Coordinating Committee for Geoscience Programmes
in East and Southeast Asia
(CCOP)
Mines and Geosciences Bureau
(MGB)

44th CCOP Annual Session

21 - 26 October 2007
Cebu, The Philippines

Proceedings

Thematic Session on
"Awareness and Cooperation in Geosciences for Safer, Healthier and Wealthier Communities"

Convenor
Sevillo D. David Jr.

Editors
Anthony Reedman, Nguyen Hong Minh and Niran Chaimanee

CCOP Technical Secretariat
September 2008

Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP)

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EDITORIAL NOTE

Either full papers, short summaries or abstracts were submitted for each of the verbal presentations delivered at the CCOP Thematic Session (October, 2007) on the subject of "Awareness and Cooperation in Geosciences for Safer, Healthier and Wealthier Communities". All are included in this volume, most after some limited editing, mainly aimed at correct English usage, but responsibility for scientific content rests with the individual authors and an independent peer review process has not been undertaken by CCOP prior to publication.

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Thematic Session on

"Awareness and Cooperation in Geosciences for Safer, Healthier and Wealthier Communities"

With Four (4) Sub-Themes

1) **Geohazards Monitoring, Precaution and Mitigation**
2) **Role of Geoscience / Climate Change**
3) **Geoscientific Researches and Studies**
4) **New Methods and Technologies**

at the 44th CCOP Annual Session

21 - 26 October 2007, Cebu, The Philippines

ORGANIZATIONS

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FOREWORD

The Coordinating Committee for Geoscience Programme in East and Southeast Asia (CCOP) is an intergovernmental organization that contributes the publication of the technical proceedings of the CCOP Thematic Session annually. At the 44th CCOP Annual Session held in Cebu, The Philippines, the CCOP Thematic Session is jointly organized by CCOP and Mines and Geosciences Bureau (MGB) and focused on Awareness and Cooperation in Geosciences for Safer, Healthier and Wealthier Communities with four (4) sub-themes, 1) Geohazards Monitoring, Precaution and Mitigation, 2) Role of Geoscience/Climate Change, 3) Geoscientific Researches and Studies and 4) New Methods and Technologies.

The Session brought international experts on geohazards, climate change, geoscience and development issues, etc., to exchange their experience and ideas on the selected theme within the region and others areas.

Thanks and congratulations are attributed to the Organizing Committee and the editors for arranging what will undoubtedly be an exciting and informative publication in yet another of the Thematic Sessions which are now becoming a traditional strength of the CCOP Annual Session. Last but not the least, we would also like to take this opportunity to express our appreciation to the authors for their contribution in the session and to the delegates for their active participation and discussions.

Hee-Young Chun, Ph.D.
Director
CCOP Technical Secretariat

CONTENTS

Page

OPENING REMARKS……**1**

Sub-Theme 1 : Geohazards Monitoring, Precaution and Mitigation

1) National Geohazards Mapping and Assessment Program of the MGB-DENR-Philippines
Dr. Karlo L. Queaño……..**5**

2) Developing a "Rapid Earthquake Damage Assessment System (REDAS)" Software for the Philippines *(Abstract)*
Dr. Maria Leonila P. Bautista, et.al.....**9**

3) A Landslide Monitoring System in China : Present Status and Future Prospects
Dr. Zhang Zuochen, et.al..... **10**

4) A Community Based Landslide - Warning Network in Thailand
Mr. Worawoot Tantiwanit……....**21**

5) Geo-Hazards in Vietnam: Their Investigation, Monitoring and Mitigation
Department of Geology and Minerals of Vietnam.....**29**

6) Self-Help, Community-Help and Public-Help: Lessons from the Earthquakes in Kobe and Chuetsu *(Abstract)*
Dr. Seiji Suzuki……..…….…..**38**

Sub-Theme 2 : Role of Geoscience / Climate Change

7) Geology as a Contributor to National Economies and Their Development
Dr. David Ovadia…….…**41**

8) Climate Change Issues: Examples of Earth Science Solutions *(Abstract)*
Dr. Jean Claude Guillaneau……....**49**

9) Do We Need a Permanent and Stronger ICOGS? *(Abstract)*
Dr. Arne Bjorlykke……..…**50**

10) Activities of Asian Disaster Reduction Center (ADRC) concerning Awareness and Cooperation in Geosciences
Dr. Takaaki Shiratori……..…**51**

11) The Role of Geoscience Information Systems in Sustainable Regional Development Planning in Asia *(Abstract)*
Dr. Kimberley J. Patrick and Dr. Tom S. Loutit……..…**56**

Sub-Theme 3 : Geoscientific Researches and Studies

12) Assessment of Coastal Geo-Environmental Changes in the West of Bohai Bay, China
Dr. Wang Hong……..….….**59**

13) Recent Geological Studies and Age Dating of Ground Water in Jeju Island
Dr. Byoung-Woo Yum, et.al..... **69**

14) Implementing Geological Information on Natural Hazards in Urban Planning - Reconstruction of Banda Aceh, Indonesia *(Abstract)*
Dr. Volker Steinbach…….…...**78**

15) Characteristic Seafloor Morphology and Geology of a Tropical Lagoon
Dr. Seong-Pil Kim, et.al.....**80**

16) Offshore Fault Assessment : Implication to Predict Earthquake and Tsunamigenic Potential Along the Coastal Area of Muria Peninsula, Central Java
Dr. Subaktian Lubis…….…… **89**

Sub-Theme 4 : New Methods and Technologies

17) Landslide Susceptibility Mapping Using an Efficient Artificial Neural Network Computing Method, Satellite Images and GIS
Dr. Joel C. Bandibas, et.al…….…..… **95**

18) Assessment of Runout Distance of Debris Flows Using an Artificial Neural Network Method
Dr. Byung-Gon Chae, et.al……...**100**

19) Reduction of Acid Rock Drainage Using a Phosphate Coating Technology
Dr. Jae-Gon Kim and Dr. Sung-Won Park……**109**

OPENING REMARKS

by

Hee-Young Chun, Ph.D.
Director, CCOP Technical Secretariat

CCOP Thematic Session in Conjunction with the 44th Annual Session

"**Awareness and Cooperation in Geosciences for Safer, Healthier, and Wealthier Communities**"

Marco Polo Plaza Hotel
Cebu City, Philippines
October 24-25, 2007

Mr. Horacio Ramos,
Permanent Representative of the Philippines to CCOP,
Director, Mines and Geosciences Bureau, Department of Environment and Natural Resources

Dr. Eikichi Tsukuda,
Chairperson, CCOP Steering Committee, and
Director General, Geological Survey of Japan

Dr. Jos de Sonneville,
Vice Chairperson of the CCOP Advisory Group
Director, International Cooperation, Netherlands Institute of Applied Geoscience

Mr. Chairman of the Thematic Session,

Distinguished speakers and colleagues,

Good afternoon, Ladies and Gentlemen,

Thank you, Mr. Chairman, for inviting me to say a few words in the opening of this year's the 7th Thematic Session "**Awareness and Cooperation in Geosciences for Safer, Healthier, and Wealthier Communities**" organized in conjunction with the CCOP 44th Annual Session.

The Thematic Session, as the result of the CCOP Advisory Group's advice given the during the Annual Session in 2000, is a part of the CCOP Annual Session program, which provides the opportunity for Member, Cooperating Countries and Organizations to address scientific and strategic issues of common interest to CCOP. The Session also serves as a forum for exchange of experiences and ideas among CCOP on the selected theme.

We are all now facing increasing challenges in building a sustainable future for the communities and I believe that one of the right ways is to raise better awareness and promote closer cooperation among us in order to let geosciences input more for societies.

I would like to congratulate the Organizing Committee for very great efforts in collecting a record number of comprehensive papers on this theme that makes the programme to be updated even at the last minute. I also would like to thank our distinguished speakers who had come over the long way to this Cebu Island, the "Queen City of the South" of the Philippines, to share their knowledge and experiences in how geosciences could contribute for the Safer, Healthier, and Wealthier Communities.

In the following one and half days, we will witness the great achievements of CCOP geoscientists in geohazards monitoring, precaution, and mitigation; in development of new methods and technologies; new results of geoscientific researches and studies; and some shared ideas on role of geoscience in building the better future for the communities.

I am sure that this Thematic Session will gain a great success and thank all of you for your support and participation.

Thank you.

24 October 2007

Sub-Theme 1 :

Geohazards Monitoring, Precaution and Mitigation

National Geohazards Mapping and Assessment Program of the Mines and Geosciences Bureau-Department of Environment and Natural Resources (MGB-DENR) - Philippines

Karlo L. Queaño and the MGB Geohazard Assessment Team
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ABSTRACT

Following the major landslide incident in 2006 at Guinsaugon, Leyte, which virtually wiped out the whole community, the Mines and Geosciences Bureau-Department of Environment and Natural Resources (MGB-DENR) immediately set out to rationalize and accelerate the implementation of the National Geohazards Mapping and Assessment Program. The primary aim of this program is either to reduce or, if possible, to totally mitigate the negative impacts of natural hazards, particularly landslide and flooding, on the populace. Five components comprise this program: (a) capacity building; (b) data acquisition, generation and integration; (c) conduct of field surveys; (d) generation of geohazard maps and; (e) conduct of an information and education campaign. To date, a total of 826 (translating to 12,600 barangays) out of the target of 1,200 priority municipalities have already been covered by the Geohazards Mapping and Assessment Program throughout the country. This translates to about 436, 1:50,000 scale geohazards quadrangle maps that have been produced so far. The MGB-DENR is also in the forefront of conducting suitability assessments of possible relocation sites for barangays that are highly susceptible to goeohazards. This activity is being carried out in close coordination with the LGUs, other government agencies in addition to non-governmental and civic organizations.

BACKGROUND

The Philippines, by virtue of its geologic and geographic setting is prone to natural hazards. Geologically, active subduction on both sides of the archipelago (i.e, the Eurasian Plate subducting beneath the Manila-Negros-Sulu Trench to the west, and the Philippine Sea Plate beneath the East Luzon Trough-Philippine Trench to the east) renders the region susceptible to volcanic and earthquake-related hazards (e.g., landslides, ground rupture, ground shaking and tsunami). A significant number of typhoons (often exceeding fifteen a year) also make the country prone to hazards such as flooding, storm surge, and rain-induced landslides. It is not surprising therefore that in the 20th century, the Philippines was the country that experienced the greatest number of natural disasters, with India and United States next in line (Kovach, 1995).

As early as the time of its inception, The Mines and Geosciences Bureau-Department of Environment and Natural Resources (MGB-DENR) appreciated the need to conduct geohazards assessments across the archipelago. Previously reported assessment work of the MGB includes that of Espiritu (1966), of Paderes (1973) and of Santiago and others (1982).

It was, however, in 1999, when a landslide devastated a subdivision (the Cherry Hills) in Antipolo City, Rizal Province, that the need to conduct a geohazard assessment assumed an even greater urgency. Accordingly, as an additional requirement to the issuance of an Environmental Compliance Certificate (ECC) to proponents of land development projects, the DENR required all proponents of housing projects and other land development and infrastructure projects, private or public, to undertake an Engineering Geological and Geohazard Assessment. However, even though the order, known as the DENR Administrative Order 2000-28, was intended to comprehensively address and mitigate the possible impacts of geologic hazards, it proved not to be entirely adequate, especially in areas where land developments were already in place prior to 1999. In February 2006, another major landslide occurred, this time virtually wiping out a community in Southern Leyte. This infamous event, the Guinsaugon Landslide, urgently called for a more substantive and effective effort to address the geohazards problem in the country.

THE NATIONAL GEOHAZARDS MAPPING AND ASSESSMENT PROGRAM

Following the directive of the President of the Philippines to fast track the landslide and flood hazard assessment of the country, particularly in areas along the eastern Philippine seaboard, the MGB-DENR immediately set out to rationalize and speed up the implementation of its National Geohazards Mapping and Assessment Program. This is aimed at reducing the negative impact and destructive effects of natural hazards on the populace. Specifically, the program aims to (a) identify various geological features and their associated hazards; (b) generate geohazard maps and reports; (c) identify relocation sites, properties and infrastructures to be affected and; (d) inform the local officials about the susceptibility of their community/municipality to the various geohazards and make the information generated from the mapping available to authorities responsible for land use planning and classification as well as for disaster preparedness, management and mitigation.

