2020-2024
KIGAM Basic Research Projects

2019. 06.

KIGAM Korea Institute of Geoscience and Mineral Resources

Geological Survey of the National Territory and Publication of Geological & Geological Thematic Maps

Connectivity to KIGAM R&R: (Upper roles) providing public technology and information on national territory geology to ensure public safety and social problem-solving

◇ **Necessity**: providing customized national territory geological information for balanced national territory development, security, and disaster response

□ Objectives

Production and publication of domestic geological and geological thematic maps* with up-to-date geological information

* 1:50,000 scale national geological map, 1:100,000 scale geological map, 1:250,000 scale quaternary geological thematic map, 1:100,000, 1:250,000, 1:750,000 scales marine geological thematic map

○ Development and application of advancement techniques for optimizing public technology and information on national territory geology

○ Establishment of the stratigraphy and interpretation of the tectonic environment of the coastal area of central-western Korean Peninsula

□ Necessities

○ Importance: growing needs to efficiently provide integrated geological technology and information for a balanced national territory development, public safety, and social problem-solving

○ Urgency: development and application of advancement techniques as response measures to current issues, climate change, land development, nuclear energy

○ Specialty: production and publication of national geological map and geological thematic map for optimizing national territory

☐ Research Contents

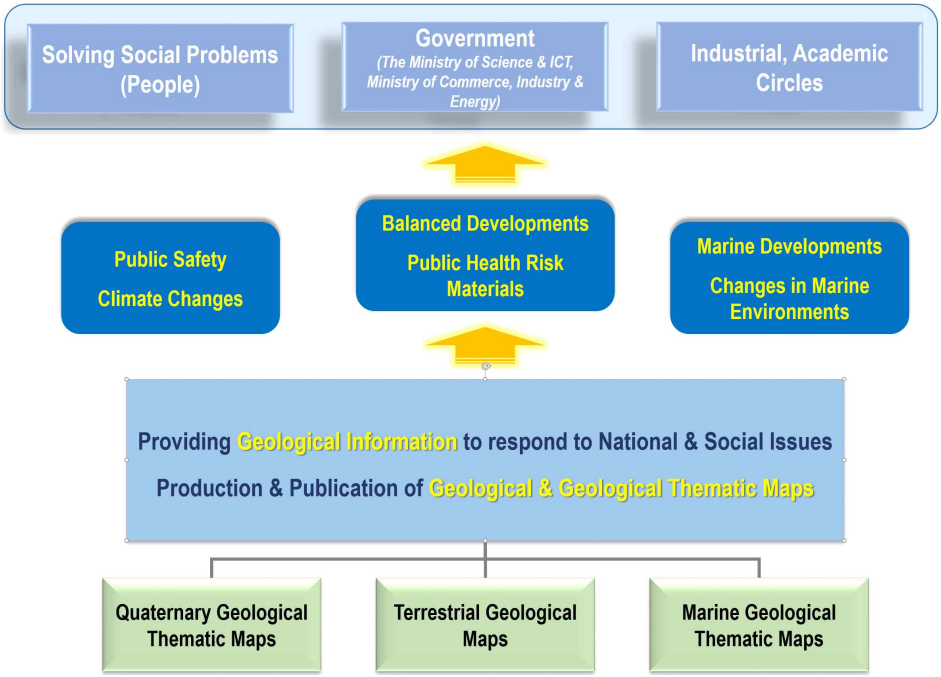
Detailed Technologies	Description / R&D Scope and Contents
Production and publication of domestic geological and geological thematic maps* with up-to-date geological information	☐ Production and publication and revision of terrestrial geological map • Publication of 30 sheets of 1:50,000 national geological map (2023), 100% completion of national geological map by publishing additional 15 sheets by 2025 (359 sheets) • Publication of 4 sheets of the new 1:100,000 geological maps through revision of 1:50,000 national geological map • Revision and publication of 1:50,000 national geological map within the new 1:100,000 geological map ☐ Production and publication of quaternary geological thematic map • Publication of 9 sheets of 1:250,000 Quaternary geological map of Busan/Ulsan/Pohang, etc ☐ Production and publication of marine geological thematic map • Publication of 8 types of 1:100,000 marine geological thematic map of Busan coastal area (2 of 22 regions 9% completed) • Revision of 18th series of 1:250,000 regional-scale marine geological map • Publication of 1:750,000 marine geological thematic map (4 type from the Yellow Sea, 4 types from the East Sea)
Development and application of advancement techniques for optimizing public technology & information on national territory geology	☐ Establishment of a consistent and integrated geological information production & service system • Advancement through production and revision of up-to-date & standardized geological information • Establishment of a service system with optimized geological & environmental information
Establishment of the stratigraphy and interpretation of the tectonic environment of the coastal area of central-western Korean Peninsula	☐ Establishment of a standard stratigraphy of the coastal area of central-western Korean Peninsula • Standardization of the Korean-type geological information on the core area of continental collision belt in the central-western coast ☐ Interpretation of tectonic environment of central-western Korean Peninsula • Detailed comprehensive research on new tectonic province through revision of the geological map of the Korean Penisula • Integrated analysis of the central-western coastal area overprinted with various and complicated geological records of subduction-suture-collision

Performance Indicators	Milestones					Outputs
	2020	2021	2022	2023	2024	
Publication of 1:50,000 national geological map (currently 88%)	Baeknyeong-do etc 14 sheets geological survey	Baeknyeong-do etc 14 sheets publications (92%) /Oe Naro-do etc 4 sheets geological survey	Oe Naro-do etc 4 sheets publications (93%) /Kokum-do etc 7 sheets geological survey	Kokum-do etc 7 sheets publications (95%) /Ui-do etc 8 sheets geological survey	Ui-do etc 8 sheets publications (97%) /Mijo-do etc 4 sheets geological survey	33 sheets of 1:50,000 scale National Geological Map (316/359 sheets to 349/359 sheets, 97% completion)
Publication of 1:100,000 geological map	Cheorwon/ Seoul/ Baeknyeongdo /Incheon 4 sheets geological survey (20%)	Cheorwon/ Seoul/ Baeknyeongdo /Incheon 4 sheets geological survey (40%)	Cheorwon/ Seoul/ Baeknyeongdo /Incheon 4 sheets geological survey (60%)	Cheorwon/ Seoul/ Baeknyeongdo /Incheon 4 sheets geological survey (80%)	Cheorwon/ Seoul/ Baeknyeongdo /Incheon 4 sheets geological survey (100%)	4 sheets (Cheorwon/Seoul/ Baeknyeongdo/ Incheon, of 100,000 scale Geological Map (4/45 sheets, 8% completion)
Publication of 1:100,000 geological thematic map (Quaternary/marine)	Busan quaternary geological map (1:100,000 scale, 30%)	Busan quaternary geological map (1:100,000 scale, 70%)	Busan quaternary geological map (1:100,000 scale, 100%)	Ulsan quaternary geological map (1:100,000 scale, 30%)	Ulsan quaternary geological map (1:100,000 scale, 70%)	2 sheets of 1:100,000 scale Busan Quaternary Geological and Paleoenvironmental Maps (2/20 sheets, 10% completion)
	Busan offshore (1:100,000 scale, 20%)/ Series 18 revision (1:250,000, 20%) /Yellow Sea (1:750,000, 4 sheets)	Busan offshore (1:100,000 scale, 40%)/ Series 18 revision (1:250,000, 40%)	Busan offshore (1:100,000 scale, 60%)/ Series 18 revision (1:250,000, 60%)	Busan offshore (1:100,000 scale, 80%)/ Series 18 revision (1:250,000, 80%) /East Sea (1:750,000, 4 sheets)	Busan offshore (1:100,000 scale, 100%)/ Series 18 revision (1:250,000, 100%)	Submarine Geological Map (offshore Busan 1:100,000, 8 sheets) Series 18 (1:250,000, 5 sheets revision) East Sea and Yellow Sea (1:750,000, 4 sheets each)

□ Research Strategies

○ (Procedure) by accommodating ‘national territory public technology & information’ relevant to the institute’s higher-order R&R based on “Public safety and social-problem solving”, we produce and publish domestic terrestrial & marine geological map and geological thematic map updated with geological information custom to response measures for latest national & social issues.

○ (Process system)



□ Connectivity to KIGAM R&R (Role and Responsibility)

Major role ① of R&R strategic planning is the production and publication of domestic geological map and geological thematic map with updated custom geological information.

Higher-order Role	Major Roles	
1. Providing public technology & information on national territory geology to ensure public safety and social problem-solving	Role 1	Providing customized national territory geological information for balanced national territory development, security, and disaster response
	Type	A. Innovative growth - Smart City, C. Social issues/Safety - ⑤ Disaster/Natural disaster
	Detailed role ①	Providing national territory geological information custom to respond to national & social issues

○ Serving customers (ministries, local bodies, institutes, academies, industries, etc.) with advanced geological information and technology on behalf of the government

□ Connectivity to Government Policy

National task (The country responsible for my life - National strategy 3. National Security and life-conserving relief society)

- 55. Establishment of national responsibility system for safety accident prevention and disaster safety management

○ National task (Peace and prosperity in the Korean Peninsula - National strategy 2. Inter-Korean cooperative relations and Denuclearization of the Korean Peninsula)

- 90. Implementation of the new economic plan and economic unification of the Korean Peninsula

○ Provide directions and standards for government research and development (R&D) investment in 2020

- ⑦ Establish social safety network through integrative-cooperative-participative R&D projects according to the complexity of the natural disaster

□ Technical and Economical Impacts

○ Respond immediately to various national and social issues that include balanced national territory development, public safety (earthquakes, landslides, nuclear wastes, etc.), social issues (groundwater contamination, public health risk materials-radon, asbestos, etc.) by providing customer based customized national territory geological information

○ Comprehensive seafloor mapping supports a range of decisions regarding offshore development and provide baselines for geological monitoring change

□ Utilization of Research Outputs

○ Enhance reliability through intellectualization of national territory geological information, and provide customized national territory geological information to customers (ministries, local bodies, research institutes, academia, industries, etc.)

○ The seafloor geological information is essentially used for Naval operations, marine geological hazards assessments and offshore developments

○ Strengthen cooperation with universities and provides datasets obtained during cartography for academic researches

Research of the Rock Characteristics in Deep Geological Environment for the HLW* Geological Disposal

☐ Objectives

○ Development of a multidisciplinary integrated DB and establishment of standard procedures for investigation and analysis through conducting the rock characterization in the deep geological environment for HLW geological disposal

☐ Research Contents

Detailed Technologies	Description / R&D Scope and Contents
Identification of evaluation parameters for each rock type and item, and Establishment of standard procedures for investigation and analysis	☐ Identification of crucial evaluation parameters for each rock type and item • Identifying crucial evaluation parameters to determine rock type for HLW geological disposal • Rock type: granite, granite gneiss, mudstone, volcanic rocks • 6 items: geology, geochemistry, hydrogeology, mechanics, geophysical exploration, geothermy ☐ Establishment of standard procedures for investigation · analysis of crucial evaluation parameters • Verifying investigation and analysis methods of crucial evaluation parameters • Establishing standard procedures for investigation · analysis of the deep geological characteristics
Development of evaluation parameters DB, distribution, and range for each tectonic province and rock type	☐ Development of crucial evaluation parameters DB for each tectonic province • Obtaining deep geological data through the deep drilling • Establishing DB for integrated evaluation parameters based on standard procedures • Developing DB of at least 12 evaluation parameters in 6 items ☐ Development of evaluation parameters distribution and range for each tectonic province and rock type • Developing evaluation parameters distribution and range of based on DB • Using these results to determine rock type for HLW geological disposal and HLW disposal system

* HLW: High-level radioactive waste

Performance Indicators	Milestones					Outputs
	2020	2021	2022	2023	2024	
Identification of evaluation parameters for each rock type and item & Establishment of standard procedures for investigation and analysis	Identification of evaluation parameters for each rock type and item	Verification and establishment of granite investigation and analysis technology	Verification and establishment of mudstone investigation and analysis technology	Verification and establishment of granite gneiss investigation and analysis technology	Verification and establishment of volcanic rocks investigation and analysis technology	Standard procedures for investigation and analysis of crucial evaluation parameters
Development of evaluation parameters DB, distribution, and range for each tectonic province and rock type	Design of database system of evaluation parameters (D-GIVES)	Development of evaluation parameters DB for granite (at least 12 evaluation parameters in 6 items)	Development of evaluation parameters DB for mudstone (at least 12 evaluation parameters in 6 items)	Development of evaluation parameters DB for granite gneiss (at least 12 evaluation parameters in 6 items)	Development of evaluation parameters DB for volcanic rocks (at least 12 evaluation parameters in 6 items)	Integrated DB of deep geological characteristics on major rock type for each tectonic province
					Development of distribution and range of crucial evaluation parameters	Technical report of distribution and range for crucial evaluation parameters

Drilling plans	2020	2021	2022	2023	2024	Total 10 holes
	Granite 2 holes 750m	Mudstone 2 holes 750m	Granite gneiss 2 holes 750m	Volcanic rocks 2 holes 750m	Additional 2 holes 750m	

* HLW: High-level radioactive waste

** Crucial evaluation parameters: these will be derived from over 100 evaluation parameters reported in the previous project. Assessing the importance of parameters rather than convenience.

1. Application: this research results can be used for not only HLW geological disposal but also ESS, CCS, and geothermal development, etc.
2. Cooperation: we will cooperate with Deep Subsurface Research Center and Groundwater Research Center.
3. Differentiation: this project is different from existing projects in that we will research about applicability of various host rock types for HLW disposal. Previous projects focused on only granite.
4. Scope: this project is aimed at the evaluation of host rock type for HLW disposal. Not aimed at evaluation of site for siting.
5. Strategy: due to the inhomogeneity of the geology, more drilling are needed. We will actively use the existing cores and previous drilling research results.

National Geoscience Data Center (NGDC) Construction through Research Data Repository and Geodata Platform Development

Connectivity to KIGAM R&R: (Upper role) providing the national geology public technology/information for the resolution of the people security and life problem

◇ **Necessity**: Establishing systematic collection · management system for national geological information, ② needing a geodata platform that provide geological information and integrated solutions to solve for various national · social issues

□ Objectives

Geoscience research data integrated management system construction

○ Development of open geodata platform for data sharing, utilization and service of geoscience research data

○ National Geoscience Data Center (NGDC) construction through open geodata platform operation

□ Necessities

○ Despite the high scientific and technological assets of historical/academic value, research data is not available due to the lack of management, preservation, sharing and utilization system.

○ With the recent developments in technology and equipment, the types and amounts of research data are rapidly increasing, and the paradigm of global science and technology is shifting from data intensive fusion research to open science.

- In addition to creating new value and enhancing research productivity, it is necessary to construct a geodata platform that can be instantly utilized when various disaster events such as climate change and earthquake occur.

○ KIGAM, which is the only Korean geological and mineral resource research institute, has a mission to play a central role as a national data center for the comprehensive collection, management, preservation and sharing and utilization of various research data produced in the field of geoscience.

