REGULAR TRAINING COURSE ON Exploration and Development of Mineral Resources

The International School for Geoscience Resources of KIGAM presents an intensive training course on Exploration and Development of Mineral Resources. The course takes place at the Ara room of International School for Geoscience Resources (IS-Geo) of KIGAM in Daejeon (Korea) in April 18 to May 13, 2016 and includes the following 4 modules.

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• Agenda

This course consists of two parts, “exploration geology” and “exploration management and evaluation”. This course provides from an introduction of ore and mineral deposits genesis, a certain metallic and non-metallic mineral deposits: different commodities from aluminium to zirconium, different marine and continental depositional environments, to different techniques from geology, geophysics through geochemistry. In the middle of the course we also provide various exploration methods, and how to design the method of spatial database for mineral potential analysis and the method of analysis of relationship between deposit and related factors which involves database using GIS/RS. At last, this course treats a reasonably rigorous and comprehensive exposure to the fields of resources/reserves estimation and financial valuation of mining projects, and deep ocean deposits as well as field trip to Korean mining.

• Course Covered
  o Ore and mineral deposits genesis
  o Exploration models and techniques for sediment-hosted mineral deposits
  o Fluid inclusion studies
  o Exploration Methods for Mineral Resources
  o Exploration Management and Targeting
  o Structural geology
  o Economic Evaluation of Mineral Projects

• Course Requirements: Prerequisite
  o Background in general geology, mineralogy, petrology and structural geology
  o Experience with optical methods in mineral identification
  o Understanding of fundamental processes in geodynamics and geological processes
  o Having the command of both spoken and written English
  o Having computer using skills, particularly being familiarity with the use of Excel spreadsheet software essential and basic linear algebra for economic evaluation
• **Who should Attend?**

  o Persons dealing with mineral resources and/or being engaged in mineral exploration for newly joined and newly qualified staff of geological surveys and governmental agencies, and advanced-level geologists who have not gathered any practical experience
  
  o Geologists, mineralogist or geophysicists who have a basic knowledge and limited experience in economic geology but want to broaden their knowledge especially in the field of sedimentary/sediment-hosted mineral deposits.
  
  o Geographers and engineers in land management who have a good background in minerals and geology and work at the interface between extractive and environment geology (E & E issues)
  
  o National or local government officials, preferably middle manager, researchers and engineers engaged in the field of mining and mineral resources
Module 1. Exploration Methods for Mineral Resources – Dr. Saro Lee/ Dr. Myeong-Jong Yi/Dr. Seong Kon Lee/ Dr. Hyoungrea Rim / Dr. Byung-joo Lee

- **Summary of topic contents and learning objectives**

For the mineral resources exploration, geophysical methods are commonly used to discover unknown ore deposits and to delineate the geologic structures related with mineralization. In this module, basic principles of geophysical exploration are given as an introduction of geophysical methods for the mineral exploration. Among various geophysical methods, gravity, magnetic, electrical and electromagnetic methods are discussed since these methods are the most frequently used for mineral resources exploration. A few case histories of mineral exploration will be given to provide a practical guide to the real exploration at work. Also, the module will provide how to design spatial database for mineral potential analysis and method of analysis of relationship between deposit and related factors involves database using GIS/RS.

- **Day 1. Introduction of mineral potential mapping using GIS – Dr. Saro Lee(April 18)**

This topic involves introduction to predictive modelling and mapping of mineral potential. This is a basic course for the practical exercises of mineral potential mapping using GIS. Before exercises, you can learn how to design spatial database for mineral potential mapping and method of analysis of relationship between deposit and related factors involves database using GIS.

- **Introduction of GIS and GIS S/W**
- **Introduction of Mineral Potential Mapping**
- **Mineral Potential Mapping Technique using GIS**

- **Day 2. Introduction to electrical and electromagnetic methods for mineral resources – Dr. Myeong-Jong Yi/Dr. Seong Kon Lee (April 19)**

For the mineral resource exploration, geophysical methods are intensively used to target the unknown mineralization zones in the subsurface. In this topic, brief introduction to Exploration Geophysics is given as a general topic. Since electrical and electromagnetic (EM) methods are the most important geophysical methods in the mineral resources exploration, principles of electrical and EM methods and their practical issues are given. To provide an insight to these methods, several case histories of mineral resources exploration by electrical and EM methods are presented.