Immediately following the Guinsaugon landslide tragedy in Southern Leyte, the MGB-DENR carried out the assessment of possible relocation sites for displaced and affected families in Guinsaugon. The MGB-DENR proceeded with the geohazard assessment of areas in Southern Leyte Province including Panaon Island. With assistance from the Japan International Cooperation Agency (JICA), this was immediately followed by the assessment of the rest of Leyte Island (Leyte Province) and Biliran Province. The geohazards mapping campaign was then intensified with the fielding of two teams, each of which comprised geologists from the central office (located in Quezon City) and from the regional offices of the MGB-DENR. Priority was given to densely populated, highly developed and rapidly growing areas and those historically prone to geohazards.

To date, the MGB geohazard teams have covered many areas in Cagayan, Isabela, Nueva Vizcaya, Nueva Ecija, Bulacan, Rizal, Laguna and Camarines Norte in Luzon. In Mindanao, the team has already covered the eastern region, consisting of Surigao del Norte, Surigao del Sur, Agusan del Norte, Agusan del Sur, Compostela Valley, Davao Oriental and Davao del Sur. In addition to Leyte province, geohazards assessment in the Visayan region had already been conducted, particularly in Iloilo and Bohol provinces. Simultaneous with the conduct of the broad scale geohazards mapping and assessment of the priority areas of the eastern sea board, hazards mapping and assessment have also been undertaken by the regional offices in specific critical areas or municipalities within their jurisdiction.

In summary, a total of 826 out (translating to 12,600 barangays) of the target 1,200 priority municipalities were already covered by the Geohazards Mapping and Assessment Program throughout the country. This translates to about 436, 1:50,000 scale geohazards quadrangle maps have been produced so far.

METHODS ADOPTED IN THE GEOHAZARDS PPROGRAM

The MGB-DENR's geohazard program has 5 components, namely, (1) capacity building; (2) data acquisition, generation and integration; (3) conduct of field surveys; (4) generation of geohazard maps and; (5) conduct of information and education campaigns. The first component was intended mainly to standardize the procedures and activities under the National Mapping Program. This is achieved through the conduct of training sessions and seminars which are attended by all geologists who are directly involved in the project, from both the central and from all regional offices of the MGB

As in most geological studies, the MGB also conducts a preliminary desk study of an area to be assessed as a means of acquiring and generating data prior to the field survey. The study typically involves analysis of aerial photographs and of other available images at various scales and compilation of geologic maps from all available sources. The data are then verified by a team of about 6-10 MGB geologists during the field survey. To provide a more systematic way of assessing a region as well as to ensure that the assessment is comprehensive, especially covering "populated areas", the geohazard assessment and mapping activity proceeds at the "community or barangay level". Using a set of parameters (e.g., slope angle, degree of weathering of rocks, degree of fracturing of rocks, presence of tension cracks, presence of old/inactive landslides and recent/active landslides, etc.), each of the barangays covered is assessed for susceptibility to landslides (low, moderate or high). To standardize the assessment, MGB geologists use a common landslide and flood assessment form as agreed earlier during the capacity building seminar. MGB geologists also provide landslide advisory information to barangay officials, informing them of their area's susceptibility to landslide hazards together with the appropriate recommendations. Municipal mayors and provincial governors are also given a report summarizing the results of the MGB geohazard assessment and mapping in their respective areas. The final outputs of the assessment are thematic (landslide and flood susceptibility) maps generated using GIS-based software.

A very important component of the program is the conduct of province-wide Information and Education Campaigns (IECs). This activity serves as the opportunity explain to the local government officials, as well as to people's organizations and other civic groups, the results of the work done in the concerned province. Formal and informal lectures and discussions are conducted and posters, geohazard maps and information VCDs are handed out to participants during the course of the program. In so doing, the activity serves as a way of increasing public awareness so that tragedies similar to the Cherry Hills Landslide and Guinsaugon Landslide incidents are less likely to be repeated. Under the MGB geohazard program, IEC activities have already been conducted in Leyte and Surigao provinces.

A further major activity of the geohazards mapping program that bears a direct impact on disaster management and rehabilitation is the conduct of suitability assessment of possible relocation sites. The MGB-DENR is in the forefront of this very important undertaking which is being carried out in close coordination with the LGUs, other government agencies, and non-government and civic organizations. The activity was highlighted during the aftermath of the Guinsaugon tragedy, as noted above, and more recently by the rehabilitation and relief efforts following the destruction brought about by mudflows at the height of typhoon Reming in December 2006.

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Developing a "Rapid Earthquake Damage Assessment System (REDAS)" Software for the Philippines

Maria Leonila P. Bautista, et. al.
Philippine Institute of Volcanology and Seismology

ABSTRACT

The few minutes after the occurrence of a large and potentially damaging earthquake are very crucial in making timely decisions; especially information regarding the deployment of relief and rescue operations. The Philippine Institute of Volcanology and Seismology (PHIVOLCS) of the Department of Science and Technology (DOST) agency is the agency mandated to issue earthquake bulletins and provide pertinent information to the public after an earthquake. This responsibility becomes very important when large-magnitude earthquakes occur and the public wants to know immediately the possible impacts and damage that a given event might have caused. To address this concern, a simple and user-friendly simulation tool or software, which can give a rapid estimate of the possible seismic hazards and can be used for inferring the severity of impacts to various elements-at-risk, was developed. This software is called "Rapid Earthquake Damage Assessment System" or REDAS. The software was developed by PHIVOLCS through a Grant-in-Aid from DOST.

REDAS aims to provide quick and near real-time simulated earthquake hazard information to disaster managers for assessing the distribution and extent of the impacts of a strong earthquake. This could help them decide and prioritize the deployment of timely rescue and relief operations. The second objective is for the software to serve as a tool in convincing land-use planners, policy makers, city and town development planners and even local government executives to consider earthquake hazards in their planning and development efforts in order to ensure long-term mitigation of seismic risks.

The hazards that could be computed using this tool are ground shaking, earthquake-induced landslides, liquefaction and tsunami. The risk database that is being built continuously in REDAS includes population centers, roads and communication networks, lifelines, high rise buildings, hospitals, schools, churches, banks, markets, hotels, fire stations, power plants, dams, and other critical facilities. The other capabilities of REDAS include earthquake sorting, production of seismicity maps, query of data points, production of maps of different sizes, on-screen map digitization, and more importantly, allowing users to build their own risk database.

To date, the software has been provided to some local government units (LGU) as part of the READY Project of the National Disaster Coordinating Council. READY multi-hazard maps are also incorporated in REDAS to make it multi-hazard in approach including hydrometeorological hazards. For each LGU, training on its use is also provided and the participants are also taught how to build their own risk database using maps and GPS. The software is still being continuously improved by obtaining feedback and inputs from users to make it more attuned to their needs.

***Keywords**: Seismic hazard assessment, Earthquake risk mitigation, earthquake disaster mitigation software.*

A Landslide Monitoring System in China: Present Status and Future Prospects

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China Geological Survey

Zhou Pinggen, Hou Shengshan, Li Ang
China Institute of Geo-Environmental Monitoring, China Geological Survey

ABSTRACT

This paper introduces the status of landslide hazards prevention in China and the construction of an early warning and monitoring system. In recent years, in accordance with the principle of "from precaution to mitigation", an integrated system for landslide prevention in China has been constructed. In landslide prone areas, a landslide monitoring and early warning system based on detailed survey and risk assessment, was set up, consisting of national and regional professional landslide monitoring networks and regional landslide early warning system together with and a mass (community) monitoring and early warning network.

This paper also compares the status of landslide prevention work in China with that in other countries, and reviews the prospects for future landslide monitoring and early warning systems in China.

Keywords: *landslides, geological hazards, monitoring, early warning, system construction*

INTRODUCTION

Landslides are some of the most serious hazards endangering lives and properties in China. The statistics issued by the Ministry of Land and Mineral Resources (MLR), indicate that as many as 1000 people die from landslide events every year in China, and the yearly economic loss can exceed 1 billion Yuan. In 2006, 663 died and 111 were missing due to landslides, equivalent to a direct economic loss of 4.32 billion Yuan.

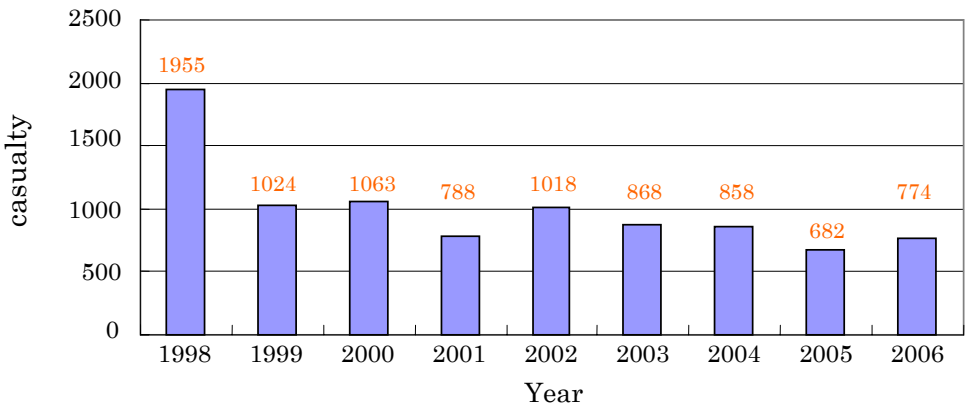


Figure 1. Casualties due to landslides in China during 1998-2006.

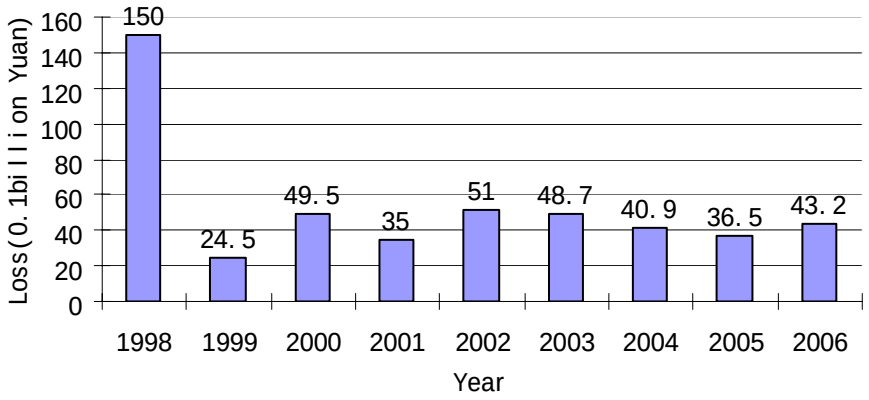


Figure 2. Direct economic losses caused by landslides in China during 1998-2006.

FRAMEWORK OF LANDSLIDE MONITORING AND EARLY WARNING SYSTEM IN CHINA

In recent years, according to the principle of "from precaution to mitigation" for landslide prevention, a landslide prevention system was established in China. In landslide prone areas, the landslide monitoring and early warning system, based on detailed survey and assessment, was constructed consisting of a professional landslide monitoring network (regional and main landslide body), a regional landslide early warning network and a mass monitoring-early warning network.