☐ Research Contents

Detailed Technologies	Description / R&D Scope and Contents
Establishment of integrated data management system for geoscience research data repository (GDR)	☐ Expand scope of geoscience research data collection and registration • Collection and registration of past materials such as maps and documents related to geoscience • Collection and registration of geological sample data such as boring cores, rocks, and fossils • Collection and registration of geological survey, exploration and measurement data • GI(Geo-image) data collection, processing and registration ☐ Enhancement of geoscience research data repository (GDR) system • Development of large amount of research data quality management and quality evaluation function • Enhancement of GIS-based data retrieval and visualization function • Expand metadata considering International Geo-Sample Number (IGSN) and external donation data • Develop guidelines for research data management, sharing and utilization • Construction of H/W and S/W infrastructure for research data management and utilization and development of management and operation technology
Development of open geodata platform for sharing, utilizing and servicing geodata	☐ Development of open geodata platform for geodata sharing · utilization · service • Data refining, processing, standardized smart geodata management technology and infrastructure construction based on user demand • Development of participatory open platform for geodata sharing, utilization and service • Linkage with related institutional systems based on metadata and Linkage with national research data platform • Development of geoscience data journal system and linkage with open geodata platform
Construction of National Geoscience Data Center (NGDC)	☐ Construction of National Geoscience Data Center (NGDC) • Construction of National Geoscience Data Center (NGDC) by activating research data repository and open geodata platform • Construction of support center for sharing · utilization of the open geodata platform • Establishment of data sharing network with domestic/overseas related organizations

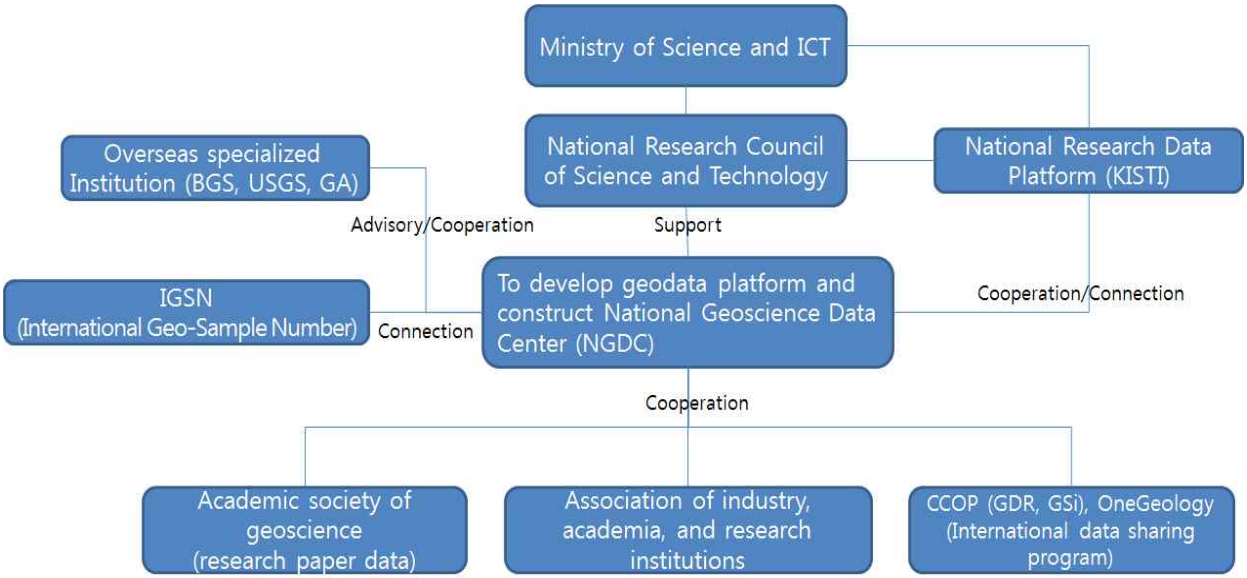
<table>
<tr><td></td><td></td></tr>
</table>

<table>
<tr><th rowspan="2">Performance Indicators</th><th colspan="5">Milestones</th><th rowspan="2">Outputs</th></tr>
<tr><th>2020</th><th>2021</th><th>2022</th><th>2023</th><th>2024</th></tr>
<tr><td rowspan="4">Building a digital geoscience research data repository</td><td colspan="2">Advancement of research data management system</td><td colspan="3">Establishment of research data quality management and evaluation system</td><td rowspan="4">Digital Geoscience Research Data Repository (GDR)</td></tr>
<tr><td>Improved collection and management functions</td><td>Development of sharing and utilization function</td><td rowspan="2">Development of quality management and evaluation guidelines</td><td rowspan="2">Development of prototype of quality control and evaluation system</td><td rowspan="2">Development and utilization of quality control and evaluation system</td></tr>
<tr><td colspan="2">Development of collection, management, sharing and utilization guidelines</td></tr>
<tr><td colspan="5">Collection and registration of geoscience research data
(Expanding the scope of data registration through collaboration with related organizations in domestic and abroad)</td></tr>
<tr><td rowspan="2">Building a open geodata platform and National Geoscience Data Center (NGDC)</td><td colspan="3">Development of Open Geodata platform</td><td rowspan="2">Building of open geodata platform sharing and support center</td><td rowspan="2">Designation as a national data center (NGDC)</td><td rowspan="2">Open geodata platform and National Geoscience Data Center (NGDC)</td></tr>
<tr><td>Development of open geodata platform prototype</td><td>Advance -ment of open geodata platform and trial service</td><td>Open geodata platform service</td></tr>
</table>

□ Research Strategies

(Procedure) development of a management system for geoscience research data in accordance with the organization's top R&R based 'Providing customized geological information and integrated solutions' based on 'Resolving the people's safety and living problems', establishing a multi-disciplinary industry-academic-research cooperation network for developing a geodata platform and establishing a national data center that can provide optimal geological information customized to national issues centered on the users.

(Process system)



□ Connectivity to KIGAM R&R

○ Strategies for implementation of the R&R on the construction and operation of geodata platform and national data center

Higher-order Role	Major Roles	
1. Providing the national geologic technology/information for the resolution of the people' s safety and living problem	Role 1	Providing a customized geological information for national land development, security and disaster response
	Type	A. Innovation growth - Smart city, C. People living research/safety field - ⑤ Disaster
	Detailed role ③	Construction and operation of geodata platform and national data center

○ Systematic collection and management of geoscience research data on the national land by establishing a cooperative system for industry, academia and research and the construction of a digital data repository of geoscience research data that can provide information that can quickly respond to national and social issues by converting research data into big data are a unique role of KIGAM.

○ The final purposes of the project which are to transform geoscience research data into big data and establish a geodata platform that can provide integrated solutions for resolving various national and social issues by utilizing artificial intelligence and

big data technologies are consistent with the performance of the KIGAM's unique mission that contributes to the safety of the people and the growth of innovation of Korea.

□ Expected Outcomes

Promoting the sharing and utilization of research data through the establishment of geoscience research data management and preservation system of the national level

- ㅇ Providing quick and accurate data when necessary not only natural disasters such as earthquakes, landslides and underground water pollution, but also civil construction and underground resource development
- ㅇ Based on data likened to crude oil in the 4th Industrial Revolution, it is used to create new industries in the field of geoscience and develop new technologies for national people's safety through convergence with ICT technologies such as AI and IoT.

□ Utilization of Research Outputs

- ㅇ Data intensive geoscience research platform is utilized for R&D innovation and ecosystem development to promote joint research.
- ㅇ GDR is utilized as a national geoscience research data repository and hub.

Development of Platform to Utilize GeoBigData and GeoAI

◇ **Connectivity to KIGAM R&R:** (Upper roles) providing public geological technology/information to enhance public safety and resolve related issues

◇ **Necessity:** ① increased demands for geological data-based analytics and services, ② needs for knowledge-based GeoAI utilization platform as integrated solution to current geological issues

☞ "Resolving safety/living issues of citizens and improving national competitiveness through intelligent geoscience and mineral resources services"

□ Objectives

Development of goal/demand-oriented GeoBigData collection technology and establishment of GeoBigDataSets

○ Development of GeoAI utilization technology for GeoBigData-based analysis and prediction

○ Establishment of platform for integrated management/utilization of GeoBigData-GeoAI

□ Necessities

○ Change in paradigm of public information in intelligent information society: Need for intelligent information processing technology built on big data analysis or AI-based prediction and detection to overcome problems arising from increased data transmission and processing

○ Increased demand for services providing public geological technology/information: Need to provide information and analytical services at national level in response to increased interest in disasters such as sinkholes and earthquakes

○ Becoming a strong information hub based on big data in geoscience and mineral resources: Establishment of advanced analysis and management system for vast amounts of geological data accumulated over time, and development of integrated utilization system to gain new insights from geological data

□ Research Contents

Performance Indicators	Milestones					Outputs
	2020	2021	2022	2023	2024	
Development of goal/demand-oriented GeoBigData collection technology, and establishment of GeoBigDataSets	Definition of GeoBigDataSet management system, system design, and integration with internal/external services	Development of GeoBigDataSet common framework and big data collection system	Establishment of goal/demand-oriented GeoBigDataSet	Development of goal/demand-oriented GeoBigDataSet management system	Field-based advancement of Goal-oriented GeoBigDataSet	Goal/demand-oriented GeoBigDataSet
Development of GeoBigData-based GeoAI utilization technology	Development of GeoBigData processing technology	Development of utilization technology for geoscience and mineral resources based on GeoBigData and GeoAI	Optimization of GeoAI-based utilization technology for platform implementation	Development of physics-based/data-driven GeoAI convergent analytics technology	Field-based advancement and specialization of GeoAI	GeoAI-based GeoBigData utilization technology
Establishment of integrated GeoBigData-GeoAI management/utilization platform	Design of GeoBigData management (refinement/processing/analysis) system and platform	Development of GeoBigData management (refinement/processing/analysis) trial system and platform	Development of analytic algorithm based on coupling of GeoBigData and GeoAI	Development of GeoBigData-GeoAI integrated system	Trial operation of GeoBigData-GeoAI integrated service	GeoBigData-GeoAI integrated platform

□ Research Strategies

(Procedures) establishment of multi-disciplinary international research system to provide customized public geological technology and information, and establishment of GeoBigData/GeoAI-based platform through intelligent convergent technology research, and establishment of big data/AI geological information platform

○ (Process system)

- Cooperation with ICT industries: Cloud computing technology, calculation for AI learning
- Establishment of multi-disciplinary research system: Big data processing and analysis technology
- Establishment of international joint research system: AI-based simulation and prediction technology

- Benchmarking of leading institutes: Management and service system, latest AI trends
- Service promotion and improving effectiveness: Strengthening linkage with national data center

□ Connectivity to KIGAM R&R

R&R strategic planning related to development of platform to utilize GeoBigData and GeoAI

Higher-order Role	Major Roles	
1. Provide public geological technology/information to enhance public safety and resolve related issues	Role 1	Provide customized geological information for balanced land development, security, and disaster response
	Type	A. Innovative growth - Smart city, C. National life research/safety - ⑤ Disaster
	Detailed role ①	Provide customized geological information to address national/social issues
	Detailed role ③	Establish/operate geodata platform and national data center

○ Institutional mission of providing customized geological information for balanced land development, security, and disaster response fulfilled through

○ Establishment of systematic geological information data collection and management system through integrated GeoBigData-GeoAI platform

○ Establishment of public real-time geological information system through big data /AI-based collection/analysis/prediction of geological information

□ Connectivity of Government Policy

Government project (Nation taking responsibility for the people - National strategy 3. Safe society that ensures well-being of citizens)

- 55. Establishing a national safety prevention and disaster management system
- 59. Creating a sustainable national territorial environment

○ Government project (Economy for mutual prosperity - National strategy 4. Driving the fourth industrial revolution through advancements in science and technology)

- 33. Establishing software and ICT infrastructure to lead the fourth industrial revolution
- 35. Creating an autonomous, responsible ecosystem of innovation in science and technology

○ Directions of government R&D investment directions and 9 major investment areas of 2020

- ④-1 (Response to 4th industrial revolution) Accelerating production of outcomes in geoscience and mineral resources through knowledge-based ICT convergence
- ⑦ (Establishment of social safety net) Providing platform to collect/analyze/predict geological information based on big data and AI

○ Key projects under the 4th Basic Plan of Science and Technology (Feb. 2018) (11. Strengthening response to the 4th industrial revolution)

- ① Acquisition of AI-based technology: Strategic acquisition of key AI technology in geoscience and mineral resources, and creation of cooperative ecosystem
- ③ Strengthening of data sharing/utilization capacity and establishment of data utilization infrastructure: Establishment of platform to utilize GeoBigData and GeoAI

□ Expected Outcomes

○ Reliability enhancement of public geological information through intelligentization and provision of customized public geological information service

○ GeoData-Platform-based Service through smartization of public geologic information and establishment of multi-disciplinary collaborative network

Research of Active Intraplate Tectonics and Development of Fault Segmentation Model

◇ **Connectivity to KIGAM R&R**: (Upper roles) leading to public Geo-information and Geo-technology for public safety and awareness

◇ **Necessity**: increase in damages due to intraplate earthquake Difficult to predict intraplate earthquake than interplate earthquake

☞ **Need to study on the Korean-type intraplate fault behavior and recurrence model**

□ Objectives

Assessment of major crustal deformation region in South Korea based on tectonic parameter analysis

○ Development and substantiation of a fault segmentation model of the relatively active area within an intraplate region

□ Necessities

○ Impact damage probability due to abrupt earthquake: In the intraplate environment such as Korea, it is difficult to predict earthquake location and recurrent interval and one event could make serious damages

- Need to establish an integrated system for production, analysis, and management of highly reliable information on the crustal deformation
- Need to study on systematic characterization of geological features of the Korean peninsula

○ National necessity of basic and long-term preparations: Offering the basic data to publish national earthquake risk (or hazard) maps, which contribute the public safety

□ Research Contents

Detailed Technologies	Description / R&D Scope and Contents
Evaluation of crustal deformation activity based on advanced data	□ Acquisition and production of crustal deformation information □ Assessment of crustal deformation through pattern · correlation analysis
Development of intraplate fault segmentation model	□ Development of intraplate fault segmentation technique * Fault segmentation: Division a fault into several parts with different characteristics □ Substantiation study using a major large fault (over 100 km in length)

Performance Indicators	Milestones				Outputs
	2020	2021	2022	2023	
Advancement of crustal deformation information/ Assessment of major deformation region	Acquisition and production of crustal deformation information	Advancement of crustal deformation information	Extraction and analysis of pattern · correlation between deformation factors	Assessment of major deformation region and high-damageable area based on stress modeling	Offering highly developed crustal deformation information Proposal on earthquake damageable zone
Development of fault segmentation model	Basic study on fault segmentation	Development of intraplate fault segmentation model	Evaluation of fault segmentation model through a TESTBED study using a major large fault	Proposal on the segmentation model of the TESTBED fault	Technique of intraplate large fault segmentation/ Result of substantiation study

□ Expected Outcomes

Acquisition of original technology concerning active tectonics and intraplate fault segmentation in the Korean Peninsula

- ㅇ Reduction of damage and economic costs in various industries through essentially basic data for preparing national earthquake preparedness technology
- ㅇ Expansion of experts in fault-earthquake fields of Korea and promotion of international status through domestic/international collaboration
- ㅇ Realization of national security by strengthening earthquake response capability

Development of Strong Ground Motion Prediction and Earthquake Early Warning System Specialized in Southeast Korea

Connectivity to KIGAM R&R : (Upper roles) development of geo-scientific techniques and information to the public for ensuring the safety and lives of the people

◇ **Necessity**: after the 2016 Gyeongju and 2017 Pohang earthquakes occurred in the southeast Korea, our needs for the development of seismic hazard assessment and response technology, specialized in the region, were highlighted, ② it is necessary to develop the technology of quantitative seismic hazard assessment and earthquake early warning system, based on site-specific strong ground motion characteristics in the southeast Korea

□ Objectives

Developing strong ground motion simulation methods, using dynamic earthquake rupture modeling and multi-variate site effect for quantitative seismic hazard assessment in the southeast Korea

○ Developing a hybrid earthquake early warning system, specialized in the southeast Korea, considering strong ground motion characteristics and seismic networks in the region

□ Necessities

○ After the 2016 Gyeongju and 2017 Pohang earthquakes occurred in the southeast Korea, it becomes important to develop systematic and advanced seismic hazard assessment and response technologies in the region

○ In a low seismicity region with very few recorded strong ground motion data, such as the Korean Peninsula, simulated strong ground motion data, obtained by dynamic rupture modeling and multi-variate site effects, can be effectively used for the development of quantitative seismic hazard assessment and response technologies

○ It is important to develop a rapid seismic hazard response system such as a hybrid earthquake early warning system, optimized for the southeast Korea by considering seismic wave propagation and seismic networks in the region

☐ Research Contents

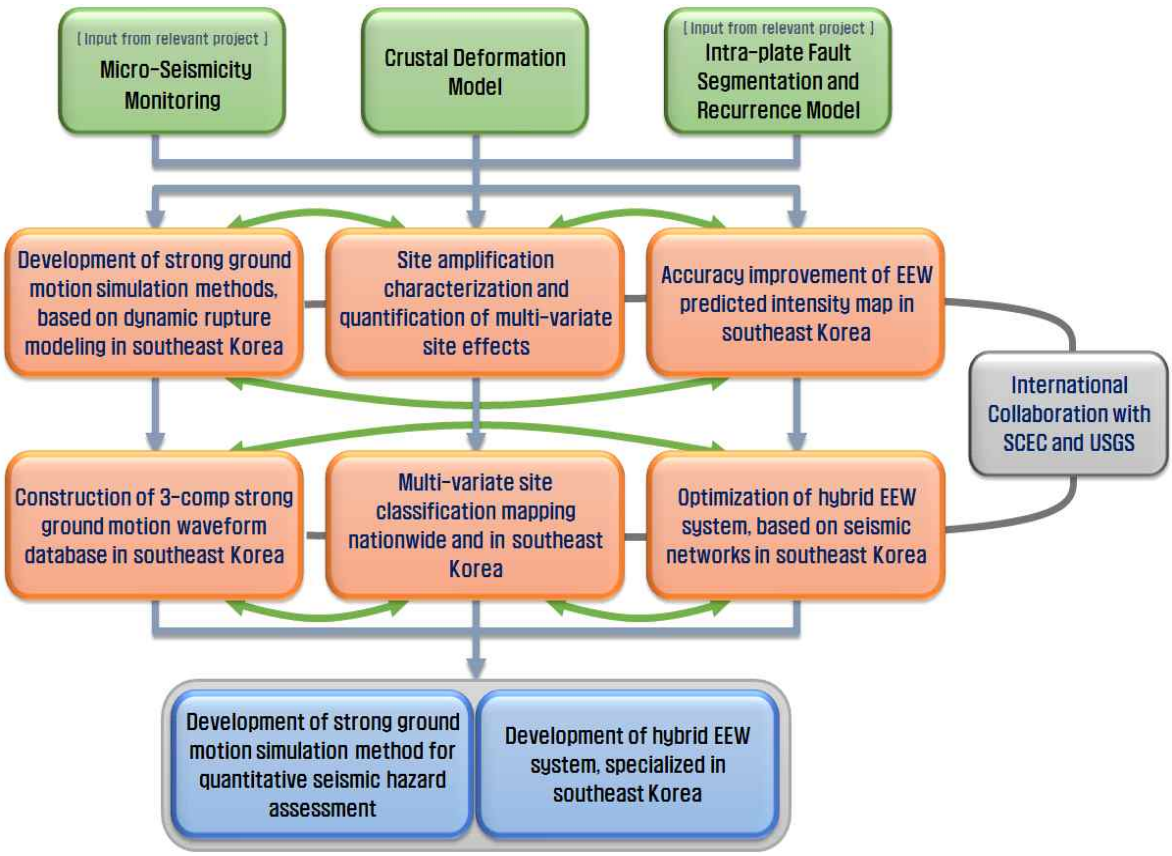
Detailed Technologies	Description / R&D Scope and Contents
Strong ground motion simulation, based on dynamic rupture modeling	☐ Strong ground motion characteristics, based on dynamic rupture modeling and site effects in the southeast Korea • Dynamic rupture modeling, based on active tectonics and crustal deformation studies • 3D seismic wave propagation analysis, based on earthquake rupture and crustal velocity structure in the Korean Peninsula • Multi-variate site effect quantification and site classification mapping, based on site-specific ground motion amplification characteristics
Earthquake early warning (EEW) system development, specialized in the southeast Korea	☐ Earthquake early warning (EEW) system development, utilizing seismic networks in the southeast Korea • Hybrid EEW system performance assessment and optimization, utilizing simulated strong ground motion data • EEW predicted intensity accuracy improvement for several big cities, utilizing constructed site effect information • Development of realtime natural period display system before and after earthquakes, utilizing continuous motion monitoring systems in facilities

Performance Indicators	Milestones				Outputs
	2020	2021	2022	2023	
3-comp strong ground motion waveform simulation capability, based on earthquake rupture modeling	Development of strong ground motion simulation modules (source and path)	Integration of strong ground motion simulation modules	Application of strong ground motion simulation in the southeast Korea	Construction of strong ground motion waveform DB in the southeast Korea	3-comp strong ground motion waveform simulation capability
	Influence factor identification of ground motion amplification characteristics	Derivation of multi-variate site effect quantification parameter	Construction of nationwide and southeast site property information	Nationwide and southeast multi-variate site classification mapping	Nationwide multi-variate site classification map
Construction of EEW system, specialized in the southeast Korea	-	Accuracy of EEW predicted intensity map in big cities of the southeast Korea (2 km)	Accuracy of EEW predicted intensity map in big cities of the southeast Korea (< 1 km)	Optimization of hybrid EEW system, based on seismic networks in the southeast Korea (Inland events: 10 seconds)	Hybrid EEW system, specialized in the southeast Korea

□ Research Strategies

(Procedure) ① Developing earthquake rupture models, specialized in the southeast Korea, based on multi-disciplinary studies including active tectonics, crustal deformation, and micro-seismicity monitoring, and performing 3D seismic wave propagation modeling with high performance computing (HPC), ② Building 3-comp strong ground motion waveform database, considering quantitative multi-variate site amplification properties, ③ Optimizing hybrid earthquake early warning system, utilizing seismic networks and strong motion database in the southeast Korea, ④ International collaboration with world leading research groups such as SCEC and USGS, etc.