- **Introduction to Geophysical Exploration for Mineral Resources**
- **Electrical methods for Mineral Exploration**
- **Electromagnetic methods**
• **Day 3. Potential methods for mineral exploration and field practice of geophysical surveys – Dr. Hyoungrea Rim/ Dr. Myeong-Jong Yi (April 20)**

Potential methods such as gravity and magnetic have played an important role for mineral exploration, especially very first step of exploration with regional scale. For understanding of potential methods, data processing, several interpretation methods, inversion process for illuminating subsurface structures are presented. To understand field procedure of geophysical methods, field demonstration of geophysical data acquisition is given. The trainee will have chance to participate in the data acquisition in gravity, magnetic, resistivity surveys.

  - Gravity and Magnetic methods
  - Field Practice of Gravity & Magnetic methods
  - Field Practice of DC Resistivity Survey method

• **Day 4. Data Processing in Practice/Structural Geology for mineral exploration – Dr. Myeong-Jong Yi /Dr. Byung-Joo Lee (April 21)**

This topic involves introduction to predictive modelling and mapping of mineral potential. This is a basic course for the practical exercises of mineral potential mapping using GIS. Before exercises, you can learn how to design spatial database for mineral potential analysis and method of analysis of relationship between deposit and related factors involves database using GIS.

  - Overview of Mineral Potential Mapping
  - Mineral Potential Mapping Technique using GIS
  - Mineral Potential Mapping using Probability Method
  - Mineral Potential Mapping using Statistic Method

➤ **Structural Geology for mineral exploration**

Structural geology is the study of the three-dimensional distribution of rock units with respect to their deformational histories.

  - to know the history of deformation (strain) in the rocks and
  - to understand the stress field that resulted in the observed strain and geometries

  **Structural Geology** can be applied to economic geology, both petroleum geology and mining geology
Day 5. Field excursion at Chaesok-gang, Cretaceous sedimentary basin – Dr. Byung-Joo Lee (April 22)

In the field excursion area which is the Cretaceous sedimentary Kyokpo Basin and the basement, three types of faults are recognized: dextral strike-slip faults, normal faults and reverse faults. The strike-slip faults can be subdivided into three sets (Banwol Fault, Jongam Fault and Gunghangchi Fault). Among the strike-slip faults, the Banwol fault, which is running along the northern coastline, has conjugate sinistral strike-slip faults of NW direction. The normal faults of nearly WEW direction well develop at the northeastern coastline and the reverse faults of NS direction are distributed in the western coastline.

These different sets of the faults can be simultaneously formed by the compression of about 110° direction. The compression also resulted in the formation of thrusts and slumped beds or asymmetrical folds, which have well-developed NNE-NS strike of the axial plane. The thrusts and folds only occur within any particular horizons are covered with overlying undeformed strata, indicative of syn-depositional origin.

The dextral sense of strike-slip faults, the systematic development of fault systems, and the syn-depositional deformation of sediments collectively suggested that the Kyokpo Basin was formed by dextral strike-slip regime, about 110° compressional direction. Conclusively the Kyokpo basin is interpreted as a fault wedge basin (transpressional basin) rather than a pull-apart basin (transtensional basin).
Module 2. Mineral deposit systems: principles and genetic concepts - Dr. Franco Pirajno

- **Summary of topic contents and learning objectives**

  The opening day of the course discusses the general concepts of ore deposits geology, overview, historical notes and a general introduction on mineral systems.

- **Day 1. Magmatic mineral systems (April 25)**

  Day 1 provides a general view of igneous geology, description of mineral systems that are formed directly from magmas and the latest conceptual models on their genesis.
  - Introduction, basic principles, magmatic mineral systems
  - Ni-Cu-PGE in layered intrusions and Alaskan type intrusions
  - Komatiites
  - Anorogenic alkaline complexes, kimberlites, carbonatites and rare earths mineralisation
  - Diamondiferous kimberlites and lamproites
  - Large igneous provinces, tectonics and ore systems associated with mantle dynamics

