; study of heat and moisture flow in structures, energy consumption, human comfort and health; and design of practical systems.

ME 409 Numerical Heat Transfer and Fluid Flow. (3-0) Three hours.
Prerequisites: ESM 311, ME 309, and ME 349; or CHE 253 and CHE 306.
Theory and practice of computational heat transfer; finite volume method for simulating fluid flow and heat transfer; computer graphics as a means of interpreting results of computation; and design applications of numerical heat transfer.

ME 411 Finite-Element Analysis in Heat Transfer. (3-0) Three hours.
Prerequisites: ME 309, ESM 311, and ME 349; or MTE 353.
The course focuses on the utilization of existing commercially available finite-element computer codes for analysis of conduction and convective heat transfer processes. Computer codes currently available on the College of Engineering network are used.

ME 415 Energy Systems Design. (2-0) Two hours.
Prerequisites: ME 309 and ESM 311.
Techniques of analysis and design of energy systems, including piping networks, heat exchangers, and prime movers. Emphasis is on modeling and computational solutions.

ME 416 Energy Conservation and Management. (3-0) Three hours.
Prerequisites: ME 309; ME 305; and ECE 320 or ECE 225.
Analysis of energy systems, including fossil fuels, steam, cogeneration, waste heat recovery, heating, ventilation, air-conditioning, control, and energy-management systems. Topics include conservation in electrical load, lighting, building envelope, and insulation; alternative energy sources; economic analysis; energy auditing; and fuel sources and supplies.

ME 417 Heating, Ventilating, and Air-Conditioning System Design. (2-3) Three hours.
Prerequisite: ME 407 or ME 416.
Design of conventional and unconventional environmental systems: air-conditioning, heating, refrigeration, control systems, and thermal storage.

ME 418 Combustion Engines. (2-3) Three hours.
Prerequisite: ME 305.
Theory, design, and performance of combustion engines; fuels, oxidants, and propellants; and combustion, dissociation, ionization, and engine emissions.

ME 441 Introduction to Biomedical Engineering. (3-0) Three hours.
Prerequisites: MATH 238, PH 106, and either ESM 201 or ESM 361.
Introduction to the relationship between engineering and medicine. Modeling musculoskeletal and cardiovascular systems. Review of medical devices such as non-invasive imaging devices, biopotential electrodes and amplifiers, and assistive technology.

ME 450 Dynamic Machine Components. (3-0) Three hours.
Prerequisites: ESM 264 and ME 350.
This course covers the selection and application of machine elements in dynamic systems. Specific components covered include transmission elements (gears and pulleys), mechanisms (linkages and cams), shafting, bearing systems, and prime movers.

ME 460 Thermal Systems Instrumentation. (2-3) Three hours.
Prerequisite: ME 360.
Corequisite: ME 415.

Selection and use of pressure, temperature, fluid flow, and heat transfer instrumentation. Hands-on experiences with fluid flow, heat transfer, refrigeration, and heat engine equipment. Statistical design of experiments. Writing proficiency is required for a passing grade in this course.

ME 464 Mechanization of Automated Systems. (3-0) Three hours.
Prerequisite: ME 360.
Emphasis is on the design of mechanisms and mechanical devices used in automatic machines and robotic systems: synthesis procedures for designing component devices, spatial mechanisms, motion programming, and computer-controlled mechanisms.

ME 465 Introduction to Automated Manufacturing Systems. (2-3) Three hours.
Prerequisite: ME 372.
Fundamental concepts of design, analysis, and simulation associated with industrial robotic systems. Introduction to and application of interactive computer analysis and computer graphics techniques. Topics include robot kinematics and dynamics, the inverse kinematics problem, interactive computer graphics and numerical integration techniques, and robot motion planning and trajectory specification.

ME 466 Computer Graphics and Automated Manufacturing. (3-0) Three hours.
Prerequisite: Junior standing in the College of Engineering or permission of the instructor.
Introduction to the application of high-resolution, three-dimensional graphics in mechanical engineering. Topics include animation of mechanical systems and solid modeling software.

ME 470 Mechanical Vibrations (also ESM 470). (3-0) Three hours.
Prerequisites: ME 372 and ESM 250.
Free and forced vibrations, both undamped and damped; and systems with many degrees of freedom formulated and analyzed by matrix methods. Experimental techniques of vibration measurement are introduced.

ME 471 Fundamentals of Acoustics. (3-0) Three hours.
Prerequisites: MATH 238, PH 106, and either ECE 320 or ECE 225.
Fundamental physical principles underlying wave propagation and resonance in mechanical systems. Introduces applications and provides experience in acoustic and audio measurements and the associated instrumentation.

ME 475 Control Systems Analysis. (3-0) Three hours.
Prerequisites: ME 349 and ME 372.
Classical and modern feedback-control system analysis; and block diagrams, state variables, stability, root locus, and computerized analysis. Includes an introduction to modern control techniques.

ME 476 Machine Servo Systems. (3-0) Three hours.
Prerequisite: ME 372 or permission of the instructor.
Corequisite: ME 475 or equivalent.
Hardware and software of machine servo systems with emphasis on the selection of components and integration into working systems. Hands-on experience with servo actuator systems in the laboratories.

ME 484 Introduction to the Finite-Element Method. (3-0) Three hours.
Prerequisite: ME 350, CE 331, AE 341, or graduate student standing.

Use of a commercial finite-element analysis program to perform linear static analyses in the presence of applied loads and thermal conditions. Emphasis is on applications using finite-element analysis programs as engineering tools.

ME 485 Introduction to Computer-Aided Design (also ESM 485). (3-0) Three hours.
Prerequisites: GES 126, ME 349, ME 372, and ESM 250.
Elements of computer-aided design including finite-element stress analysis, dynamic system simulation, and numerical optimization. Interactive computer programs are used to design mechanical systems.

ME 488 Modern Product Realization (also GES 488). (2-2) Four hours.
Prerequisites: ME 283 and ME 383.
Overview of modern thinking on product design and manufacturing enterprises, i.e., modern product realization. Students participate in an advanced design-and-build project making use of the Bevill Center for Advanced Manufacturing Technology.

ME 489 Mechanical Engineering Design I. (2-3) Three hours.
Prerequisites: Senior standing in the College of Engineering and ME 350.
Corequisite: ME 415.
Introduction to concepts and techniques of engineering design, with supporting mathematical material. Guest lecturers present professional aspects of engineering. The Capstone Design Project is begun and carried on through ME 490 (ME 489 and ME 490 are taken in consecutive semesters).

ME 490 Mechanical Engineering Design II. (0-6) Three hours.
Prerequisite: ME 489.
In this semester-long internship experience, three-student teams serve as consultants to an industrial client. Emphasis is on conducting a professional design study and preparing written and oral presentations of the proposal.

ME 491 Special Problems (Area). Variable hours.
This is a special topics lecture class or an assigned problem class. Credit is based on the amount of work undertaken.

ME 497 Mechanical Engineering Project. (0-9) One to three hours.
An individual analytical, experimental, or design project. Research on an assigned problem culminates in a required report.

Master Program: Mechanical Engineering

ME 500 Intermediate Fluid Mechanics (also AE/ESM 500). (3-0) Three hours.
Prerequisites: MATH 238, ME 215, and ESM 311.
Development and use of the integral and differential forms of the equations of continuity, momentum, and energy with ideal fluids and compressible fluids. Introduction to several advanced topics in fluid mechanics, including potential flow, boundary layer flow, and compressible flow.

ME 501 Mechanical Engineering Analysis I. (3-0) Three hours.
Prerequisites: ME 349, ME 372, and ME 309.
Analysis of mechanical engineering systems, including the presentation and application of advanced analytical techniques for continuous and discrete dynamic systems.

ME 502 Transport Phenomena. (3-0) Three hours.
Prerequisites: ME 215 and ESM 311.
Steady and transient mass, energy, and momentum transport in ideal and real substances.

ME 504 Compressible Flow Theory. (3-0) Three hours.
Prerequisite: AE 313, ME 313, or ME 503.
Theory of characteristics, axially symmetric supersonic flows, linearized theories, and similarity solutions, including application to airfoils. Hypersonic similarity is also covered.

ME 509 Intermediate Heat Transfer. (3-0) Three hours.
Prerequisites: ME 309 and ESM 311.
Intermediate treatment of conduction, convection, and radiation heat transfer.

ME 517 Controlled Environment System Design. (3-0) Three hours.
Prerequisite: ME 407 or ME 416.
This course is not open to undergraduates or to students who have earned credit for ME 417. Design and simulation of conventional and unconventional environment-control systems: heating, ventilating and air-conditioning (HVAC); thermal storage; solar; geothermal; demand reduction; and measurement and control.

ME 518 Principles of Combustion I. (3-0) Three hours.
Combustion thermodynamics, flame temperature and equilibrium compositions, ignition processes, detonation and deflagration, diffusion flames, similitude, and assigned papers.

ME 550 Advanced Mechanical Design. Three hours.
Constitutive relationships, Castigliano's method, fatigue, stochastic relationships, time-dependent properties, and other advanced topics.

ME 553 Mechanical Reliability. (3-0) Three hours.
Prerequisites: ME 350 and ME 450.
Probabilistic methodology for assessing the reliability of mechanical systems at the design stage.

ME 561 Techniques in Experimental Research. (2-3) Three hours.
Prerequisite: ME 360.
Design of experimental research systems and study of instrumentation, transducers, and related electronic components. Data acquisition, error analysis, experiment planning, and proposal writing are included.

ME 562 Intermediate Dynamics (also ESM 562). Three hours.
Modeling and analysis of dynamic systems with emphasis on Newtonian and Lagrangian techniques; Hamilton's principles; and application to three-dimensional motion of rigid bodies.

ME 571 Fundamentals of Acoustics. (3-0) Three hours.
Prerequisites: MATH 238, PH 106, and either ECE 320 or ECE 225.
Fundamental physical principles underlying wave propagation and resonance in mechanical systems. Introduces applications and provides experience in acoustic and audio measurements and the associated instrumentation.

ME 577 Advanced Linear Control (also AE/ECE 577). (3-0) Three hours
Prerequisite: ECE 475.

Modern techniques for the analysis and design of linear control systems. Matrix formulation; multivariable control systems; state-variable concepts; discrete-time systems; optimization; and statistical design methods.

ME 578 Nonlinear Control Systems (also AE 578). (3-0) Three hours.
Classical and modern methods for analysis and design of nonlinear automatic control systems. State variables, phase plane, describing functions, relay control, and optimal and adaptive control systems are covered.

3. UNIVERSITY OF CALIFORNIA RIVERSIDE

Earth Sciences Department

MAJOR COURSES

GEO 001. The Earth's Crust and Interior (4) Lecture, 3 hours; laboratory, 3 hours; one 1-day field trip. An introduction to the physical development of the Earth. Emphasis will be on Earth materials (rocks and minerals), processes (weathering, erosion, mountain building), structures (folds and faults), and current theories regarding the Earth's crust and interior.

GEO 002. The Earth's Dynamic Surface (4) Lecture, 3 hours; laboratory, 3 hours; one 2-day field trip. Prerequisite(s): none. Introduction to physical processes operating at the Earth's surface, emphasizing the interaction of the atmosphere, hydrosphere, and lithosphere. Focus given to development of landforms (such as rivers, glaciers, and deserts), dynamics and geological consequences of water movement and storage at the Earth's surface, and the role of climate and climate change in the formation and evolution of Earth's landscapes.

GEO 003. Headlines in the History of Life (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): none. Evolution of life beginning with precellular life. Topics include the origin of sex, multicellularity, vertebrate classes, morphological specializations, adaptive radiations, extinction dynamics, and the biology of dinosaurs. Cross-listed with BIOL 010.

GEO 004. Natural Hazards and Disasters (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): ENGL 001A or equivalent (may be taken concurrently). Application of basic principles of climate and geology to recognition of natural hazards and their mitigation. Topics include fires, freezes, floods, winds, landslides, volcanic eruptions, earthquakes and tsunamis. Emphasis is on confronting hazards of concern to home-buyers, planners, and conservationists in the western United States, especially southern California.

GEO 005. The Cosmos Factory (4) Lecture, 3 hours; discussion, 1 hour. A survey of selected topics in the earth and planetary sciences as applied to the present concepts of the cosmos, the nature and origin of the universe, and emphasizing recent problems in geophysics, geology, geochemistry, and planetary sciences.

GEO 006. The Violent Universe (4) Lecture, 3 hours; discussion, 1 hour. An introduction to violent phenomena that power the universe, specifically phenomena that illustrate basic astrophysical principles. Topics include impacts in our planetary system: explosions of stars, bursts of star formation, galaxy collisions, black holes, quasars, cosmic jets, and the "Big Bang." Cross-listed with PHYS 006.

GEO 007. Minerals and Human Health (4) Lecture, 2 hours; discussion, 1 hour; field, 30 hours per quarter. Prerequisite(s): none. An introductory overview of the role of minerals in human life and industrial activities. Discusses basic concepts of mineralogy and modern methods of mineral studies. Topics include the impact of minerals on human health, the role of minerals in modern biotechnologies, asbestos and silica problems, occupational diseases caused by inhalation of mineral dust, and environmental protection in California.

GEO 008. Earthquake Country (4) Lecture, 3 hours; discussion, 1 hour. An introduction to the study of earthquakes and the problems of living in earthquake country. Why earthquakes occur, how they are recorded, and what the effects are on man and his structures. The scientific and social consequences of earthquake prediction.

GEO 009. Oceanography (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): none. A general introduction to the geological, physical, chemical, and biological processes related to the characteristics and evolution of the ocean system. Students gain an understanding of the important role oceans play in regulating climate and the cycling of elements on the Earth's surface and how the ocean system has been, and continues to be, one of the most important influences on life.

GEO 010. Minerals, Energy, and Society (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s):

MATH 005 or equivalent. An introduction to the occurrence, availability, marketing, and usage of metals, minerals, petroleum, and other geologic resources, including both historic and recent trends. Conflicts between modern society's need for increasingly scarce resources and mounting environmental problems. Political and economic influences on international mineral and energy markets. Designed for non-geology majors, particularly those in economics, business administration, political science, education and environmental science.

GEO 020. Introduction to Geostatistics (1) Lecture, 5 hours per quarter; laboratory, 15 hours per quarter. Prerequisite(s): a grade of "C-" or better in one of the following courses: BIOL 010/GEO 003, GEO 001, GEO 002. Introduces basic statistical techniques used in descriptive and inferential data analysis in geology, geophysics, geochemistry, and paleobiology. Stresses the geological application of statistics by using data acquired and analyzed within laboratory sessions.