○ (Process system)



□ Connectivity to KIGAM R&R

R&R strategic planning to track seismicity and active faults

Higher-order Role	Major Roles	
1.Providing geo-scientific information to the public to solve the issue of "ensuring the safety and lives of the people"	Rrole 2	Development of techniques to track seismicity on active faults and to respond to earthquake disasters
	Ttype	C. research of people's lives/safety - disaster/catastrophe
	Detailed role ②	Response to earthquake disasters using an earthquake early warning system

□ Connectivity of Government Policy

○ President Moon's Plan for a 5-year National Task on 100 Issues

- 55. Building national regime to control disaster and safety
- 56. Building a integrated disaster management system

○ It is the top priorities of government that strengthen research capacity and allocate budget and human resources on earthquake and natural disasters research (MSIT's promoting Science & Technology srategy in the research on the peoples' livelihood, '18.3.).

- The early responses to earthquake and natural disasters include:
  a. assigning emergency-response persons in charge,
  b. performing real-time monitoring by a task group,
  c. and communicating with the public by releasing information and verification of events.

○ The Gyeongju('16.9.12.) and the Pohang('17.11.15.) earthquakes intensified peoples' concern about earthquake disasters in the Korean Peninsula.

- The earthquakes increased the necessity to understand the geology of Korea including active faults and geological information in the Korean Peninsula.

□ Expected Outcomes

Advanced seismic hazard assessment in the vicinity of active fault zones, considering site-specific physics-based strong ground motion simulation methods

- ㅇ Seismic hazard mitigation, utilizing a region-specific hybrid EEW system
- ㅇ Rapid seismic hazard response, utilizing a ground motion display system and an earthquake damage assessment system

□ Utilization of Research Outputs

- ㅇ 3-comp strong ground motion waveforms, obtained by dynamic rupture modeling, can be efficiently applied to advanced seismic hazard assessment and performance based earthquake engineering in the vicinity of active fault zones
- ㅇ Rapid earthquake information distribution to local government officers and major facility operators, utilizing the region-specific hybrid EEW system
- ㅇ Rapid earthquake damage response by earthquake magnitude estimation and quantitative damage estimation, utilizing seismic accelerometers installed in national infra-structure facilities

Development of integrated geophysical monitoring system at depth for assessing earthquake and fault activities at South-eastern Korea

◇ **Connectivity to KIGAM R&R**: (Upper roles) resolving national security and life problems, and providing public technology/information of national geology

◇ **Necessity**: enhancement of research competitiveness to manage national earthquake disaster, through fundamental technology development for seismic risk assessment based on earthquake and fault activities

☐ Objectives

Construction of integrated geophysical monitoring system optimized to geotectonics environment in Southeastern Korea

- Design and construction of integrated geophysical monitoring system
- Operation of an integrated geophysical monitoring system and development of data analysis technology

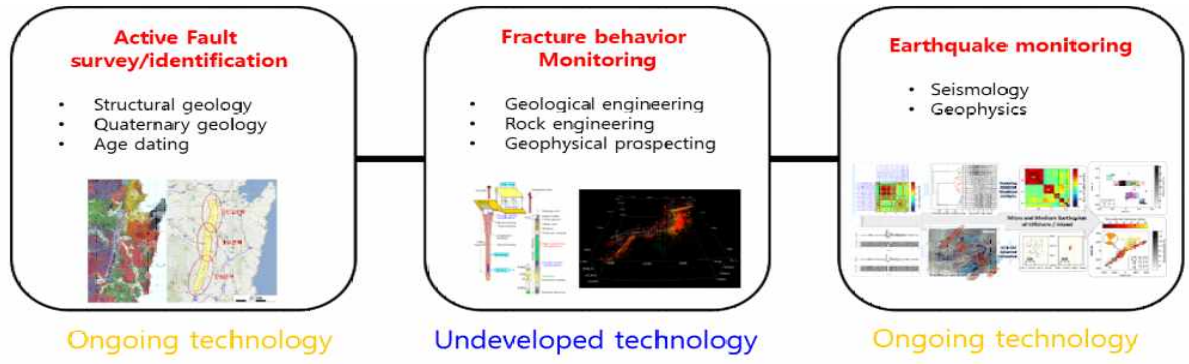
○ Planning basic concepts for comprehensive monitoring of deep fault in Southeastern Korea

☐ Necessities

○ After the Gyeongju earthquake (Sep. 2016) and the Pohang earthquake (Nov. 2017), it is needed to map the active faults in Southeastern Korea and to monitor behavior of earthquake, fault activities, and crustal stress change, continuously

⇨ To that end, it is urgent to develop an integrated geophysical monitoring system using deep boreholes to monitor earthquakes and fault activities more precisely

⇨ Due to the lack of domestic experiences, it should be stepwise implementations to improve the completeness of the monitoring system



☐ Research Contents

Detailed Technologies	Description / R&D Scope and Contents
1 km-depth integrated geophysical monitoring system	☐ Design of integrated geophysical monitoring system for 1 km-depth • Development of borehole design and completion techniques for 1 km-depth monitoring system depending on the rock type (lithology) • Development of Sensor selection and system design technique under high-temperature and high-pressure conditions ☐ Construction of 6 integrated geophysical monitoring system for 1 km-depth • Required monitoring item: groundwater level, temperature, pressure, strain, microseismicity, strong motion, surface displacement
Monitoring system operation and data analysis technology	☐ Construction and operation of monitoring network • Operation system linked with KIGAM earthquake network system • Data processing / analysis / visualization / reporting procedure by monitoring items ☐ Development of integrated analysis technology • Integrated analysis for monitoring data • Fault behavior monitoring by integrated analysis
Basic plan of integrated geophysical monitoring system for deep faults in Southeastern Korea	☐ Upgrade (expansion and enhancement) plan of a comprehensive monitoring system for deep faults in Southeastern Korea • Selection of precise monitoring zone by monitoring system data analysis ☐ Basic plan of deep fault drilling and monitoring (DFDM[1]): location, depth, monitoring item, etc

1) Deep Fault Drilling & Monitoring

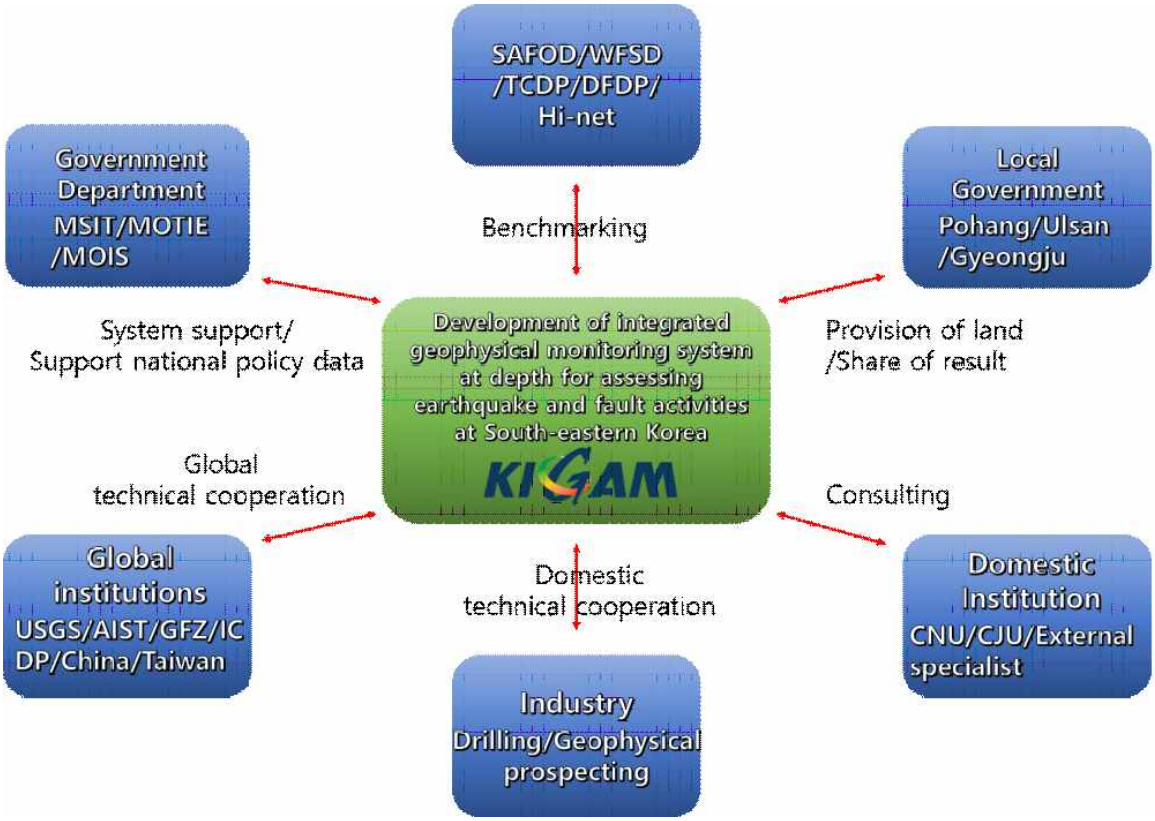
Performance Indicators	Milestones				Outputs
	2020	2021	2022	2023	
Construction of 1-km depth integrated geophysical monitoring system (construction number (cumulative number))	1.5*(3)	1.5**(4.5)	1.5*(6)	-	A total of 6 integrated geophysical monitoring system for 1 km-depth
Operation and data analysis technology	long-term operation and maintenance procedures	monitoring system operation/ analysis S/W v1	automatic microseismicity processing module	monitoring system operation/ analysis S/W v2	operation/ analysis system, fault activities analysis technology
Basic plan of integrated geophysical monitoring system for deep faults in Southeastern Korea	-	precise monitoring zone selection	upgrade plan for monitoring system	details for deep fault drilling and monitoring (DFDM)	expansion of pre-existing monitoring system / design of DFDM

* (Drilling + Installation + Completion) of 1 site & (Installation + Completion) of 1 site
** (Drilling + Installation + Completion) of 1 site & drilling only has been carried out in 1 site, and the number in brackets indicates the number of cumulative systems

□ Research Strategies

(Procedure) organization of industry-academia-government cooperation for development of integrated geophysical monitoring system for assessing earthquake and fault activities at deep subsurface of South-eastern Korea, based on the top R&R "Resolving national security and life problems, and providing public technology/information of national geology"

(Process system)



□ Connectivity to KIGAM R&R

○ R&R strategic planning for construction of integrated geophysical monitoring system at depth for assessing earthquake and fault activities at South-eastern Korea

- More precise monitoring of earthquake activities in major fault zones and advancement of related infrastructure for development of a hybrid early earthquake warning technology optimized for Korean geological environment

Higher-order Role	Major Roles	
1. National security, resolving national life problems, and providing public technology/ information of national geology	Role 2	development of earthquake · active fault tracking and response technology
	Type	C. National life research/safety - Disaster
	Detailed role ①	Identification of large-scale earthquake reoccurrence model inside plate

□ Connectivity of Government Policy

National task (Nation responsible for my life - National strategy3. Safe society that protects national security and life)

- 55. Establishment of national accountability system for safety accident prevention and disaster safety management

○ National task (Nation responsible for my life - National strategy3. Safe society that protects national security and life)

- 56. Establishment of integrated disaster management system and strengthening capacity for immediate response

□ Expected Outcomes

○ Reduction of the damage caused by large-scale geological disasters and the infrastructure of major national facilities (SOC facilities such as nuclear power plants, radioactive waste disposal sites, etc.)

○ Scientific-investigations of the causes of earthquake and fault activities in Southeastern Korea and establishment of basic technology on monitoring system for high-risk active faults

○ Establishment of disaster response system linked with national disaster prevention system

□ Utilization of Research Outputs

○ With the development of 1 km-depth borehole based integrated geophysical monitoring system, it is possible to improve the accuracy of seismic observation and to visualize the structure of the deep faults in Southeastern part of Korea by imaging the behavior of deep faults that have never been identified at the surface. And also, it can be used as an essential verification material for evaluating crustal movement - fault - earthquake relationship.

○ Besides, it can encourage the potential of challenging projects such as SAFOD with deep fault direct drilling and monitoring, or earthquake prediction that are now considered impossible.

It can be used as basic data for expanded application to integrated geophysical monitoring system at Southeastern Korea including deep fault direct drilling and monitoring with deep boreholes.

○ Optimal design plan of monitoring borehole and system can be utilized as guidelines for deep monitoring for geothermal energy/ CCS/ high-level radioactive waste disposal site. It can be applied to the construction of monitoring system of observation/injection hole for development of deep subsurface resources.

Development of Techniques for Precise Seismicity Tracking and Integrated Seismic Data Management

Connectivity to KIGAM R&R: (Upper roles) development of geo-scientific techniques and information to the public for ensuring the safety and lives of the people

◇ **Necessity**: Development of delicate seismic analysis techniques in the local and regional scales to mitigate earthquake damages in active fault zones,

② "Increasing demands on sufficient and necessary information for the earthquake research" → Standardization, production and services of earthquake information to fulfill the requirements from industries, universities, and institutes

☞ **Precise active seismicity tracking techniques based on seismic data from local and regional observations**

□ Objectives

Development of techniques for precise active seismicity tracking and real-time data quality control based on the seismic data from local and regional observations

○ Establishment of an advanced data-sharing platform and a next-generation integrated seismic data management system

□ Necessities

○ It is necessary to quantitatively assess micro-seismic activities and earthquake hazards in fault zones in order to mitigate the damages in the areas.

○ It is necessary to advance techniques for improving seismic and various geophysical observation system and to optimize an analysis system for array and network data in order to scrutinize natural and man-made events in the Northeast Asia.

○ It is necessary to standardize and provide services for earthquake information such as instrument calibration and response, strong ground motion data, meta data, and ShakeMap scenarios, which are essential for a variety of seismic applications.

□ Research Contents

Detailed Technologies	Description / R&D Scope and Contents
Tracking seismicity in active fault areas	□ Detecting and analysing micro-seismicity in seismically active zones • Construction of a highly-densed seismic network (average station spacing 2~5 km) • Construction of a highly-reliable analyzing technique with robust waveform analysis(Mc < 0.9) • Monitoring of micro-seismicity in active fault zones
Analyzing regional seismicity in the Northeast Asia	□ Enhancing detection capability for regional seismicity in the Northeast Asia • Advancement of an operational technique for seismic and various geophysical observation systems • Optimization of an analysis system for array and network data • Establishment of a SHI event database for the region of the Northeast Asia
Providing seismic information to the public and managing integrated seismic data	□ Providing public services of seismic information and building an integrated seismic management system □ Developing an integrated seismic management system equipped with a robust data quality control algorithm • Improvement of a real-time information sharing system to support the governmental agencies • Launching of a customized seismic information portal

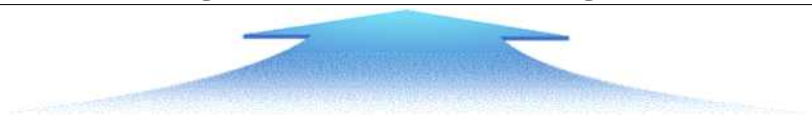
Performance Indicators	Milestones				Outputs
	2020	2021	2022	2023	
Tracking micro-seismicity precisely	Construction of a highly-densed seismic network	Detection of micro-seismicity, identification of phase, estimation of source parameters based on waveform library	Development of tracking and energy estimation for micro-seismicity	Discrimination of seismic sources based on waveform library and machine learning	Active micro -seismicity map (Mc < 0.9)
Analysing regional seismic events in Northeast Asia	Re-evaluation of current seismic DB and improvement of a review system	Construction of a seismo-acoustic event database and an analysis system	Optimization of analysis techniques for array and network data	Construction of integrated SHI DB system	SHI DB in the Northeast Asia
Real-time quality control and integrated seismic management system	Construction of a HA data archiving system based on Cloud	Development of a smart real-time waveform QC technique	Development of an integrated data management system for local and regional seismic data	Development of KISS3G package for industries, universities, and institutes	3-Generation integrated seismic management system (KISS3G)
Public service system for disseminating seismic information	Survey of seismic information demand and modeling of customized services	Development of information/data processing and web-based pre-processing techniques	Development of a next-generation real-time information sharing system for governmental agencies (KISAMS v3)	Launching of a seismic information sharing service for industries, universities, and institutes	Seismic information portal

□ Research Strategies

(Procedure) the process will construct international collaboration networks and promote a step-wise project management to fulfill one of the institute's top-priority roles, "keeping the safety and lives of the people." It will lead to make solutions for precise seismicity tracking, earthquake disaster evaluation, proper response to earthquake disaster and information sharing with expert groups and the public.