- **Day 2. Magmatic-hydrothermal mineral systems (April 26)**

  Day 2 introduces the important features of magmatic-hydrothermal fluids and examines the ore systems that are created by igneous intrusions, illustrated by a comprehensive set of world-wide examples. The end of Day 2 concludes with a “lesson from the past”, showing how easily some key features can be missed during mineral exploration.
  - Introduction to hydrothermal processes; wall rock alteration, fluid inclusions, stable isotopes, hyperspectral mapping, remote sensing
  - Intrusion-related and convergent margins porphyry deposits
  - Intraplate porphyry Mo deposits
  - Epithermal systems
  - Carlin-type and skarns
  - Iron oxides copper gold (IOCG) and Kiruna type deposits
  - Lessons from the past


  We discuss the ocean floor (processes leading to the formation of mineral deposits related to spreading centres, back-arc and convergent margins), hydrothermal activity in rift-related volcano-sedimentary basins, SEDEX and copperbelt type deposits, and the Red Sea brines.
  - Features of the ocean floor, ophiolites and related hydrothermal processes
• **Day 4. Non-magmatic mineral systems (April 28)**
In this session we discuss a wide range of mineral systems, for which no direct magmatic input can be demonstrated. In this are included supergene-related mineral deposits, as well as a brief look at the role of bacteria (sulphate-reducing and S-oxidising) and gas hydrates
  - Introduction orogenic and non-orogenic Au lodes and base metals
  - Laterite-hosted mineral systems
  - Non-sulphide supergene mineral deposits
  - Mississippi Valley type (MVT) deposits; black shales
  - Uranium deposits and sedimentary phosphate deposits
  - Iron and manganese deposits
  - Test

• **Day 5. Culture Trip (April 29)**
Module 3. Mining Engineering – Dr. Ryu Chang-Ha/Dr.Debasis Deb/ Dr.Changwo Lee

• Summary of topic contents and learning objectives
• Day 1. Blasting Techniques for Surface and Underground Mining (May 2)- Dr. Ryu Chang-Ha

Day 1 introduces the blasting techniques for surface and underground mining. Explosive blasting is a very useful and economic tool for rock breakage. However, use of explosives in mining and civil engineering requires a contradictive skill to maximize the productivity as well as to minimize the environmental impact. The main objectives of this course are to provide the principles of explosive blasting and to understand the design parameters required for optimum blast design.

- Introduction; Rock Breakage by Blasting
- Blast Design for Surface Mining
- Blast Design for Underground Mining
- Controlled Blasting Techniques
- Environmental Impact of Explosive Blasting

• Day 2. (May 3) –Dr.Debasis Deb

Day 2 deliberates on the introduction of mining technology with the emphasis on selection of mining methods. Fundamental principles of surveying techniques and its applications, ore grade estimation with various techniques will also be deliberated upon on that day. Drilling is an essential part of mining and other engineering disciplines dealing with rock mass. Apart from these, shaft sinking methods will be discussed with introduction to loading and hauling techniques. The contents of the day are:

- Selection of mining engineering and methods
- Introduction to mine surveying
- Ore grade estimation and cut-off grade
- Introduction to drilling technology
- Shaft sinking and other mine access
- Introduction to material handling and haulage
Day 3. (May 4)- Dr. Debasis Deb
Coal is a cheap fuel for generation of energy and mostly used in thermal power plants and steel production. In the third day, introduction to various underground coal mining methods will be presented with due consideration of stability, safety and production. Apart from discussing on equipment utilization and manpower deployment, details of pillar and artificial support design, stowing and ventilations aspects will also be deliberated. The contents are:

- Development of coal mine and pillar design
- Depillaring method in bord (room) and pillar method
- Longwall mining method
- Equipment and production calculations
- Underground coal mine ventilation
- Artificial supports and stowing

Day 4. (May 5)- Dr. Debasis Deb
Minerals are precious and their use for mankind is limitless. Several minerals are found in ore bodies which may occur deep inside the earth crust. Selection of underground metal mining method depends on the shape and size of ore body, joints and strength of ore body, properties of hanging and footwall rocks. In Day 4, the most commonly used mining methods will be deliberated providing inputs in rock mechanics, production calculations and support system. The contents are:

- Present status of UG metal mining
- Selection of mining methods based on properties of ore body
- Mechanized Cut & Fill method
- Shrinkage stoping method
- Sublevel and VCR methods
- Mine support systems
• **Day 5. (May 6) - Dr. Debasis Deb**