GEO 030. Introductory Mineralogy (5) Lecture, 3 hours; laboratory, 5 hours; two half-day and one 1-day field trips. Prerequisite(s): either CHEM 001B and CHEM 01LB or CHEM 01HB (CHEM 001B, CHEM 01LB and CHEM 01HB may be taken concurrently); GEO 001 with a grade of "C-" or better. A study of common and important minerals and their identification using structural and crystallographic methods. Stresses distinctive structural and chemical features, diagnostic physical and optical properties, and the growth and development of minerals in various geologic environments.

UPPER-DIVISION COURSES

GEO 100. Introductory Petrology (5) Lecture, 3 hours; laboratory, 6 hours; four field trips per quarter. Prerequisite(s): GEO 030 and GEO 123 with grades of "C-" or better. Introduction to the nomenclature and classification of igneous and sedimentary rocks and their metamorphosed equivalents. Topics include identification of the major rock-forming minerals and common rocks in hand samples and thin sections, and interpretation of rock fabrics and textures. Explores tectonic setting and the origins of major rock types.

GEO 101. Field Geology (5) Lecture, 2 hours; weekly 1-day field trips. Prerequisite(s): GEO 100 and GEO 115 with grades of "C-" or better or consent of instructor for concurrent enrollment. Introductory course in field geology. Covers methods of mapping igneous, metamorphic, and sedimentary rocks. Includes construction of planimetric and topographic maps, use of aerial photographs, and instruction in basic surveying techniques.

GEO 102. Summer Field Geology (14) Field, 6 hours. Prerequisite(s): GEO 101 with a grade of "C-" or better or consent of instructor. Geological mapping and interpretation; writing of geological reports.

GEO 115. Geologic Maps and Landforms (5) Lecture, 2 hours; laboratory, 6 hours; field, 30 hours per quarter. Prerequisite(s): GEO 001 (may be taken concurrently); MATH 004 or MATH 005, or MATH 008A. Examines characteristic patterns of bedrock outcrops, surficial deposits, the related landforms, and their representation on maps. Covers unconformities, folds, faults, intrusions, alluvial fans, river terraces, and landforms indicative of glaciers, volcanoes, landslides, and earthquakes. Applies map information to resource and hazard evaluation.

GEO 116. Structural Geology (5) Lecture, 2 hours; laboratory, 6 hours; three .5-day field trips; two 1-day field trips. Prerequisite(s): GEO 115 with a grade of "C-" or better; PHYS 040A. Examines geological structures in the field. Covers the graphical solution of structural problems and laboratory map study, the genesis of rock structures and physics of rock deformation, and Mohr diagrams and elementary stress analysis.

GEO 118. Sedimentology and Stratigraphy (5) Lecture, 2 hours; laboratory, 6 hours; two 1-day and one 2-day field trips. Prerequisite(s): GEO 100 with a grade of "C-" or better. The study of the principles of sedimentology and the comparative study of the origins of sediments and sedimentary rocks from various modern and ancient clastic, carbonate, and mixed siliciclastic-carbonate depositional environments. Emphasis is placed on field and stratigraphic relationships as well as on petrographic and hand specimen identification.

GEO 123. Analytical Mineralogy (5) Lecture, 3 hours; laboratory, 6 hours. Prerequisite(s): Either CHEM 001C and CHEM 01LC or CHEM 01HC; GEO 030 with a grade of "C-" or better. Advanced techniques in mineralogy. Covers optical crystallography, with an introduction to X-ray diffraction, electron microscopy, and other analytical techniques.

GEO 124. Advanced Petrogenesis (4) Lecture, 2 hours; laboratory, 6 hours; two 1-day field trips. Prerequisite(s): GEO 100 with a grade of "C-" or better. Explores advanced topics in the petrogenesis of igneous and metamorphic rocks in the Earth's crust and mantle. Examines field and structural relationships of crystalline rocks and how thermodynamics, experimental phase equilibria, and computer modeling are used to study petrogenesis. Each student completes a field and laboratory research project and prepares a written and oral report on the project.

GEO 132. Groundwater Geology (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): CHEM 001B and CHEM 01LB or CHEM 01HB; MATH 009B or MATH 09HB; PHYS 040A. Covers the nature and behavior of waters in geologic media; including the chemical nature of groundwaters and geothermal fluids; principles of fluid flow in sediments and rocks; chemical reactions between solutes and geologic media; geologic aspects of contaminant migration in groundwaters; behavior of geothermal fluids; elementary computer modeling of groundwater and geothermal fluid flow in geologic media.

GEO 137. Environmental Geochemistry (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CHEM 001C, CHEM 01LC, or equivalents; GEO 001 with a grade of "C-" or better or GEO 002 with a grade of "C-" or better. Examines the chemical principles of geologic processes at and near the Earth's surface. Topics include geochemical cycles of the elements during chemical interactions of the Earth's crust, hydrosphere, and atmosphere; applications of thermodynamics and kinetics to the study of low-temperature geologic processes; and the use of isotopic techniques in age dating and tracing geologic processes.

GEO 138. Soil Morphology and Classification (4) Lecture, 3 hours; laboratory, normally 3 hours; two 1-day field trips. Prerequisite(s): ENSC 100/SWSC 100; GEO 001 or GEO 002; or consent of instructor. The study of soils as they occur in the field and their relations to current and past environmental conditions. Use of field and laboratory data to understand soil genesis, causes of soil variability, fundamentals of soil classification, and land use potentials. Laboratory emphasizes the description and interpretation of soils and landscapes in the field. Cross-listed with ENSC 138 and SWSC 138.

GEO 140. Introduction to the Physics of the Earth (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): GEO 001 with a grade of "C-" or better; MATH 009C or MATH 09HC; PHYS 040C. Application of classical physics to the study of the Earth. Origin of the Earth, its gravitational, geomagnetic, and geothermal characteristics, seismicity and the dynamics of the Earth's crust, plate tectonics, and continental drift.

GEO 144. Earthquake Seismology (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): MATH 010A, MATH 010B, MATH 046, PHYS 040A, PHYS 040B, PHYS 040C; or consent of instructor. Introduction to the theories and observations of earthquake seismology. Students use physical principles and mathematical techniques to study the earthquake process, wave propagation, and ground motion. The laboratory emphasizes computer-assisted analysis of various types of seismic data, as well as simple modeling techniques.

GEO 145. Shallow Subsurface Imaging (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): GEO 001 with a grade of "C-" or better; MATH 009A or MATH 09HA; MATH 009B or MATH 09HB; PHYS 002A or PHYS 040A; PHYS 002B or PHYS 040B; PHYS 002C or PHYS 040C; or consent of instructor. Covers techniques of geophysical investigation of the shallow subsurface as they apply to solving groundwater, environmental, archaeological, and engineering problems. Emphasizes methods, survey design, and interpretation with focus on case studies. Laboratory consists of both field training and computer exercises using geographic information systems for analysis of spatial data.

GEO 151. Principles of Paleontology (4) Lecture, 3 hours; laboratory, 3 hours; one 1-day field trip. Prerequisite(s): BIOL 010/GEO 003 with a grade of "C-" or better or BIOL 005C. Emphasis is on understanding fossils as living organisms. Topics include fundamentals of evolution and the fossil record, introductory morphometrics and biosystemic theory, functional morphology, and metazoan organization and classification.

GEO 152. Principles of Invertebrate Paleobiology and Paleoecology (4) Lecture, 2 hours; laboratory, 3 hours; three 1-day field trips. Prerequisite(s): BIOL 005C with a grade of "C-" or better or BIOL 010/GEO 003 with a grade of "C-" or better. Topics include evolution and the fossil record, paleoecology, classification theory; the nature of adaptive radiations, and extinctions. Cross-listed with BIOL 152.

GEO 153. Biodiversity through Time (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): BIOL 010/GEO 003 with a grade of "C-" or better or BIOL 005C. Focuses on the history of biodiversity and the responses of organisms to episodes of profound environmental change. Outlines the major features of evolutionary history chronicled by fossils, the dynamics of evolutionary radiations and extinctions, and the implications of paleontological data for current issues in biodiversity.

GEO 157. Automated Geographic Information Systems (4) Lecture, 2 hours; laboratory, 6 hours. Prerequisite(s): upper-division standing. Review and analysis of automated geographic information systems, data structures, databases, and coordinate systems. Techniques of spatial partitioning, interactive map editing and design, and computer graphics. Computation and display of map projections. Analysis of trends in earth resources data handling.

GEO 161. Quaternary Paleoenvironmental Change (4) Lecture, 2 hours; laboratory, 2 hours; two 2-day field trips. Prerequisite(s): GEO 001 with a grade of "C-" or better or GEO 002 with a grade of "C-" or better. Examines geological evidence of environmental change throughout Quaternary times ("Ice Age") to provide a framework for understanding natural environmental change and for predicting future change.

GEO 162. Geomorphology (4) Lecture, 2 hours; laboratory, 6 hours; one 2-day field trip. Prerequisite(s): upper-division standing or consent of instructor. A study of surficial processes related to the development and evolution of landforms and landscapes at the Earth's surface. Emphasis is on weathering regimes, mass wasting and hillslope development, river process, and form. Examines erosional and depositional processes in tectonic, volcanic, arid, karst, glacial, and coastal landscapes.

GEO 167. Conservation Biogeography (4) Lecture, 3 hours; laboratory and field, 3 hours. Prerequisite(s): BIOL 005C with a grade of "C-" or better or BIOL 010/GEO 003 with a grade of "C-" or better. Application of biogeographic and ecological theories in the conservation of plants, animals, and wildlands. Topics include biological preserve design, ecological consequences of land development, and wildlife-habitat relationships.

GEO 168. Biogeography (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): BIOL 005C with a grade of "C-" or better or BIOL 010/GEO 003 with a grade of "C-" or better or consent of instructor. Analysis of world vegetation patterns, migrations, and ecological considerations at scales ranging from geologic to historical. Topics include plant migration, endemism, continental species patterns, ecological convergence, island biogeography, and world species diversity.

GEO 169. California Vegetation (4) Lecture, 3 hours; laboratory, 3 hours; two 1-day field trips. Prerequisite(s): BIOL 005C with a grade of "C-" or better or BIOL 010/GEO 003 with a grade of "C-" or better. Survey of the flora, distribution, and ecology of California ecosystems, including Mediterranean shrubland, conifer forests, desert scrub, valley forbfields, and exotic grasslands. Discusses vegetation in relation to climate, physiography, fire, landscape steady states, biological invasions, paleobotany, and broad-scale change due to land development, invasive species, grazing, and fire suppression.

GEO 190. Special Studies (1-5) Individual study, 3-15 hours. Prerequisite(s): upper-division standing; consent of instructor and department chair. Individual study to meet special curricular needs. Course is repeatable to a maximum of 9 units.

GEO 191. Undergraduate Seminar in Geological Sciences (1) Seminar, 1 hour. Prerequisite(s): open to upper division Geological Sciences majors only. For undergraduate students who desire formal participation in the weekly departmental seminar. In addition to attending the seminar, students must write abstracts describing two of the presentations. Graded Satisfactory (S) or No Credit (NC). May be repeated to a total of 6 units.

GEO 195A. Senior Thesis (3-5) hours per week to be established by supervisor. Prerequisite(s): senior status; consent of instructor. Preparation of a thesis based upon supervised field and/or laboratory research and literature review in the geological sciences. The thesis may be undertaken as a one-, two-, or three-quarter sequence. In the case of a two- or three-quarter sequence, the final grade will be deferred until completion of the last quarter. Total credits for GEO 195A, GEO 195B, and GEO 195C may not exceed 9 units.

GEO 195B. Senior Thesis (3-5) hours per week to be established by supervisor. Prerequisite(s): senior status; consent of instructor. Preparation of a thesis based upon supervised field and/or laboratory research and literature review in the geological sciences. The thesis may be undertaken as a one-, two-, or three-quarter sequence. In the case of a two- or three-quarter sequence, the final grade will be deferred until completion of the last quarter. Total credits for GEO 195A, GEO 195B, and GEO 195C may not exceed 9 units.

GEO 195C. Senior Thesis (3-5) Prerequisite(s): senior status; consent of instructor. Preparation of a thesis based upon supervised field and/or laboratory research and literature review in the geological sciences. The thesis may be undertaken as a one-, two-, or three-quarter sequence. In the case of a two- or three-quarter sequence, the final grade will be deferred until completion of the last quarter. Total credits for GEO 195A, GEO 195B, and GEO 195C may not exceed 9 units.

GEO 198-I. Independent Internship (1-12) Field, 3-36 hours. Prerequisite(s): consent of instructor, undergraduate advisor, and department chairman. Independent study in a surrogate job condition under non-university supervision. Internships are normally in public or private institutions such as planning departments, research labs, or industry. Position, task, method of reporting completion and accomplishments, and units must have prior agreement among student, instructor, and supervisor. One unit for every three hours per week spent in internship. Graded Satisfactory (S) or No Credit (NC).

GRADUATE COURSES

GEO 203. Mineral Equilibria (4) Lecture, 4 hours. Prerequisite(s): GEO 137 or consent of instructor. Applications of thermodynamics and kinetics to evaluating equilibria among minerals and fluids in geological environments. Emphasis placed on equilibria in geothermal systems, ore deposits, metamorphic and igneous rock, and groundwater.

GEO 205. Geohydrology (4) Lecture, 3 hours; laboratory, 3 hours; one 1-day field trip. Prerequisite(s): GEO 132 or ENSC 163. Fluid flow in geologic media; resource evaluation; and relevant geologic hazards and geotechnical problems.

GEO 206A. Stratigraphy (4) Lecture, 2 hours; laboratory, 6 hours. Prerequisite(s): GEO 118; consent of instructor. Covers rock stratigraphy and time stratigraphy with an emphasis on their principles, history, and methods. Includes reading and analysis of pertinent literature and field trips.

GEO 206B. Stratigraphy (4) Lecture, 2 hours; laboratory, 6 hours. Prerequisite(s): GEO 118; consent of instructor. Covers time stratigraphy and biostratigraphy with an emphasis on their principles, history, and methods. Includes reading and analysis of pertinent literature and field trips.

GEO 212. Ecological Systems in Space and Time (4) Lecture, 2 hours; discussion, 1 hour; field, 30 hours per quarter. Prerequisite(s): BIOL 117 or BIOL 152/GEO 152 or equivalent or consent of instructor. Focuses on how ecological systems are interpreted and reconciled at the community, landscape, and paleontological scales and on the role of extrinsic factors operating at each of these scales. Examines the historical development of our understanding of ecological systems at various scales. Cross-listed with BIOL 212 and ENTM 212.

GEO 219. Theory of Systematics (4) Lecture, 2 hours; discussion, 2 hours. Prerequisite(s): BIOL 112/BPSC 112/ENTM 112 or equivalent or consent of instructor. Examines topics developed around a series of classical and recent papers on the principles, philosophy, and methodology of modern systematics and phylogenetic methods. Cross-listed with BIOL 219 and ENTM 219.