(Process system)

Vision	Provision of geo-scientific techniques and information to the public for ensuring the safety and lives of the people
Goal	Development of techniques for precise seismicity tracking and integrated seismic data management



Performance Indicator	Major Contents	Promotion Roadmap 2020	2021	2022	2023	Co-operation
Tracking micro-seismicity precisely	Construction of a highly-densed seismic network					Domestic Universities / Foreign Organizations (LLNL/ISC)
	Detection of micro-seismicity, identification of phase, estimation of source parameters based on waveform library					
	Development of tracking and energy estimation for micro-seismicity					
	Discrimination of seismic sources based on waveform library and machine learning					
Analysing regional seismic events in Northeast Asia	Re-evaluation of current seismic DB and improvement of a review system					Domestic Universities / Foreign Organizations (USGS NEIC CTBTO)
	Construction of a seismo-acoustic event database and an analysis system					
	Optimization of analysis techniques for array and network data					
	Construction of integrated SHI DB system					
Real-time quality control and integrated seismic management system	Construction of a HA data archiving system based on Cloud					Government (MIS, KMA) / Industries · Universities · Institutes / Foreign Organizations (IRIS DMC)
	Development of a smart real-time waveform QC technique					
	Development of an integrated data management system for local and regional seismic data					
	Development of KISS3G package for industries, universities, and institutes					
Public service system for disseminating seismic information	Survey of seismic information demand and modeling of customized services					Government / Industries · Universities · Institutes
	Development of information/data processing and web-based pre-processing techniques					
	Development of a next-generation real-time information sharing system for governmental agencies (KISAMS v3)					
	Launching of a seismic information sharing service for industries, universities, and institutes					

□ Connectivity to KIGAM R&R

R&R strategic planning to track seismicity and active faults

Higher-order Role	Major Roles	
1.Providing geo-scientific information to the public to solve the issue of "ensuring the safety and lives of the people"	Role 2	Development of techniques to track seismicity on active faults and to respond to earthquake disasters
	Type	C. research of people's lives/safety - disaster/catastrophe
	Detailed role ②	Response to earthquake disasters using an earthquake early warning system

- ㅇ It is the institute's unique responsibility that contributes to the national safety and secures the lives of the people by tracking seismicity on active faults, building seismicity maps and sharing seismic hazard information with the public.
- ㅇ It is the institute's unique responsibility that develops geo-scientific technology and provides information services to the public by producing seismic research information and sharing it with the community of industries, universities and institutes.

□ Connectivity to Government Policy

- ㅇ President Moon's Plan for a 5-year National Task on 100 Issues
  - 55. Building national regime to control disaster and safety
  - 56. Building a integrated disaster management system
- ㅇ It is the top priorities of government that strengthen research capacity and allocate budget and human resources on earthquake and natural disasters research (MSIT's promoting strategy in the research on the peoples' livelihood, '18.3.)
  - The early responses to earthquake and natural disasters include:
    a. assigning emergency-response persons in charge,
    b. performing real-time monitoring by a task group,
    c. and communicating with the public by releasing information and verification of events.

The Gyeongju (‘16.9.12.) and the Pohang (‘17.11.15.) earthquakes intensified peoples’ concern about earthquake disasters in the Korean Peninsula.

- The earthquakes increased the necessity to understand the geology of Korea including active faults and geological information in the Korean Peninsula.

□ Expected Outcomes

- ㅇ National safety can be attained by providing to the public reliable research products based on earthquake information and hazard assessment of active faults.
- ㅇ The national prestige can be attained by securing seismic and geophysical monitoring in the Northeast Asia and sharing this information with international organizations.
- ㅇ Overlapped investment to the infrastructure and observational gaps can be reduced by building an integrated data management system.

□ Utilization of Research Outputs

- ㅇ Seismic hazard can be evaluated by modeling strong ground motion with sub-surface fault information obtained from the map of active micro-seismicity.
- ㅇ Strengthening capacity to monitor seismic events in the Northeast Asia, including North Korea’s nuclear tests, can be utilized for deciding national security policy.
- ㅇ The integrated seismic management system can be used for real-time data quality control and data sharing with other institutes.

Precise Exploration Technology Development and Resources Prediction for Energy Storage Minerals (V, Li)

□ Objectives

Development of 3-D precision exploration and resources evaluation techniques for energy storage minerals (Drilling cost reduction by more than 10% compared to existing reservoir evaluation technique)

○ Resources prediction of domestic energy storage minerals (Resources prediction of domestic Li and orthmagmatic vanadium deposits)

□ Necessities

○ The unstable supply of lithium and vanadium has intensified due to the surge in demand for electric vehicles (EV) and energy storage devices (ESS).

○ Recent recognition of vanadium as a key material in green technology for renewable energy: The Li-ion batteries for ESS are currently mainstream, but the importance of VRFB (Vanadium Redox Flow Battery) in terms of fire safety and life time is increasing.

○ Secure supply and demand of vanadium for VRFB: Vanadium accounts for 30% of the development and production costs for VRFB. The surge in vanadium prices and the failure in new vanadium deposit discovery may lead to difficulties in secure supplies.

○ Need for original and long-term alternatives: Recent conflict on rare earth elements between China and Japan has emphasized the necessity of national long-term alternatives for mineral resources. China's secondary cell makers are aggressively entering new markets for EVs and ESSs based on stable supply and demand of raw materials through the completion of vertical integration of mining development and secondary cell production.

☐ Research Contents

Detailed Technologies	Description / R&D Scope and Contents
Development of 3-D precision exploration and resources evaluation techniques for energy storage minerals	☐ Development of 3-D precision exploration technique for energy storage minerals • Development of exploration techniques for vanadium /lithium ore bodies by ore genesis, and of mineral geochemistry vectoring • Development of 3-D airborne resource exploration technology based on unmanned air vehicle • Development of 3-D geophysical exploration technique for deep-seated vanadium/lithium deposits ☐ Development of 3-D ore body prediction and resources evaluation techniques for energy storage minerals • Development of 3-D ore body prediction technique using AI technology • Development of precise evaluation technique for mineral resources using fusion of drilling data and precision exploration data
Exploration of potential mineralized belt, and resources prediction for domestic energy storage minerals	☐ Regional-scale exploration of Potential mineralized belt, and resources prediction for energy storage minerals • Exploration of Potential mineralized belt using airborne explorations/regional investigation of ore deposits/surface geophysical explorations • 3-D GIS DB Construction for exploration data based on a 3-D geological modeling platform • resources estimation using prediction technique for potential ore bodies

Performance Indicators	Milestones				Outputs
	2020	2021	2022	2023	
Development of 3-D precision exploration and resources evaluation techniques for energy storage minerals (Test-bed mine verification)	Development and application of 3-D precision exploration techniques (ore deposit investigations/ unmaned airborne surveys/deep geophysical exploration)	Verification/ advancement of 3D precision exploration technology, and construction of basic model of predicted 3D ore body	3-D precision exploration of test-bed mine, and verification drilling and advancement for predicted ore body	Development of precise evaluation technique for mineral resources using fusion of drilling data and exploration data, and (drilling) verification	3-D precision exploration/ resources evaluation techniques for energy storage minerals
Exploration of potential mineralized belt, and resources prediction	DB construction using existing data of energy storage minerals, and basic exploration of potential orthmagmatic vanadium deposits in the northwest region (soyeonpyeong-do, Boreum, Yeoncheon)	Precise exploration of potential orthmagmatic vanadium deposits in the northwest region, and basic exploration of orthmagmatic vanadium deposits in the southeast region (Hadong-Sancheong, Hongcheon, Yangyang) amd lithium deposits (Uljin, Jecheon)	resources prediction of potential orthmagmatic vanadium deposits in the northwest region, and precise exploration of orthmagmatic vanadium deposits in the southeast region and lithium deposits	resources prediction of orthmagmatic vanadium deposits in the southeast region, and lithium deposits	resources prediction of domestic orthmagmatic vanadium/ lithium deposits

□ Expected Outcomes

World’ s top domestic secondary cell companies can strengthen their international competitiveness by stabilizing supply chain of lithium and vanadium raw materials

ㅇ Domestic VRFB ecosystem and strong foreign competitiveness would be achieved through secure domestic vanadium resources since the VRFB has characteristics of high charge/discharge efficiency, semi-permanent life, and high safety.

ㅇ It is expected to improve economic efficiency and overseas competitiveness for undeveloped domestic iron ore deposits through converting undeveloped small scale, low-grade iron ore deposits to high value-added vanadium deposits.

Domestic mineral resource sector is on the decline due to its low competitiveness. The increase of research and exploration activities for vanadium will form an autonomous industry-academia-government coalition, and it will be possible to anticipatively respond to the rapid change of the international vanadium resource market.

Development of Mineral Processing, Metallurgical, and Applied Technologies for Utilizing Domestic Vanadium Mineral Resources

◇ **Connectivity to KIGAM R&R**: (Upper roles) development of technologies that secure, utilize, and recycle mineral resources, which drive resources industry in Korea

◇ **Necessity**: Need to ensure stable supply of core minerals to the base industry of the 4th Industrial Revolution, ② urgent need to develop applied technologies of domestic vanadium mineral resources ← "Full-volume import of vanadium industrial materials from overseas"

☞ **Urgent need to develop mineral processing, metallurgical, and applied technologies for self-reliance of vanadium industrial materials**

□ Objectives

Development of low-cost, environmentally-friendly mineral processing technology of low grade vanadium ores to continuously produce their concentrates (V_2O_5 concentrate grade > 1.5%)

○ Development of continuous environmentally-friendly metallurgical technology to produce high purity vanadium for EES* materials (V_2O_5 > 99%)

* ESS (Energy Storage System), [2]VRFB(Vanadium Redox Flow Battery)

○ Technology development of vanadium electrolytes of VRFB for the next generation EES (Electrolyte energy efficiency > 85%)

□ Necessities

○ Increasing demand for VRFBs for ESS in the era of the 4th Industrial Revolution: Recent fire accidents of large-capacity LIB (Lithium Ion Battery) for EES that have resulted in severe social and economic loss call for a safer alternative ESS. Research and development on VRFBs for ESS is expanding and their market share is expected to grow up to 25% by 2027.

○ Needs for stable supply of essential industrial materials such as vanadium: Increasing

high demands (160,000 tons by 2027) of vanadium for VRFBs and strongly-earthquake-resistant, high-strength steel may cause it to be in short supply.

Needs for development of domestic vanadium mineral resources: For self-reliance of expensive vanadium, of which the full-volume is now imported from overseas, there is a pressing need to develop mineral processing, metallurgical, and applied technologies of local vanadium-incorporating ilmenite.

□ Research Contents

Detailed Technologies	Description / R&D Scope and Contents
Low-cost, environmentally-friendly mineral processing technology of low grade vanadium ores	□ Core processes for unit separation and continuous integrated separation of vanadium ores • Characteristics of the degree of mineral liberation and their use for selective crushing and grinding • Unit separation processes using gravitational, magnetic, electrostatic, and optical properties (V_2O_5 1.5%) • Integrated continuous operation of unit separation processes (100kg/h)
Customized metallurgical technology for production of high purity vanadium	□ Pyro- and hydro-metallurgical purification processes of vanadium concentrate • Salt-roasting leaching and direct acid/alkali leaching processes (V_2O_5,>99%) • Vanadium purification and its compound synthesis processes • Continuous extraction and purification processes for recovery of high purity vanadium
Production of ESS materials from vanadium concentrate and high-purity vanadium	□ Production of next generation ESS materials from vanadium concentrate and high-purity vanadium • Synthesis of vanadium sulfate solutions • High-efficiency reduction process • Purification of harmful impurities

<table>
<tr><th rowspan="2">Performance Indicators</th><th colspan="5">Milestones</th><th rowspan="2">Outputs</th></tr>
<tr><th>2020</th><th>2021</th><th>2022</th><th>2023</th><th>2024</th></tr>
<tr><td rowspan="2">Mineral processing technology of vanadium ores</td><td colspan="2">Low-cost, environmentally-friendly unit separation process</td><td colspan="3">Integrated continuous separation system</td><td rowspan="2">In-house technology of vanadium mineral processing and test products

V2O5 concentrate
- Grade > 1.5%
- Recovery rate 80%
- Scale 100kg/h</td></tr>
<tr><td>· Characteristics of the degree of mineral liberation
· Unit separation process of vanadium ores</td><td>· Low-cost, environmentally-friendly separation process
· Design of a continuous separation system</td><td>· Advanced continuous separation process
· Scale-up design of a continuous system</td><td>· Optimization of separation process for continuous concentrate production</td><td>· Integrated continuous separation system of vanadium concentrate</td></tr>
<tr><td rowspan="2">Metallurgical technology of vanadium ores</td><td colspan="2">Processes of high-efficiency extraction of vanadium and production of 98% purity V2O5</td><td colspan="3">Processes of high-efficiency extraction of vanadium and production of 99% purity V2O5</td><td rowspan="2">High-efficiency vanadium extraction technology and test products

V2O5 material
- Leaching efficiency > 86%
- Purity> 99%
- Recovery rate > 82%
- Scale 10kg/d</td></tr>
<tr><td>· Elemental technology of vanadium leaching and recovery from ilmenite concentrate</td><td>· Core technology for vanadium purification</td><td>· Unique KIGAM process (leaching efficiency>86%, purity≥99%)</td><td>· Bench scale KIGAM process ≥ 10 kg/d (production cost≤4.5$/lb)</td><td>· KIGAM vanadium extraction process</td></tr>
<tr><td rowspan="2">Applied technology of vanadium ores</td><td colspan="2">Low-cost technology for high-performance EES materials</td><td colspan="3">Low-cost production of high-performance EES materials</td><td rowspan="2">Applied technology of high-purity vanadium and test products

EES materials -
Cost reduction by 30%
- Purity 99.8%
- Energy efficiency > 85%
- 150 L/d</td></tr>
<tr><td>· Design of elemental technology for low- cost production
· Design of reduction technology
· Design of purification technology</td><td>· Elemental technology for low- cost production
· Reduction technology
· Purification technology</td><td>· Low-cost production process (Cost reduction by 30%)</td><td>· Reduction and purification processes (purity > 99.8%, energy efficiency >85%)</td><td>· Optimized low-cost technology for high-performance EES materials and test production (150 L/d)</td></tr>
</table>

□ Expected Outcomes

Strengthen advancement of the ESS industry and self-reliance of the VRFB ecosystem through the development of technologies that ensure stable supply of core EES materials of the 4th Industrial Revolution

- Contribute to establish a stable supply chain of core EES materials and turn Korea into a major production nation through the development of applied technologies of domestic vanadium mineral resources
- Cultivate proactive management ability in response to the radical change of vanadium markets by establishing networks between industry-academia-research institution for vanadium recovery and application

○ Enhance advance and competence of Korean industries that both develop and apply vanadium in support of unique KIGAM in-house technologies for utilizing domestic vanadium mineral resources

○ Transform public awareness and strengthen industry competency by associating labor-intensive mineral processing companies with the high-tech energy industry

Technology Development of Commercialization and Discovery of Bio-Mineral Material for Local Innovation

◇ **Connectivity to KIGAM R&R**: (Upper roles) development of a technology for securing, utilizing and recycling of mineral resources that drives the national mineral resources industry

◇ **Necessity**: Demand for technological support in next-generation bio-health industries "Increased demand of mineral materials for bio-industry and import dependency", ② Need for support from government research institutes to strengthen local R&D and revitalize local economy

☞ **Necessity for technology to discover and utilize bio-minerals from local clay resources**

□ Objectives

Development of bio-applications and commercialization technology using locally deposited resources, that can be safely eaten or applied to skin, for the 4th industrial revolution

□ Necessities

○ Necessity for development of new resources and materials due to the surge in bio-mineral demand in bio-health sector, one of the major industries in Korea

○ Need for a new R&D model to transform stagnant mining industry in Korea into a promising industry via connection between mining and bio-industry