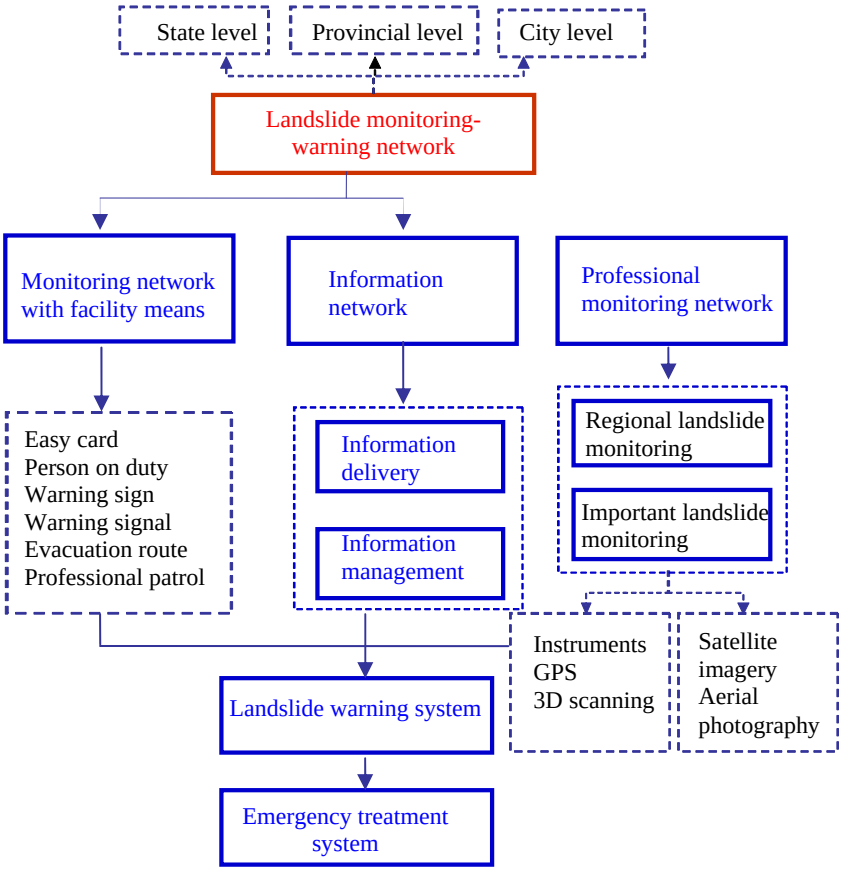


Figure 3. Sketch map showing the components of the landslide monitoring system.

The national landslide monitoring network, consisting of 31 provincial stations and 217 city stations, has already been set up. Using this network, the professional and mass monitoring work was undertaken and the losses decreased significantly. There are three levels in the national landslide monitoring network system. The first level is the national network, the second is the provincial network, and the third is a city network. (Figure 3)

The landslide monitoring work comprises professional monitoring and mass (community) monitoring. According to the features of landslides in China and the landslide early identification technique, a combination of professional and mass monitoring has been established.

Mass Landslide Monitoring and Warning Network of Local People

The mass monitoring and warning network is conducted by the local population under the direction of the local government (county and town). Local people monitor the landslides using various methods and under the guidance of professionals. The "easy cards", referred to in Figure 3, are a variety of pamphlet delivered to every family in the dangerous areas to inform them of the hazards in their vicinity. The local people were also trained by experts. The mass monitoring network has three levels: county, town, and village. In the Three Gorges Reservoir area, the mass monitoring network was set up on about 1000 landslides with approximately 800 trained monitoring personnel.

Professional Landslide Monitoring and Warning Network

The professional landslide monitoring and warning network includes a regional monitoring and warning and monitoring of dangerous landslides.

In recent years, on the basis of detailed surveys, the regional landslide monitoring and warning networks were established in Yaan (Sichuan), Ailaoshan (Yunnan), Lanzhou-Tianshui area (Gansu), Yanan (Shaanxi), Quanzhou (Fujian), Jiuling (Jiangxi) and Beijing mountainous area. The monitoring system, including rainfall monitoring, water content monitoring, remote sensing and multi-parameter monitoring on dangerous landslides, plays a significant role in the hazard mitigation.

For dangerous landslides, good quality apparatus and new techniques have been used. Surface displacement, underground displacement, ground stress, ground water, pore water pressure, sound emission and rainfall data were real-time monitored. The relevant data were acquired continuously and warning signals could then be sent out in a timely manner. This also gives reference data for landslide analysis. In the Three Gorges Reservoir area, GPS network was set up, and more than 100 landslides were monitored by this means. Dangerous landslides, such as Lianziya, Huanglashi, Huangtupo, Baota landslides, were monitored by multi-parameter methods, especially at the Lianziya landslide, monitoring apparatus was installed such that data could be continuously transmitted to a computer where a relevant database and software on landslide prediction have been developed.

CASE-STUDY OF REGIONAL LANDSLIDE MONITORING AND FORECASTING SYSTEM IN YAAN, SICHUAN

The Yucheng District of Yaan City is located in the west of the the Sichuan Basin, at the intersection of the Sichuan Basin and the Tibetan Plateau (102°51′-103°12′E, 29°40′-30°14′N). The area is 1067 km^2 with a population of 330 thousand. Over 90% of Yucheng District is mountainous. The slopes are underlain by Mesozoic sedimentary rocks; sandstones interblended with mudstones The climate is sub-tropical, and Yucheng District is known as the "sky funnel" because of the high annual precipitation of about 1750 mm. Rain falls mainly during May to October, with the highest in July and August.

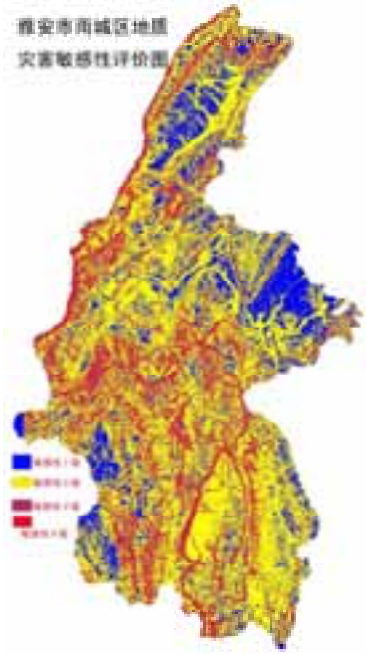
Detailed landslide surveys are carried out to obtain the location, scale, characteristics, and the main factors influencing the triggering of the landslide. Then the regional landslide susceptibility can be assessed

Ten factors are selected for study of their respective relationships to landsliding (Table 1).

Table 1. The 10 factors used in landslide susceptibility assessment

No.	Factor	Weight
1	Slope gradient	0.1
2	Aspect	0.03
3	Rock type	0.15
4	Plant cover	0.04
5	Altitude	0.06
6	Structural geology	0.06
7	Slope type	0.07
8	river	0.07
9	road	0.1
10	Annual precipitation	0.1

Using the bi-varient statistical method (Hou, et al., 2006), the contributions to landsliding from each factor are calculated and then the susceptibility classified into four levels in order to construct the regional landslide susceptibility map (Figure 4). The accuracy of this method is shown in Figure 5.



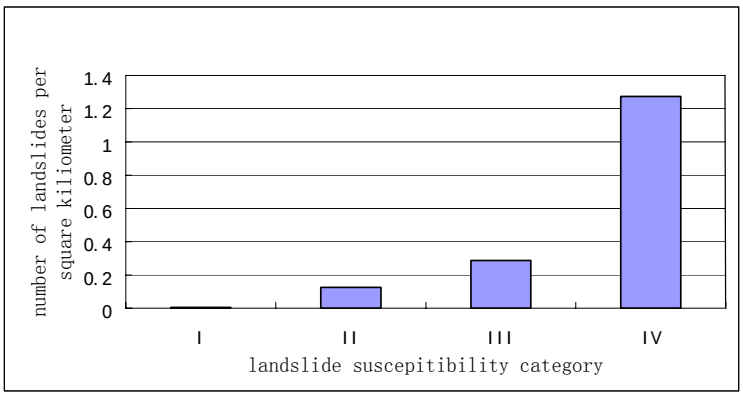


Figure 4. Landslide susceptibility map of Yucheng District, Yaan City.

Figure 5. Evaluation of the landslide susceptibility assessment.

The regional rainfall monitoring network was established with 13 automatic CAWS600R rain gauges. (Figure 6)

Figure 6. Regional rainfall monitoring network.

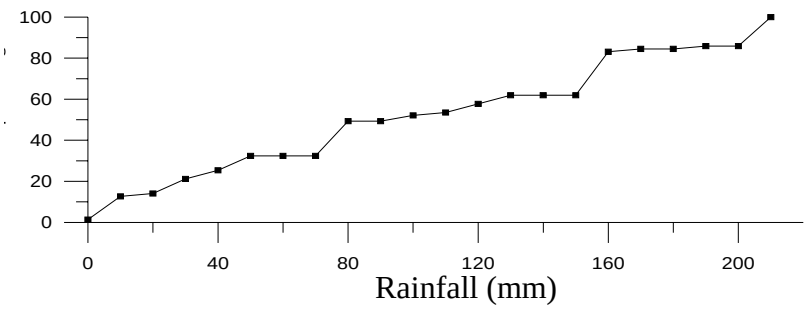


Figure 7. The relationship between 1 day rainfall and landslide.

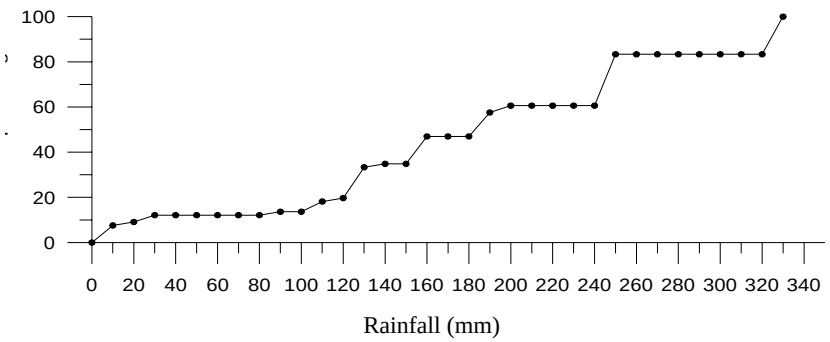


Figure 8. The relationship between 3-day rainfall and landslide.

Using the landslide survey data, the effect of rainfall on the occurrence of regional landslides was assessed (Figures 7, 8 and Table 2). The amounts of one-day and three-day cumulative rainfall strongly control the occurrence of regional landslides. The triggering effect of rainfall was also classified into four levels.

Table 2. Landslide-triggering categories of rainfall.

Triggering category	**3 day rainfall** (mm)	**1 day rainfall** (mm)
1	0－100	0－20
2	100－150	20－50
3	150－240	50－100
4	＞240	＞100

A method to assess the landslide hazards using the susceptibility and triggering levels is shown in Table 3. The hazard assessments are also classified into four levels: most serious (FOUR); serious (THREE); medium (TWO) and fairly safe (ONE).

Table 3. Assessment of landslide hazard levels

Susceptibility degree / Triggering category	I	II	III	IV
1	ONE	ONE	ONE	TWO
2	ONE	TWO	TWO	THREE
3	ONE	TWO	THREE	FOUR
4	TWO	THREE	FOUR	FOUR

A flowchart of the landslide warning system is shown in Figure 9.

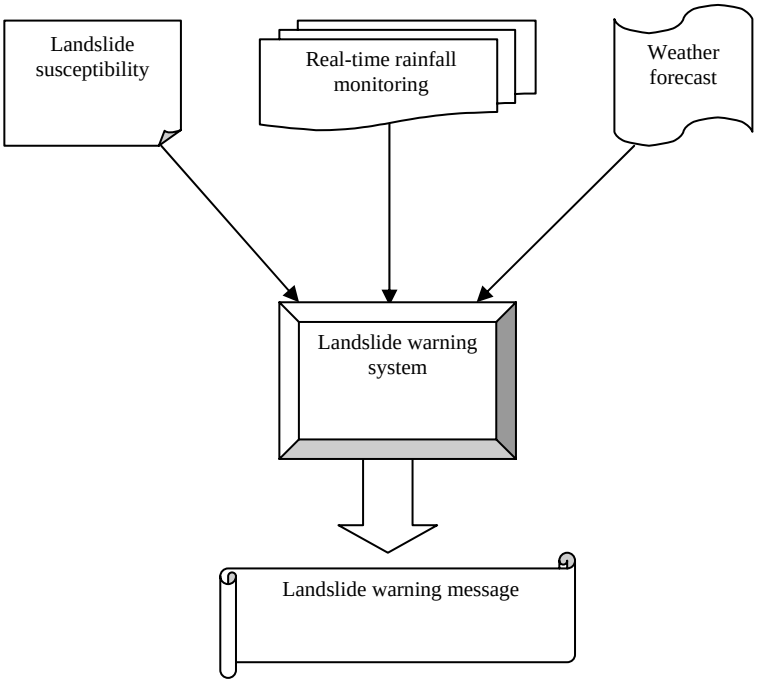


Figure 9. Flowchart of the landslide warning system.