GEO 221. Electron Microscopy and Microanalysis (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): graduate standing or consent of instructor. Introduction to electron microscopy and microanalysis of inorganic solids including minerals and synthetic materials. Students learn the physical principles, strengths, and limitations of the method. Laboratory provides hands-on experience with scanning and transmission electron microscopes and interpretation of images and data.

GEO 223. Seminar in Geobiology (1) Seminar, 2 hours. Prerequisite(s): graduate standing or consent of instructor. Lectures, discussions and demonstrations by students, faculty and invited scholars on current research topics in Geobiology. Graded Satisfactory (S) or No Credit (NC). Course is repeatable.

GEO 225A. Geology of Carbonate Rocks (4) Lecture, 2 hours; laboratory, 6 hours. Prerequisite(s): GEO 118; consent of instructor. Covers characterization, recognition, and interpretation of carbonate rocks. Laboratory work includes study of polished and thin sections of selected suites of rocks.

GEO 225B. Geology of Detrital Rocks (4) Lecture, 2 hours; laboratory, 6 hours. Prerequisite(s): GEO 118; consent of instructor. Covers characterization, recognition, and interpretation of detrital rocks. Laboratory work includes study of polished and thin sections of selected suites of rocks.

GEO 226. Soil Geomorphology (4) Lecture, 2 hours; laboratory, 6 hours; two saturday field trips per quarter. Prerequisite(s): ENSC 138/GEO 138/SWSC 138, GEO 162, or equivalents. Examines the interaction of pedogenic and geomorphic processes during the Quaternary, with an emphasis on the rate of these processes. Group research includes field data collection and analysis. May be taken Satisfactory (S) or No Credit (NC) with consent of instructor and graduate advisor. Cross-listed with SWSC 226.

GEO 239. Advanced Topics in Resource Geology (4) Seminar, 4 hours. Prerequisite(s): GEO 100; consent of instructor. Covers topics in nonrenewable mineral and energy resources, such as petroleum resources; nuclear energy and waste disposal; toxic metals and groundwater contamination; and coal resources and global warming. Discusses geologic and environmental aspects of these resource issues. Content may vary from year to year. Requires oral and written research reports. Course is repeatable to a maximum of 8 units.

GEO 241. Advanced Field Geophysics (14) Lecture, 10 hours; laboratory, 16 hours; field, 14 hours. Prerequisite(s): GEO 140; proficiency in a word processing, spread sheet, or programming language. Advanced applications of modern geophysical field techniques to the solution of complex geological problems, using seismic refraction and reflection, electrical and electromagnetic, potential field, and well-logging methods.

GEO 243. Earthquake Physics (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): GEO 144, MATH 010A, MATH 010B, MATH 046, PHYS 040A, PHYS 040B, PHYS 040C; basic computer programming experience; or consent of instructor. MATH 146A, MATH 146B, and MATH 146C are recommended. An exploration of the physics of the earthquake process. Students use both numerical models and theoretical and analytical tools to learn about the processes of fault fracture, rupture propagation, and slip, and their relation to ground motion in earthquakes. Requires an independent project in computer earthquake modeling.

GEO 245. Principles and Applications of Geochronology (4) Lecture, 2 hours; laboratory, 3 hours; field, 30 hours per quarter. Prerequisite(s): consent of instructor. Examines methods of dating Quaternary successions, including isotopic, physical, chemical, and stratigraphic techniques. Fieldwork and laboratory emphasize the collection, preparation, and analysis of samples using modern methods.

GEO 247. Electrical Exploration Methods (4) Lecture, 3 hours; laboratory, 4 hours. Prerequisite(s): MATH 009A, MATH 009B, MATH 009C, PHYS 040C; or consent of instructor. Study of electrical properties of Earth's materials. Galvanic resistivity methods in a multilayered medium. Potential distribution and interpretation of empirical data. Electrical well logging. Elements of telluric and magneto-telluric sounding.

GEO 249. Field Methods in Quaternary Geology (4) Discussion, 2 hours; laboratory, 6 hours; three 2-day field trips. Prerequisite(s): GEO 101 or GEO 162 or consent of instructor. Geologic field problems and associated techniques for reconstructing Quaternary geologic, climatologic, and hydrologic events recorded in the landforms, stratigraphy, and weathering profiles of selected regions. Field techniques include relative and calibrated dating analysis, section measurements, morpho- and lithostratigraphic analysis, and map constructions in fluvial, lacustrine, glacial, coastal, and eolian environments.

GEO 250. Graduate Seminar in Geological Sciences (1) Seminar, 1 hour. Prerequisite(s): graduate student status. Oral reports by graduate students, faculty, and visiting scholars on current research topics in geological sciences. Graded Satisfactory (S) or No Credit (NC). Course is repeatable.

GEO 251 (E-Z). Advanced Topics in Paleontology (3-5) Seminar, 3 hours; laboratory, 0-6 hours. Prerequisite(s): consent of instructor. Selected advanced topics in paleontology. Content varies from quarter to quarter. After consultation with the instructor, students enroll in only the seminar (3 units) or in both the seminar and laboratory (4-5 units). May be taken Satisfactory (S) or No Credit (NC) with consent of instructor and graduate advisor. Course is repeatable.

GEO 252. Marine Paleoecology (3) Lecture, 1 hour; discussion, 1 hour; two 1-day field trips. Prerequisite(s): graduate standing. Examines fundamental principles of paleoecology and the measurement of biodiversity, abundance, and biomass from the fossil record. Covers the significance of mass extinctions, diversification events, and environments on the Earth's changing

marine ecosystem. Includes taphonomy, ichnology, and field studies. Course is repeatable to a maximum of 6 units.

GEO 253. Advanced Topics in Petrology and Geochemistry (3-5) Seminar, 3 hours; laboratory, 0-6 hours. Prerequisite(s): consent of instructor. Selected advanced topics from petrology and geochemistry of igneous, metamorphic, and sedimentary rocks. Course content varies from year to year. Course is repeatable to a maximum of 6 to 10 units.

GEO 255. Advanced Topics in Sedimentary Petrology (4) Seminar, 2 hours; laboratory, 6 hours. Prerequisite(s): GEO 225A, GEO 225B. Selected advanced topics from sedimentary petrology and physical stratigraphy. Course content varies from year to year. Course is repeatable.

GEO 256. Earth's Deep Interior: Frontiers in Mantle Petrology and Mineralogy (4) Lecture, 2 hours; discussion, 2 hours. Prerequisite(s): GEO 001 or GEO 030 or equivalent. Discusses mineral reactions in extreme conditions in the Earth's mantle and at the core-mantle boundary, the possible fate of continental and oceanic plates subducted to Earth's deep interior, and new models of the origin and evolution of mantle convection and plumes. Graded Satisfactory (S) or No Credit (NC). Course is repeatable to a maximum of 8 units.

GEO 257 (E-Z). Advanced Topics in Geophysics (4) Seminar, 3 hours; outside research, 3 hours. Prerequisite(s): consent of instructor. Selected advanced topics from geophysics. Course content varies from quarter to quarter. Each segment is repeatable to a maximum of 12 units.

GEO 259. Tectonics of California (4) Lecture, 2 hours; seminar, 2 hours. Prerequisite(s): consent of instructor. Geological, geophysical, and paleontological bases of interpreting tectonic development of California, with special emphasis on southern California. Interdisciplinary approach will be emphasized. Weekly reading assignments, active participation in discussions, and appropriate field and library research will be required. Participants will prepare two papers and give presentations.

GEO 260. Global Climate Change (4) Seminar, 3 hours; term paper, 3 hours. Prerequisite(s): PHYS 002C or PHYS 040C or consent of instructor. Explores global climate change in historic and geologic time scales. Topics include ocean-atmosphere feedbacks, El NiÒo, Pacific decadal oscillation, anthropogenic CO2, volcanism, cosmic rays, polar ozone depletion, global climate modeling, stable isotopes, "ice house" Pleistocene climates, "greenhouse" climates of the Mesozoic and Tertiary, plate tectonics, and the "snowball" Earth.

GEO 264. Biogeochemical Cycles through Time (3) Lecture, 3 hours; two to three 2-day field trips. Prerequisite(s): BIOL 010/GEO 003; CHEM 001C or equivalent; GEO 001; GEO 002; or consent of instructor. A comprehensive exploration of the major biogeochemical cycles at and near Earth's surface. Emphasis is on microbially mediated cycling of elements and isotopes within diverse sedimentary environments and the cause-and-effect relationships with the ocean and atmosphere. Explores 4 billion years of biospheric evolution in light of these cycles. May be taken Satisfactory (S) or No Credit (NC) with consent of instructor and graduate advisor.

GEO 265. Special Topics in Earth and Environmental Sciences (1-3) Seminar, 1-3 hours. Prerequisite(s): graduate standing. Involves oral presentations and small-group discussions of selected topics in the areas of biogeochemistry, global climate change, geomicrobiology, earth surface processes, and interplanetary life.† Graded Satisfactory (S) or No Credit (NC). Course is repeatable as content changes to a maximum of 10 units. Cross-listed with ENSC 265.

GEO 268. Seminar in Biogeography (4) Seminar, 2 hours; research, 6 hours. Prerequisite(s): graduate standing. Topics include Mediterranean ecosystems, fire ecology, naturalization of exotic species, succession and ecosystem steady state theory, and mapping of vegetation. Course is repeatable to a maximum of 8 units.

GEO 290. Directed Studies (1-6) Prerequisite(s): consent of instructor. Research and special studies in the geological sciences. Graded Satisfactory (S) or No Credit (NC). Course is repeatable.

GEO 297. Directed Research (1-6) Prerequisite(s): consent of instructor. Research for individual graduate students in geological sciences. Graded Satisfactory (S) or No Credit (NC). Course is repeatable.

GEO 299M. Research for Master's Thesis (1-12) research, 3 hours per unit. Prerequisite(s): consent of instructor. Thesis research. Graded Satisfactory (S) or No Credit (NC). Course is repeatable.

GEO 299P. Research for Dissertation (1-12) research, 3 hours per unit. Prerequisite(s): consent of instructor. Research for dissertation, arranged in consultation with the staff. Graded Satisfactory (S) or No Credit (NC). Course is repeatable.

PROFESSIONAL COURSES

GEO 301. Teaching of Geosciences at the College Level (1) Seminar, 1 hour. Prerequisite(s): graduate standing in Geological Sciences. A program of weekly meetings and individual formative evaluation required of new Teaching Assistants for Geosciences courses. Covers instructional methods and classroom/section activities most suitable for teaching Geosciences. Conducted by the Teaching Assistant Development Program. Graded Satisfactory (S) or No Credit (NC). Course is repeatable.

GEO 302. Teaching Practicum (1-4) Seminar, 1-4 hours; practicum, 2-8 hours. Prerequisite(s): restricted to those graduate students appointed as Teaching Assistants. Supervised teaching of upper and lower-division courses in Geosciences. Required of all Teaching Assistants. Graded Satisfactory (S) or No Credit (NC). Course is repeatable for credit, but units not applicable toward degree unit requirements.

4. THE UNIVERSITY OF KANSAS

Department of geology

Bachelor Program: General Geology

GEOL 505 COMPUTERS IN GEOLOGY 3 N
An introduction to the use of computers in the geosciences. Topics addressed emphasize geologically oriented applications, but also include a general introduction to computer hardware and software. Specific topics addressed include spreadsheet calculations, gridding, contouring, filtering, scientific visualization, geological imaging, computer-aided mapping, treatment of geological phenomena

GEOL 511 OPTICAL MINERALOGY
Theory and application of optical crystallography as a determinative tool in mineralogy and petrographY; study of minerals using oil immersion and thin-section techniques.

GEOL 514 ROCK PROPERTIES 1 U
A study of the physical properties of the crystalline rocks, with emphasis upon the relationship of these properties to the chemical and mineralogical composition and to the geophysical properties of the rocks. Topics will include measurement of density, acoustic velocity, magnetic susceptibility, and electrical resistivity.

GEOL 521 PALEONTOLOGY
(OLD) A study of the structure and evolution of ancient life; the nature and diversity of life through time; the interactions of ancient organisms with their environments and the information that the study of fossils provides about ancient environments; the use of fossils to determine the ages of rocks and the timing of past events in earth history; and the patterns of extinction through time..

GEOL 521 PALEONTOLOGY 3 N
A study of the structure and evolution of ancient life; the nature and diversity of life through time; the interactions of ancient organisms with their environments and the information that the study of fossils provides about ancient environments; the use of fossils to determine the ages of rocks and the timing of past events in earth history; and the patterns of extinction through time.

GEOL 528 THE BIOLOGY AND EVOLUTION OF FOSSIL PLANTS 3 N
A lecture course in which fossil plants, protists and fungi are examined throughout geologic time. Emphasis will be directed at paleoecology, biogeography and the stratigraphic distribution and composition of ancient floras.

GEOL 528 THE BIOLOGY AND EVOLUTION OF FOSSIL PLANTS 3 N
A lecture course in which fossil plants, protists and fungi are examined throughout geologic time. Emphasis will be directed at paleoecology, biogeography and the stratigraphic distribution and composition of ancient floras. (Same as BIOL 640.) Prerequisite: BIOL 413, or permission of instructor.

GEOL 529 LABORATORY IN PALEOBOTANY 1 U
An examination of selected fossil plants throughout geological time and the techniques used to study them; laboratory will include identification and the use of plant fossils in biostratigraphy.

GEOL 529 LABORATORY IN PALEOBOTANY 1 U
An examination of selected fossil plants throughout geological time and the techniques used to study them; laboratory will include identification and the use of plant fossils in biostratigraphy.

GEOL 532 STRATIGRAPHY 4 N
A study of the principles of lithostratigraphy, biostratigraphy, and sequence stratigraphy. Methods of analysis of stratiographic data focus on the interpretation of earth history. The stratiographic record of North America is presented for evaluation of its geologic history. Three lectures and one laboratory per week. Required field trip

GEOL 532 STRATIGRAPHY 4 N
A study of the principles of lithostratigraphy, biostratigraphy, and sequence stratigraphy. Methods of analysis of stratiographic data focus on the interpretation of earth history. The stratiographic record of North America is presented for evaluation of its geologic history. Three lectures and one laboratory per week. Required field trip

GEOL 535 PETROLEUM AND SUBSURFACE GEOLOGY 4 N
A general study of the occurrence, properties, origin, and migration of petroleum. Examples are studied of typical oil fields throughout the world. Petroleum discovery methods and valuation of properties are considered. Well logs, cuttings, subsurface maps and cross-sections are studied in the laboratory.