☐ Research Contents

Detailed Technologies	Description / R&D Scope and Contents
Discovery of new bio-mineral material (Value creation of minerals unspecified by the law)	☐ Discovery of new bio-mineral material using low value minerals unspecified by the law(Yakdol, marine mud) • Field exploitation, evaluation of geo-chemical quality and toxicity • Development of purifying technology for human use
Development of practicalization technology for high value bio-minerals (Value enhancement of domestic clays)	☐ Development of alternative materials to microplastics using domestic clay • Control technology of particle size and formulation for clay microbeads • Utilization technology and evaluation of clay microbeads (toothpastes / cosmetics) ☐ Development of bio-mineral complex for high-tech industries • Production, evaluation, and efficacy test of bio-mineral complex (animal medicine / medical biosensors / inorganic nutrition supplements) • Commercialization technology and R&BD

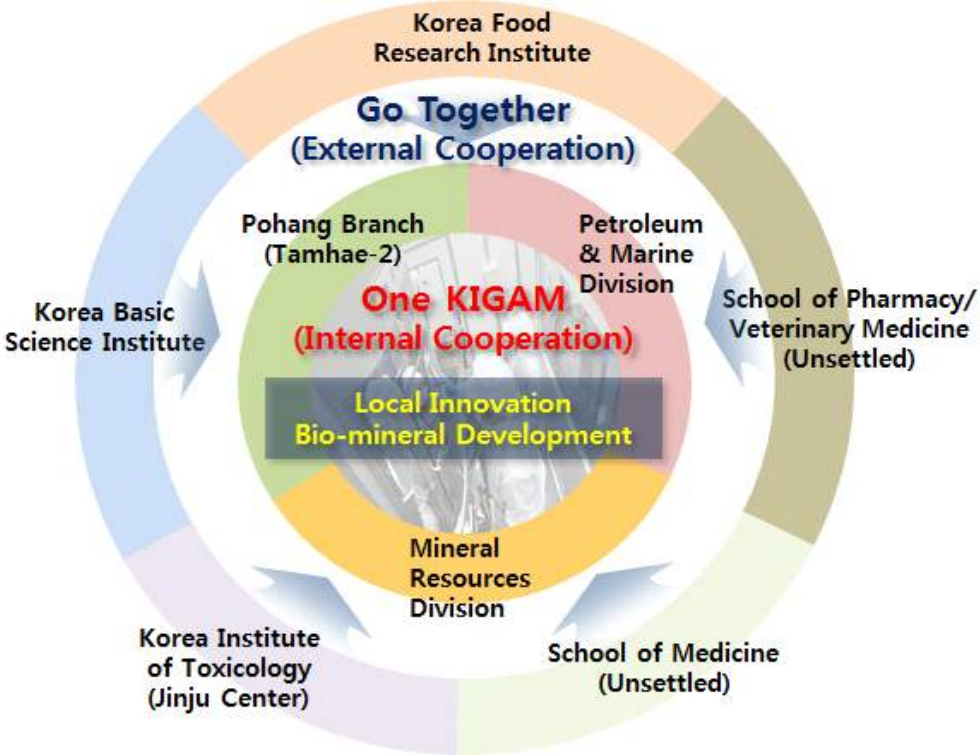
Performance Indicators	Milestones					Outputs
	2020	2021	2022	2023	2024	
Discovery of new bio-mineral materials (Value Creation of Minerals Unspecified by the Law)	Oral Administration Safety Verification (Mid-term Repeat Toxicity Test/Yakdol)	Marine Mud Skin Safety Verification (Alternatives to Animal Experiments/ Mud from East Sea)	Materialization Process (Washing, Purification, Sterilization)	Prototyping/ Efficacy Test (Yakdol Feed)	Prototyping/ Efficacy Test (cosmetics using sea mud)	2 New Bio-minerals (Local Government-linked Commercialization)
Development of Utilization Technology for High Value Bio-minerals (Value Enhancement of Domestic Clay)	Pilot Production of Mother Microbeads (0.1 ton)	Microbead Size Control (5-70)	Microbead Safety Test (Mid-term Repeat Toxicity Test)	Prototyping/ Efficacy Test (Toothpastes)	Prototyping/ Efficacy Test (Cosmetics)	Source Technology for Alternatives to Microplastics (TOT)
	Clay-based Organic-Inorganic Complex Induction (Anti-virals/ 2 Biosensors)	Efficacy Test of the Complex (Pharmacokinetics of the Anti-virals/ Mineral Bioavailability)	Formulation of the Clay-based Organic/ inorganic Complex (Pharmacokinetics of the anti-virus)	Formulation of the Clay-based Organic/ inorganic Complex (hydrogel-bearing sensors))	Prototyping/ Evaluation (biosensors/ inorganic nutrition supplements)	3 Source Technologies for High Value-added Businesses (TOT)

□ Research Strategies

(Procedure) Development of high-value utilization technology and discovery of new bio-minerals by cooperation between government-funded research institute and local government, leading industrial convergence and regional economic growth

- Establishment of cooperative system and bio-mineral integrated research ground between KIGAM and local governments to discover bio-functionality of unused clay minerals and development of high-valued clay complexes
- Accelerating commercialization and maximizing economic effect via KIGAM- centered expansion of R&D and technology transfer to candidate companies
- Aquisition of self-sustained growth through activation of local economy and local government-customized technology development

○ (Process system)



☐ Connectivity to KIGAM R&R

R&R strategic planning for ‘Technology Development of Commercialization and Discovery of Bio-Mineral Material for Local Innovation’

Upper Role	Major Roles	
2. Development of securing, exploiting and recycling technology for mineral resources to lead the national resource industry	Role 1	Development of technologies to ensure the 4th Industrial Revolution-based industrial raw materials
	Type	A. Preparation to the 4th Industrial Revolution – Security of Raw Materials, D. 100 Major National Issues – Discovering and Cultivating New Industries
	Detailed role ③	Production and practicalization of mineral-based novel geo-material

- ㅇ The discovery of local bio-mineral materials and the development of high value-augmenting technologies for resources are in accordance with securing raw materials and materials for bio-industry, which is a core of the 4th industrial revolution
- ㅇ Contribution by enhancement of domestic resource value and fostering related new growth industry, enabling traditional clay material industry to enter into high-valued bio market

☐ Connectivity to Government Policy

- ㅇ Government agenda (“Economy for everyone” – Government strategy 4. The 4th Industrial Revolution Lead by Advances in Science and Technology)
  - 34. Discovering and Fostering New Industries of High Value for the Future
- ㅇ Government R&D Investment Plan in 2020 and 9 Major Investment Areas
  - ⑤ Support Activation of Local Economy Through Local-driven R&D
- ㅇ Ministry of Trade, Industry and Engergy – The 7th Industrial Technology Innovation Plan (2019~2023)
  - Advance existing industries and create new industries by integrating the old and new, such as biotechnology, nano-integration, etc.
  - Platform, Standardization, and Impirical Study-oriented Environment for New Industry Creation

National Vision Declaration for Bio-Health ('19.5)

- Focused R&D investment by more than 4 trillion KRW annually until 2025 in Bio-Health

□ Expected Outcomes

○ Creation of a new industrial ecosystem for value enhancement of domestic mineral resources and revitalization of local economy by discovering local bio-minerals and developing commercialization technologies

○ Possible advances into global market, over 1 trillion KRW economic effect, when successful in the development of improved new drugs based on international pharmaceutical standards, which will be reinforced in the future, using domestic clay resources

□ Utilization of Research Outputs

○ Enhancement of KIGAM technical competence through establishing a research company and technology transfer

○ Utilization of technical achievements and creation of new markets through technology transfer after development of bio-mineral drugs and establishment of production platform

○ Establishment of research infrastructure for domestic bio-minerals through technical exchanges and resource R&D with local mid-sized/small companies

○ Establishment of an innovation hub for fostering local mid-sized/small companies and revitalizing local economy through commercialization of geological resource technologies

Research of the Development of Master Plan for Cooperation in Northern Resources and Strategy of Feasibility Study for Cooperation Project

◇ **Connectivity to KIGAM R&R**: (Upper roles) development of a technology for securing, utilizing and recycling of mineral resources that drives the national mineral resources industry

◇ **Necessity**: It is urgent to prepare a flexible strategy for cooperation in northern mineral resources due to the expansion of the possibility of economic cooperation between the two Koreas and the policy on the new economic map of the Korean Peninsula, ② Standardized project assessment technology and project operating strategy development are required due to different reserve assessment standard/mineral resources development system/general practice in the between the two Koreas

☞ Necessity to develop strategies for cooperation in northern mineral resource and project assessment technology

□ Objectives

Establishing of National master plan for cooperation in northern mineral resources in consideration of changes in the Korean Peninsula and the international environment

○ Feasibility study for cooperation project and establishing of management(field survey, project assessment, operation plan, risk management, etc.)

□ Necessities

○ With the expansion of the possibility of economic cooperation and policy on the new economic map of the Korean Peninsula, Northern(North Korea) and South Korea are likely to expand into one market, including North Korea, and are expected to improve inter-Korean relations and pursue economic cooperation projects in earnest.

Mineral resources cooperation with Northern(North Korea) have high political and institutional risks, so flexible countermeasures are essential to environmental changes, and practical strategies for strategic approaches need to be prepared.

○ In case of improvement in inter-Korean relations, the North Korean resource development cooperation is likely to resume the Dancheon resource development project, which has been suspended since the previous agreement, so it is urgent to establish a reliable and efficient project assessment and project operation strategy for the cooperative project.

- A system is needed to effectively survey and assessment mineral resources cooperation projects of the Northern(North Korea)'s under limited conditions.
- It is necessary to develop a reliable project assessment system by developing a feasibility study methods because of Korea's reserve assessment standards and terms differ from international standards.

○ KIGAM was designated as a national statistics publishing organization in 2016 and needs to continue to produce and spread national statistics related to mineral resources

- Establishing and publishing of "Mineral commodity statistics" upon request from the Ministry of Trade, Industry and Energy since 1986
- Developed "Raw Materials of Rare Metals Trade Statistics" in 2011 and approved by Statistics Korea as national statistics in 2016

□ Research Contents

Detailed Technologies		Description / R&D Scope and Contents
Development of Master plan and Business Strategies for Cooperation in Northern Resources	Mid/short-term Strategy for Northern resources cooperation	□ Development of Master plan for Cooperation in Northern mineral resources • Cooperation strategies by scenario based on maturity of inter-Korean relations/international regulations (Cooperation types, cooperation strength, business types, etc) • Establishing a step-by-step cooperation strategy (Infrastructure building – introductory – maturation period) • Government's strategy for cooperation infrastructure, system harmonizing, financial assurance and supporting, etc. □ R&D for northern geoscience and mineral resources and establishing strategies for building cooperation infrastructure

		• Establishing research strategies for northern geoscience and mineral resources (Volcanoes, geology, environment, minerals, oil and gas) • Establishing strategies for building a cooperative infrastructure for geoscience and mineral resources in the northern (Academic exchange, Scholar Exchange, information system, etc) • 'Resources Economics Insight' (Composed of special features, policies, geology information, statistics, expert contributions, etc.)
	Practical Strategies for Evaluating and Developing Northern Mineral Resources	☐ Establishment of evaluation system for Northern minerals projects • Field survey system, • Development of Feasibility Study method and manual on Northern minerals ☐ Business model development and establishing a risk- hedging strategy of Northern minerals • Development of Business Model (Contract structure, Operating system, Environment management, etc.) • Establishment a risk-hedging strategy (Strategies for financial risk-hedging and system risk-hedging)
Establishment of Mineral Resources Statistics (National Authorization Statistics)		☐ Constructing and spreading statistics on mineral resources • Establishment of mineral products and mining statistics (No. 115002) and publication of statistical books • Statistical analysis of trade in rare metals raw materials (No. 428001) and published statistical books ☐ Analysis of the supply and demand market for mineral resources • Production, sales market analysis, and import and export structure analysis of 14 types of mineral resources

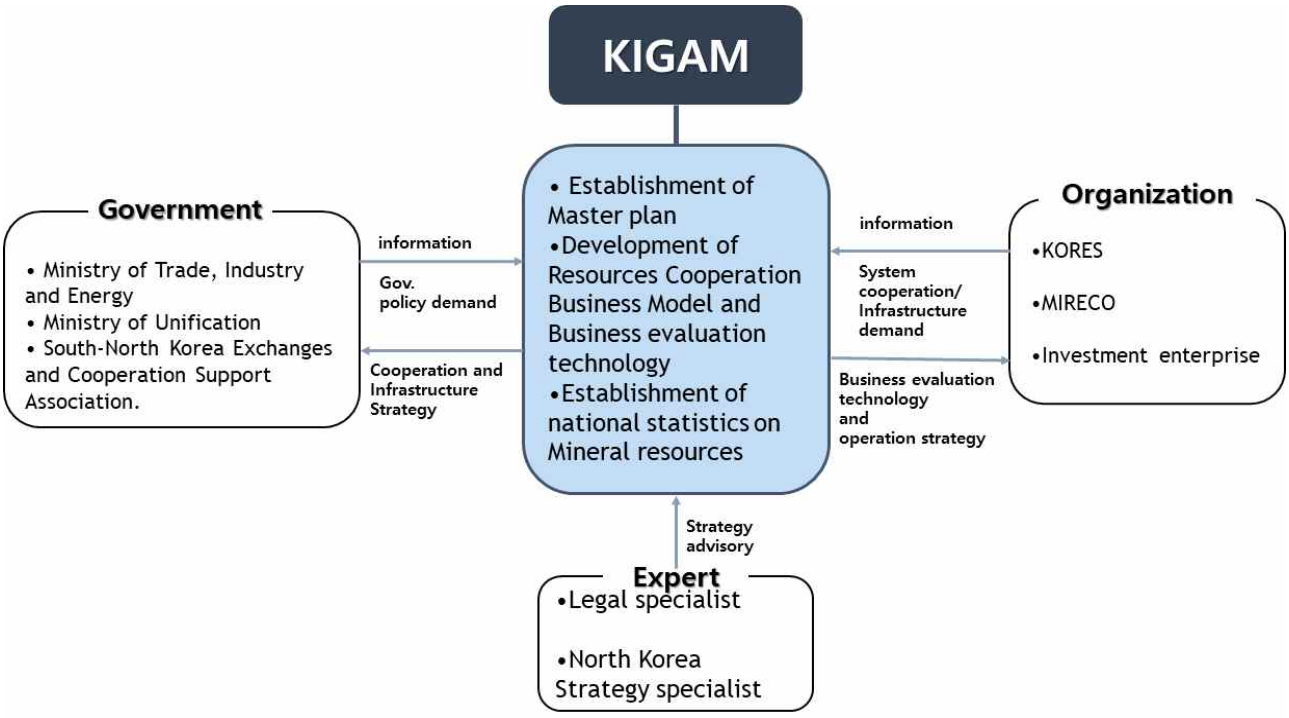
Performance Indicators	Milestones					Outputs
	2020	2021	2022	2023	2024	
Master Plan and Implementation Strategies for Northern Resource Cooperation	Establishment strategies for R&D of NRC	Establishment of Master Plan for NRC	Strategies for the Establishment of NRC Infrastructure (Systems, Personnel, Finance)	Guidelines for Feasibility study of the Northern Resource	Risk-hedging strategy and Business model for the Northern Minerals project	Strategies for Implementing NRC by Government/ KIGAM/Businesses
Establishment of Mineral Resources Statistics	publication of statistical analysis reports (4 types of annual reports/Monthly reports)	publication of statistical analysis reports (4 types of annual reports/Monthly reports)	publication of statistical analysis reports (4 types of annual reports/Monthly reports)	publication of statistical analysis reports (4 types of annual reports/Monthly reports)	publication of statistical analysis reports (4 types of annual reports/Monthly reports)	Resources Statistics D/B

* NRC: Northern Resources Cooperation

□ Research Strategies

(Procedure) following the ” South-North mineral resources cooperation “ related to R&D based on the “New Economic Map of the Korean Peninsula“, it establish a master plan for Northern mineral resources cooperation(system, support system, infrastructure) in response to the “South-North mineral resources cooperation“ and the “9-bridge“ policy for the New Northern region through cooperation with the government and a working strategy (business assessment, operation strategy, etc.) for the Northern mineral resources cooperation project under the master plan.