Ore bodies or coal seam located near the earth crust are generally mined using surface mining methods. Method of mining varies depending on the inclination of ore body, thickness and properties of ore body and host rocks. Selection of equipment is solely dependent on the rate of production, overburden thickness to be removed and depth of the pit. Surface mining is highly cost effective and may produce 50 to 80 million tonne production per annum. Hence, planning of surface mining along with slope stability are the key issues: the content of Day 5 are:

- Open pit planning and design
- Unit operations in open pit mining
- Surface coal mining with Heavy Earth Moving Machinery (HEMM) – I
- Surface coal mining with HEMM – II
- Open cast and strip mining method – I
- Open cast and strip mining method – II

• **Day 6. (May 9) – Dr. Changwo Lee**

Underground mine ventilation is described as lifeblood in the mine system to provide safe and comfort environment through providing airflow in sufficient quantity and quantity. As we go deeper due to the near depletion of easily accessible ore deposits and at the same time the regulatory standards for underground working environment get tougher, mine ventilation inevitably attracts more attention in the mine planning. Day 1 session will cover the essential topics associated with the integrated mine ventilation system design such as the ventilation systems, fluid and thermo dynamics of the airflow, hazards of mine gases, dust and heat, and mine fire and explosions.

- What is “mine ventilation” for?
- Mine ventilation systems; mine, district and auxiliary ventilation systems
- Basics of the fluid and thermo dynamics of the mine airflow; how to control the quantity and temperature/humidity
- Ventilation survey; principles and methods
- Mine gases and dust hazards; what they are and how to control them
- Mine fires and explosions; what causes them and what are the emergency management

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Module 4. Mineral Processing and Metallurgy - Dr. Heechan Cho/
Dr. Jae-chun Lee/Dr. Hyunsik Park

• Summary of topic contents and learning objectives
• Day 1. Country Report Workshop (May 10)

• Day 2. (May 11) – Dr. Heechan Cho

Crude ores extracted from the earth is highly impure and must be upgraded before they are of use to society. Mineral processing is the first process that most ores undergo after mining in order to separate the valuable minerals from the waste rock, or gangue. It provides a more concentrated material for the procedures of extractive metallurgy. The primary operations are comminution and concentration, but there are other important operations in mineral processing plant, including dewatering and tailings disposal. All these operations are discussed in this course.

- Comminution: fundamentals of size reduction, liberation, comminution laws, different types of crushers and grinding mills
- Screening and Classification: various size separation processes, movements of solids in fluid, various types of screen and classifiers
- Concentration operations: gravity concentration, flotation, magnetic and electro-static separation.
- Auxiliary operations: dewatering and tailings disposal

• Day 3. (May 12) Non-Ferrous Extractive Metallurgy - Dr. Jae-chun Lee/Dr. Hyunsik Park

• Summary of topic contents and learning objectives

Extractive Metallurgy is the art and science of producing metals and metal compounds from their primary and secondary resources and can be divided into three parts: pyrometallurgy, hydrometallurgy, and electrometallurgy with their different energy sources. The course is designed not only for post-graduate levels but also for a wide range of experts, working in the extractive metallurgy of nonferrous metals. The principal focus of this course is on the understanding of the fundamental physicochemical principles and the demonstration of application of these principles to extractive metallurgy rather than the detailed descriptions of current commercial practices. A broad review of metallurgical thermodynamics and kinetics is given to impart the basic knowledge required to predict the feasibility of metallurgical reactions and energies of a process, and the influencing factors on such processes and their productivity, respectively. Also, the course covers the basic principles of various unit processes for the extraction of metals, their separation and concentration, and
reduction/recovery with emphasis on their application to the extractive metallurgy of nonferrous metals

- **Subjects Covered**
  - Metallurgical Thermodynamics and Kinetics
  - Solution Chemistry and Slag Chemistry
  - Principles of Extraction of Metals
  - Separation and Concentration of Metals
  - Reduction and Recovery of Metals

- **Course Requirements: Prerequisite**
  - Background in general chemistry, physical chemistry, thermodynamics
  - Understanding of fundamental processes in metallurgical processes
  - Having the command of both spoken and written English