GEOL 535 PETROLEUM AND SUBSURFACE GEOLOGY 4 N
A general study of the occurrence, properties, origin, and migration of petroleum. Examples are studied of typical oil fields. Well logs, cuttings, subsurface maps and cross-sections are studied in the laboratory

GEOL 555 MINERAL AND ENERGY RESOURCES 3 N
A study of the distribution and extent of mineral and energy resources and the present and future problems of supply of minerals, oil and gas, coal, nuclear resources, and geothermal energy. Will include analysis of the role of minerals in national and international affairs, in our social and economic system, and in urban planning and environmental planning. Prerequisite: Introductory course in geology or geography or consent of instructor.

MATH 124 MULTIVARIABLE CALCULUS 3 N
Partial Differentiation, multiple integration, vector calculus. Infinite Series. Not open to those who have taken MATH 123.

MATH 223 VECTOR CALCULUS 3 N
Multivariable Calculus, Multiple Integration, Vector Calculus.
Prerequisite: MATH 122 or MATH 142 or equivalent.

MATH 220 APPLIED DIFFERENTIAL EQUATIONS 3 N
Linear Ordinary Differential Equations, Laplace Transforms, Systems of Equations, Applications. Prerequisite: MATH 122 or MATH 142 or equivalent. Not open to those who have taken MATH 320.

MATH 290 ELEMENTARY LINEAR ALGEBRA 2 N
Systems of Linear Equations, Matrices, Vector Spaces, Linear Transformations, Applications. Prerequisite: MATH 122 or MATH 142 or equivalent. Not open to those who have taken MATH 590.

5. RUTGERS UNIVERSITY OF NEW JERSEY
Department of Geological Sciences

Introductory Geology I: Planet Earth
Introductory geology for the non-science major, designed to give a broad, basic understanding of the planet on which we reside, its age and origin, composition and evolution, interrelationships of Earth's major physical systems, scientific revolutions in Earth Science, and the role the physical Earth plays in global politics and economics. Prof. M.T. Feigenson / Prof. R.W. Schlische / Prof. C. Swisher / Dr. J.V. Browning / Dr. P. Sugarman

Introductory Geology I: Physical

Geological concepts, principles, processes, chemistry, and physics of the Earth and the interplay of Earth Systems. Course explores the Earth as a whole, its origin, structure, composition, history and the nature of the processes that resulted in its formation and its present state. Prof. C. Swisher

Introductory Geology II: Historical
Principles and concepts of plate tectonics and reconstructing past geography and environments; the history of Earth's climate, environments, biogeochemical cycles, and life through time. Designed for majors and minors.

Introductory Geology Laboratory
Development of geologic concepts and principles through experiments and field observations.

Honors Introductory Geology Laboratory
Fundamentals of physical geology. Field observations and measurements of geologic processes and outcrops.

Earthquakes and Volcanoes
Plate tectonics and the origin of earthquakes and volcanoes: causes, mechanisms, consequences, and effect on man.

Environmental Geology
Analyses of issues and case studies related to cleaning of the environment, finding and using resources, predicting and mitigating natural disasters, and understanding global change.

Water Planet
Survey of the science, environmental impact, and resource allocation of water on the Earth. Characteristics of water; hydrologic cycle; runoff and erosion; river systems; past and present climates; water quality; political and economic aspects of water.

Evolution and Geologic Time
Major events in the evolution of life on earth; evolutionary pattern and process through geologic time; relationship of macro- and microevolutionary theory.

Dinosaurs
Survey of dinosaurian evolution and diversity. Discovery and collection; reconstruction of anatomy, behavior, physiology, and habitats; origin, evolutionary radiation, and extinction.

Earth's Resources and the Global Economy
Geological occurrence, exploration, production, and distribution of oil/gas, mineral ores, and interrelationships to world politics and the global economy. World events during the course will be tracked and evaluated as to impact on the supply and demand of oil, gas and mineral commodities.

The Last 11,000 Years
Geologic events since the last ice age. Sea-level changes, volcanism, earthquakes, climatic change, erosional and depositional effects. Ancient record of events, myths

Exploration of the Oceans
Geological and geophysical exploration techniques; deep sea drilling; continental shelves; deep ocean basins; plate tectonics; coral reefs; offshore petroleum exploration; marine archaeological discoveries; Monitor, Titanic.

Earth and Life Through Time
Relationship between the development of continents and oceans, changes in sedimentary environments, and the evolution of life through time. Designed for non-majors.

Mineralogy
Introduction to crystallography, optics and crystal chemistry, systematics of rock-forming minerals. Laboratory: crystal chemical calculations, minerals in hand specimen and thin section.

Petrology
Description, geological setting, and origin of igneous and metamorphic rocks. Laboratory: hand specimens and thin sections of igneous and metamorphic rocks.

Paleontology
The principles of paleontology. Classification, relationships, and evolutionary history of invertebrate fossils. Laboratory study of morphology of invertebrates

Structural Geology
Geometrical expression of brittle and ductile structures; strain, stress, and rheology; deformation mechanisms; introduction to tectonics and regional structural geology; computer applications.

Sedimentary Geology
Interpretation of sedimentary rocks; their relation to depositional environment and processes. Analysis of sedimentary sequrences in time and space. Principles of correlation.

Fundamentals of Mineralogy and Petrology
Systematics of rock-forming minerals.

Introduction to Geochemistry
Application of chemical principles and techniques to geologic problems. Geochemical structure of the earth, element distribution, Eh-Ph diagrams, and phase-equilibrium diagrams.

Ore Deposits
Geochemistry, mineralogy, and origin of ore deposits. Physical- chemical, ore-forming processes and their relation to geologic environment.

Geomorphology
The evolution and classification of landforms and the processes involved in their development.

Field Geology
Methodology of field investigations and field and subsurface mapping: aerial photo and topographic mapping; construction of geologic maps and cross sections; seismic interpretation; written report. Field activities takes place in Fundy rift basin, Nova Scotia, Canada. Classroom activities take place at the Fundy Geological Museum, Parrsboro, Nova Scotia.

Geologic Field Methods
Overview of geological field methods including geologic mapping, measuring stratigraphic sections, collecting fracture data, surveying techniques, and seismic interpretation; computer applications of field methods; written report.

Introduction to Geophysics
Principles of seismic exploration, refraction, reflection, deep earth seismology, gravity, magnetics, electrical surveys, heat flow. Application of geophysical techniques to the study of the subsurface

Hydrologic Processes
Introduction to physical principles of water cycling through the Earth's atmosphere, lithosphere, and biosphere, with emphasis on water storage, flux, and flow pathways among the various reservoirs near the land surface.

Environmental Geochemistry
Distribution of elements in the sedimentary environment; behavior of trace metals in sediments and waters.

Geological Modeling
Computer techniques for collection, processing, interpretation, and presentation of geological and geophysical data. Computer-based modeling exercises in geologic and geophysical exploration and environment assessment.

Remote Sensing for Geological Sciences
An applied course focusing on hands-on methods for extracting useful geologic information from aerial and/or satellite imagery. Topics covered include: EM characteristics of rocks, identifying geologic features in imagery, extracting geologic phenomena with image processing techniques, and mapping geologic data within a GIS. Concepts are relevant for environmental, energy, and planetary geology applications.

Hydrogeology
Introduction to physical and chemical principles of fluid flow and mass transport through geologic media, with emphasis on quantitative characterization of groundwater systems.

Tectonics and Regional Structural Geology
Theories of tectonics, regional tectonostratigraphic analysis, development of the earth's Phanerozoic orogens.

The Quaternary Period
The last 2 1/2 million years has been a time of climate change. The course includes methods used to determine time and extent of continental-scale ice sheets; history of sea level change and appearance of land bridges; animal migrations; peopling of the New World; and paleo indians of New Jersey.

Marine Geology
Structure and oceanographic setting, marine sediments, evolution of ocean basins and margins.

Paleoecology
Evolution in an ecological context: analysis of ancient living systems; evolution of marine ecosystems in geologic time.

History of the Earth System
Integration of atmospheric, oceanographic, geological and biological concepts with an historical perspective to introduce the major processes that have shaped Earth's environment; climatic

processes on geological time scales; the evolution of organisms; the cycling of elements; the feedbacks between these processes.

Independent Studies in Geology
Topic of study chosen in consultation with a faculty adviser.

Honors in Geology
Research project chosen in consultation with a faculty adviser.
Economic Geology
Geochemistry of hydrothermal ore deposits, including studies of alteration, ore mineral solubility, fluid inclusions, mass transfer, and stable and radiogenic isotopes.

Studies in Paleontology
Topics include methods and case studies in systematics, evolution and extinction, paleogeography, paleoclimate, and other topics of current interest. Emphasis on the relationship between geological and biological processes.

Sedimentary Geology
Topics of current interdisciplinary research in sedimentary geology. Sequence stratigraphy, facies models, sea-level change, unconformities/hiatuses, tectonics, climate change, evolution, mass extinctions.

Structure and Formation of the Earth
Topics of current research on the internal structure of the earth. Mantle structure, phase changes, seismic discontinuities, trace element/isotopic properties, mineral physics, core formation, meteorites, moons, asteroids.

Geodynamics
Topics of current research in structural geology, geophysics, and tectonics. Deformation of the crust and mantle; convection in the mantle and core; the gravity and magnetic field of the earth; plate tectonics and the origin of earthquakes and volcanoes.

Mineral Phase Relations
Free-energy diagrams and phase diagrams, equilibrium and kinetics, nucleation theory, undercooling, diffusion. Major groups of rock-forming minerals; comparison of laboratory data and theoretical models with assemblages, compositions, and morphologies actually observed in slowly cooled and rapidly cooled rocks.

Meteoritics
Petrology and geochemistry of meteorites, origin of solar system, thermal history of asteroids.
Petrology
Basic principles of thermodynamics applied to solid-solid and solid-liquid equilibria in silicate systems; igneous and metamorphic processes that structured the petrology of the earth's crust and mantle through time.

Metamorphic Petrology
Principles of thermodynamics applied to the stabilities of mineral assemblages in meta-igneous and meta-sedimentary rocks of the earth's crust; fluids in the crust; metamorphism and plate tectonics.

Volcanology

Geologic settings of volcanos; geophysical and geochemical constraints on the origin of magmas; energetics and periodicity; volcanos and earthquakes; eruption mechanisms; volcanic hazards and prediction; geothermal power and volcanogenic ore deposits.

Depositional Environments
Examination of clastic depositional environments, with emphasis on sedimentary processes. Sediment sampling and analyzing; sedimentary structures; grain characteristics; facies models.

Advanced Tectonics
Examination of (1) the diversity of structural styles and tectonic settings worldwide using outcrop, well, and seismic data; (2) the results of geometric and experimental modeling; and (3) restoration techniques.

Advanced Structural Geology
Advanced topics in structural geology including: extensional tectonics, fracture mechanics, fault-population systematics, and practical structural geology (seismic expression of structural styles, analogue modeling of geologic structures, and restoration of geologic structures).

Mesozoic-Cenozoic Stratigraphy
Study of the Mesozoic-Cenozoic stratigraphic sequences in different basinal settings and relationship to tectonic history.

Marine Sedimentology
Examination of the physical processes of sedimentation on the continental shelf and continental slope environments. The interrelationship between organisms and sediment as well as environmental problems.

Paleoceanography
Paleoecology, paleoclimatology, and paleogeography of marine microfossils; study of major paleoceanographic events and their relationships to stratigraphy and sedimentary facies.

Groundwater Modeling
Procedures of setting up a numerical model of groundwater flow and transport using Visual Modflow and GMS Femwater.

Evolutionary Paleoecology
Seminar on the evolution of ecological systems in geologic time; application of evolutionary theory to paleoecological patterns and processes.

Marine Geology
Structure and evolution of ocean basins, continental margins, and marine sediments.

Isotope Geochemistry
Studies of stable and radiogenic isotopes in the earth's mantle and crust. The use of isotopes in age dating, source tracing, and geothermometry.

Geophysics I
Theory and application of seismic refraction, seismic reflection, deep earth seismology, surface waves, and heat flow. Collection and interpretation of seismic data.

Geophysics II
Theory and application of gravity, magnetics, paleomagnetics, and electrical prospecting. Measurement and interpretation of potential field anomalies.

Numerical Methods in Paleoecology
Digital computational methods for paleoecologists and paleontologists; measurement systems and data transformation; statistics; discrete association and gradient analytic techniques for paleoecological research. Emphasis on applied data analysis.

Studies in Micropaleontology
Paleoecology and biostratigraphy of foraminifera; identification and interpretation of microscopic organic remains in rocks and sediments.

Advanced Studies in Geology (BA, BA)
[Course may be taken more than once.] Special topics chosen each term. Recent topics include:
SEQUENCE STRATIGRAPHY
EXTENSIONAL TECTONICS
FRACTURE MECHANICS

Seminar in Geology (BA)

Research in Geology (BA, BA)

Quaternary Studies Seminar
A multidisciplinary (geology, geography, biology, meteorology, oceanography, paleontology and soils) course focused on specific questions or problems related to the Quaternary time period.

6. AKITA UNIVERSITY
Faculty of Engineering and Resource Science
Department of Erath Sciences and Technology

Master Program: Resources Sciences

Resource Geology
Quaternary stratigraphy, sedimentology, geomorphology and tephrochronology as a basis for the history of Quaternary environmental changes.
Genesis of ore deposits and their time-spatial variations based on analyses of kinetic processes such as atom diffusion within minerals, crystal growth of sulfide minerals, and ore textures.
Calcareous nannofossil biostratigraphy, sedimentology, and historical geology as a basis for the exploration of petroleum and natural gas.
Genesis of mineral deposits based on the chemistry of ore-forming fluid, especially by fluid inclusion and stable isotope studies.

Igneous Petrology
Petrology with special emphasis on the time-space characteristics of igneous rocks in relation to crustal evolution and tectonic developments.
Geochemical and isotope characteristics of magmatic materials and circulation of elements in the earth's interior.

Petrology and Sr-isotope geochemistry of volcanic rocks and mantle xenoliths, with special reference to Quaternary volcanism in the northeast Honshu arc, Japan.

Geothermal Energy and Geophysics
Geological and geochemical application for the geothermal resource exploration and genesis, with special reference to alteration mineralogy, age determination and remote sensing.
Studies on the interior and outer layer of the earth and the history of them based on the geophysical methods such as paleomagnetism, rock magnetism, and measurements and analysis of earth's magnetic and electric fields.
Research on subsurface velocity structures of active volcanoes and sedimentary basins by means of active and passive seismological methods.

Resource Development with Environment Sustenance
Sustainable resource exploitation and its influence upon environment in aspects of natural material circulation.
Cenozoic volcanic stratigraphy and geology of formations consisting mainly of volcanic products, especially in the region of back arc volcanism in the northeast Honshu arc, Japan.
Studies on system engineering for resources production and underground environment.
Theoretical and applied studies on the development of fluid energy resources, such as petroleum, natural gas and geothermal energy.