○ (Process system) ① Establishing the foundation for actively responding to the government’s policy demand and institutionalizing research results through regular consultations and sharing of research results with the government (Ministry of Unification and Ministry of Trade, Industry and Energy, etc) ② Establishing effective strategies and cooperative infrastructure through periodic meeting with agency/company and experts in Northern mineral resources cooperation



□ Connectivity to KIGAM R&R

R&R strategic planning for northern (North Korea) mineral resources cooperation and development of assessment technology

Role	Major Roles	
2. Technology development for securing, utilizing and recycling of mineral resources to drive the national resource industry	Role 2	R&D for the promotion of Northern mineral resources development in preparation for the unified Korea/ Reinforcement of Resource Strategy Functions
	Type	D. Top 100 Government Tasks - Development of Inter-Korean Relations by Revitalizing Inter-Korean Exchanges
	Detailed role ③	Establishing a cooperation strategy and project assessment for Northern minerals

○ Establishing strategy for Northern mineral resources cooperation and technology development for feasibility study are consistent with the basic responsibility of agency-specific duties leading the national resource policy

- Ministry of Trade, Industry and Energy, Supporting for the establishment of overseas resource development plan and basic mining plan, etc.
- Ministry of Unification and local government, Support for the establishment of strategies for inter-Korean resource cooperation in oil and mineral resources

□ Connectivity to Government Policy

○ National Tasks (Korean Peninsula of peace and prosperity - National Strategy 2. reconciliation and cooperation between the two Koreas and denuclearization of the Korean Peninsula)

- 90. A New Economic Map of the Korean Peninsula and Implementation of Economic Unification

* (New economic map of the Korean Peninsula.) energy-resources belt in Donghae area: south and north Korea jointly develop Mt. Kumgang, Wonsan/Dancheon, and Chongjin/Nasun, since then jointly development area connect to Russia and Donghae

* (Economic cooperation) promotion of cooperation for the utilization of joint resources between South and North Korea

2nd Basic Mining Plan ('15~' 24) (strategy 3. Realizing the mineral resource security, 3-3 Joint development of mineral resources in North Korea)

- ⑤ Establishing a plan to advance the project of mineral resources development in North Korea

○ Statistics Korea designation, KIGAM publish National authorized statistics in field of mineral resources

- "Mineral commodity and mineral resources statistics((115002)" and "Raw Materials of Rare Metals Trade Statistics(428001)"

□ Expected Outcomes

○ Contribute to strengthening the government's resource security and establishing an effective resource development investment strategy through establishing master plan and implementation strategy for resource cooperation of Korea Peninsula and Northeast Asia

- Enhancement of negotiation power and project efficiency of government and private company in Northern resource cooperation

* Contribute to establishing direction of Northern resource cooperation and preparing a cooperation agenda of government(MOTIE, MOU)

○ Supporting domestic resource developers for creating a business opportunity in Northern country by supporting project assessment/implementation strategy/information/technology/human network

○ Suggestion of R&D direction for leading a Northern cooperation of KIGAM

○ Supporting a national resource policy such as security and resource management, mineral resources industry policy and related technology development policy through the providing of accumulated domestic mineral statistics DB and information on domestic mines

□ Utilization of Research Outputs

KIGAM and National R&D strategy for Northern mineral resources

- ㅇ KIGAM and Government plan for building a Northern mineral resources infrastructure
- ㅇ Linkage with the government (MOTIE, MOU) implementation strategy for Northern mineral resources cooperation and using a major strategy for negotiating the development of Dancheon resource
- ㅇ Share and transfer research results to use as guideline for Northern mineral resources project investment of private company
- ㅇ Efficient providing by using DB and website mineral statistics and market information to government, local government, mining registration office, mine safety office, bank of Korea, mining company and resources consumption company

Petroleum System Evaluation in Korean Shelf Area and Development of Shale EGR+ Methods

◇ **Connectivity to KIGAM R&R**: (Upper roles) original technology development for securement of unconventional oil and gas resources

◇ **Necessity**: Provision of fundamental data for exploration of a promising petroleum reservoir in Korean shelf area, negotiation on the decision of Korean shelf boundary, establishment strategy for termination of Korea-Japan co-development agreement in 2028, ② increasing necessity of environment-friendly enhanced recovery technology targeting matured shale gas reservoirs due to additional shale field in North America from domestic private companies

□ Objectives

Construction of precise three dimensional basin-scaled geology and petroleum generation model for estimation of domestic petroleum system

○ Development of EGR+ original technology for matured shale gas reservoirs using CO_2 injection technology

□ Necessities

○ Securement of additional economic feasibility and soaring demand for environment -friendly enhanced recovery technology for shale gas reservoirs, which have a fast decline of production

- Many of domestic companies have shale reserves in North America. SK innovation and a few of companies keep trying to find additional reserves.
- Development and management of shale gas reservoirs using CO_2 are not still commercialized and they are mainly being developed by lab-scaled R&D
- Improvement of economic feasibility of reserves owned by domestic resource development companies by enhanced recovery of shale gas using not only storage of CO_2 but also absorption-desorption replacement of that

Necessity of fundamental and long-term strategy construction for development of Korean shelf area with systematic and accurate assessment of petroleum system in the domestic territorial waters

- Fundamental data for a policy establishment for oil and gas development, securement of surface place for CO_2 storage to reduce greenhouse gases, Increasing necessity of data for diplomatic and marine policy establishment in terms of decision of Korean shelf boundary
- Necessary provision of computerized three dimensional distribution data about the ocean floor and geological structure in all industry areas utilizing subsurface space

□ Research Contents

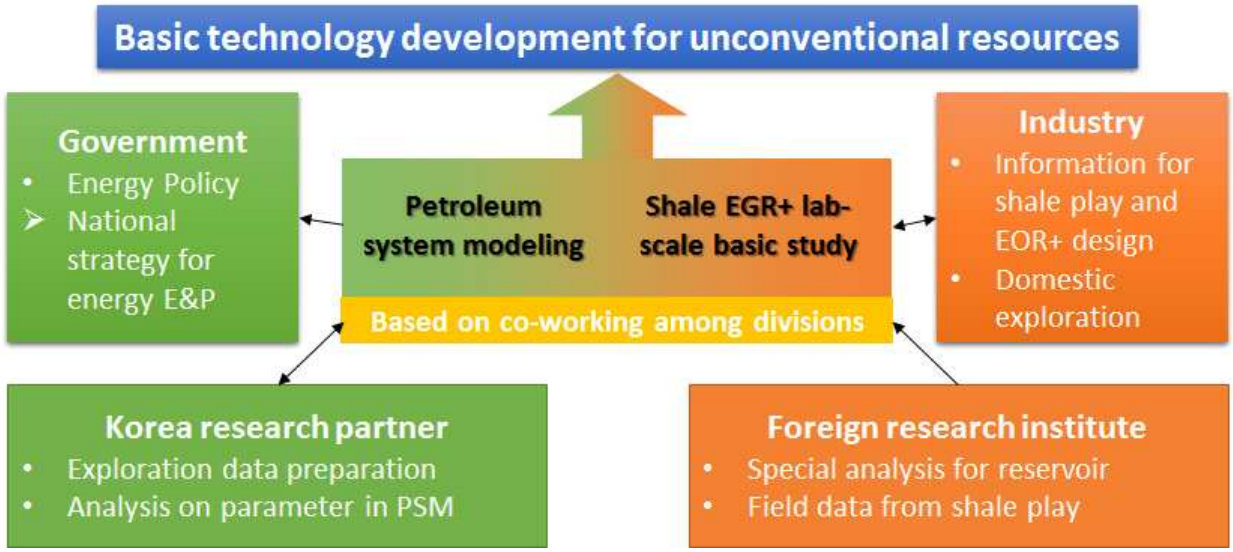
Detailed Technologies	Description / R&D Scope and Contents
Construction of exploration data integrated 3D basin-scaled geology and precise petroleum generation model for estimation of petroleum system	☐ Analysis of basin development procedure in domestic territorial waters and element technology research of hydrocarbon flow mechanism in formations ☐ Obtainments of basin-scaled 3D geology model (regional structure-grid model based on sequence of strata) using integrated interpretation of geological/geophysical data of Korean shelf ☐ Estimation of petroleum system by flow modeling and hydrocarbon generation in sedimentary basin of Korean shelf ☐ Development of a viewer for 3D geology model (Grid-based entry model) and provision of geological information DB
Obtainments of lab-scaled EGR/EOR+ original technology for matured shale gas reservoirs using CO_2 injection technique	☐ Adjustment technology for desorption process of CH_4 in shale formations ☐ Improvement technology of replacement efficiency of CH_4-CO_2 in shale fracture and micro porosity ☐ Development of enhanced efficiency technology for fracturing by injection of CO_2 or mixed gas ☐ Optimized development of productivity improvement and storage efficiency analysis with computational simulation of CH_4-CO_2 behavior in shale formations

<table>
<tr><th rowspan="2">Performance Indicators</th><th colspan="5">Milestones</th><th rowspan="2">Outputs</th></tr>
<tr><th>2020</th><th>2021</th><th>2022</th><th>2023</th><th>2024</th></tr>
<tr><td rowspan="2">Construction of exploration data integrated 3D basin-scaled geology model and precise petroleum generation model for domestic petroleum system estimation</td><td>Acquisition and analysis of sequence of strata input data in Korean shelf of the South Sea</td><td>Construction of basin-scaled sequence of strata-structure model in Korean shelf of the South Sea</td><td>Acquisition and analysis of sequence of strata input data in the southwestern East Sea</td><td colspan="2">Construction of basin-scaled sequence of strata-structure model in the southwestern East Sea</td><td>Basin-scaled 3D sequence of strata-structure model of the South Sea and the East Sea (grid based entry model)</td></tr>
<tr><td>Securement of 3D petroleum system modeling element technology</td><td>Acquisition of input data of hydrocarbon generation and flow mechanism in Jeju-basin</td><td>Construction of PSM in Jeju Basin</td><td>Acquisition of input data of hydrocarbon generation and flow mechanism in southwestern East Sea</td><td>Construction of PSM in southwestern East Sea</td><td>Precise 3D petroleum system model (internal analysis and provision to national oil companies)</td></tr>
<tr><td rowspan="2">Securement of original technology for lab-scaled EGR/EOR+ for matured shale gas reservoirs using CO_2 injection technology</td><td>Geochemical characterization of clay mineral in major shale formations</td><td>Building of analysis system of CH_4 desorption and quantification of non-adsorption gas</td><td>Deduction of controlling factor for CH_4 desorption performance and quantification of adsoprtion-desorption gas</td><td>Quantifiaction of CO_2-CH_4 replacement in each shale gas play</td><td>Best condition for desorption of CH_4</td><td>Decision of lab-scaled CO_2-CH_4 replacement performance and CH_4 desporption condition</td></tr>
<tr><td>Development of CO_2 fracturing experiment method and building the experiment system</td><td>Development of analysis technique of fracture network aspect by CO_2 fracturing</td><td>Analysis of CO_2 fracture network aspect for each facies and fracture fluid</td><td>Drawing the best fracturing scenario considering rock facies using field sample</td><td>Design for secondary fracturiong and CH4 recovery by CO_2 injection</td><td>Decision of an optimized CO_2 fracturing method and concept design (candidates) for EOR/EGR+ of shale gas reservoirs</td></tr>
</table>

□ Research Strategies

(Procedure) platform research based on a fusion study system between divisions and a research of special analysis based on field samples by collaboration with domestic and abroad professional research institutes. Focusing on exploration technology of next generation and a leading securement of enhanced recovery technology. Realization of publicness by intensive provision of precise data and concept design considering the needs of government and industry

○ (Process system)



□ Connectivity to KIGAM R&R

R&R strategic planning for development of assessment of petroleum system and shale EGR+ technology

Upper Roles	Major Roles	
3. Development of original technology for national future energy securement with oil and gas resources	Role 1	Development of original technology for securement of unconventional oil and gas resources
	Type	D. A hundred of national task - Excavation and cultivation of environmental-friendly future energy
	Detailed role ①	Development of original exploration and recovery technologies for unconventional gas resources

○ Development of estimation of petroleum system and environmental-friendly recovery enhancement technology is proper duty of a public research institute for national energy security

- Using construction of precise petroleum system model in domestic territorial waters, estimation of formation behavior and potential amount of petroleum is connected to the own duty of the institute
- Securement of environment-friendly enhanced recovery technology for shale gas reservoirs, emerging main energy source, is corresponding to the duty for the national future energy security with original technology for gas recovery

□ Connectivity to Government Policy

National task (The nation to be responsible for people' s life - national strategy 3. the secure society to protect security and life of people)

- 60. the conversion to safe and clean energy by the denuclearization policy

○ The fourth plan for the development of energy technology ('19.6). The recovery of ecosystem of resource development by the renovation of a resource technology based on ICT

- Improvement of a productivity of utilized intelligence information and R&D for the reduction of hazard rate
- To secure natural gas by enhancement of a productivity from shale reservoirs with the integrity of infrastructures

○ The fourth basic plan for science and technology ('18.2.) Key science technology (Department of energy and resources)

- Intelligent integrated technology for resource exploration, Development and process technologies based on ICT

○ The second basic plan for development business of gas hydrate ('19. planned)

- Forwarding to secure the commercial production technology ('35) by sustainable long-term production technology, development of management of environmental effect, economic evaluation, and so on

□ Technical and Economical Impacts

○ Providing standard for marine stratigraphy and geologic model to have systematic management of Korean adjacent sea and subsurface

○ Expansion of CCS target to shale reservoirs and expectation of a new industry creation with a scale enlargement of CCS market

○ Preoccupancy of EGR/EOR+ technologies for unconventional petroleum resources as an unexplored area and continuous provision of original technologies corresponding to the needs of petroleum industry.

□ Utilization of Research Outputs

A design of new play using the precise petroleum system model of the domestic territorial waters and a support for building of Korean shelf development strategy by additional deductions of promising structures

○ Securement of academical consistency by a provision of a regional geological model for Korean shelf as basic data and its proliferation for research infrastructure of related areas

○ Securement of the track record by field demonstration tests targeting old shale gas reservoirs of North America and provision of technical support about recovery enhancement of matured shale gas reservoirs

Development of the Integrated Geophysical Survey and Real-scale Data Processing Technologies for 3D High-resolution Imaging of the Marine Subsurface

Connectivity to KIGAM R&R: (Upper roles) development of the core technologies of the oil and gas exploration for securing national future energy

◇ **Necessity**: Need for advanced technologies and infrastructures of the high-resolution state-of-the-art processing and interpretation to increase values of multi-functional big-data obtained by the newly-built research vessel,

② Need for technologies of producing and analyzing real-scale high-resolution 3D geologic model to investigate factors of national offshore geohazards

☞ **Technologies of producing/evaluating high-resolution shallow/deep marine subsurface structures for investigating geohazards in the national maritime territory and increasing success rate of oil and gas exploration by utilizing the 3D/4D newly-built research vessel**

□ Objectives

Development of the high-resolution 3D integrated geophysical survey technology for marine acoustic/elastic media

ㅇ Development of the imaging (Waveform inversion, prestack depth migration) technologies for 3D elastic data

ㅇ Development of the 3D velocity/property mapping and integrated analysis technologies based on the drilling core data

* Integrated geophysical survey: State-of-the-art technologies of producing and interpreting a real-scale high-resolution 3D geologic/property model for shallow and mid-depth subsurface by combining and merging long core drilling, 3D survey with dense streamer configuration (P-cable), and 3C-3D survey.

□ Necessities

ㅇ (Need for huge energy resources) to satisfy the growing demand of energy resources, we still need to develop advanced high-level survey/production technologies and to

enhance the success rate of geophysical exploration.

(Maximizing utilization of the newly-built research vessel) we need to raise values of multi-functional dataset obtained by the newly-built research vessel and to secure marketable high-resolution/high-speed processing skills to enter the global market of geophysical exploration.

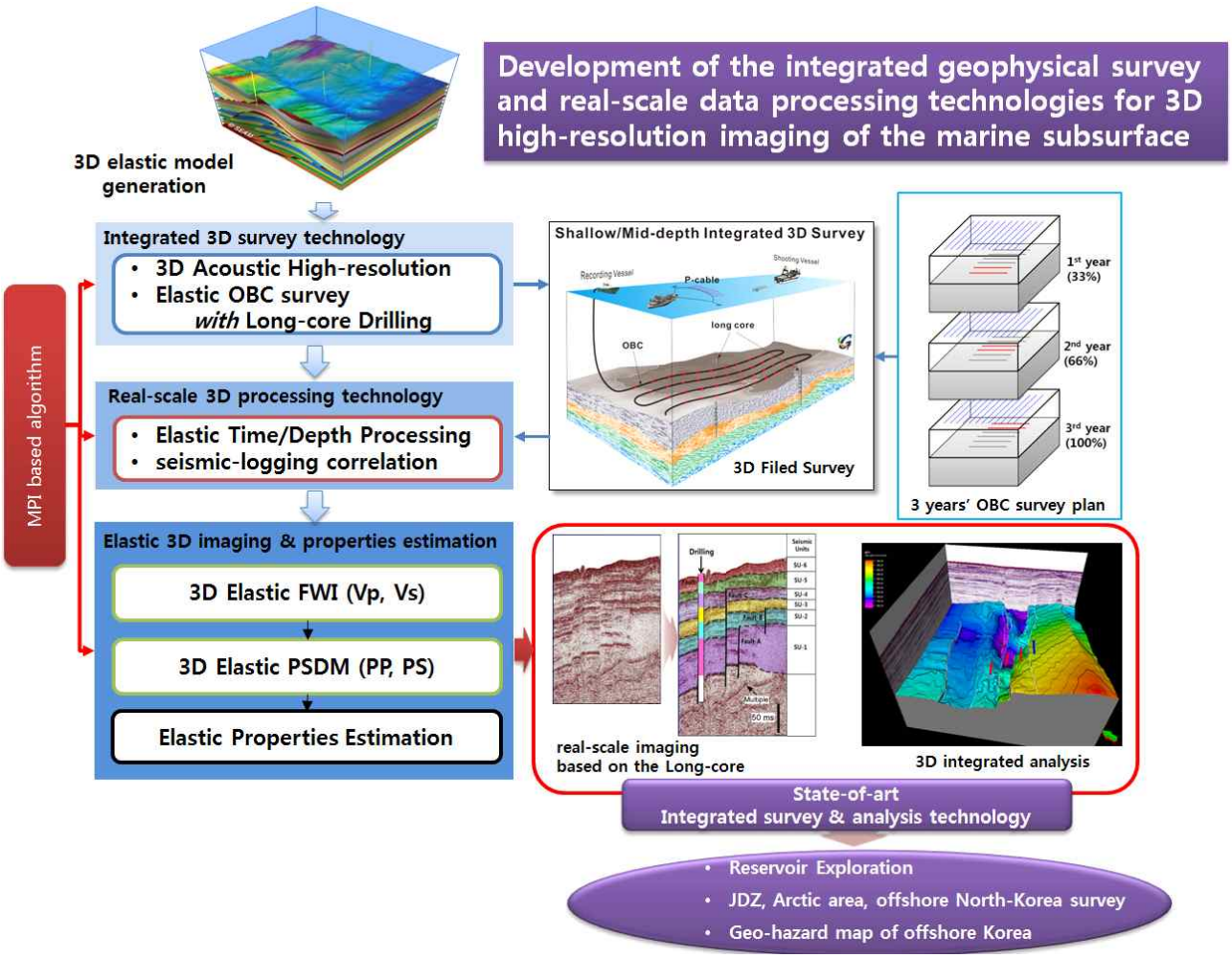
○ (Establishing archive of high-resolution data to handle offshore geohazards) to investigate factors of geohazards in detail offshore Korea, we need advanced skills of producing and analyzing real-scale high-resolution 3D marine geologic model.