On July 13, 2006, a landslide warning message was sent out (Figures 10-12). Most of the landslides (90%) in the following 24 hours occurred in our FOURTH level of landslide warning. The detailed warning at a larger scale can increase the precision both spatially and temporally.

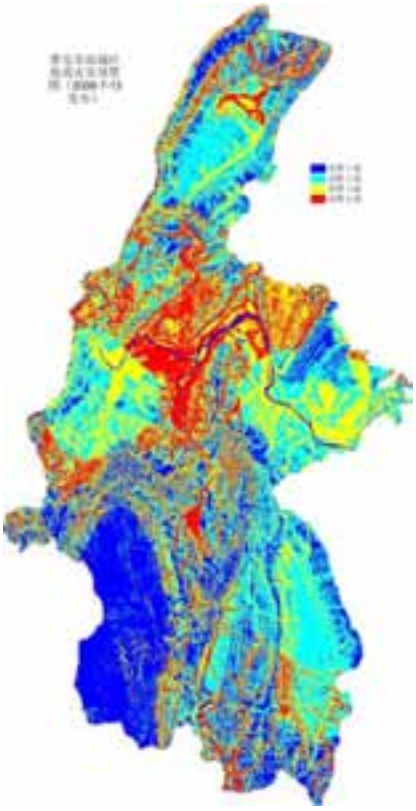
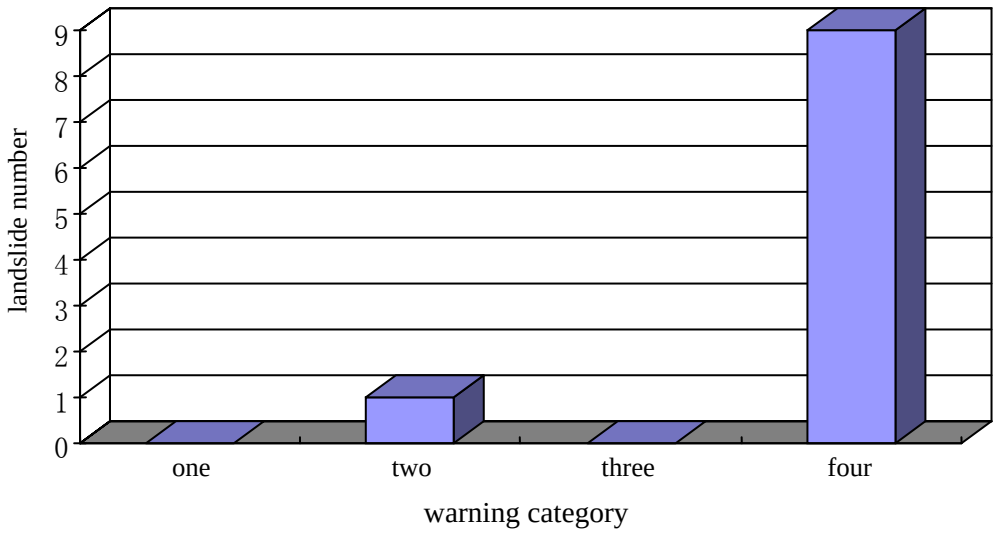


Figure 10. Landslide warning on 2006.7.13.

Figure 11. Landslides induced by 2006.7.13-rainfall.

Figure 12. The effectness of the landslide warning on 2006.7.13



PROSPECTS FOR THE CONSTRUCTION OF EARLY WARNING SYSTEMS FOR GEOLOGICAL HAZARDS

Development and Construction of Landslide Hazard Early Warning System

Landslide risk assessment and integrated disaster mitigation technologies

Using the results of hazard and risk assessments, geological hazards can be mitigated by engineering and administrative measures such as layout and land utility planning (Bernknopf, R.L., R.H. Campbell, D.S. Brookshire & C.D. Shapiro, 1988). Currently, risk assessment and integrated disaster mitigation technologies in China have adopted many important changes, such as attaching great importance to integrated studies of regional and urban multi-category disasters while continuing to strengthen single-category disaster studies; strengthening studies on social attributes of disasters while continuing to strengthen studies on natural attributes of disasters; and that disaster mitigation work has transformed from passive relocation into active disaster prevention with systematic disaster mitigation measures including disaster surveys, reports, prevention, counter-action, relief and financing construction projects. At the same time, the nation has done much in establishing integrated disaster information systems, making a disaster mitigation framework, conducting integrated disaster forecasting and setting up integrated disaster mitigation demonstration areas.

Multi-Parameter, Automatic Monitoring Instruments and Techniques

Landslide monitoring and surveying technologies and methods have developed globally. At present, the trend is to develop automatic and high-precision telemeter systems. The survey apparatus is developed to be of high precision, good quality, wide application, and highly automated (Lahusen, R.G. 1996; Mark E. & Richard G. Lahusen, 1998). In recent years, with the development of electro-photographic laser technology and advanced computer technology, various advanced high-precision electro-theodolite and laser telemeter have appeared, serving as effective new means for landslide surveys. Survey and data processing is a time and energy-consuming activity, China has so far only established real-time survey systems on a few landslide sites.

Landslide Forecast and Warning Technologies and Methods

Studies of forecast and warning methodologies are concentrated on the following aspects: (1) phenomena forecast method on landslide transformation; (2) S-T curve variety trend judging methodology; (3) Saito method and advanced Saito method (Saito, M. 1965); (4) statistical mathematical modelling method; (5) golden section method; (6) nonlinear dynamic model method; (7) rainfall parameter forecasting method (Keeper, D. et. a1.,1987); (8) acoustic emission parameter forecasting method; and (9) multi-parameter forecasting method. Although landslide forecast and warning studies have been flourishing, such studies have seen little progress since the “Saito method” was introduced in 1965. As for the effects of the methods, methods (1), (2), and (3) contributed to successful forecasts before landsliding occurred whereas methods (4), (5) and (6) verify landslides after the sliding event. Thus, it is difficult to judge their effects precisely. The other methods are still under study. This shows that current studies are dominated by qualitative or semi-quantitative forecasts mainly based either on geological analysis and experience or by trend pattern quantitative forecasts based on monitoring data. Landslide forecast and warning studies are mainly oriented to quantitative

landslide forecast and warning theories based on qualitative geological analysis and actual data. As geological process of landsliding has complex and various engendering conditions and inducing factors as well as random and unstable changes, dynamic information on landslide changes is difficult to get. Furthermore, the current dynamic survey technology on landslides is not sufficiently credible, and landslide theories are not perfect. So, landslide survey and forecast has always been regarded as a very difficult 'frontier theme'.

STUDIES CONDUCTED IN CHINA OF KEY TECHNOLOGIES FOR LANDSLIDE DISASTER EARLY-WARNING

Application of Remote Sensing Technology

It is planned to use high-resolution remote sensing images, combined with field surveys, to conduct landslide disaster investigation and to use risk assessment (scale: 1:50,000) in landslide prone areas and studies on large-scale landslide disaster monitoring applications will be used in important projects and important regions.

Automatic Landslide Monitoring and Survey Technology as well as Mid-Term and Short-Term Forecast Technology Studies

It is planned to establish automatic landslide monitoring and survey systems based on multiple parameters. Besides typical survey parameters, methods such as infrared and laser locating three-dimensional survey and photographic image analysis survey will be employed to survey micro-motions of landslides on the ground, and methods such as seepage deformation propagation and deep displacement acoustic transmission surveys in the drilled underground space to provide important parameters for judging the shear surface of selected landslides. It is also planned to study basic characteristics, structures, and critical information of typical landslide disasters, to conduct simulation experiments on the formation and development processes of some typical landslide disasters, and to develop landslide survey technologies and methods based on GIS information and AI technologies for mid-term and short-term prediction.

GIS-based Landslide Disaster Risk Assessment Technologies and Integrated Geological Hazard Information

For a management and decision-making support system, it is planned to develop geological hazard data collection, catalogue, storage and database technological modules based on 3S technology, in order to build up an integrated technological platform for information management, to establish a geological hazard integrated information management centre, to study and develop geological hazard numerical simulation and physical simulation technology, to develop geological hazard survey methods, to develop 'hazardous area' layout and risk assessment technological modules, and to conduct studies on geological hazard prevention and harness auxiliary decision-making modules.

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A Community Based Landslide-Warning Network in Thailand

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ABSTRACT

Thailand is located in the topical monsoon zone and heavy rain is very common when storms and typhoons are approaching Thailand. Heavy rain in mountainous areas is very dangerous because it can cause landslides and flash floods. A study by the Department of Mineral Resources (DMR) of Thailand suggests that there are 2,371 villages located in landslide hazard zones. In the last decade, landslide data shows that the number of landslide events and impacts seem to be increasing. This might be attributed to many factors ranging from change of environment to change of settlement pattern. To solve landslide hazard problems, DMR has established local warning networks or self-protection networks in risk areas. The networks include local people working for their communities or villages as volunteers. They were trained to have knowledge on landslide behaviour and how to observe the upstream warning signs. During the monsoon season they will be the guards at check points or at the foot of mountains where they can clearly see streamwater. When they detect signs of landslide development such as a distinct rumbling sound, they will warn other people in risk areas downstream. Moreover, DMR established the Geohazards Operation Center in Bangkok to monitor landslide activity and to coordinate with the local networks and relevant agencies. When heavy rain is approaching landslide prone areas, the center will disseminate landslide watch bulletin and inform the networks through television, radio, facsimile and mobile phone. The local networks can also call the center to get more information and the real time situation from their areas. Furthermore, the center coordinates closely with the Thai Meteorological Department (TMD) concerning rainfall prediction and with the Department of Disaster Prevention and Mitigation (DDPM) and provincial governors on landslide management.

***Keywords**: landslide, watch, warning, network.*

INTRODUCTION

Thailand is located in the tropical monsoon zone between 5º 37' – 20º 27' N and 97º 22' -105º 37' E. It covers an area of 513,115 km^2 with a population of 65 million. Thailand is comprised of 76 provinces and geographically divided into 5 regions; northern, north-eastern, central, east and southern. High mountainous areas can be mainly seen in the northern, southern and eastern regions, while the central region is mainly lowland with high mountains in the western border. In general, the north-eastern region is high plateau but it still has mountains at the south and north borders.

From historical data, landslide disasters usually occurred in the northern and southern regions. One of the most famous landslide disasters in Thai history happened in Katoon, Nakhon Si Thamarat Province in 1988. It killed and injured 230 people and damaged a lot of houses, infrastructures, and agricultural areas. Total damage cost was estimated around 1,000

million Baht. There was a lull of 12 years without any significant landslide disasters. Then, large landslide events began to occur nearly every year, starting with the large events in Phetchabun Province in 2000 and in Phrae and Phetchabun Provinces in 2001.

The Department of Mineral Resources (DMR), realizing that landslides will cause problems in the future, has conducted many projects on landslide investigations, researches and studies. In addition, DMR has established local warning networks, as well as the Geohazards Operation Center in Bangkok, for landslide monitoring. Presently, DMR utilizes the Center as focal point to coordinate with the networks and relevant agencies including the Thai Meteorological Department (TMD) and the Department of Disaster Prevention and Mitigation (DDPM), as well as the various provincial governors.

LANDSLIDE HAZARDS IN THAILAND

Landslide hazards in Thailand are assessed by DMR by utilizing a landslide predictive model based on Geographic Information System (GIS). The factors employed in model calculation are geology, elevation, adjust aspect, slope, flow accumulation, flow direction, vegetation, soil type and wetness (Pantanahiran, 1994). The result of the model is used in the creation of landslide hazard zone maps, in scales of 1:250,000 for provincial level and 1:2,500,000 for the whole country. Based on the assessment, there are 2,371 villages located in landslide hazard zones in 51 provinces. The villagesare mainly scattered in the northern and southern regions.