7. TOHOKU UNIVERSITY
Graduate School of Environmental Studies
Master Program: Geosystem and Energy Sciences

Common Lectures A
Introduction to Environmental Studies

Common Lectures B
Seminar on Environmental Sciences
Environment and Civilization I
Joint Lectures on Environmental Sciences (Program)
Introduction to Regional Environment and Socio-Cultural Studies
Introduction to Geosystem and Energy Sciences
Introduction to Environmental Chemistry and Ecoengineering
Introduction to Ecomaterial Design and Process Engineering

Basic Lectures Offered in the Field of Specialization
Earth System and Global Change
Surface and subsurface measurements for environmental science
Mass and Energy Transport in Geochemical Processes

Lectures Offered in the Field of Specialization
Environmental and Technology Policy
Treatment and Remediation for Environmental Substance
Environmental Law and Policy
Solar-Terrestrial Environment Study
Atmospheric Chemistry

Remote sensing for environment study
Advanced energy and environment
Simulation of climate change
Geosphere Transport Phenomena
Environmental Geomechanics
Environmental evaluation of the Earth's crust
Applied Crust Exploration Engineering
Design of Crustal Complex Fracture Systems
Geothermal Energy Extraction Engineering
Environmental Perspective on the Energy Flow
Energy and resources
Internship for Master Course Students

Special Lecture Ⅰ

Special Seminar Ⅰ

Signal Processing
Theoretical Basis of Fluid Dynamics
Solid Mechanics
Thermal Science and Engineering
Computer Science
Solid State Physics
Energy Systems Engineering
Numerical Analysis
System Control Engineering
Atmospheric Dynamics
Satellite Oceanography
Atmospheric Radiation
Special Lecture on Physical Oceanography
Physical Climatology
Seminar on Geosystem and Energy Sciences
Master Course Seminar on Geosystem and Energy Sciences

Ph.D. Program: Geosystem and Energy Sciences

Basic Lectures Offered in Interdisciplinary Fields
Advanced Earth System and Global Change
Advanced Environmental Studies on Geothermal Energy
Advanced surface and subsurface measurements for environmental science

Environment and Civilization Ⅱ

Internship for Doctor Course Students
Presentation & Discussion
History of Modern Technology

Special LectureⅡ

Special Seminar
Seminar on Geosystem and Energy Sciences
Doctor Course Seminar on Geosystem and Energy Sciences

8. KYUSHU UNIVERSITY

Courses

(1) Evaluation of soil behaviour and earth reinforcement practice
(2) Advanced Nuclear Physics and the Applications
(3) High Energy Elementary Particle Reaction
(4) An Introduction to Environmental Engineering
(5) Resources Processing
(6) Seismic Design for Structure
(7) Computational Mechanics of Structures
(8) Introduction to Transportation Engineering and Planning
(9) Solid Waste Management and Resource Recovery
(10) An Introduction to Environmental Hydraulics
(11) Radiation Effects and Nuclear Materials
(12) Wastewater Engineering
(13) Environmental Geology
(14) Geo-thermics
(15) Geothermal Reservoir Engineering
(16) Ground Control Engineering
(17) Hydrology and Water Resources Systems
(18) Structural Design and Concrete Engineering
(19) Geotechnical Hazards
(20) Introduction to Geo-disaster Prevention
(21) Systems and Control Engineering
(22) Resistance and Propulsion of Ship
(23) Marine Safety and Vessel Maneuverability
(24) Ship Design and Ocean Development

9. UNIVERSITY OF AUCKLAND NEW ZEALAND
Geothermal Institute, Faculty of Science
Post graduate Certificate in Geothermal Energy Technology

GEOTHERM 601: Geothermal Resources and Their Use

Lectures cover basic features of geothermal resources, classification and development, assessment of reservoirs, fluid production and steamfield equipment, electricity generation, reservoir engineering, environmental considerations, development planning and geothermal project economics. Approximately 60 hours of lecture, lab and field work. The final grade is based on assignments (25%), a test (15%) and the final exam (60%).

Lecture Topics Include: Properties of water and use of steam tables; Worldwide settings of geothermal systems & volcanism; Plate tectonics & classification of geothermal systems; Geology and geothermal systems in New Zealand; World geothermal development; Surface manifestations; Steamfield equipment; Chemical features of geothermal fluids; Methods of electricity generation; Fluid production, separation & transmission; Dimensions and time scale of geothermal reservoirs; Introduction to Reservoir Engineering; Stored Heat/simple Resource Assessment; Flow in porous media; Geoscientific assessment of reservoirs; Environmental considerations; Direct use of heat; Planning of geothermal development.

GEOTHERM 601: Geothermal Energy Technology

Lectures cover general geoscience, thermodynamics, fluid mechanics and heat transfer, ground water hydrology, and corrosion and scaling. Approximately 60 hours of lecture, lab and field work. The final grade is based on assignments (25%), two tests (40%) and field activities (35%).

Lecture topics include: Geological concepts and terminology; Thermodynamics fundamentals; Geochemistry fundamentals; Introduction to Engineering Economics; Heat Transfer fundamentals; Fluid mechanics; Volcanoes and volcanic rocks; How to give a seminar; Groundwater hydrology; Site Investigations; Heat Loss; Chemical Geothermometry; Field methods; Corrosion; Scaling/

GEOTHERM 603: Geothermal Exploration

Lectures cover mapping thermal features, reservoir permeability, well logging, hazards, chemistry of geothermal fluids, aqueous and gaseous geothermometers, rock properties, and geophysics exploration methods. Approximately 60 hours of lecture, lab and field work. The final grade is based on assignments (25%), a test (15%) and the final exam (60%).

Lecture Topics Include: Geology; Mapping geology and thermal features; Photogeology; Permeability; Well logging; Geothermal and volcanic hazards; Hydrothermal alteration; Remote Sensing; Geophysics; Rock Properties; Resistivity; Gravity; Magnetics; Magnetotelluric; Seismic; Geochemistry; Fluids in the crust; Boiling-mixing; Gases; Geothermometry; Stable isotopes.

GEOTHERM 620: Geothermal Engineering

Lectures cover fluid dynamics, principles of heat and mass transfer, energy cycles, basic components of fluid production and utilization, concepts of energy conversion, optimization, and criteria for good design and plant maintenance. Approximately 60 hours of lecture, lab and field work. The final grade is based on assignments (25%), a test (15%) and the final exam (60%).

Lecture Topics Include: Heat Transfer; Power cycles; Reservoir Engineering; Geothermal power cycles; Heat Exchanger; Fluid flow; Waste heat rejection; Pipe flow; Well and casing design; Economics; Consents; Environmental impact report; Corrosion; Drilling Practices; Commercial development of geothermal power projects; Quality assurance.

GEOTHERM 689: Geothermal Project

Based on a study using field, lab or theoretical methods, students are required to submit a report on some aspect of geothermal exploration, development or exploitation.

10. DOKUZ EYLÜL UNIVERSITY
Faculty of Engineering

Undergraduate courses

Mathematics I
Physics I
Chemistry I
General Geology
Basic Science Technology
Technical English I
Principles of Kemal Atatürk and Revolution History
Turkish Language
Mathematics II
Physics II

Chemistry II
Statics
Technical Drawing
Introduction to Computer Programming
Technical English II
Principles of Kemal Atatürk and Revolution History
Turkish Language
Sports / Fine Arts
Mineralogy
Geophysical Methods
Strength of Materials
Geological Mapping
Paleontology
Principles of Stratigraphy
Dynamic
Topography
Introduction to Statistics
Structural Geology
Historical Geology
Optical Minerology
Topographic Application (*)
Petrography
Geochemistry
Rock Mechanics
Hydrogeology
Sedimentology - Sedimentary Petrography
Environmental Geology
Field Geology
Engineering Geology
Ore Deposits
Drilling Techniques
Petrology
Fuels Geology
Subsurface Geology
Geological Field Mapping (Summer Field Work)
Technical Elective
Photogeology and Remote Sensing
Soil Mechanics
Dam-Tunnel Geology
Design of Rock Slopes
Geotechnical Tests
Groundwater Hydrology
Mineral and Spring Waters
Groundwater Chemistry
Hydrogeological Prospection
Report preparation Techniques in Applied
Geology
Geothermal Systems
Clay Minerals
Marble and Marble Technology

X-Ray Methods
Mineralogy of Gem Stones
Applied Mineralogy
Computer Application in Mineralogy and Petrology
Ceramic Raw Materials
Metamorphic Petrography
Pegmatites
Evaporites
Marble Deposits in Turkey and World
Coal Geology
Ore Microscopy
Mining Law and Environmental Impact Assesment Reports
Introduction to Mining
Geoenvironmental Geochemistry
Sample Preparation Methods
Environment Geochemistry
Reserve Estimation
Mining Geology
Rare Earth Elements
Economy of Energy
Industrial Raw Materials
Neotectonics and Quaternary Geology
Natural Disasters and Earth Sciences
Methods of Structural Analysis
Tectonic Belts of the Western Anatolia
Computer Applications in Geology
Field Geology in Landslided Areas
Geology of Turkey
Techniques of the Geological Mapping
Plate Tectonics
Correlation Methods
Determination of mineralogical composition as well as textural and grin size analyses
Jewellery materials with quartz, agate, chalcedory jasper etc. and decorative objects
Determination of the Physical Properties of Rocks
Determination of the Natural, Dry and Water Saturated Unit Weight
Determination of Porosity and Water Content
Degree of Saturation, Water Absorption by Weight
Determination of Rock Hardness
Core Samples Obtained From Rock Blocks on Uniaxial Compressive Strength and Undirect Tensile Strength
Point Load Test on Core and Hand Specimens
Determination of the Slake Durability Properties of Weak Rocks
Freezing and Thawing of Marbles
Determination of Rock Surface Roughness
Schmidt Hammer Testing of Rocks
Atterberg Limit Determination of Cohessive Soils
Sieve Analysis of Granular Soils
Unconfined Compressive Strength Test of Soils

11. MIDDLE EAST TECHNICAL UNIVERSITY, TURKEY

Faculty of Engineering
Department of Geological Engineering

UNDERGRADUATE COURSES

GEOE 104 Geology For Civil Engineering
Structure of the Earth. Geological cycles, minerals and rocks. External processes on land and in the sea. Internal processes, including deformation of rocks and earthquakes. Topics of interest to Civil Engineering students.

GEOE 105 Introduction to Geological Engineering
The Earth and its crust. Economic resources of the crust. Geological hazards (earthquakes, volcanic eruptions, landslides), Hydrologic environment. Opportunities in Geological Engineering. Engineering ethics and professional responsibilities.

GEOE 201 General Geology
Structure of the Earth. Elements, minerals, and rocks of the Earth's crust. Igneous and metamorphic processes. Weathering. Sedimentary processes. Geological external processes. Rock formation. Earth's dynamic processes and rock deformation. Map studies.

GEOE 203 Introduction to Earth and Planetary Sciences
A course designed to introduce geology and planetology to non-Geological Engineering students. It discusses rocks (igneous, sedimentary and metamorphic), time in general and geological record in particular, origin of life and theory of evolution, geologic structures, Earth's crust, mantle and core, comparative planetology, origin of solar system and universe.

GEOE 207 Principles of Mineralogy and Petrography
Introduction to mineralogy and petrography. Physical, chemical and descriptive mineralogy. Classification of minerals, description of common rocks. General classification of igneous, sedimentary and metamorphic rocks particularly for field use. Identification of common minerals and rocks in hand specimens.

GEOE 208 Mapwork
Concepts of geological features on topographic maps. Scale and orientation. Three dimensional view in problem solving. Use of space geometry in geological map problems. Introduction to basic design concepts through geological maps. Prerequisite: GEOE 209.

GEOE 209 Physical Geology
Framework of Earth processes and products. Concepts and terminology of basic geological features. Interrelation of various branches of the scientific study of Earth.

GEOE 210 Petrography
Description of rocks. General classification of igneous, sedimentary and metamorphic rocks (particularly for field use). Identification of common rocks in hand specimens and under the petrographic microscope. Prerequisite: GEOE 213.

GEOE 213 Mineralogy
Elementary crystallography, physical and chemical mineralogy, chemical classification. Optical properties of minerals. Identification of minerals in hand specimens and in thin sections.

GEOE 214 Principles of Stratigraphy
Depositional processes and classification of depositional environments. Stratification, unconformities, and facies concepts. Fundamentals of stratigraphic nomenclature. Lithostratigraphic, biostratigraphic, chrono- stratigraphic and geochronologic units.

GEOE 215 Principles of Structural Geology
Introduction to diastrophic and non-diastrophic rock structures. Study of contacts, unconformities, diapirs, folds, joints, faults, foliations, and lineations. Kinematics of diastrophic structures. Prerequisite: GEOE 231. (Offered to non-GEOE students only).

GEOE 231 Elements of Geology
Shape and Structure of the Earth. Elements, minerals and rocks of the crust. Igneous and metamorphic processes. Weathering. Sedimentary process. Actions and geologic agent. Rock formation. Earth's dynamics and rock deformation. (Offered to non-GEOE students only).

GEOE 300 Summer Practice I
Getting familiar with the work of a private or state organization where geological engineering is practiced. A report, introducing the organization and outlining the activities and equipment concerned, must be submitted to the Department of Geological Engineering during the Registration Period following Summer Practice I.

GEOE 303 Geophysical Prospecting
Introduction to geophysical surveying methods and their applications to engineering and geological problems. Global aspects of seismology. Computing laboratory works and case studies.

GEOE 304 Igneous and Metamorphic Petrology
Modal and chemical classification of igneous rocks. The genesis and evolution of magmas, magma generation at different tectonic settings. Igneous rock suites. Metamorphic reactions and metamorphic assemblages. Thermotectonic modeling and interpretation of plate tectonic settings of metamorphism. Field studies of metamorphic and igneous rocks. Prerequisite: GEOE 210.

GEOE 309 Historical Geology and Paleontology
Ordering geologic events. Geological time concepts and methods of correlation. Chronological earth history and life record. Classification of the major fossil groups and their significance in the evolution of life.

GEOE 310 Sedimentary Petrology
Origin and classification of sedimentary rocks. Texture, mineralogy, composition, structure and diagnosis of siliciclastic, volcaniclastic and non-clastic sedimentary rocks. Prerequisite: GEOE 213.

GEOE 313 Structural Geology
Review of common diastrophic and non-diastrophic rock structures. Introduction to themechanical properties of rocks. Kinematics of bending, fracture, shear and flow. Application to the study of faults, folds, cleavage, joints, foliation, and lineation. Use of stereograms in structural studies. Plate tectonics. Prerequisites: GEOE 208 and GEOE 214.

GEOE 318 Geochemical Thermodynamics
Fundamental concepts-systems, states, equilibrium; the first, second, and third law of thermodynamics; enthalpy, entropy, and free energy. Thermodynamics of solutions. Phase

equilibria and phase diagrams. Mineral equilibria-equilibrium constant partial pressure and activity diagrams, Eh-pH diagrams. Prerequisite: CHEM 112.