- **Day 4. (May 13) KIGAM Lab Tour**
About the instructor (Module 1) – Dr. Saro Lee

Saro Lee got his B.Sc. degree in geology (Yonsei University, Seoul, Korea) in 1991, M.Sc. in GIS-based geological hazard mapping (Yonsei University, Seoul, Korea) in 1993, and Ph.D. in landslide susceptibility mapping using GIS (Yonsei University, Seoul, Korea) in 2000. He is currently a principal researcher at Geological Research Division, KIGAM. He is also full professor of University of Science and Technology (UST). He started his professional career in 1995 as a researcher in the KIGAM. He spent many years as a part time lecturer in the department of earth system sciences, geology and military affairs at the Yonsei University, Chungnam National University, Kyungpook National University and Daejeon University. He carried out many International Cooperative Research Projects in the field of mineral potential and geological hazard in Brazil, Bhutan, Cambodia, China, Indonesia, Malaysia, Philippines, Thailand and Vietnam. Also He managed and had lectures KOICA International Training Program 7 times (Mineral Exploration and GIS/RS) for participants from many Countries. His research interest includes geospatial predictive mapping with GIS and RS such as landslide susceptibility, ground subsidence hazard, groundwater potential, mineral potential and habitat mapping. He has published about 100 peer reviewed SCI(E) papers. Also he has a citation more than 5,000 and h-index of 41 in Google. For his outstanding research achievement, he received the award of prime minister in 2003 and the KIGAM research award in 2003 and 2005.

About the instructor (Module 1) – Dr. Myeong-Jong Yi

Dr. Myeong-Jong Yi is the principal researcher in exploration geophysics and mining engineering department of Korea Institute of Geoscience and Mineral Resources (KIGAM). He received his B. Eng. (1992) in petroleum and mineral resources engineering, M. Eng. (1994), and Ph.D. (2000) in applied geophysics from Seoul National University, Korea. He was a post-doctoral research fellow of University of Waterloo in Canada (2005~2006). He has over 15 years’ experience in the research for the development of geophysical exploration technologies. His main expertise is the development three-dimensional subsurface imaging technology using electrical and electromagnetic (EM) methods. Therefore, his research interests are inverse theory, dc resistivity imaging technique, radar method, and EM methods. And, his works include application of geophysical methods to the mineral resources exploration, geotechnical and environmental problems, and archaeology.
About the instructor (Module 1) – Dr. Seong Kon Lee

Dr. Seong Kon Lee is the principal researcher in geothermal resources research team, geologic environment division of Korea Institute of Geoscience and Mineral Resources (KIGAM). He received his B. A. (1991), M. Sc. (1993), and Ph.D. (1998) in exploration geophysics from Seoul National University, Korea. He was the post-doctoral research fellow of CEMI (Consortium for Electromagnetic Modeling and Inversion), University of Utah, USA during 2003.7~2005.6. His research interest includes magnetotelluric (MT) modelling and inversion for geothermal and mineral applications, and marine electromagnetics for detection of hydrothermal deposits. He is the main developer of the codes, MT2DInvMatlab for MT 2D inversion, and IBCEM and IBCEMIP of CEMI for integral equation electromagnetic modelling in inhomogeneous background conductivity, which are published in international peer-reviewed journals.

About the instructor (Module 1) – Dr. Hyoungrea Rim

Dr. Hyoungrea Rim is the senior researcher in exploration geophysics and mining engineering department of Korea Institute of Geoscience and Mineral Resources (KIGAM). He received his B. A. (1996), M. Sc. (1998), and Ph.D. (2005) in geophysics from Seoul National University, Korea. He was the post-doctoral research fellow of Colorado School of Mines (CSM) in USA (2009~2010) and continuing collaboration with CSM. He is interested in potential method all scales, namely from micro to global. He has firstly introduced microgravity method to handle engineering problem such as detecting cavities in Korea. He has carried out airborne magnetic and radioelement survey over 10 years. Recently he has expanded his research interests to gravity gradient and magnetic gradient method.