In Thailand, landslides usually occur from May to December. This corresponds with the rainy season, which is influenced by the south-west monsoon, and with the rain front or heavy rain area moving from north to south. Thus the landslides usually start occurring in the northern provinces in May, and in the southern provinces later in the year. The events move southward and finish at the end of peninsular Thailand or Yala Province in December. This fact can be seen from historical events data (Table 1).

Landslide occurrence in Thailand seems to be increasing. Landslides occurred nearly every year after 2000. There were 2 or 3 events in some years. This might be a result of changes in rainfall pattern and settlement pattern. This can be observed in the Uttaladit landslide in 2006 when rainfall data broke the record of 38 years. New settlements have developed in mountainous areas due to increase of population, moving people into the landslide hazard zone. Moreover, forests are cleared for new houses and for agriculture, increasing the risk of landslides.

Figure 1. Shows a village in Chiang Mai Province located in landslide hazard zone.

Mairaing W. (2003) observed that, in the past, Thai people usually lived in calm settlement areas which were surrounded by natural forests. However, as the country developed, natural forests have been cleared for agricultural and urban utilization.

Table 1. Shows historical data of large landslides in Thailand.

Areas	Regions	Dates	Damages
Katoon, Piboon District, Nakhon Si Thammarat Province	Southern	22 November 1988	Villagers were killed and injured more than 230 persons. 1,500 houses were damaged. Total damaging cost is 1,000 million Baht.
Kelewong, Lansaka District, Nakhon Si Thammarat Province	Southern	22 November 1988	12 casualties, 142 houses were destroyed.
Thantip, Lomsak District, Phetchabun Province	Northern	11 September 2000	10 casualties, 2 missing and 363 damaged houses
Wangchin District, Phrae Province	Northern	4 May 2001	43 casualties, 4 missing and 18 damaged houses and 100 million Baht of total damage
Namkho, Lomsak District, Phetchabun Province	Northern	11 August 2001	136 casualties, 109 injures, 4 missing, 188 destroyed houses and 645 million Baht of total damage
Namraek, Maechaem District, Chiang Mai Province	Northern	15 September 2002	180 households were evacuated before the event.
SopMuey, Mae Hong Son Province	Northern	20 May 2004	400 effected people and 100 houses were damaged.
Om Koy, Chiang Mai Province			1 casualty and 100 effected people in 14 villages
Mae Ramad District, Tak Province			5 casualties, 391 injures, 8,846 effected people
Oanang, Muang District, Krabi Province	Southern	17 October 2004	14 guesthouses were damaged.
Huai Somphai, Muang, Krabi Province	Southern	18 October 2004	3 casualties, 1 injure and 25 damaged houses.
Thanto District, Yala Province	Southern	12 December 2005	2 casualties and 1 damaged house
Thesaban, Pai District and Namrin, Pang Mapha District, Mae Hongson Province	Northern	13 August 2005	7 casualties, 21 injures and 26 damaged houses
Nopute, Bunnung Star District, Yala Province	Southern	20 December 2005	18 houses were totally destroyed and 55 houses were partly damaged.
Labrae, Thapra and Muang District, Uttaladit Province Srisatchanalai District, Sukhothai Province Muang District, Phrae Province	Northern	23 May 2006	83 casualties, 33 missing, 673 destroyed houses and 308 million Baht of total damage

ESTABLISHMENT OF LOCAL WARNING NETWORKS

The occurrence of landslides can not be prevented. Landslides generally happen in mountainous areas where people are usually far from help. In such areas and in bad weather or heavy rain, communication often breaks down and roads might be cut off. It is nearly impossible for government agencies to reach the area and help local people during such times. The best solution to the problem is to increase the self-protection capability, landslide awareness and knowledge of people in risk villages. In 2003, the DMR started a training course for villagers to themselves when landslides occur. The course entitled Landslide Warning Network Training has presently trained 7,385 villagers in 19 provinces.

To establish the network, DMR staff had to visit local people especially the heads of villages. The staff explained landslide hazards in the area to the local people and show evidence of landslide in the past such as big boulders, landslide deposits and flood level. Then the staff asked the heads of villages to choose 6 - 9 villagers to participate in the training and become volunteers. Normally, the training is organized in groups of villages which are located in the same catchment area. The volunteers are trained by the staff about the knowledge of landslide behaviors and their impacts. Landslide signs and how to observe them are also taught in the course. Then observation sites or check points are selected by the staff and volunteers. The check point should be located on the hill near a stream or river flowing to the villages where the volunteers can notice water level and debris. When they hear rumbling sound from the mountain or spot the water level changing very rapidly, they must send signals to warn people in their village and inform other villages downstream (Figure 2). In the training, the evacuation routes and assembly areas for each village is also planned.

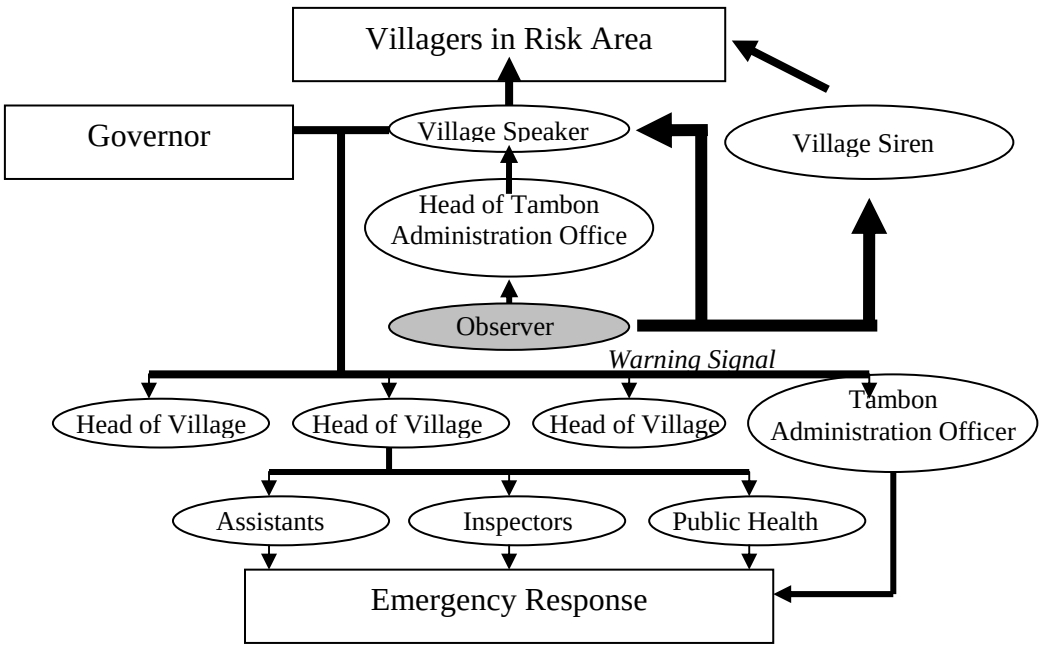

Figure 2. Shows the flowchart of the local warning network.
(modified after Tantiwanich, 2005)

There are presently 159 local networks, 7,385 volunteers in 911 communities or villages, in 19 provinces. The first network was established in 2003. Since then, DMR has developed many technologies and tools to support the network. One of these is the establishment of the Geohazards Operation Center to monitor hazards and inform the network when the hazards are coming. To keep in touch with the networks, to inform them about new technologies and tools and to re-encourage them, DMR arranges workshops to retrain all networks every year. In 2007, DMR plans to retrain the networks in 12 provinces. As of this report, the networks in 8 provinces have already been retrained for the year.

GEOHAZARDS OPERATION CENTER

In conjunction with the local warning networks in landslide risk areas, DMR established the Geohazards Operation Center in Bangkok. The center works in the national level and has main responsibilities in landslide monitoring, coordination with the local networks and investigation of urgent cases.

For landslide monitoring, the critical indicator is rainfall. The center receives weather data from the Thai Meteorological Department (TMD) via internet and facsimile. The data include satellite images, weather radar and rainfall measurements. The satellite images show overview of cloud cover areas. The areas are checked by weather radar data to confirm rainfall. If the weather radar detects heavy rain having a period longer than 3 hours, the staff of the center will call the local networks to get real time information from the local area and to confirm rainfall situation. Rainfall data from remote areas are available since the local networks have been trained to measure rainfall (Figure 3).

Figure 3. Rainfall Station being managed by the local networks.

When heavy rain is confirmed or estimated rainfall is higher than 100 mm/day and it is still raining, the center will disseminate watch bulletin. The bulletin is also issued in special cases, such as when tropical cyclone is approaching. Usually, the bulletin is sent through facsimile to television and radio stations, as well as relevant agencies. Recently, the networks in risk areas are informed by telephone and Short Message System (SMS) via mobile phone. After they receive the information the networks will be on the duty at the check points to observe landslide signs and to prepare to warn their villages.

The local networks can also call the center to get information about the weather or to report landslide and flash flood information. The information is very important for the center and for other people. The center distributes the information to other networks and uploads the information on DMR website. The local networks and other agencies can contact the center anytime because the center is working 24/7.

When a large landslide occurs anywhere in Thailand, the center sends a team of experts as a rapid team to the landslide area. The team has the duty of assessing the landslide hazards and other hazards which might happen again in the area. The team's assessment is reported to DMR, local government and relevant agencies. This includes recommendations and measures to prevent and mitigate the hazards.

NETWORK COORDINATION

Presently, DMR is working as focal point for landslide monitoring in Thailand. The Geohazards Operation Center is used as monitoring and coordinating office of DMR. The center closely coordinates with the local networks and key agencies including TMD, DDPM, Department of Public Relation, TV and radio stations, and offices of provincial governors.

Since the beginning of the landslide project, DMR has coordinated with TMD on the issue of weather forecasting because rainfall is crucial in landslide monitoring. TMD provides rainfall data to DMR twice a day via facsimile, in the morning and at noon time. The staff of DMR can also estimate rainfall from weather radar data which are updated and posted every hour on the website of TMD. Then the rainfall data are used together with landslide risk data and data from the local networks to formulate watch bulletins to inform people in risk areas. In special cases, for example when typhoon, tropical cyclones or depressions approach, speed, direction and weather condition are provided by TMD. These cases usually generate heavy rain and cause landslides in affected areas. Therefore, DMR has to evaluate the affected areas and disseminate landslide watch bulletins in advance.

DDPM is another very important office in disaster management because it has branch offices in every province. The heads of the offices are also secretaries of governors in disaster management. Therefore, all activities related to the management will be forwarded to the offices. In landslide management, DMR coordinates with DDPM in local network establishment and data exchange. Especially in the local network training, the DDPM staff always participated as one of lecturers. During periods of heavy rain, DMR disseminates landslide watch bulletins to DDPM and, reciprocally, DDPM sends landslide event data and damage data back to DMR.

The Department of Public Relation, TV and radio stations are communication channels that can forward information from DMR to the local people. In general, landslide watch information is presented together with weather news on television and radio. All of these agencies are connected to the DMR by facsimile.

Landslide watch bulletins are very important information for governors to manage landslide disasters. The governors receive the bulletin from DMR via facsimile. When a large landslide event occurs, the concerned governor can promptly order local people to move to places of safety.

Local volunteer networks play a very crucial role in the warning network system because these people live and work in landslide risk areas. When DMR disseminates a watch bulletin, the volunteers receive the information through TV, Radio, Telephone and SMS. The moment they receive information, the volunteers must be on duty at their assigned check points and follow information from DMR. When they observe landslide signs in the upper stream, they must send signal to warn their villagers and other villages.

All the above-mentioned agencies and the local networks are presently integrated as community-based landslide warning network in Thailand. Since the beginning of 2007, DMR has disseminated 27 landslide watch bulletins. A great number of coordination and data exchange between DMR and the local networks and other agencies has taken place (Figure 4). After the local networks received the information, the volunteers were on duty at check points and some villages were evacuated as landslides or flash floods were observed.