GEOE 324 Principles of Petroleum Geology
Nature of oil and gas. Generation, migration and accumulation of petroleum. Properties of reservoir and source rocks. Trapping mechanisms. Exploration techniques.

GEOE 326 Field Geology
Reading topographic maps. Equipment used in geological mapping. Organization and interpretation of geological maps. Preparation of generalized columnar sections and cross-sections. Techniques of measuring stratigraphic sections. First aid and safety in the field. Ethics in earth sciences. Prerequisite: GEOE 313.

GEOE 327 Field Geological Mapping
Use of topographic maps, compass, altimeter and GPS in the field. Recognition and description of rock units, and geological structures. Geological nomenclature. Geological mapping in the field. Preparing of illustrations and writing a geological report. Corequisite: GEOE 326.

GEOE 400 Summer Practice II
Experience in the field, laboratory or office work of a private or state organization where geological engineering is extensively practiced. Students should be actively involved in one or more ongoing projects. A report, outlining the work in which the student has been involved, must be presented to the Department of Geological Engineering during the Registration Period following Summer Practice II.

GEOE 401 Mineral Deposits
Mineral resources concepts, textures and structures of mineral deposits, paragenesis and zoning, geothermometry, major theories ore genesis, magmatic segregation, contact metasomatism, hydrothermal deposits, massive sulfides, residual and mechanical concentration, sedimentation, oxidation and supergene enrichment, metamorphism, metallogenic concepts.

GEOE 402 Mineral Deposits of Turkey
Mineral deposits in relation to plate tectonics concepts. Metallogenic concepts. Mineral deposits of Pontids. Menderes Massif and Western Anatolia. Kırşehir Massif and Central Anatolia. Eastern Anatolia. Taurids and Border Folds. Reserve base and mineral inventory concepts.

GEOE 404 Geology of Turkey
Review of lithologies, distribution, tectonic setting and origin of the main geological belts in Turkey.

GEOE 406 Earthquake Geology
Mechanism and resources of earthquakes. Global distributions of earthquake epicenters and their relationship with the plate boundaries. Earthquake prediction and paleoseismology. Destructive effects of earthquakes. Major earthquake belts in Turkey and their relationship with fault zones.

GEOE 407 Engineering Geology
Review of engineering properties of rocks and soils. Stages of site investigation. Engineering geological evaluation of dam and reservoir sites, and tunnels. Introduction to soil and rock slope stability. Types and sources of construction materials. Case histories. Prerequisite: CE 364.

GEOE 408 Geomorphology
Origin of landscapes and geomorphic features. Cycle of erosion. Denudation, chronology of rivers, lakes and landscapes. Characteristics of karstic regions. Principles of geomorphological mapping.

GEOE 409 Photogeology
Principles of stereoscopic vision. Identification of drainage patterns and geomorphological interpretation. Identification and interpretation of rock units, folds, faults and joints from aerial photographs. Preparation of geological maps and cross-sections from aerial photographs. Prerequisite: GEOE 313.

GEOE 410 Petroleum Geology
Physical and chemical properties of oil and gas; generation and accumulation of oil; traps; Regional distribution of oil; reservoir mechanics; subsurface exploration techniques. Geodynamic evolution of the major tectonic units.

GEOE 412 Exploration and Mining Geology
Guides for exploration. Economic framework or exploration and mining operations. Methods of systematic collection, correlation and interpretation of geological data through phases of reconnaissance and exploration. Sampling and estimating reserves. Examination and evolution of prospects. Geological work at developing and operating mines.

GEOE 414 Environmental Geology
Environmental concepts of population and environment. Hazardous Earth processes; flooding, mass movements, earthquakes, and coastal hazards. Human interaction with environment. Groundwater contamination and the geological aspects of waste disposal. Environmental health.

GEOE 416 Micropaleontology
Value of micropaleontologic studies in geologic exploration. Sampling and sample preparation techniques. Microfossil groups including foraminifera, nannoplanktons, calpionellids and radiolaria. Microfossils as chronometers of the Phanerozoic and as paleoenvironmental and paleogeographic indicators. Stratigraphic section analysis by using micropaleontologic data.

GEOE 417 Metamorphic Petrography
Classification and description of common metamorphic rock types in hand specimens and under the microscope. Textures and structures of metamorphic rocks. Concepts of metamorphic zones and facies. Metamorphic rock associations. Metamorphic rocks and global tectonics. Prerequisite: GEOE 210.

GEOE 418 Geochemistry
Crystal chemistry-principles and rules for atomic substitution. Composition of universe (sun, planets, meteorites). Composition and evolution of Earth and its reservoirs (core, mantle, crust, hydrosphere, biosphere, atmosphere). Major and trace element behaviour in magmatic processes-melting and crystallization models. Products of magmatic processes-volcanics and granitoids. Geochemistry in sedimentary and metamorphic processes.Prerequisite: GEOE 318.

GEOE 419 Gemology
Brief information about crystallography, physical and chemical information to recognize the gemstones. Polishing and faceting technics. Origin and occurrence of the gemstones. Descriptive gemology. Prerequisite: GEOE 213.

GEOE 420 Geostatistics
Introduction to probability concepts. Testing hypothesis. Testing normal populations of geological nature. Analyses of geological sequences. Runs tests. Regression analysis, auto-correlation, crosscorrelation, crossassociation in stratigraphy. Transition matrices. Further analyses of geological problems. Prerequisite: ES 303.

GEOE 422 Coal Geology
Coal forming environments, coal-bearing sediments and formation of coals. Classification of coals, coal chemistry, coal petrology. Paleobotany and palynology. Coal basins of Turkey and the world. Industrial uses of coal.

GEOE 423 Hydrogeology
Elements of surface hydrology. Origin, occurrence, and movement of groundwater. Water-bearing properties of rocks and sediments. Well hydraulics. Groundwater exploration. Drilling, development, and completion of water wells. Regional groundwater flow. Groundwater budget. Sea water intrusion in coastal aquifers. Groundwater quality. Prerequisite: CE 374.

GEOE 424 Geothermal Systems
Definition and classification of geothermal systems, heat flow, geothermal anomalies and their plate tectonic framework. Prospecting for geothermal resources. Water chemistry in geothermal exploration, estimation of reservoir temperatures, effects of mixing and underground boiling. Heat extraction from geothermal reservoirs. Geothermal resource assessment. Environmental aspects of geothermal energy development.

GEOE 425 Computer Applications in Geological Engineering
Application of computer techniques to the solution of problems related with Geological Engineering. Use of word processing, data management. Finite differences, finite elements and geostatistics software.

GEOE 428 Industrial Rocks and Minerals
Characteristic features of industrial rocks and minerals. Place value and unit value concepts. Classifications of industrial rocks and minerals. Geologic occurrences, physical and chemical properties, uses and economics of igneous, metamorphic and sedimentary rocks and minerals related to pegmatitic, hydrothermal, metamorphic and sedimentary processes.

GEOE 429 Geowriting
Form and content of geological reports. Maps, cross sections, vertical sections, columnar sections, correlation charts, orientation of photos, scale factor. Reference citations. Figures, plates and tables. Assignment of term papers.

GEOE 430 Groundwater and Well Hydraulics
Basic definitions. Theory of groundwater flow. Steady and unsteady radial flow to wells in confined, unconfined, and leaky aquifers. Design of pumping-test programs. Analysis and evaluation of pumping test data. Use of computers in groundwater flow and pumping test analysis. Prerequisite: GEOE 322.

GEOE 431 Introduction to Remote Sensing
Overview and history of remote sensing and earth observation. Application of electromagnetic radiation principles to remote sensing. Interactions of energy-matter in atmosphere and earth

surface. Sensors and platforms. Available satellite systems for earth observation. Future trends. Prerequisite: Consent of the Department.

GEOE 432 Hydrogeochemistry and Water Quality
Hydrogeochemical processes controlling the water quality in natural environments. Analytical determination and evaluating the quality of the physical and chemical properties of water. Sources and control of water contamination. Prerequisite: GEOE 322 or consent of the Department.

GEOE 433 Marine Geology
Physical and chemical environments of the oceans and related marine basins. Clastic and chemical processes of sedimentation. Types, distribution, rate of accumulation and abundance of sediments. Character of geological environments of ocean floor. Heat flow, seismic, magnetic and gravity features of ocean floor.

GEOE 434 Igneous Petrography
Classification and description of common igneous rock types in hand specimens and under the microscope. Textures and structures of igneous rocks. Modal and chemical analysis of igneous rocks. Calculation of norms. Magma and formation of igneous rocks. Petrographic provinces and igneous rock associations. Prerequisite: GEOE 210.

GEOE 435 Exploration and Development of Groundwater Resources
Geological, geophysical, and geochemical methods for exploration and development of groundwater resources. Hydrogeological mapping. Water well drilling techniques. Well logging. Water well design. Installing well screens. Development and completion of water wells. Well sterilization. Corrosion and incrustation. Pumps and power units. Well and pump cost factors, operation and maintenance. Prerequisite: GEOE 322 or consent of the Department.

GEOE 436 Stratigraphic and Paleontologic Analyses in Exploration
Treatment of stratigraphic and paleontologic data in geologic exploration. Stratigraphic correlation. Facies analysis. Use of fossil record in recognition of sedimentary rock bodies. Biostratigraphic, paleoenvironmental and paleogeographic applications.

GEOE 437 Geomechanics
Classification and index properties of rocks. Rock strength and failure criteria. Initial stresses in rocks and their measurements. Planes of weakness and deformability of rocks. Application of geomechanics in geological engineering. Prerequisite: ES 224.

GEOE 438 Engineering Geological Mapping
Principles of engineering geological mapping. Methods of data collection, evaluation, and presentation. Stripe method and zoning concept in engineering geological mapping. Cost effective mapping. Preparation of thematic engineering geological maps in planning of land-use and the location, construction and maintenance of various engineering structures. Prerequisite: GEOE 407.

GEOE 439 Geology and Paleobiology
Nature of the Earth's interior. Elements, minerals and rocks of the Earth's crust. Surface and internal processes. Stratigraphy, geologic time concept and chronologic Earth history. The origin of life. Major events in the history of life. The evolutionary process and the fossil record. (Offered to non-GEOE students only) Prerequisite: Consent of the Department.

GEOE 441 Applied Mineral Science

Relationships between fundamental properties and behavior of minerals in natural environments and industry. Applications based on surface, electrical, magnetic, mechanical, thermal, optical and nuclear properties. Adsorption on minerals and ion exchange. Mineral catalysts, fluxing capacity. Minerals, health hazards and natural environments. Ceramics, glasses, abrasives, conductors, mineral pigments, mineral dusts. Prerequisite: GEOE 213 or consent of the Department.

GEOE 443 Aerial Thematic Mapping
Fundamentals of thematic mapping using aerial photographs. Recognition and identification of different landforms. Terrain characteristics. Thematic mapping approaches. Case studies.

GEOE 445 Aerial Photography
Fundamentals of aerial photographs and aerial camera; mission planning in airborne remote sensing. Errors in airborne systems. Orthophotos. Mosaics. Parallax calculations. Establishment of stereograms, use of terrestrial stereophotography.

GEOE 447 Digital Terrain Analysis
Handling of various interpolation techniques of geo-spatial data. Recognition and classification of different terrain aspects, terrain morphometry, interpretation of Digital Terrain Model (DTM)and derivatives, production of thematic maps and analysis of selected terrains.

GEOE 480 Management in Geological Engineering
Basic concept and principles of management. Planning, organizing, staffing, directing and controlling of field and laboratory projects in organizations where geological engineering is the main practice.

GEOE 490 Graduation Project
Independent geological work, guided by an academic advisor. Subject must consist of fieldwork, literature search, and labwork, ending with a formal report. Prerequisite: GEOE 308 or consent of the Department.

GEOE 491 Geological Engineering Design I
Basic concepts in engineering and design. Engineering ethics. Needs and information analysis.

12. ARISTOTLE UNIVERSITY OF THESSALONIKI
Faculty of Sciences

Bachelor Program: Geology

MATHEMATICS I (GGN 101Y)
A. The derivatives of functions of one variable (derivatives of implicit and parametrical functions) and their applications. Integrals and their applications. Arithmetical methods of integration. B. Multivariate functions (basic concepts, partial derivations and their applications, multiple integrals and their scientific applications). C. Vector analysis (basic concepts, vector functions, directed derivative, line integrals and their applications). D. Sequences and their applications.

PHYSICS (GGN 102Y)
Thermodynamics: Heat, temperature, ideal and real gases, laws of thermodynamics, entropy, Carnot cycle, chemical and compositional equilibrium. Radiation: Kirchoff's law, thermal radiation laws, photothermal conversion of sun energy. Electricity and Magnetism: Electric charge, electric field,

potential, dielectrics in electric field, capacitors, electric current, magnetic field, mutual induction, magnetic properties of matter. Atomic spectra: Photoelectric phenomenon, wave properties of particles, hydrogen atom, Zeeman effect. Chapter of Optics.

CHEMISTRY (GGN 103Y)
Introduction. Chemistry laws. Principles of chemical equilibrium. Periodic system. Introduction to the atomic structure. Theory of the chemical bonds. Main chemical elements.

CRYSTALLOGRAPHY (GMO 104Y)
Geometric crystallography (methods of research and description of crystal polyhedra, description of the 32 crystal classes, crystal systems, crystal intergrowths). Crystal lattice (lattice forms, reverse lattice, symmetry groups). Research of crystal structure by X-rays (X-rays characteristics-single crystal methods, powder diffraction methods).

INTRODUCTION TO GEOLOGY (GGG 105Y)
Branches and laws of Geology. Cosmogeny, Geologic Phenomena. Exogeneous and Endogenous forces. Situation of the beds. Volcanism. Plutonism. Geodynamic theories.

MINERALOGY (GMO 106Y)
Mineral chemistry and chemical composition of minerals. Physical properties of the minerals. Mineral genesis (chemical and mineralogical composition of the Earth's Crust -Phase diagrams - Phase Rule - Magmatic environment - Metamorphic environment - Sedimentary environment). Determinative mineralogy (physical properties and use of them - chemical tests). Systematic mineralogy.

OPTIONAL
ANALYTICAL CHEMISTRY (GGN 107E)
Concentration of solutions. Homogenous and heterogeneous equilibrium of ionic solution (weak acid - base, water, precipitates and complex ions). Properties and reactions of cations of V groups, including detailed analysis of each group. Gravimetric analysis (principals and quantitative determination of iron and calcium). Titrimetry (principals and acid-base, precipitation, argentimetry, complexometric and redox titrations. UV-Vis molecular spectroscopy. AASspectroscopy.