About the instructor (Module 1) – Dr. Byung-Joo Lee

Dr. Byung-Joo Lee is now a research fellow of the NexGeo Company and an emeritus researcher of KIGAM. He was working for the geological mapping division and the geo-hazard division for 36 years. He received his B. A. (1975) and M. Sc. (1977) in structural geology from Kyung-book National University, Korea. And He got Ph.D. (1988) in structural geology from Orleans University in France. He published more than 15 sheets of geological map of Korea and 100 papers in structural geology field. He is also published several papers in the geotechnical field. As a structural geologist he contributed his research in the
About the instructor (Module 2) – Prof. Dr. Franco Pirajno

He is a senior geoscientist in the Geological Survey of Western Australia (GSWA) and adjunct professor at the Centre for Exploration Targeting (University of Western Australia). In his career, Franco Pirajno gained considerable experience in tectonics, ore deposit geology and mineral exploration in Europe, southern Africa, South East Asia, New Zealand, the southwest Pacific, China, Greenland, southern Siberia and Australia. Prior to joining the GSWA in 1993, worked for the Anglo American Corporation of South Africa Ltd, as Exploration Geologist, following his research doctoral degree at the University Federico II of Naples and a spell as a post-doctoral research scientist at the Vesuvius Volcano Observatory. He participated and supervised exploration projects in many parts of southern Africa, Australia, New Zealand, the South West Pacific islands and Indonesia. In 1983 he appointed to the Chair of Economic Geology at Rhodes University, Grahamstown, South Africa. As the director of MSc courses at Rhodes, he was involved in research on precious metals and base metals mineral deposits in Namibia and South Africa. The MSc courses in Exploration Geology and in Economic Geology (course + research) were very intensive and professionally orientated. Under his direction, the emphasis of these courses was on field-based studies of ore deposits, their genesis and tectonic settings. This afforded the unique opportunity of examining and studying a great number and range of mineral systems in the southern African subcontinent. In the last 19 years he worked extensively in Western Australia’s Proterozoic terranes and it was instrumental in the discovery of a new large igneous province in Australia. He was a visiting professor at Peking University in 2003 and China University of Geosciences, Beijing in 2004. As the holder of the “Distinguished Foreign Professor” he was posted at Hefei University of Technology. He was appointed as the chairperson of SEG Fellowship Admissions Committee for 2009-2011, the associate editor 2008-2014 for the Australian Journal of Earth Sciences and for the GeoScience Frontiers journal of Peking University in 2012, on the Editorial Board of Russian Geology and Geophysics and Lithos, the appointed editor-in-chief of Ore Geology Reviews in May 2012, and the series editor of Solid Earth Sciences (Springer) in November 2012, the member of the steering committee of the Large Igneous Provinces Working Group. Since 2003, he intensely engaged in field work and studies of geology and mineral deposits in Australia, China and parts of southern Siberia. Supervised and/or reviewed 56 MSc and PhD theses. He is the author of four text books, and co-author of a monograph on the metallogeny of New Zealand, three chapters in edited books, more than 150 peer-reviewed papers, Guest Editor of 5 special issues of international journals and 66 mining/exploration reports.
About the instructor (Module 3) – Dr. Debasis Deb

DEBASIS DEB, Ph.D., 1997 (University of Alabama, USA), is a Professor in the Department of Mining Engineering at Indian Institute of Technology (IIT) Kharagpur. Earlier, he worked as Research Associate in the University Alabama and Korea Institute of Geoscience and Mineral Resources (KIGAM), South Korea, and as Visiting Assistant Professor in the Southern Illinois University Carbondale, USA. His research interests are rock mechanics and ground control, numerical modelling, underground space design and backfill technologies. He has taken several research projects related to development and applications of FEM, XFEM, SPH and XDIC procedures in rock mechanics. He has undertaken over 60 research and consultancy projects and currently involved in designing the biggest underground metal mine in India. He has to his credit over 140 Peer-reviewed research papers, three books and three patents. Dr. Deb is the recipient of prestigious “National Geoscience Award” for the year 2013 from the President of India for his contribution in the field of Mining Engineering.