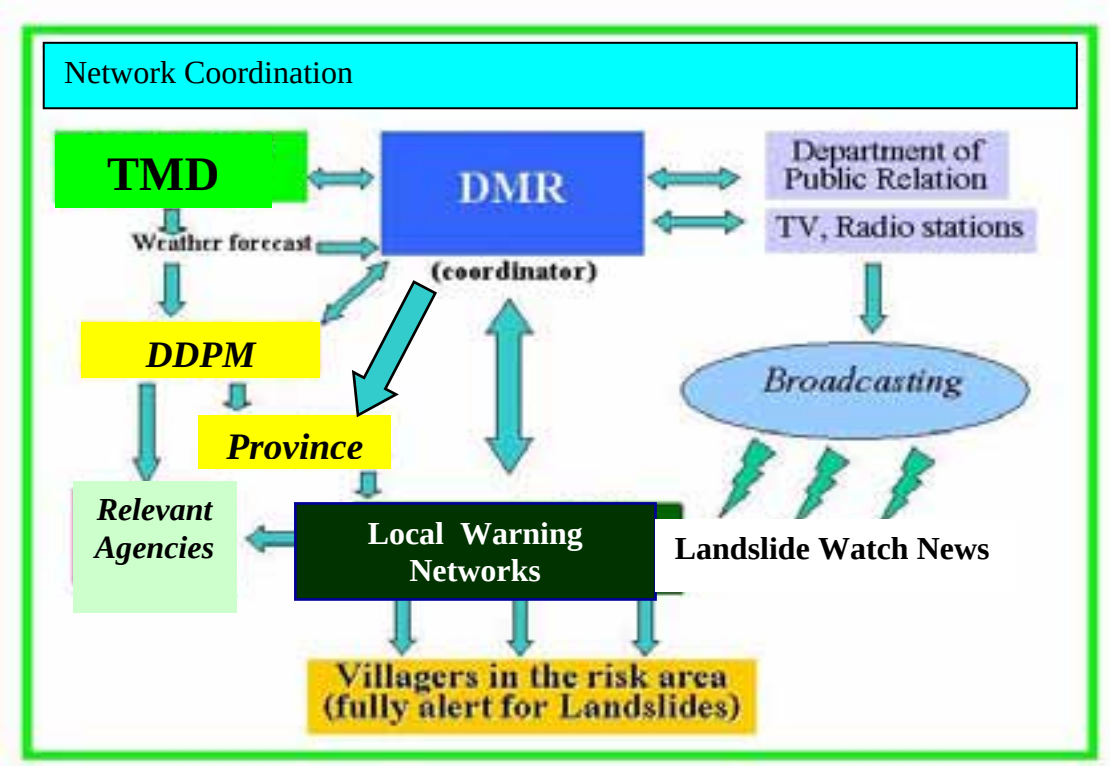

Figure 4. Shows the community-based landslide warning network coordination in Thailand. (Modified after Environmental Geology Division, 2003 a, b, c, d)

CONCLUSION

Landslides presently occur quite often in Thailand. Its occurrence starts from May to September in the northern part and October to December in the southern part. Landslide hazards and risks were assessed by DMR. The assessment found that there are 2,371 villages in 51 provinces in risky areas.

To mitigate landslide impacts, DMR established the local warning networks and Geohazards Operation Center. The local warning networks are village volunteers who work as guards at foot hills or stream/river check points to observe landslide signs. They are on duty only when heavy rains approach or when they receive landslide watch information from DMR. The volunteers were trained to have knowledge in landslide behavior, warning and evacuation. They were also trained to measure rainfall and how to coordinate with DMR. At this moment, there are 159 networks and 7,385 volunteers in the high risk areas of 19 provinces. Due to changing states of technology and knowledge and to maintain the networks, DMR has a plan to retrain the volunteers every year. DMR also established the Geohazards Operation Center to monitor landslide and to coordinate with the local networks and relevant agencies. The center is open 24/7 and is in close coordination with TMD, DDPM and governors. Satellite data, weather radar data, and rainfall measurements from TMD are used by the center to predict heavy rain. When the center detects heavy rain longer than 3 hours and heavy rain is confirmed by the local networks, the center disseminates landslide watch bulletins to relevant agencies and the local networks. DDPM and governors who have authority in disaster management are also alert to support villages in risk areas. This experience has shown that the local villages or communities play a very important role in the landslide warning network and in helping them save themselves and others.

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Geo-Hazards in Vietnam: Their Investigation, Monitoring and Mitigation

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Ministry of Natural Resources and Environment

ABSTRACT

There are about 20 types of geo-hazards known in Vietnam: earthquakes, active faults, surface faulting, land subsidence, landslides, rock falls, flash flood, mudflows, riverbank and coastal erosion, sedimentation causing changes of shipping channels, desertification as well as arsenic, fluoride and radioactive pollution. These are categorized into 4 genetic groups: endogenous, exogenous, mixed and human-generated hazards.

Having, in recent yrars, realized the adverse effects of geo-hazards, the Vietnamese Government has invested in and surveys and research on geological hazards. Geological hazard and geo-environmental mapping surveys at scales of 1: 50,000 and 1: 25,000 have been carried out in urban areas; geo-hazards surveys at scales of 1: 200,000, 1: 100,000, and 1: 50, 000 scales have been carried out in the Northwestern, Northeastern, Mid-Central, Central Highland and South-Central regions and in some shallow offshore areas (0-30m water depth). These surveys are aimed at finding the causes of the geo-hazards and solutions either to prevent or mitigate their effects.

Although some preliminary results have been obtained in this new field of study, the geo-hazard surveys still suffer from many limitations due to a variety of reasons and are not meeting fully the actual requirements. Vietnam is still lacking modern systems for geo-hazard research as well as a network for monitoring with the exception of seismic , which can only record the parameters of earthquakes that have taken place, and some experimental flash flood monitoring stations in Northwestern region. There is a lack of laboratory and investigation equipment and, in addition, there is still no national database of geological hazards. These limitations render the research and survey work inadequate to meet their actual requirements.

To cope with this problem, the Government has entrusted the Ministry of Natural Resources and Environment (MONRE) to take the lead in the formulation of a program for building a forecasting and warning network for natural risks and hazards including earthquakes, tsunamis, tropical low pressure, typhoons, floods, and other geo-hazards as well as to formulate and implement the project "Forecasting and precaution network for natural environment risks to 2010 and with vision on 2020". The general objectives are to establish a strategy for preventing and mitigating damage caused by geo-hazards, to strengthen the national capacity on planning in cope with geo-hazards and to build a forecasting and precaution network for geo-hazard risks.

OVERVIEW

At present, geo-hazards occur ever more widely in the world with ever increasing intensity due to global climate change, movements of the Earth crust and environmentally unfriendly economic activities. In Vietnam, geo-hazards also occur increasingly in various areas such as highlands and coastal plains and at any time of the day or night, causing great losses to human livelihood and property.

In the Northern mountainous region of Vietnam alone, from 1990 to the present, thirty flash flood events have occurred, causing 988 people to be either killed or be missing, 698 people injured; 13.280 houses destroyed and almost 180.000 hectares of agricultural land and crops to be adversely affected. Vietnam experienced the heaviest calamities since the beginning of the 21st century in the year 2005, with a total estimated loss of 5,232 billion VND (equivalent to about 500 million USD).

Recently, in August 2007, the extremely high rainfall, in some places up to 800-900mm/day, caused floods over vast areas of the central provinces of Vietnam with accompanying mudflows and landslides in many areas from the mountainous to coastal areas of Ha Tinh and Quang Binh provinces. Seventy five 75 people were killed and estimated losses 1,200 billion VND (equivalent to about 120 million USD) resulted. Coastal erosion occurs in many places at the rate of 50m/year over a length of up to 3,000m as in the estuarine area of Bac Lieu. River bank erosion occurs even in large cities, such as Ho Chi Minh City, forcing hundreds of households to be resettled.

For the economy of Vietnam, the above losses are very serious.

GEO-HAZARDS INVESTIGATION, MONITORING, AND PRECAUTION IN VIETNAM

Within the territory of Vietnam about 20 types of geo-hazards have been recorded belonging to 4 genetic groups: endogenic, exogenic, mixed endo-exogenic and anthropogenic, commonly comprising: earthquakes, active faulting, surface faulting, land subsidence, landslides, rock falls, flash floods, mudflows, riverbank and coastal erosion, sedimentation causing changes of shipping channels, and desertification. Recognizing the adverse effects of geo-hazards, the State of Vietnam is now paying much attention to, and provided funding for, the research and investigation of geo-hazards. This includes environmental geology and urban geological surveys at 1:50,000 and 1:25,000 scales in 64 urban areas. Geo-hazards surveys and investigations include mapping at scales of 1:500,000, 1:200,000, 1:100,000 and 1:50,000 in large areas of the Northwest, Eastern North, Mid Central, Central highland and Southern Central regions as well as in the shallow offshore areas (0-30m water depth) of Vietnam. The primary objectives of these activities are to find the causes of the hazards and to and delineate high risk areas and propose prevention and mitigation measures.

Vietnam has established national natural resources and environmental monitoring network covering several aspects of measurement and monitoring (hydrology and meteorology, earthquake, groundwater, environment, radioactivity). Every year this monitoring network is supplemented with new monitoring stations and equipment.

For many years, the Institute of Geophysics (under the Vietnamese Academy of Science and Technology - VAST) has carried out investigations in collaboration with other geological organizations in the country for compiling an earthquake zoning map of Vietnam. This map shows that there are areas with medium to low magnitude earthquakes according to MSK-64 scale, and serves as a scientific basis for anti-seismic design of building structures.

Vietnam has paid attention to the risks of earthquake-generated tsunami and actively participates with other countries in the establishment of early warning systems. To strengthen the awareness and capacity of the State agencies and communities in responding to these hazards, the Government has promulgated, and disseminated widely, a regulation on information, warning, and mitigation of earthquakes and tsunami (2006).

Various geophysical maps (magnetic field, soil resistivity, gravity, radioactivity) at 1:500.000 and 1:100.000 scales covering the whole territory of Vietnam and 1:200.000 and 1:50.000 scales covering selected areas have been compiled since 1982.

During the last 10 years, Vietnamese geoscientists have spent much effort in studying geo-hazards which are common and cause much damage such as: landslides (especially in vulnerable sections along the important transportation routes), river bank erosion, soil erosion, coastal erosion, mudflows and collapse in karsts areas.

These hazards occur frequently and in many locations during the rainy season, causing heavy losses to people and property. The results of geo-hazards investigation are due to the efforts of many geologists. Although some initial results have been obtained, as this is a new field for study, research staff are still lacking, the State budget allocation is still limited, and the studies in many aspects have not met the requirements desired. At present, there is insufficient modern equipment and adequate methodologies for investigating geo-hazards and there is still no comprehensive network for monitoring and warning of geo-hazards. The network of seismic stations has the task to record the parameters of earthquakes which have occurred. The natural resources and environment monitoring network is used for long-term monitoring for parameters of the environment and natural resources (land, water) but cannot monitor and forecast such geo-hazards as surface faulting, flash floods and coastal erosion. The number of scientific and technical staff specializing in geo-hazards investigation is still small and dispersed in many organizations. There are still no mechanisms for comprehensive multi-disciplinary cooperation in geo-hazards monitoring and the exchange and mutual assistance at both the national and international scale is still limited. Testing and survey equipment is still lacking and frequently incompatible, monitoring databases are dispersed, and there is still no international geo-hazards data base.

AWARENESS ON THE ROLE OF GEOSCIENCES IN MAKING THE SOCIETY SAFER, HEALTHIER, AND WEALTHIER

The Government of Vietnam is aware of the important role of geosciences in the sustainable development of the nation. Although the economy experiences many difficulties, the Government has tried to invest in many basic survey programs in the field of geosciences. The results of basic survey have been used by the Government, Ministries, and Provinces in formulating polices and socio-economic development plans for the nation and the regions.

Vietnam is clearly aware of the importance of the relationship between nations, at both the regional and global scales, with respect to environmental issues and calamities brought about by geo-hazards. Thus, the Government is actively engaged in international conventions for mitigating the adverse impacts of natural calamities (Agenda-21, Kyoto protocol-2005) and is undertaking activities for the International Year of Planet Earth.

Global warming and sea level rise phenomena have attracted the interest of Vietnamese and international earth scientists. According to their prediction, if the sea level rises by 1m, 12.2% of the land area of Vietnam will be lost and this will threaten the lives of 17 million people in the coastal areas. In reality, this process has been expressed in various forms of impacts in the coastal zone of Vietnam (salt-water intrusion reaching ever further inland, prolonged flooding, etc.). To curb the global warming and mitigate its impacts requires great efforts and collaboration of the international community of which Vietnam is a member.