PHILOSOPHY OF SCIENCE (GGP 108E)
Philosophy and Science relation. The methodology and nature of scientific knowledge. Methods of acquiring scientific knowledge. Social character of scientific knowledge. Necessity of studying scientific problems. Philosophic problems of specific sciences with emphasis on Geology. Historial evolution of scientific knowdelge.
STATISTICS (GGN 210Y)
Elements of probability theory - Distributions of some useful statistics - Descriptive statistics - Methods of point estimation - Confidence intervals and tests of hypotheses for the mean, the variance and the proportion for one and two samples - Test of Goodness -of Fit - Contingency tables - Tests of homogeneity - the method of least squares - Regression - Tests of hypotheses and Confidence intervals in simple linear Regression - Simple, multiple and partial correlation coefficient.

INTRODUCTION TO SEISMOLOGY (GGP 211Y)
Elements of elasticity theory and elastic waves. Instruments of recording earthquakes. Seismic waves and their propagation in the Earth's interior. Seismometry. Magnitude and energy of

earthquakes. Seismic activity of the Earth and its distribution. Earthquake generation and prediction. Macroseismic results of earthquakes. Simulated motions. Antiseismic protection.

ROCK-FORMING MINERALS (GMO 212Y)
Elements of Optical Mineralogy. Silicate minerals. Nesosilicates, Sorosilicates, Cyclosilicates, Inosilicates, Phyllosilicates, Tectosilicates. Non silicates. Composition, structure, optical properties, genesis, alteration and occurrence of the main rock-forming minerals.

FIELD COURSES (GGN 213Y)
The field courses refer to the courses of Geology, Mineralogy and Seismology.

MATHEMATICS II (GGN 214Y)
Vector analysis. Matrices.

OPTIONAL
PHYSICAL CHEMISTRY (GGN 215E)
Laws of thermodynamics and applications to geological systems. Thermodynamic functions and fundamental equations. Principles and laws of thermochemistry and their applications. Homogeneous and heterogeneous thermodynamic equilibrium. Phase equilibrium and phase diagrams. Experiments on thermodynamics and the properties of liquids.

BIOLOGY (GGN 216E)
Historical review, the origin of life. Methods used in the research of cell structure and function. Cell biology. Molecular biology (genes, DNA duplication, gene expression, protein synthesis, mutations, chromosomal abnormalities). From cells to organisms (developmental processes of cells and organisms, tissues and organs, organism defense). Mechanism of heredity. Mendel's laws, sexual orientation, genetic engineering, biotechnology, applications. Evolution, natural selection, the origin of species.

Fundamental principles. Compositional groups. Origin of metamorphic rocks. Factors of metamorphism. Types of metamorphism. Classification of metamorphic rocks. Grades of metamorphism. Mineralogy of metamorphic rocks. Graphical representation of the mineral parageneses. Thermal metamorphism. Regional metamorphism. Geotectonic regimes of regional metamorphism. Mig-matites. Oceanic metamorphism. Burial metamorphism. Dynamic metamorphism.

VERTEBRATE PALAEONTOLOGY (GGG 426Y)
Fossilization of vertebrates. Classification of vertebrates: Agnatha, Chondrichthyes, Osteichthyes, Amphibians, Reptiles, Aves, Mammalia. Paleoanthropology.

PHYSICAL GEOGRAPHY (GGE 427Y)
Geomorphology. Origin, evolution, description and classification of the morphological types on the surface of the Earth. Elements of Oceanography.

FIELD COURSES (GGN 428Y)
The field courses refer to the courses of Palaeontology, Physical Geography and Petrology.

OPTIONAL
MICROPALAEONTOLOGY (GGG 429E)
Introduction. Foraminifera. Radiolaria. Ostracoda. Diatoms.

CRYSTAL STRUCTURE (GGN 430E)
Introduction to geometry and symmetry of lattice. Kinematics theory of refraction. Scattering. Atomic factor of structure. Temperature impact. Methods of structure determination: Principles of monocrystal refraction, Grain mount refractometry, Identification of crystal bodies, Application of Rietveld methods. Application of computer languages to structure condition of the compounds. Applications to Mineralogy and Geology.

CLIMATOLOGY - CLIMATE OF MEDITERRANEAN AND GREECE (GMC 431E)
Weather-Climate-Climatic parameters and factors. Solar radiation, sunshine. Temperatures on earth surface. Atmospheric humidity. Clouds and precipitation. Local winds. Ocean currents. El Ninio Phenomenon. Classification and geographical distribution of climates. The Mediterranean Climate. Location and geomorphology of Greece. Air masses. Atmospheric pressure. Pressure systems and winds over the Greek area. Isolation, cloudiness, fog, air and soil temperature. Absolute and relative air humidity, geographic distribution of the precipitation over the Greek area. Storms and hail. Snow and snow-covered ground. Classification of climate in Greece.

SEISMIC METHODS OF GEOPHYSICAL PROSPECTING (GGP 432E)
Seismic methods of Geophysical prospecting (elements of elastic waves propagation, generation of elastic waves in seismic prospecting, recording instrumentation of elastic waves, methods of seismic reflection and refraction).

GEOLOGICAL DATA ANALYSIS (GGP 433E)
Time series analysis, spatially distributed data, multivariate methods, examples in geological and meteorological data analysis using computer applications.

ORE DEPOSITS (GMO 534Y)
Principles. Processes of formation of mineral deposits. Magmas and mineral deposits. Magmas and mineralizing fluids. Magmatic segregation deposits. Pegmatites. Contact metasomatism. Hydrothermal processes. Hydrothermal alteration. Porphyry copper deposits. Volcanogenic deposits. Submarine exhalative and volcanogenic proccesses. Weathering. Residual concentration (laterites, bauxites). Oxidation and supergene sulphide enrichment. Sedimentary deposits. Metamorphosed and metamorphic deposits. Classification of mineral deposits. Morphology of ore-bodies. Ore textures and structures.

GEOCHEMISTRY (GMO 535Y)
The subject and history of Geochemistry. The Earth in relation to the Universe. Formation of basaltic-gabbroic melts. Magmatic gasses. Geochemical classification of the elements. Crystal chemistry. Geochemistry of igneous rocks. Geochemistry of sedimentary rocks. Geochemistry of metamorphic rocks. The nature of the hydrosphere. The nature of the atmosphere.

PHYSICS OF THE LITHOSPHERE (GGP 536Y)
Structure of the Crust and Upper Mantle (distribution of the velocities and attenuation of seismic waves, gravity distribution, variation of elastic parameters, density and pressure. Deformation and kinematics of the lithosphere (seismological and other geophysical methods).

STRUCTURAL GEOLOGY (GGG 537Y)
Rock deformation. Petrofabrics. Geological structures. Tectonics. Brittle deformation. Folds. Microtectonics and schistosity. Statistial methods. Geotectonics, orogenies, epirogenies.

STRATIGRAPHY AND HISTORICAL GEOLOGY (GGG 538Y)
Introduction. Stratification. Unconformities. Lithostratigraphy. Biostratigraphy. Chronostratigraphy. Geochronology. Stratigraphic Correlation. Phases. Study of all geological periods. (Paleogeography, Paleontology, Paleobiogeography, Tectonic events, Paleoclimatology).

OPTIONAL
ENGLISH OR GERMAN GEOLOGICAL TERMINOLOGY I (GGN 539E)
Geological texts and exercises in English or German.

THEORY OF OSCILLATIONS AND ELASTIC WAVES (GGP 540E)
Oscillations (harmonic oscillation, superposition of harmonic oscillations, analysis of oscillations, free oscillation, free oscillation with damping, forced oscillation). Theory of elasticity (stress, strain, stress-strain relationship). Elastic waves (wave equation, body waves, surface waves).

INDUSTRIAL MINERALS AND ROCKS (GMO 541E)
Terminology. Classification of industrial minerals and rocks. Origin of industrial minerals and rocks. Deposits of industrial minerals (asbestos, quartz crystals and quartz raw materials, feldspars, magnesite, talc). Deposits of industrial rocks (perlite, clays and clay minerals, bentonite, kaolin, phosphates).

GEOCHRONOLOGY (GMO 542E)
Isotope geology. General aspects concerning the application of age determination methods in rocks and minerals. The K-Ar method. The Rb-Sr method. Age determination of sediments. The U-Pb method. The 14C method - the Re-Os method. The fission track method.

HYDROMETEOROLOGY (GMC 543E)
Definitions-objectives. The water budget. Elements of the surface cyclone of water. Meteorological contributions to surface cycle of water (rain, mechanisms, types, calculation of rain water of an area). Storm models. Probable rainfall maxima. Evaporation-Calculation methods.

PALAEOANTHROPOLOGY (GGG 544E)
Primitives. Evolution trends. Cercopithecuses. Miocene Anthropoids. Interelationship and significance to the human evolution. Pliocene Antrhropoids. Australopithecuses. Appearance and evolution of the Homo race. Evolution stages of Homo erectus. Primitives of Homo sapiens, Neadertals, recent Homo sapiens. Skull of Petralona and other paleoanthropologic findings of the Greek area.
ORE DEPOSITS II (GMO 645Y)
Classification of metallic mineral deposits. Greek metallic mineral deposits. Specific metallic mineral deposits. Deposits of iron and the ferro-alloy metals. Deposits of the nonferrous metals. Deposits of precious metals. Deposits of minor metals and related non-metals. Deposits of fissionable metals.

HYDROGEOLOGY (GGG 646Y)
Surface hydrology. Hydrological balance. Underground water distribution and storage. Underground water flow. Underground water action in porous media.

SEDIMENTOLOGY (GGE 647Y)
Structure and texture of sediments. Depositional environments and models. Clastic and nonclastic sediments. Elements of applied sedimentology.

GEOLOGICAL MAPPING (GGG 648Y)
Geological maps. Geological sections. Geometric cartography. Three-dimensional representations. Special mapping. Field exercises.

FIELD MAPPING (GGG 649Y)
Practical exercises on the field. Groups of students under the supervision of a member of the teaching staff go on field trips and map an area.

FIELD COURSES (GGN 650Y)
The field courses refer to the courses of Sedimentology, Structural Geology, Stratigraphy, Neotectonics, Ore Deposits and Geophysics.

OPTIONAL
ENGLISH OR GERMAN GEOLOGICAL TERMINOLOGY II (GGN 651E)
Articles from scientific magazines. Texts and exercises in English or German.

IGNEOUS PETROGENESIS (GMO 652E)
Structure and composition of the Earth's interior. Distribution of igneous rocks. Magma composition and physical properties. Magma genesis and geotectonics. Use of major, trace and rare earth elements in petrogenesis. Isotope geochemistry. Origin and evolution of igneous rocks. Basaltic magma-granitic magma-partial melting. Phase equilibria. Phase diagrams.

APPLIED - ENVIRONMENTAL GEOCHEMISTRY (GMO 653E)
Geochemical research and its contribution to the environment protection. Primary and secondary environment. Index elements. Geochemistry of rocks, soils, river sediments, waters, vegetation, gas-liquid fuels and natural gases. Toxicity of minerals and elements in the environment and in the man's health. Environmental uses of industrial minerals and rocks. Geochemical proposals of environmental impacts.

APPLIED SEISMOLOGY AND ENVIRONMENT (GGP 654E)
Parameters of earthquake generation. Methods for the determination of fault plane solutions and focal parameters in Greece and broader area. Seismic hazard assessment in the area of Greece.

GRAVITY AND MAGNETIC METHODS OF GEOPHYSICAL PROSPECTING (GGP 655E)
Methods of gravity prospecting (density of rocks of the Earth, gravity parameters, instrumentation, data acquisition processing and interpretation). Magnetic prospecting (magnetic parameters, magnetic susceptibility of rocks, instrumentation, data acquisition processing and interpretation.

DIGITAL CARTOGRAPHY AND GEOGRAPHICAL INFORMATION SYSTEMS (G.I.S.) (GGE 656E)
Digital cartographic data structure (raster and vector). Map conversion form vector to raster form and vice-versa. Spatial representation of cartographic data. Projection systems in Greece. Satellite aided positioning system GPS and applications to geosciences. Principal components and functions of an idealized GIS. Spatial and non-spatial data input in GIS, processing analysis and output products (maps, tables, etc). Digital Elevation Models (DEM)deriving from topographic and satellite data and their use in geosciences. Interfacing Remote Sensing and GIS for geological purposes.

HISTORICAL CLIMATOLOGY WITH ELEMENTS OF PALAEOCLIMATOLOGY (GMC 657E)
Theories of climatic change. Evolution of earth's climates during the geological centuries. Evolution of climate during the last millenniums (since the end of the last ice age). Climate evolution during the historical years. Climate evolution during the period of instrumental meteorological observation. Climate in the last century. Human impacts on climate. Climate in the future.

ENGINEERING GEOLOGY (GGG 758Y)
Geological and engineering geological data of rocks. Engineering geological reconstructions and structures. Physical and mechanical properties of rocks. Methods of study. Landslides. Foundations, Dams, Tunnels, Pipes.

GEOLOGY OF GREECE (GGG 759Y)
Detailed study of the internal and external Hellenides (lithostratigraphy, magmatism, structural tectonics).

OPTIONAL

PETROLEUM GEOLOGY (GMO 760E)
Chemical and physical characteristics of hydrocarbons. Generation of petroleum and natural gas. Source and reservoir rocks. Migration of hydrocarbons. Entrapment of hydrocarbons: Anticlinal, fault and stratigraphic traps. World oil and gas deposits. Hydrocarbons exploration. Drilling of oil and gas wells. The logging of boreholes. Recovery techniques.

METAMORPHIC PETROGENESIS (GMO 761E)
The use of the Phase rule; Shreinemaker's analysis. Thermodynamics of the metamorphic reactions. Estimation of equilibrium conditions based on thermochemical data. Estimation of thermochemical parameters according to experimental results. Fugacity, activity, ideal solutions. Geothermometry. Geobarometry. Equilibrium constants in solid-gas mixtures. Metasomatism. Non-ideal solutions. Liquid phase during metamorphism. Application of statistical thermodynamic methods to petrological subjects. PT diagrams.

ELECTROMAGNETIC METHODS OF GEOPHYSICAL PROSPECTING (GGP 762E)
Electrical methods of geophysical prospecting (electrical resistance of rocks, resistance methods, the equipotential lines method, methods of induced polarization, natural potential and telluric currents). Electromagnetic methods of prospecting. Magnetotelluric and radiometric methods.

GROUNDWATER EXPLOITATION AND MANAGEMENT (GGG 763E)
Groundwater flow and water catchment works, calculation of hydraulic parameters. Superposition of flows. Artificial supply of aquifers. Economic data of underground water exploitation. Springs. Underground water reserves.

NEOTECTONICS (GGG 764E)
Microstructure analysis of Neogene and Quaternary. Extensional and compressional facies. Multiphase neotectonics. Brittle deformation. Quantitative tectonics. Neotectonic evolution of the Greek and the broader Mediterranean area.