□ Research Contents

Detailed Technologies	Description / R&D Scope and Contents
Development of high resolution 3D acoustic/elastic integrated geophysical survey technologies	☐ Developing high resolution 3D survey technology for shallow subsurface using densely distributed receivers ☐ Developing 3D survey technology using ocean bottom cable (3C-3D) for the full elastic media ☐ Developing integrated geophysical survey technologies (dense receiver/OBC) for the acoustic/elastic media
Development of 3D elastic data imaging technologies	☐ Developing advanced processing technologies for 3D real-scale integrated geophysical survey data ☐ Developing 3D elastic full waveform inversion (FWI) / pre-stack depth migration (PSDM) modules ☐ Feasibility test on imaging the field data ☐ Basic research on the seismic data processing using the machine learning
3D velocity/property distribution mapping and integrated analysis technologies based on the drilling core data	☐ 3D precise velocity mapping for shallow subsurface using the drilling core data and verifying its feasibility ☐ Developing a deeper velocity inversion algorithm via correlation-based analysis between the integrated geophysical survey data and drilling core data ☐ Developing a technique of evaluating shallow geologic structure (faults, shallow gases, slides etc.) using high-resolution property map

Performance Indicators		High resolution 3D integrated geophysical survey technology	3D elastic media imaging module	Processing and analyzing algorithm for 3D integrated geophysical survey data based on the long-core data
Milestones	2020	· 3D survey with dense receivers (2 array, 6 m grid resolution) · 3C-3D OBC survey (33% of entire survey area) · Technology for the shallow subsurface velocity measurement (Less than 1kHz frequency, 8 m depth)	Modeling engine for 2D elastic FWI & PSDM module	Time-domain processing of survey data (Time-domain 3D stack image of dense-receiver data and OBC data)
	2021	· 3D survey with dense receivers (4 array, 3 m grid resolution) · 3D multi-components OBC survey (66% of entire survey area) · Analyzing property of long-core (100 m depth, 2 sites)	2D elastic FWI & PSDM modules	Time-domain migration of integrated survey data (Time-domain 3D migration image of dense-receiver data and OBC data)
	2022	· 3D survey with dense receivers (4 array, 1.5 m grid resolution) · 3D multi-components OBC survey (100% of entire survey area) · Analyzing property of long-core (100 m depth, 2 sites)	3D elastic FWI & PSDM modules	Depth-domain processing of survey data (Depth-domain 3D imaging of dense-receiver data and OBC data)
	2023	· 3D integrated survey with multi-components OBC / dense receiver (4 array, 1.5 m grid resolution, Integration of entire 3D data after 3D OBC infill survey) · Analyzing property of long-core (100 m depth, 2 sites)	Numerical test of 3D elastic FWI & PSDM modules and generalization	Joint processing of integrated survey data and OBC data (Processing using correlation analysis of drilling core data and 3D property distribution map)
	2024	· Merging the 3D integrated survey data with OBC / dense receivers based on the log data and reprocessing the merged data · Developing correlation-based extrapolation skill	Module optimization/ Enhancement its feasibility for the survey field data	Integrated analysis of the survey data (3D maps of subsurface Vp/Vs, faults, shallow gas, and submarine slides)
Outputs		Integrated geophysical survey (drilling core/dense receiver data/OBC) and skills of data regularization / normalization)	Generalized modules of 3D elastic FWI & PSDM	Processing skill for 3D integrated survey data / Integrated analysis skill

□ Research Strategies



□ Expected Outcomes

Increasing usage of geology/resources exploration carried by the newly-built research vessel via developing state-of-the-art skills of processing/imaging/analyzing multi-functional survey data on the occasion of the commission of the newly-built research vessel ('23)

○ Securing marketable proprietary technologies of 3D imaging not only acoustic but also elastic media survey data (Securing marketability via achieving more than 90% comparing the top class)

○ Contributing to national security, geohazard response, efficient utilization of maritime territory via enhancing abilities of comprehensive investigation, database

construction, evaluation-response for submarine geologic environments (Construction of geologic loss map including seafloor faults with 1.5-m high resolution)

Contributing to invention of national new industry having high value-added and securing energy-resources via core research infrastructure for oil and gas exploration and advanced application technologies (Expansion of overseas resources territory through joint exploration with domestic and overseas leading exploration companies / institutes)

Development of Deep Subsurface Characterization for Safe Underground Storage/Disposal

Connectivity to KIGAM R&R: (Upper roles) development of deep subsurface characterization and long-term prediction technology essential for the utilization of deep underground space

◇ **Necessity**: The increasing importance of deep subsurface characterization technology essential for the demand of deep underground space utilization, as promoted by the nuclear phase-out policy (high-level waste deep underground disposal, underground research laboratory, and deep borehole disposal),

② Environmental and sustainable development by efficient utilization of deep underground space

☞ **The core technology of deep subsurface characterization and utilization to ensure national security and energy resources**

□ Objectives

Achievement of 90 % out of twenty deep subsurface characterization items up to the depth of 5 km

- 60% by 2018 (12/20) / Stratigraphic structure and discontinuity characteristics by 2019 / Electrical resistivity, in-situ stress, heat production rate and density until 2023

○ Development of numerical analysis platform for simulating coupled T-H-M behavior of discontinuous rock mass

□ Necessities

○ The necessity of fundamental technology related to deep subsurface characterization promoted by the increasing importance of radioactive waste disposal according to the nuclear phase-out policy and the growing demand for deep underground space utilization (high-level waste deep subsurface disposal, underground research laboratory, deep borehole disposal)

The necessity of developing fundamental technology to characterize deep subsurface for potential collaboration projects between South and North Korea regarding mineral and energy resources

○ Contribution to solving pending national issues and securing an unrestricted base of life through the development of deep underground spaces and the suggestion of sustainable utilization models, which are emerging as countermeasures for a response to the New Climate Regime and sustainable growth

□ Research Contents

Detailed Technologies	Description / R&D Scope and Contents
Development of deep subsurface characterization technologies (maximum depth of 5 km)	□ Development of assessment technologies for T-H-M characterization factors at a deep depth • Heat production rate, permeability, electrical resistivity, density • Development of assessment technology for hydraulic fracture network characterization □ Enhancement of deep subsurface characterization system • Development of integrated analysis technology of T-H-M characteristics • Verification of experiments and assessment technologies for coupled behavior at high-pressure and high-temperature conditions □ Development and commercialization of deep subsurface characterization equipment • Development of hydraulic fracturing system to a depth of 1.5 km • Development of 3D borehole curvature measurement system to a depth of 1.5 km
Development of THM coupled numerical analysis platform for discontinuous rock mass	□ Development of numerical analysis method on THM coupled behavior based on discontinuum model • Design and implementation of coupled behavior algorithm • Development/verification/application of coupled behavior analysis module □ Field application of continuum based T-H-M coupled numerical analysis platform • Construction of continuum based T-H-M coupled numerical analyses application (DECOVALEX, underground research laboratory, deep mining, etc.)

Performance Indicators	Milestones				Outputs
	2020	2021	2022	2023	
Percentage achievement of deep subsurface characterization	75% (15/20) Electrical resistivity	80% (16/20) In-situ stress	85% (17/20) Heat production rate	90% (18/20) Density	Deep subsurface characterization ratio 90%
Development of THM coupled numerical analysis platform for discontinuous rock mass	Analysis of THM coupled interaction and design of coupling algorithm	Implementation and verification of THM coupled behavior analysis algorithm	Development of THM coupled behavior analysis module	Construction of THM coupled analysis application	THM coupled behavior analysis platform & application performance based on continuum /discontinuum method

□ Research Strategies

(Procedure) establishment of the base for utilization of characterization technologies through the close partnership with the institutes related to deep subsurface development/utilization (CO_2 storage, high-level waste geological disposal, underground energy storage and underground research facilities), in addition to securing technological competitiveness through international cooperative research with foreign advanced institutes (FRACOD, DECOVALEX, DESTRESS and ERIA)

○ (Process system)

□ Connectivity to KIGAM R&R

R&R strategic planning related to the development of Thermal-Hydro-Mechanical (THM) characterization technologies based on borehole and underground space

Higher-order Role	Major Roles	
④-1. Development of technology to cope with global environmental change using deep underground space	Role 1	Development of fundamental technologies for deep subsurface characterization and long-term prediction essential for utilization of deep subsurface
	Type	C. National life research/Environment-Comfort area - Climate change, ② Greenhouse gases
	Detail role ①	Deep subsurface characterization and modeling

○ Deep subsurface characterization research is consistent with the institute' s mission to contribute to the achievement of Intended Nationally Determined Contribution (INDC) and improvement of the quality of life of the people through the deep underground space technology innovation.

□ Connectivity to Government Policy

○ 20th National Strategy (Secure society to protect national security and life)

- To contribute to secure reliable safety for tectonic disasters, enhancing national benefits, improving negative social recognition of deep subsurface disposal facilities for high-level radioactive waste and site selection reliability, and making safety policy of the deep subsurface infrastructure of relevant government departments

○ National task (98. Response to climate change such as greenhouse gas emissions, 99. Adaption to climate change such as extreme weather events)

- To contribute to developing the climate change mitigation technology for sustainable growth by efficient utilization of deep underground space utilization (CO_2 underground storage, deep borehole disposal, underground research facilities)

○ National affairs (101. Expansion of new and renewable energy and fostering industry)

- Various underground energy storage technologies are indispensable for the expansion and spread of new and renewable energy and efficient management of electric power demand. It is capable of contributing to the creation of new energy storage market through activation of underground energy storage technology.

□ Expected outcomes

Strengthening external competitiveness through localization of crucial technologies for utilization and development of deep underground space

- ㅇ Reduction of the cost for site selection, construction, and maintenance of the deep underground space of about 300 billion won per year
- ㅇ Securing constructing technologies for high-level radioactive waste disposal at deep subsurface and increasing national benefit by exporting technology to overseas

□ Utilization of Research Outputs

- ㅇ In Korea, there is no technology for measurement and integrated analyses of T-H-M characterization factors at a deep depth of 5 km-level. T-H-M characterization technology is a challenging and creative technology held only by a few advanced institutes worldwide. We expect to reduce enormous cost induced by overseas technology service through the technology development, and use the technology as a basis and verification data for establishing the safety policy of the deep subsurface infrastructure of the government department.
- ㅇ We plan to secure the national self-reliance of technology through development and commercialization of hydraulic fracturing system and 3D borehole curvature measuring system at a depth of 1.5 km essential for deep subsurface characterization, and transfer developed technologies to related industry.
- ㅇ Continuum/Discontinuum based THM complex coupled behavior analysis technique can be applied to the design, construction and operation of facilities in the future by directly applying to the high-level radioactive waste disposal at deep depth, deep underground research laboratory and deep mining. We expected to use the technique in earth science fields such as deep fault and volcanic behavior modeling.

By acquiring and analyzing data through the application of technology to the deep borehole, it can be directly applied to the identification of the cause of the earthquake, which is a national issue.

○ For the safety management of the facilities by energy sources (underground oil storage facility and underground ore excavation), it is essential to accurately figure out the characteristics of deep underground rock mass used as a fundamental primary data for safety management.

Development of Capacity Enhancement and Safety Evaluation Technologies for CO_2 Geological Storage

◇ **R&R**: implementing the sustainable society and improving the life quality
◇ **Policy**: the Third Five-Year Master Plan for Green Growth ('19.5.)
◇ **Necessity**: ① Achieving the national goal for greenhouse gas reduction
② Securing the public acceptance for future large-scale CCS project

☐ Objectives

Technology development for assessing and improving CO_2 storage efficiency for cost effectiveness of a large-scale CCS project

○ Technology development for assessing safety and risk of a large-scale CCS project site

☐ Necessities

○ Urgent needs for securing a large-scale CO_2 geological storage site to meet the national greenhouse gas reduction target by 2030

○ Technical needs for implementing safe and permanent CO_2 geological storage to address public concerns on safety after the Pohang earthquake

○ Technical needs for economic efficiency of a large-scale CCS project, including the technology development of storage efficiency enhancement

☐ Research Contents

Detailed Technologies	Description / R&D Scope and Contents
Evaluation and enhancement of CO_2 storage efficiency	☐ Storage efficiency evaluation using multi tracers ☐ Dynamic modeling for evaluating effective CO_2 storage efficiency ☐ Brine extraction and pressure management for improving CO_2 injectivity ☐ Co-injection experiment of chemical agents with CO_2 for improving CO_2 injectivity

Safety assessment of CO_2 geological storage	☐ CO_2-rock-water hydro-chemical reaction and caprock integrity analysis (including mudstone, tuff, and basalt) ☐ Experiment of biogeochemical reaction with CO_2 for improving sealing capacity ☐ Mechanical safety evaluation and injection pressure design for a large-scale CO_2 storage site ☐ Analysis of near-surface CO_2 behaviour for anthropogenic mechanical stimulation ☐ CO_2 monitoring technology using fiber optic sensors

Performance Indicators	Milestones					Outputs
	2020	2021	2022	2023	2024	
Effect of storage efficiency enhancement (%, degree of enhancement over the initial value)	Test system establishment for CO_2 storage efficiency assessment	Storage efficiency assessment for potential reservoir rock samples	Lab-scale test and verification (10%) of CO_2 storage efficiency enhancement technology	Field-scale** test and verification (↑10%) of CO_2 storage efficiency enhancement technology	Optimal application of storage efficiency enhancement technology to the candidate storage site (by 15%)	Scenarios on optimal application of technology to enhance storage efficiency by more than 15%
Effect of caprock integrity enhancement (degree of decrease in permeability before and after reaction, %)	Test system establishment for caprock integrity analysis	Integrity assessment for potential caprock samples	Major factors to control caprock integrity (more than 3 factors, sensitivity analysis required)	Lab-scale test and verification of caprock integrity enhancement technology (permeability change before and after reaction)	Pilot-scale optimal conditions to achieve permeability reduction (50% reduction in permeability)	Optimal conditions to achieve more than 50% reduction in permeability
Safety assessment (pressure, algorithm)	Geomechanical property assessment for a large-scale storage site		Geomechanical modeling to assess safety of a large-scale storage site		Injection pressure estimation for potential storage formation	Optimal range of injection pressure for the candidate storage site
	Development of fiber-optic-sensor signal analysis technique		Development of high-dense, micro-seismic monitoring data processing technique		Field test & performance improvement	Algorithm for assessing micro-seismicity

** Large-scale CO_2 loop facility at Korea Institute of Industrial Technology, overseas test site, and domestic test site are considered and will be decided in the second year of the project.