About the instructor (Module 4) – Dr. Changwoo Lee

Changwoo Lee received his B.A. in 1978 from Seoul National University, and after two years as an engineer at Daewoo Construction company and Korea Institute of Geoscience and Mineral Resources (KIGAM), he received M.S. in 1983 and Ph.D. in 1986 from Pennsylvania State University. He joined the faculty of Dong-A University in 1987. He spent one year as a visiting scholar at the Depart of Chemical Engineering, University of Sheffield in 2004 and five years as Chairperson of The Faculty Committee of the Korea Energy and Mineral Resources Engineering Program from 2009 to 2013. He was dean of the engineering college at Dong-A University from 2012 to 2014. He has been involved in the ventilation and emergency control system design in most of the long vehicle and railroad tunnel in Korea. The research currently being pursued addresses mine ventilation design for large-opening mines, development of venturi-type dust scrubber, conceptual design of the pressure balancing ventilation system and mine fire control.
About the instructor (Module 4) – Dr. Chang-Ha Ryu

Dr. Chang-Ha Ryu is the principal researcher in underground space department, geologic environment division of Korea Institute of Geoscience and Mineral Resources (KIGAM). He received his B. A. (1976), and M. Sc. (1979) in the department of Mineral and Petroleum Engineering of Seoul National University, and Ph.D. (1989) in the department of Mining Engineering of University of Utah, USA. He was the former president of Korean Society of Explosives and Blasting Engineering and is also an adjunct professor in the department of Natural Resources and Environmental Engineering of Hanyang University. His research interest includes underground and surface blast design, blast-induced ground vibration and its control, controlled blasting technique, etc.

About the instructor (Module 4) – Dr. Heechan Cho

Dr. Heechan Cho is a professor of Energy Resources Engineering at the Seoul National University. He received B.S (1978) in Mineral and Petroleum Engineering of Seoul National University, and M.S. (1986) and Ph.D. (1990) in Mineral Processing from the Pennsylvania State University, USA. He is the former president of the Korean Society of Mineral and Energy Resources Engineers. He is a member of the Korean National Academy of Engineering. His research interests are comminution, grinding circuit simulation, numerical modeling of liquid-solid flow using DEM and SPH, mineral processing, recycling of industrial waste, CO2 sequestration and clean coal technology.
About the instructor (Module 4) – Dr. Jae-chun Lee

Dr. Jae-chun Lee is currently a Principal Researcher in the Mineral Resources Research Division at the Korea Institute of Geoscience and Mineral Resources (KIGAM) and an adjunction professor in Resources Recycling Engineering at the Korea University of Science & Technology. Dr. Lee received his B.S. in metallurgical engineering, M.S. and Ph.D. in Hydrometallurgy from Hanyang University, Korea. His research deals with leaching, separation and purification of metals from primary and secondary resources, and material preparation by aqueous processing. His current research focuses on the recycling of valuable metals from industrial wastes such as waste electric and electronic equipments (WEEEs) by hydrometallurgical routes. He has authored over 250 articles in peer-reviewed journals. In 1998 he received the Honda Award from the Clean Japan Center for the recycling technology of waste printed circuit boards (PCBs). He was awarded the Order of Science and Technology Merit in recognition of outstanding contributions to the recycling technology in Korea in 2008. Dr. Jae-chun Lee was elected as a member of Materials and Energy Division, the National Academy of Engineering of Korea (NAEK) in 2015 and Foreign Fellow, The Indian National Academy of Engineering (INAE) in 2013. He is currently an Associate Editor of Hydrometallurgy.

About the instructor (Module 4) – Dr. Hyunsik Park

Dr. Hyunsik Park is a senior researcher in the Mineral Resources Research Division at the Korea Institute of Geoscience and Mineral Resources (KIGAM). His research interest lies on the high temperature mineral processing, ferrous/non-ferrous metallurgy, molten slag chemistry, slag valorisation, coal based iron-making process, sinter/coke making process, blast furnace operation, recycling waste materials by pyro-metallurgical process. Dr. Park received his B.S. in metallurgical engineering and M.S. in Materials Science and Engineering from Yonsei University in 2006. He studied chemical metallurgy for Ph.D. at School of Materials Science and Engineering of University of New South Wales, Australia. After he finished Ph.D. study in 2014, he joined Urban Mining Department at KIGAM. He is currently working on the project about recycling of industrials wastes from mining and smelting processes. Dr. Park’s research capability was obtained by enthusiasm for science and his industrial background. His working experience at copper smelter strengthened the practical knowledge on overall metallurgical processes.