VOLCANOLOGY (GMO 765E)
Volcanic activity and geotectonic processes. Volcaniclastic deposits. Lava flows and types. Transportation and deposition of volcaniclastics and flows. Ignimbrites. Epiclastic processes in

volcanic regions. Volcanic force. Prognosis of volcanic eruptions. Control of volcanic danger. Volcanoes in Greece and world-wide.

ATMOSPHERIC POLLUTION AND CLIMATIC CHANGES (GMC 766E)
Introduction to atmospheric pollution. Elements of structure and dynamics of atmosphere.Barometric systems and transportation of pollutants. Transportation theories and diffusion models of pollutants. Models of atmospheric quality in civil regions. Causes of climatic changes. The anthropogene activity and the greenhouse phenomenon. The future of climate.

APPLIED AND DYNAMIC CLIMATOLOGY (GMC 767E)
Mean synoptic situation of the atmosphere. Air masses. Atmospheric centers of action (frequencies-trajectories). Weather types. Reasons for climate generation. Satellite Climatology.

OCEANOGRAPHY (GGE 768E)
Physical and chemical properties of sea-water (salinity, temperature, density, optical properties). Dynamic oceanography (currents, waves, tides). Geomorphology and geological processes on the ocean floor, the continental margins, the continental shelf, the continental slope and the coastal zone. Description of instruments for measuring oceanographic parameters and methods for the investigation of submarine mineral raw material.

PHYSICAL AND ANTHROPOGENE ENVIRONMENT (GGE 769E)
Physical environment. Creeks, rivers, lakes, lagoons, deltaic zones, systems of erosion and deposition of materials. Anthropogene environment. Drainage and drying of physical wetlands, river dispositions, artificial lakes and reservoirs, land uses and changes, residential and industrial regions, development works, populous and social changes.

REMOTE SENSING TO GEOSCIENCES (GGE 770E)
Photographic and non-photographic imaging sensors. Remote Sensing platforms. Conventional air-photos and telemetric (non-conventional) images. Visual and digital analysis of telemetric images sush as LANDSAT, SPOT, ERS, TERRA, IKONOS etc. Applications of Remote Sensing to geomorphology, lithology, structural and tectonic geology, economic geology and multitemporal monitoring of continental and marine environment. Imaging RADAR interferometry and its capability to localize spatial displacements deriving from natural disasters such as earthquakes, volcanic eruptions, landslides.

GEOTECTONIC EVOLUTION OF THE BROADER GREEK AREA (GGG 871Y)
Comparative orogenic evolution of Hellenides. Views and models proposed for the geotectonic evolution of Hellenides in the broader Mediterranean. Neotectonic evolution and recent tectonic regime of the Hellenic arc.

FIELD COURSES (GGN 872Y)
The field courses refer to the courses Geology of Greece, Physical Geography, Hydrogeology, Engineering Geology, Environmental Geology, Industrial Minerals and Rocks, Economic Geology and Geophysics.

DIPLOMA THESIS (GGN 873Y)
The students may choose the topic of their thesis from a list of topics made out by the 5 Departments of the School.

OPTIONAL

COAL GEOLOGY (GMO 874E)
Coal as an organoclastic sedimentary rock. Peat forming environments and coalification. By rank classification of coals. Coal petrology and petrographic analysis. Chemical and physical properties of coals. Proximate and ultimate analysis of coals. Evaluation of the net or gross specific energy. Geology of coal depositional processes and age of coals. Coalfield exploration. World coal reserves and resources. Coal utilization. Coal and the environment.

DRILLING TECHNIQUES (GGG 875E)
Types of boreholes. Coring techniques. Water boreholes. Shallow and deep exploration boreholes in geothermal fields. Vertical and directional boreholes. Types of drillers. Drilling technology and procedure. Compartment of various lithological formations during drilling. Logging in boreholes. Borehole equipment and development of water boreholes.

TOPICS IN GEOPHYSICS (GGP 876E)
Selected modern topics in Geophysics are studied by the students under the instructor's supervision.

TOPICS IN METEOROLOGY - CLIMATOLOGY (GMC 877E)
Selected modern topics in Meteorology or Climatology are studied by the students under the instructor's supervision.

TOPICS IN MINERALOGY - PETROLOGY - ECONOMIC GEOLOGY (GMO 878E)
Selected modern topics in Mineralogy or Petrology or Economic Geology are studied by the students under the instructor's supervision.

TOPICS IN GEOLOGY (GGG 879E)
Selected modern topics of Geology are studied by the students under the instructor's supervision.

TOPICS IN GEOGRAPHY (GGE 880E)
Selected modern topics of Geography are studied by the students under the instructor's supervision.

GEOLOGICAL - ENVIRONMENTAL SURVEYS OF CONSTRUCTIONS (GGG 881E)
Dams, Tunnels, Roads, Airports, Ports, Foundations.

GEOTHERMAL ENERGY (GGG 882E)
Internal earth heat and heat flow. Areas with increased heat flow. Geothermal energy and potential. Geothermal fields and internal procedures. Geothermy of high-medium-low enthalpy and chemical composition of the fluids. Geothermy and environment. Methodology of geothermal exploration. Mechanical equipment. Exploitation of geothermal fiels and utilization of the geothermal potential. Corrosion and scaling problems. Main geothermal fields in Greece. Geothermal energy worldwide.

ROCK AND SOIL MECHANICS (GGG 883E)
Theories: Introduction to the main subjects of rock and soil mechanics. Practice: Experimental methods of investigation.

SYNOPTIC AND DYNAMIC METEOROLOGY (GMC 884E)
Introduction. Meteorological coordinate systems. Thermodynamic diagrams. Atmospheric observations at synoptic stations: surface and upper air. Synthesis and analysis of weather charts. Discontinuities in the atmosphere. Jet stream. Rossby waves. Development of cyclones and anticyclones. Equations of atmospheric motion. Balanced motions. Principles and conceptual model on weather modification.

MINING GEOLOGY - RESTORATION OF QUARRIES AND MINES (GMO 885E)
Mining legislation. Mine-mapping. Excavation methods. Sampling, preparation and processing of samples. Surface and underground mining. Methods of ore reserves classification and estimation. Economotechnical reports. Impacts to the environment from the exploitation of primary minerals. Drawing and restoration of regions of surficial or underground exploitation. Writing of restoration proposal.

ECONOMIC GEOLOGY (GMO 886E)
Raw materials. Prospecting and identification methods of mineral deposits. Factors and parameters of economic evaluation and estimation of mineral deposits. Exploitation programming. Specific problems in mining programs. Marketing and prices of raw materials. Raw materials policy. Recycling of raw materials. Impacts to the environment from the exploitation of primary minerals. Drawing and restoration of regions of surficial or underground exploitation. Writing of restoration proposal.

SANITARY LANDFILLS (GGG 887E)
SL operation. Pollution sources and loads. Pollution procedure of underground water. Geological, hydrogeological and physical planning criterions for SL suitability. Impacts. Geotechnical problems in the construction and operation of SL. Grading of criterions for SL selection. SL reformation, environment protection.

PRACTICAL EXERCISE (GGN 888E)
The students carry out a practical exercise under an instructor's supervision.

Master Program: Applied and Environmental Geology

SPECIAL TOPICS IN HYDROGEOLOGY (GGGM 101Y)

GEOTHERMIC FIELDS **(**GGGM 102Y**)**

NATURAL AND ANTHROPOGENIC DISASTERS **(**GGGM 103Y**)**

OPTIONAL

GEOGRAPHIC INFORMATION SYSTEMS - REMOTE SENSING APPLICATIONS (GGGM 104E)

SOIL AND ROCK MECHANICS TESTS - METHODS OF FIELD RESEARCH (GGGM 105E)

TRACING (GGGM 106E)

MANAGEMENT OF WATER RESOURCES (GGGM 207Y)

CONSTRUCTIONS (GGGM 208Y)

ENVIRONMENTAL SURVEYS (GGGM 209Y)

OPTIONAL

SANITARY LANDFILLS (GGGM 210E)

ENVIRONMENTAL EDUCATION (GGGM 211E)

ISOTOPE HYDROGEOLOGY (GGGM 212E)

SEMINARS (GGGM 313Y)

THESIS (GGGM 314Y)

13. UNIVERSITY OF APPLIED SCIENCES (FACHHOCHSCHULE) BOCHUM
GEOTHERMAL CENTER

Master Program: Geothermal Energy Systems

MATHEMATICS AND INFORMATICS

GEOTHERMICS

GROUND WATER HYDRAULICS

BASICS OF HEAT AND ELECTRICITY PRODUCTION

AIR CONDITIONING

PROJECT MANAGEMENT

PROJECT DEVELOPMENT

DEEP DRILLING TECHNOLOGY

GEOTHERMAL HEATING SYSTEMS

RESERVOIR ENGINEERING

BOREHOLE GEOPHYSICS

HYDRO- AND GEOCHEMISTRY

THESIS

OTHER UNIVERSITIES WITH GEOTHERMAL RELATED RESEARCH

1. **Oklahoma State University**
   Buildings and Thermal Systems Research Group
   Stillwater, OK 74078-8014
   "Research of the Building and Environmental Thermal Systems Research Group of Oklahoma State University includes building heat transfer, HVAC systems modeling, building

energy simulation, hydronic heating systems, geothermal heat pump systems and ground loop heat exchanger technology."

OSU is also the home of the International Ground Source Heat Pump Association, whose goal is to "promote the growth and advancement of the geothermal industry while ensuring the quality, safety, and reliability of installed systems."

2. **Oregon Institute of Technology**

   Geo-Heat Center
   3201 Campus Dr.
   Klamath Falls, OR 97601
   Phone: (541) 885-1750
   Fax: (541) 885-1754

   This organization supports development of geothermal energy resources. Although they are not a research funding source they do provide technical assistance in related technology development or applications. OIT also provides a clearinghouse service for geothermal development grants. Research at the Geo-Heat Center is supported in part by the US Department of Energy.

3. **Richard Stockton College of New Jersey**

   Certification Program in Energy Studies
   PO Box 195
   Pomona, NJ 08240
   Phone: (609) 652-1776

   Energy studies is an interdisciplinary program designed to educate students in problems associated with energy usage and to pose methods for possible solutions to those problems. "Energy prices and supplies are a major concern for homeowners, business people, and industry. The majority of residential and commercial buildings in the United States will have their energy efficiency drastically upgraded during the next decade. The geothermal heat pump project at Stockton is serving as a national model for such upgrades"

4. **Southern Methodist University**

   Geothermal Lab
   PO Box 0395
   3225 Daniel
   Dallas, TX 75275-0395
   Phone: (214) 768-2749
   Fax: (214) 768-2741

   The SMU Geothermal Laboratory is an educational/ research arm of the Department of Geological Sciences. The Geothermal Laboratory measures various parameters relating to the thermal field of the Earth and applies these observations to areas such the geothermal resources, plate tectonics behavior and the mapping of Earth's thermal properties at the surface and subsurface levels.

5. **Stanford University**

   Department of Petroleum Engineering
   Stanford Geothermal Program
   Stanford University
   Stanford, CA 94305-2220
   Phone: (650) 723-4744

The goal of the Stanford Geothermal Program is to develop reservoir engineering techniques for efficient production of geothermal resources. The primary focus is to investigate reinjection into vapor-dominated reservoirs such as The Geysers.

6. University of Nevada, Reno

Mackay School of Mines and College of Engineering
Great Basin Center for Geothermal Energy
Mackay School of Mines/168
University of Nevada, Reno
Reno, Nevada 89557

The Great Basin Center for Geothermal Energy at the University of Nevada, Reno focuses on locating and optimizing geothermal energy resources. The Center's team of scientists specializes in geochemistry, hydrogeology, geophysics, thermodynamics, remote sensing, seismology and structural geology (geologic mapping).

7. University of North Dakota

Energy and Environmental Research Center (EERC)
University of North Dakota
Grand Forks, ND 58202
Phone: (701) 777-2011

The EERC has an interdisciplinary approach to energy and environmental research. Studies begin with fundamental evaluation and characterization of the Earth's resources, followed by research into the development of innovative technologies to extract and use these resources in an efficient and environmentally safe manner. Research includes the development of analytical techniques in chemistry, mineralogy, and engineering, and applications in the areas of coal, oil, gas, biomass, geothermal energy conversion technologies, solid, liquid, and gaseous emissions; groundwater, mined lands, and energy conversion residuals.

8. University of Utah

423 Wakara Way, Suite 203
Salt Lake City, Utah USA
84108-121
Phone: (801) 581-5126
Fax: (801) 585-3540

The Geothermal Energy Unit performs basic and applied research in geothermal exploration, reservoir delineation, drilling and logging, and production. It has been funded by the U.S. Department of Energy for more than 20 years, and works closely with the geothermal industry to improve geothermal technology.

9. Virginia Polytechnic Institute and State University

Department of Geological Sciences
1046 Derring Hall
Blacksburg, VA 24061-0422
Phone:(540) 231-8912
Fax:(540) 231-3386

The southeastern United States Geothermal Data at the Regional Geophysics Laboratory in the Department of Geological Sciences at the Virginia Polytechnical Institute and State University, provides information on terrestrial heat flow and practical applications of low-temperature geothermal energy. The geothermal energy database includes temperature data from hundreds of temperature and other geophysical logs, rock thermal conductivity, and heat flow

values from New Jersey to Georgia. The program is funded primarily by the US Department of Energy.

10. Washington State University

WSU Cooperative Extension Energy Program
925 Plum Street SE, Bldg. #4
P.O. Box 43165
Olympia, WA 98504-3165
and
WSU Cooperative Extension Energy Program
222 North Havana
Spokane, WA 99202
Phone: (509) 477-6700

The Energy Program is housed within the Washington State University's Cooperative Extension and conducts research, develops tools, and disseminates information to enable people to make informed decisions about energy. The program has been affiliated with the University since 1996. Previously it was part of the state energy office.

CONCLUSIONS

- Basic training in related fields available in some countries, but in very few only on geothermal (M.S. or Ph.D.), none on EGS.
- On-the-job in-house training still quite common, and will probably remain in the near and mid-term future.
- Geothermal training should develop in near future, required by a developing industry. Proposal for an integrated route for students in Europe and guidelines for the creation of a European centre dedicated to geothermal higher education (at all levels: B.S., M.S., Ph.D.) could be useful.
- Experience already acquired in some institutions, but not always easily available on the Internet (or not in English).
- ENGINE partners (mainly from the industry) should make recommendations on new or existing programs regarding curricula and content of courses.
- ENGINE partners willing to share their expertise should ask to be included in the IGA Roster of available lecturers.
- possibility: by the end of ENGINE CA, a proposal for a series of European Summer Schools on Geothermal, based on results of EC funded projects, in the Marie Curie Program.