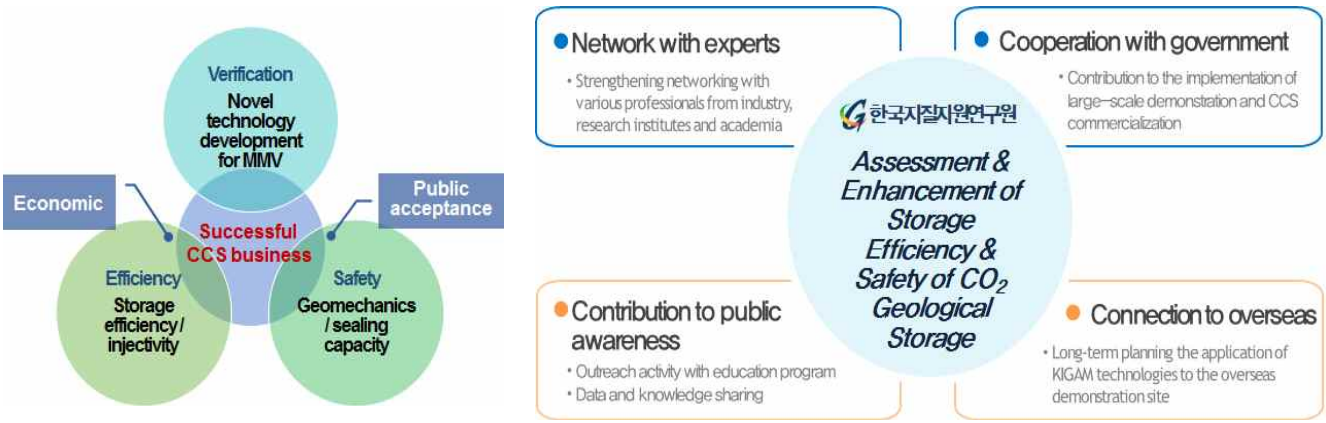
□ Research Strategies

(Network with experts) strengthening networking with various professionals from industry, research institutes and academia that can contribute to the implementation of large-scale CCS demonstration projects

○ (Cooperation with government) strengthening continued cooperation with relevant government agencies to achieve GHG reduction target by 2030

○ (Public acceptance) development of education program and participation in outreach activity to raise public awareness of CO_2 geological storage

○ (Connection with overseas project) long-term planning the application of KIGAM technologies to the overseas demonstration site, with consideration of public concerns about safety issues after the ‘17.11 Pohang earthquake



□ Expected Outcomes

○ Contribution to realization of CO_2 geological storage of 4 million tons per year in 2030, the government’s greenhouse gas reduction target

○ Reduction of public concerns about the safety of large-scale CCS technology

- Provision of scientific and technological evidence on safety

○ Implementation of cost-effective CCS project by applying storage efficiency enhancement technology

□ Utilization of Research Outputs

Applying KIGAM technology to the government-supported CCS demonstration project in the future

- Track record from the demonstration project is beneficial in entering overseas CCS technology market

○ Utilizing the results to reduce storage cost in the commercial CCS project of the private sector

- Storage efficiency enhancement through reservoir pressure management contributes to saving storage cost by extending storage operation period

○ Supporting domestic CCS related companies through technology transfer

○ Disseminating the results to educational programs for raising public awareness

Development of Technology for Exploitation and Optimal Utilization of Massive Groundwater Resources according to Climate Change

◇ **Connectivity to KIGAM R&R**: (Upper role) development of technology to cope with global environmental change to realize sustainable society and improve the quality of life of the people

◇ **Necessity**: Exploitation of massive groundwater resources and development of sustainable use technology to solve water problems (drought, disaster) due to climate change, ② Need to acquire technology for evaluating and predicting the impacts of climate change on the groundwater dependency (rivers, lakes, wetlands, etc.), which is closely related to the pleasant and comfortable living environment of the people

□ Objectives

Development of sustainable groundwater securing and utilizing technologies and evaluation of groundwater dependent systems according to climate change

- Exploitation of massive groundwater resources and development of sustainable groundwater utilization technology
- Development of technology for evaluating groundwater dependent system related to climate change

□ Necessities

○ Each country creates informational maps of groundwater that are less affected by climate change and develops utilization technologies of groundwater resources and evaluation techniques for conserving the groundwater dependent system because global climate change makes it difficult to manage surface water resources and water ecology

○ To solve water problems (drought, disaster) due to climate change, it is necessary to secure a variety of water resources, to exploit groundwater resources based on information maps such as groundwater availability map, groundwater quality map

and promising groundwater intake map, and to develop sustainable groundwater utilization technology

Since the groundwater dependence systems such as rivers, lakes, and wetlands are closely related to the people's pleasant living environment, evaluation and prediction of the impacts of the groundwater dependence on climate change is important for the conservation of biodiversity through eco-service and required for improvement of the quality of life of the people

□ Research Contents

Detailed Technologies	Description / R&D Scope and Contents
Securing large-capacity groundwater resources and sustainable groundwater utilization	□ Large-capacity groundwater information maps (Location/Distribution, water quality, water source) • Development of technologies for groundwater information maps • Mapping of groundwater distribution and quality in basin scale (1:100,000 scale) • Mapping of groundwater potential sources (1:50,000 scale) □ Sustainable groundwater utilization in water shortage regions • Optimal site selection for groundwater development in crystalline rock aquifers • Core technologies for groundwater utilization supply system • Establishment of water supply pilot system and optimal management strategies
Assessment of groundwater-dependent systems by climate change	□ Modeling for predicting groundwater-dependent system changes • Modeling of groundwater-dependent system affected by climate change • Prediction of groundwater-dependent system changes by climate change (~2100) □ Assessment of water/mass cycle in groundwater- dependent systems affected by climate change • Monitoring technologies and assessment of water/mass cycle in groundwater-dependent systems • Optimal indicator for the assessment of groundwater-dependent systems • Monitoring system and its management for assessing the groundwater environment changes by climate change

Performance Indicators	Milestones				Outputs
	2020	2021	2022	2023	
Groundwater potential zones on climate change	Groundwater information map (occurrence/quality /potential uptake source)	Groundwater distribution map (Nagdong-river watershed) and site assessment	Groundwater quality map (Nagdong-river watershed) and site assessment	Groundwater potential source map (Nagdong-river watershed) and site assessment	Groundwater distribution/quality map (1:100,000 scale) and potential source map (1:50,000 scale)
Groundwater optimal site selection and sustainable groundwater utilization in water shortage regions	Optimal site selection for groundwater development in crystalline rock aquifers in water shortage regions	Core technologies for groundwater utilization supply system	Customized water supply pilot system	Optimal management strategies for customized water supply pilot system	Sustainable groundwater utilization system in water shortage regions
Assessment of groundwater-dependent systems by climate change	Prediction of groundwater-dependent system changes (Nagdong-river watershed)	Prediction of groundwater-dependent system changes (Han-river watershed)	Prediction of groundwater-dependent system changes (Youngsan-river watershed)	Assessment of vulnerable areas of groundwater-dependent system and customized optimal strategies	Regional map for prediction of groundwater-dependent system changes
	Monitoring and assessment of water/material cycle in groundwater-dependent systems	Establishment of monitoring system of water/material cycle in groundwater-dependent systems	Establishment of monitoring D/B and assessment of water/material cycle in groundwater-dependent systems	Assessment and impact factor determination of water/material cycle in groundwater-dependent systems	Optimal indicator for climate chanage assessment in groundwater-dependent systems

□ Research Strategies

(Procedure) based on the NST BIG project linked to the R&R of the KIGAM, KIGAM will conduct demonstration research with municipalities and industry to solve the social needs of consumers (people and local governments) and support the establishment of national policies by government ministries. In addition, KIGAM will enhance its research capacity through cooperation research and technology exchange with overseas institutions, and participate in resolving global issues through cooperation with international organizations such as CCOP and UNESCO.

(Process system)

☐ Connectivity to KIGAM R&R

○ R&R strategic planning for technology development to secure and exploit sustainable groundwater resources

Higher-order Role	Major Roles	
4. Development of technology to implement sustainable society and to cope with global environment to improve the quality of life of the people	Role 2	Development of technology for conservation and integrated management of groundwater and geological environment
	Type	C. Researches on people's life/Environment, Conformability Areas: - Climate change, ④ Groundwater contamination
	Detailed Role ①	Securing sustainable groundwater resources

Development of securing and use of sustainable groundwater resources is a technology for securing groundwater resources in response to climate and environmental changes, and is in line with the mission of KIGAM for sustainable national development.

○ KIGAM will assess and predict the impacts of climate change on groundwater dependence systems (Rivers, lakes, wetlands, and so on) which are closely related to the clean and comfortable living environment of the people. That meets the mission of KIGAM to contribute to improving the quality of life of the people with contributing to response of the nation's climate change and the new climate system.

□ Connectivity to Government Policy

○ National affairs (The country responsible for my life- National strategy 3. A safe society to protect national security and life)
- 59. Sustainable establishment of national territory environment
- 61. Establishment of a sound implementation for new climate system

○ 2020 year's government R&D investment direction and nine major investment directions (Realization of happy life)
- ⑦ Establishment of social safety network through calamity and disaster R&D
- ⑨ Research to cope with climate and environment change

○ The 4th Basic plan for science and technology ('18.2.) Key performance task (18. Creation of pleasant and comfortable living environment)
- ① Securing sustainability through coping with climate change and new climate system (Prediction of climate change and Enhancement of national response capabilities)

○ Follow-up on unification of water management and integrated water management action plan (Office for government coordination, 2018.6.28)
- Integration and efficiency of water management, Resolving drought with local customized development and supply of water resources
- Recovery of naturalness and systematic management of tributary waterfront space matching characteristics of the four river basin

Modification plan of the 3rd basic plan of groundwater management ('17~' 26 year) ('17.Dec., Ministry of land, infrastructure and transport)

- Improving the life quality of the people and realization of water welfare using sustainable groundwater

□ Expected outcomes

○ Establishment of basis for utilizing domestic large-capacity groundwater in order to supply basic data and technology for local government and organization securing agricultural water and waterworks

○ Contribution of establishing strategy related to groundwater for countering climate change at the national level by providing quantitative assessment tools of groundwater, groundwater dependent surface water resources, and ecological system affection due to national level climate change.

○ Establishing measures to implement climate change reflecting local characteristics by monitoring and evaluating water resources and cycle related to climate change and deriving optimal indicator of groundwater impact

□ Utilization of Research Outputs

○ Groundwater information map will be utilized for establishing water and water management plans and development plan for national and local government. Groundwater sustainable development technology will be utilized for solving civil complaint living in water shortage area.

○ Preparation of countermeasure to solve water shortage problem by transferring technology to local government, public organization, and enterprise which needs technology related to sustainable groundwater utilization

○ Contribution to both establishment of surface water and groundwater linkage model and management of integrated water resources considering groundwater by providing prediction model of future groundwater dependent change for module of numerical model assessing water resources at national level

○ Technology transfer and commercialization of equipment and technologies related to measurement, automatic measurement, laboratory experiments, etc.

Development of the Geo-environmental Hazard Monitoring/Risk Mitigation/Management Technologies

◇ **Connectivity to KIGAM R&R**: (Upper role) development of technology to cope with global environmental change to realize sustainable society and improve the quality of life of the people

◇ **Necessity**: Climate change leads the geo-environmental disasters and the rapid land development causes environmental pollution, ② The climate change related geo-environmental disasters shows the increase of the frequency, intensity, and the extent of the damage and its integrated risk management system is required.

☞ **Disaster preparedness and response planning through establishing the risk management plan of geo-environmental hazard**

□ Objectives

Development of the landslide early warning system based on weather forecasting in urban area and its testbed application

○ Mapping of geogenic-potentially harmful elements (G-PHEs) and the development of the integrated risk management system

□ Necessities

○ Development of the landslide early warning system in urban areas: To establish the landslide early warning system in the urban areas for securing golden time to reduce damage and to develop technology for ICT-based early warning system.

○ Development of the integrated solutions to reduce the risk of geogenic pollutants: To identify the spatial distribution of G-PHEs and to provide the integrated risk management plan for the selected vulnerable area

□ Research Contents

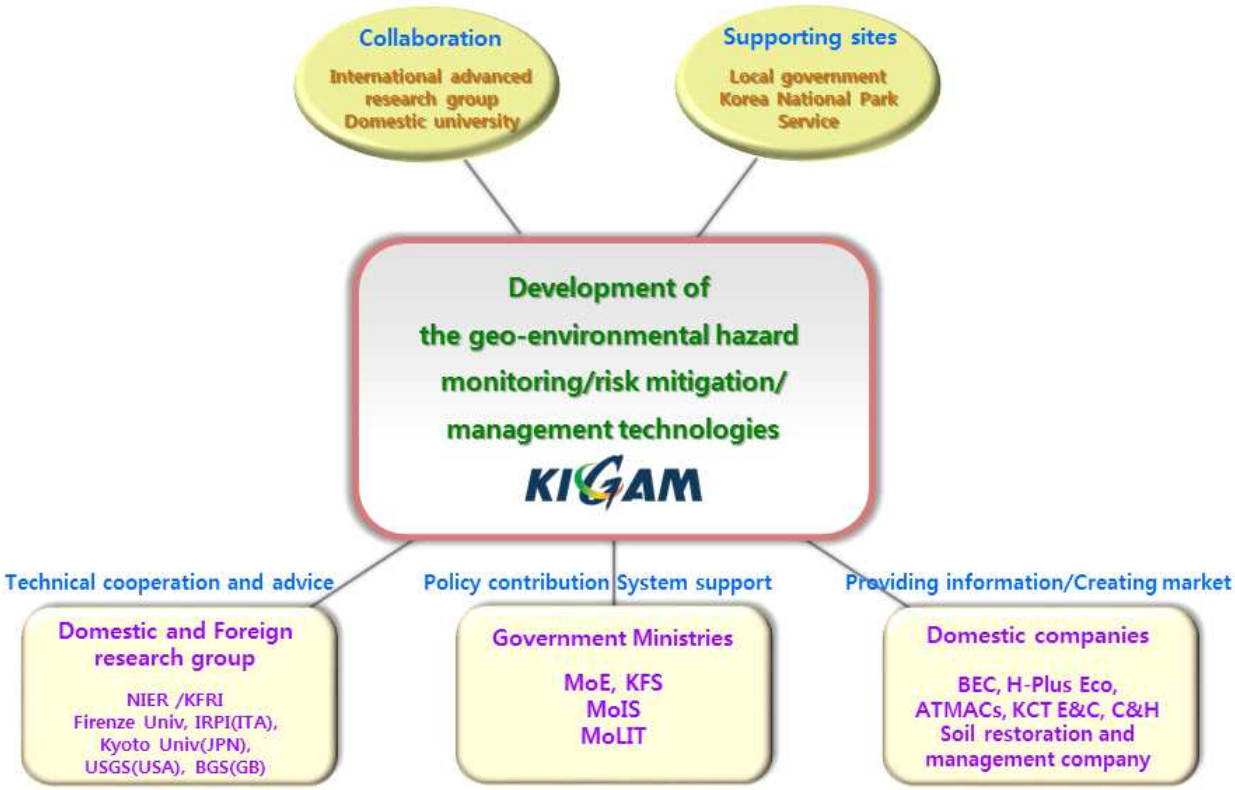
Detailed Technologies	Description / R&D Scope and Contents
Landslide early warning system based on weather forecasting in urban area and its application	□ Landslide early warning system connected to the real-time weather forecast (1 hour interval) • 1-hour-interval real-time weather forecasting and its linkage technology • Real-time (1 hour interval) landslide early warning system development □ Landslide early warning system in urban area • Installation of monitoring station • Construction and operation of early warning system □ Service based on mobile application of the landslide early warning system information • Development of sharing module of real-time rainfall and landslide prediction results
Nationwide G-PHEs mapping	□ Geogenic pollutant characterization and nationwide geochemical survey • G-PHEs selection and on-site investigation • Sample collection, chemical analysis, and archiving G-PHEs database □ Nationwide G-PHEs mapping • Statistical analysis and data interpretation • Mapping and verification
G-PHEs high risk area monitoring and the integrated risk management plan	□ G-PHEs risk assessment and remediation technology • Risk assessment method development • Biogeochemical remediation plan and its testbed application □ Field case study of the G-PHEs high risk area and risk management system development • Monitoring method development and its testbed application • Risk management system development

Performance Indicators	Milestones				Outputs
	2020	2021	2022	2023	
Landslide early warning system based on weather forecasting and its urban area application	Landslide early warning system connected to the real-time weather forecast (1 hour interval)	Real-time landslide early warning system development	System verification and application in urban area	System operation and performance verification	Real-time landslide early warning system in urban area
Nationwide G-PHEs mapping	G-PHEs field investigation	Nationwide sample collection, chemical analysis, and database buildup	Statistical analysis and data interpretation	G-PHEs mapping and verification	Nationwide G-PHEs map (1:one million)
G-PHEs high risk area monitoring and the integrated risk management plan	G-PHEs high risk area investigation	G-PHEs monitoring method development under redox-sensitive conditions and its trial application	Biogeochemical remediation plan for G-PHEs management and its testbed application	Development of G-PHEs risk management plan	G-PHEs monitoring and risk management plan

□ Research Strategies

(Procedure) to achieve the R&R goal of an umbrella organization, “Ensuring the sustainable society and improving quality of Life”, our R&D strategies are implemented by attaining the state-of-the-art technologies through the collaboration with the world leading research groups and by providing technical solutions for the government and private entities under the KIGAM’s banner of ‘the conservation and management of groundwater and geologic environment’.

(Process system)



□ Connectivity to KIGAM R&R

○ R&R strategic planning for developing the integrated risk management of geo-environmental hazards

Higher-order Role	Major Roles	
4. Technology development responding to global environmental change for securing the substantiality and quality of life	Role 2	the conservation and management of groundwater and geologic environment
	Type	C. Life/Environment/Safety - Climate change, ④ Water pollution
	Detailed role ② & ③	ICT-based landslide early warning system, the integrated risk management of geo-environmental hazards

○ The integrated risk management system is a key technology for achieving a safe society that guarantees ‘Sustainability and Quality of Life’ and meets the specific mission of KIGAM

○ Informing the public about the geo-environmental hazards obtained from the latest surveys and cutting-edge analytical techniques is in line with the KIGAM’s mission of contributing to the public safety

□ Connectivity to Government Policy

100 policy tasks (Goal III: A nation taking responsibility for each individual, Strategy 3: Creating a safe society to protect the public)

- 56. To build an integrated disaster management system and improve immediate on-the-scene response capabilities
- 59. To carry out sustainable land planning and management

○ The 2020 Government R&D Investment Direction and Standards – 9 major investment directions

- ⑦ To build the social safety network by R&D investment on disaster
- ⑨ To secure sustainable society by improving response capability to climate and global environment change

○ The 4th Science and Technology Basic Plan (' 18.2) Key task (Strategy 4. Opening an era of happiness for all through science and technology)

- 17. To ensure the safe society
- 18. To create more pleasant and comfort living environment

□ Expected Outcomes

○ The planned world leading landslide early warning system would contribute to create a safe society to protect public by rapidly and accurately alarming the risk of urban landslide and by reducing the extent of the disaster damage

○ The integrated geo-environmental hazard management system would contribute to achieve the effective land use and the conservation of geologic environment and to provide the scientific basis and management plan for reducing geo-environmental hazard risk

□ Utilization of Research Outputs

○ The weather forecast-linked real-time landslide early warning system can provide technical supports to governmental institutes in need such as Korea Forest Service, Korea National Park Service, and local government agencies and the diffusion of this technology can contribute to build the nationwide landslide early warning system.

The G-PHEs map can provide basic information about source and spatial distribution of G-PHEs to government, local government agencies, and research institutes in need. The integrated G-PHEs risk management plan may contribute to expand the domestic environmental industry and to strengthen the competitiveness of Korean remediation companies in global environment industry.