The Government of Vietnam has assigned the Ministry of Natural Resources and Environment (MONRE) to lead the program on forecasting and warning of natural hazards (earthquake, tsunami, tropical low pressure, typhoon and flood) and other geo-hazards. Thus, MONRE is now working out the project "Network for forecasting and warning of natural hazards to the year of 2010 and with a view to 2020" with the following objectives:

- To work out a strategy on preventing and mitigating damage caused by geo-hazards, and
- To strengthen the national capacity on planning in coping with geo-hazards and to build a forecasting and precaution network for the risks of geo-hazards;

The activities of the project include:

- Enhancing awareness of State authorities and the people about the risks and adverse effects of geo-hazards (landslides, earthquakes, floods, pollution, etc.);
- Proposing essential regulations for research on geo-hazards in major economic development projects;
- Gathering, training and strengthening the capacity of scientific-technical staff and experts (at both central and local levels) in prevention and mitigation of natural hazards; upgrading the equipment to be applied in research, prevention and mitigation of natural hazards;
- Preparing metadata, establishing a data base for management of geo-hazards information;
- Compiling a set of guidelines on surveying, monitoring, forecasting, and precaution of geo-hazards;
- Compiling geo-hazard forecast maps at various scales within the whole country;
- Establishing a monitoring network for geo-hazards precaution within the whole country, especially in vulnerable areas;
- Carrying out awareness campaigns in various forms concerning causes and adverse effects of geo-hazards, with the aim to strengthen the capacity of the people in preventing and mitigating the loss of lives and properties.

All the above-mentioned programs and projects have attracted the participation of many geoscientists in Vietnam. The geoscientists and geological agencies of Vietnam are the primary forces in implementing the above activities.

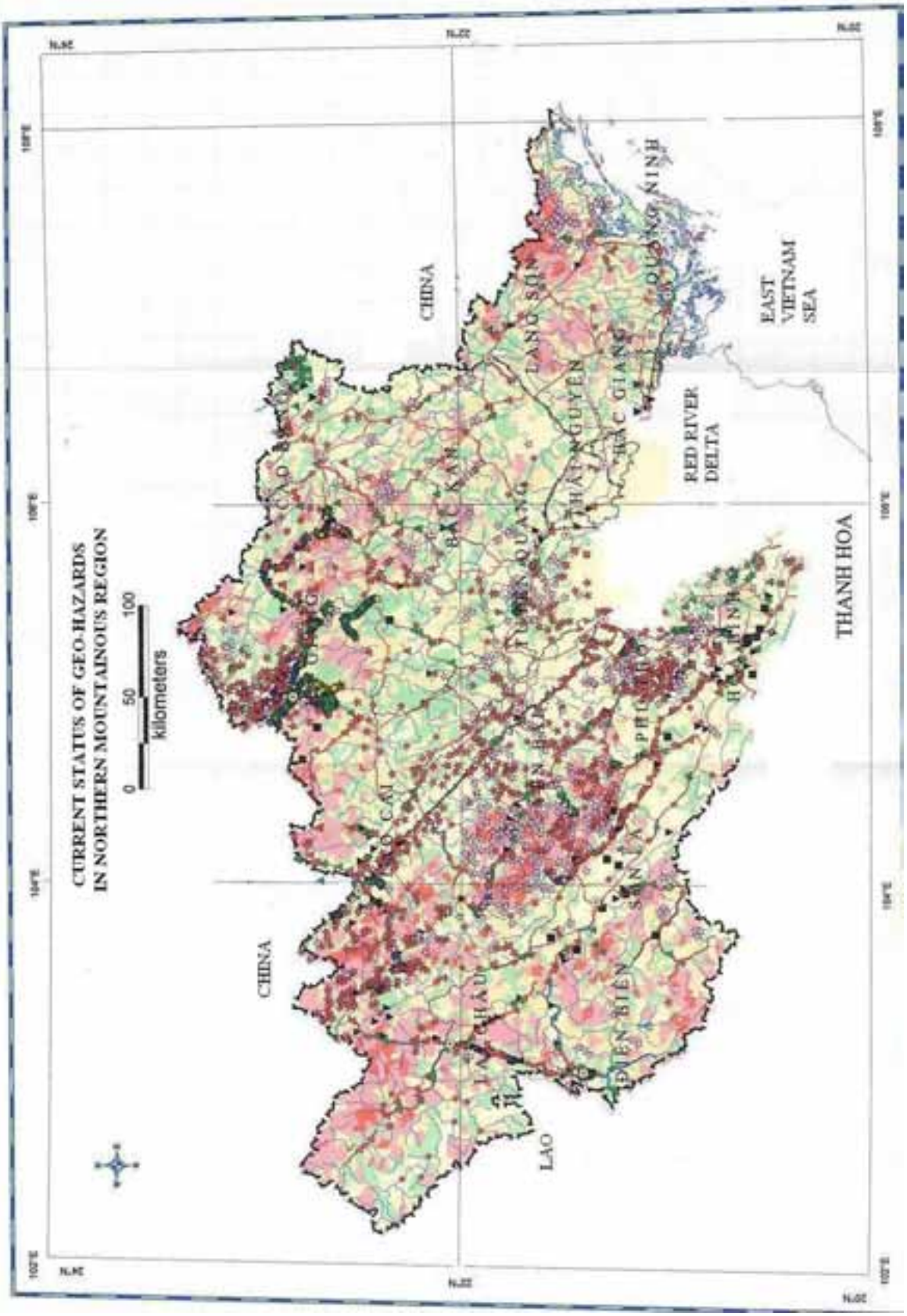
Being a country subjected to many impacts of natural hazards, Vietnam always looks forward to learn from experiences of advanced countries, both in the region and world wide, in the fields of geo-hazards investigation and mitigation.

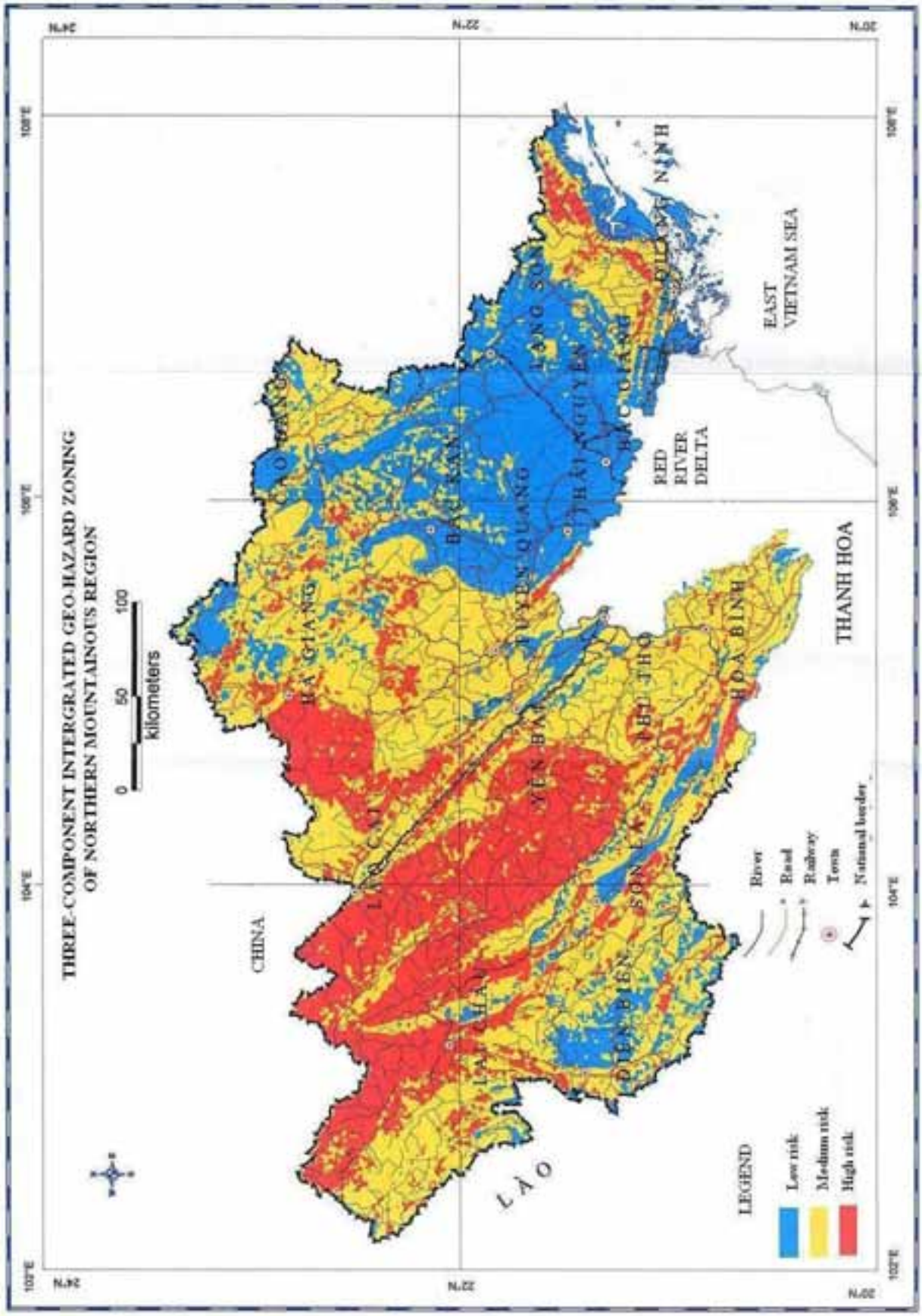
It is hoped that through international fora, Vietnam can exchange and learn more experience in managing and administering the geo-hazards investigation, monitoring and warning system and receive assistance from geoscientists in the region and worldwide to work toward a healthier and safer environment for the community.

Photo 1: Landslide damaging the provincial road No. 27 in Lam Dong province.

Photo 2: Erosion of the Red River bank in Ba Vi District (Ha Tay Province) depriving land and damaging dwelling houses.

Photo 3: Sea transgression causing coastal erosion in Ham Tan (Binh Thuan).


CURRENT STATUS OF GEO-HAZARDS
IN NORTHERN MOUNTAINOUS REGION
0
50
100
kilometers
CHINA
CHINA
LAO
LAO CAI
BAC KAN
LANG SON
THAI NGUYEN
BAC GIANG
QUANG NINH
RED RIVER
DELTA
EAST
VIETNAM
SEA
THANH HOA


THREE-COMPONENT INTERGRATED GEO-HAZARD ZONING
OF NORTHERN MOUNTAINOUS REGION
0
50
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kilometers
CHINA
LAO
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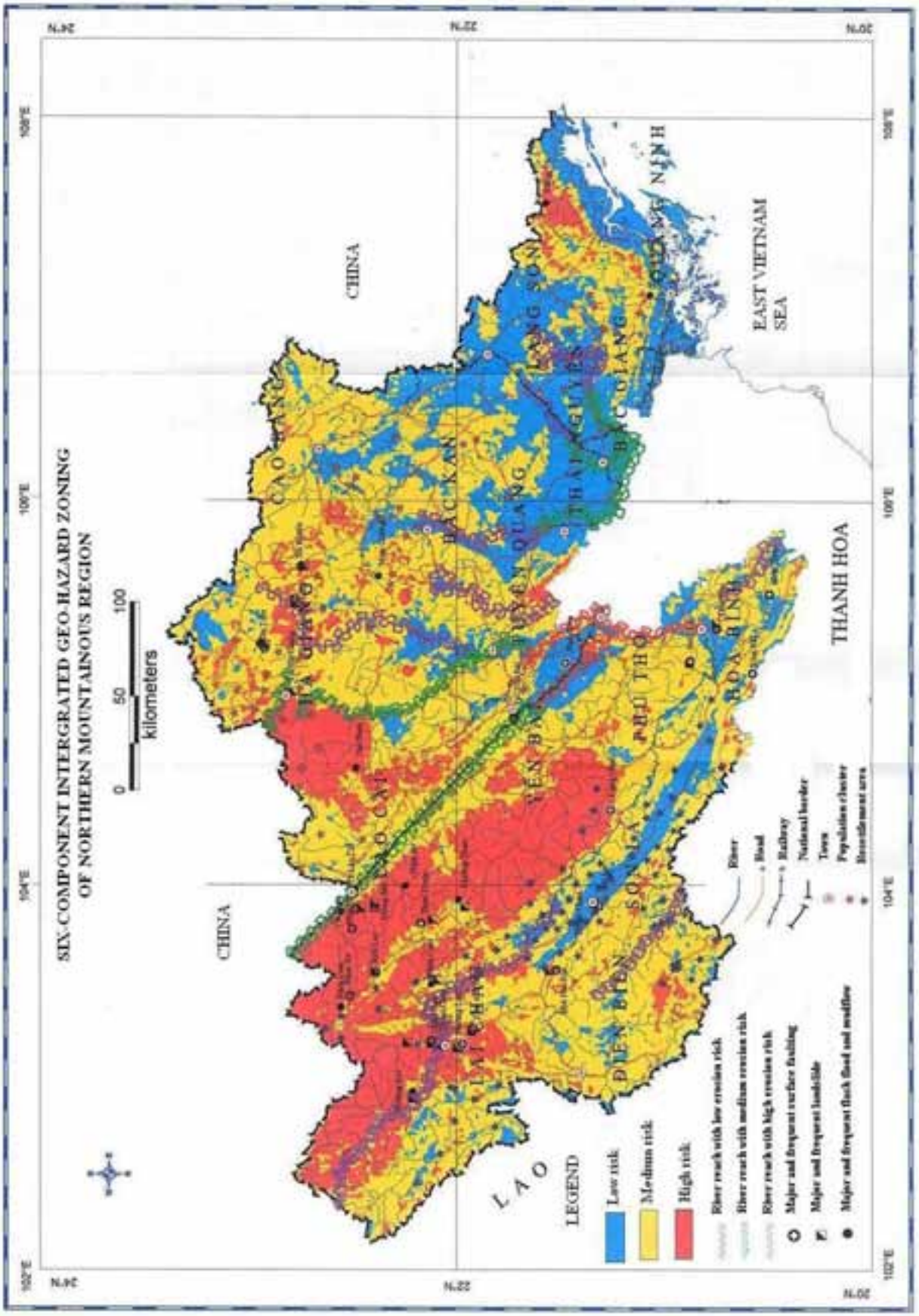
RED
RIVER
DELTA
THANH HOA
LEGEND
Low risk
Medium risk
High risk
River
Road
Railway
Town
National border


SIX-COMPONENT INTERGRATED GEO-HAZARD ZONING
OF NORTHERN MOUNTAINOUS REGION
0
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CHINA
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LAO
THANH HOA
EAST VIETNAM
SEA
LEGEND
Low risk
Medium risk
High risk
River reach with low erosion risk
River reach with medium erosion risk
River reach with high erosion risk
Major and frequent surface flooding
Major and frequent landslide
Major and frequent flash flood and mudflow
River
Road
Railway
National border
Town
Population cluster
Resettlement area

Self-Help, Community-Help and Public-Help: Lessons from the Earthquakes in Kobe and Chuetsu

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ABSTRACT

This paper will present findings from two earthquake disasters with the emphasis on self-help, community-help and public-help.

From the preliminary studies right after the Chuetsu Earthquake on July 16, 2007, researchers came across many interesting data. Among these was the information that although the magnitude of the Chuetsu Earthquake was comparable with or more likely higher than that of Kobe 1995, the death toll was less than one tenth of what had happened in Kobe, which claimed almost 6000 lives.

In Chuetsu, those who were trapped by fallen houses were immediately located and rescued. Those who lost their houses evacuated to other accommodations through their kin network or were simply offered by their neighbors to stay with them. These observations could be attributed to the fact that the local people are all familiar with one another, and they have spent their lives together as community members. This fact made it easy for them to confirm who escaped the earthquake or not in a minute. This sort of human relationship could be decisive in terms of the prevention of human loss in times of disaster.

Sub-Theme 2 :

Role of Geoscience / Climate Change

Geology as a Contributor to National Economies and Their Development

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ABSTRACT

This paper examines the direct and indirect contribution to national economies attributable to the geosciences, principally as delivered by geological survey organisations. In particular, it looks at those sectors of the economy that depend to some degree or other on the provision of geological information, and tries to quantify the cost-benefits. This analysis is done partly through case studies of countries in different stages of economic development and, by comparing geoscience dependent outputs through time, adjusted for commodity price inflation; their impact on poverty alleviation is assessed.

Primary production of natural resources is one aspect of economic contribution. However there are other factors; these include cost-damage avoidance through better understanding and mitigation of natural hazards and of support for socio-economic stability in activities such as artisanal mining and minerals trading. Finally, there are trickle down economic indicators that result from skills and educational developments associated with inward investments. Set against this is the cost of environmental damage and social disorder that are often associated with resource exploitation.

The study brings together various published materials in an attempt to set a monetary value on the collection, management and dissemination of geoscience information.

INTRODUCTION

Since the beginning of the industrial revolution in the eighteenth century, and in isolated examples going back to pre-historic times, there has been a widely accepted association between geological knowledge and economic growth. The first geological map known to us, according to Harrell and Brown[1], was drawn on a papyrus to represent the Fawakhir gold mine. Iron was smelted from ores in Aswan and smelting was also carried out at Naukratis and Defna in the Delta region. The map was drawn about 1160 BC by the Scribe-of-the-Tomb Amennakhte, son of Ipuy. It was prepared for Ramesses IV's quarrying expedition to the Wadi Hammamat in the Eastern Desert, which exposes Precambrian rocks of the Arabian-Nubian Shield. The purpose of the expedition was to obtain blocks of bekhen-stone (metagraywacke sandstone) to be used for statues of the king.

The first modern style geological map was published by William Smith in England in 1815[2]. The purpose of the map was not simply to display the geology, it was to underpin decision making in where and what to mine, where to bury and sustain, where to build and tunnel. Geology had become and applied science.

During the nineteenth and twentieth centuries, it was widely recognised that national geological survey organisations, whose role was to collect, store and disseminate geoscience information, were an important contributor to wealth creation and quality of life, but little attempt was made to quantify those contributions in cost-benefit terms. A study[3] by the United States Geological Survey (USGS) in 1993 described examples, including that of a geological re-mapping of Loudoun County in Virginia for a road corridor and waste disposal site that had avoided costs estimated to be from $1.3m to $3.5m against the original plans. An engineering geology consultancy carried out by the British Geological Survey (BGS) in 1999 at a cost of £10k was calculated to have saved the pipeline company about £10m, a cost-benefit ratio of 1:100. But such cost evaluations are rarely made, partly because they are methodological difficulties and partly because publicly funded institutions have not been required, until recent times, to justify themselves in such terms.

It is more challenging to assign monetary value to natural hazard avoidance or mitigation that result from the application of geological knowledge. Whilst damage costs in terms of rebuilding, production losses and even the value of human life, can be calculated by governments or insurance companies, it is less easy to put a price on the value of protection that results from the careful monitoring and understanding of a volcano, or the avoidance of housing developments in areas at high risk of mudslides.

ECONOMIC VALUE OF GEOLOGICAL INFORMATION IN THE MINING SECTOR

Countries, for which the primary industries of mining, quarrying and oil extraction form a significant part of their national product, are heavily reliant on geological infrastructure. This is clearly recognised by Australia and Canada, both of which maintain relatively well funded, world class geological survey organisations at both their federal and state / province levels. However, in many cases, mineral rich countries lack capacity in their geological survey organisations and depend on this being built through bilateral and multilateral aid programmes. There is competition for international inward investments, and less developed countries (LDCs) that have poor quality, old (non-digital) or unreliable geoscience information, principally geological maps, will not be attractive to investors. Such investors also look for political stability, a fair-but-firm mining code or petroleum law, reasonable infrastructure, including water supplies, absence of corruption and an available, educated and healthy work force. Thus LDCs need modern, digital and credible geoscience information and maps, and the technology and knowledge transfer suitable for the maintenance and sustainability of them.

It is relatively easy to calculate the direct costs of capacity building and maintenance in these cases, based on overall programme budgets provided by organisations such as the World Bank. Table 1 shows some recent examples of such programmes[4].

Table 1.

Country	Years	Amount (US$m)
Afghanistan	2006-2011	30
Argentina	1999-2001	23
Gabon	2005-2008	4.4
Madagascar	1999-2009	34
Mauritania	2003-2009	56
Mozambique	2001-2007	33
Nigeria	2004-2010	60
Papua New Guinea	2000-2006	11.5
Uganda	2003-2009	11.2
Zambia	1996-2008	156

Attempts to measure the benefits that result from such programmes are more difficult. In a comprehensive study[5] by Reedman *et al.* published in 2000, the authors used indirect methods to value economic growth from mining activities that were probably based on earlier geological studies, albeit with a significant time delay. They found that, in general, the cost-benefit ratios varied in orders of magnitude from 1:100 to 1:1000 but this took place over at least a decadal time period. However, the difficulty remains in making a direct connection between the cost of the geological input and the value of the mining output, which may have occurred in the absence of the geological survey's input, on the basis of investor sponsored exploration work. Furthermore, the timescales are so extensive between inputs and outputs that world demand, changing commodity prices and political upheavals or stabilisations can mask meaningful comparisons.

We have compared these relationships in case studies for South Africa, Mozambique and the Democratic Republic of the Congo (DRC), formerly Zaire. All three countries are mineral rich; South Africa is a stable and developed nation with a long established advanced capacity in the geosciences through its geological survey, universities and many private sector firms. Mozambique suffered devastating post-colonial civil wars that destroyed much of its infrastructure and left it with an inadequate geosciences capacity but has in the last few years benefited from a significant World Bank (and others) development loan (Table 1) to rebuild its geological capacity. The DRC has one of the greatest potential mineral resources in the world, but the sector is more-or-less dysfunctional because of war and political instability.

The basic economic indicators[6] of these three countries are shown in Table 2.

Table 2.

Country	Area (km^2)	Population (2006, estimated)	GDP per capita (2006)	GDP (purchasing power parity) (2006)
Mozambique	801,590	20,905,585	$1500	$29.17bn
DRC	2,345,410	67,751,512	$700	$44.44bn
South Africa	1,219,912	43,997,828	$13,300	$587.5bn

South Africa's mineral industry produced sales revenues of US$7.4 billion in 2000, representing 6.5% of the country's GDP. Sales of primary mineral products accounted for nearly 35% of South Africa's total export revenue during 2000, with gold's contribution at 12%. As a result of an increase in secondary and tertiary industries as well as a continuing decline in gold production, mining's contribution to South Africa's GDP has declined over the past 10 years (in 1991, mining's contribution to GDP was 8.4%), but has approximately retained its value in monetary terms after inflation. Thus, to a first degree of approximation, we see an established and stable economic activity producing a sectorial GDP per capita in the period 2000 to 2005 of about $800, which is dependent to some degree on a geological survey infrastructure cost[7] of $0.84 per capita per annum.

In the case of Mozambique, the mining sector accounted in 2000 for less than 2% of GDP, but provided a living, of sorts, for at least 50,000 workers in the informal artisanal sector. Part of the justification for the World Bank loan to support the geosciences capacity in the country was a planned growth of 15% per year in the mining sector between 2002 and 2005, by attracting investors partly as a result of the new maps and data[8]. In fact, growth has been better than planned, as shown by the annual percentage growth rates by mineral in Table 3, which includes natural gas[9].

Table 3.

	2002	**2003**	**2004**
Coal	57.7	-15.6	-55.0
Bauxite	6.1	29.3	-23.9
Processed bentonite	128.3	18.0	-15.5
Selected bentonite	-23.0	-57.9	-32.5
Marble in plates	-34.8	2.5	33.6
Marble block-type	41.6	-0.2	36.5
Faceable garnet	0.0	-61.3	511.0
Gold	-23.2	271.6	-10.8
Aquamarine	-44.9	-69.4	132.1
Tourmalines	578.6	370.4	170.2
Tantalite	73.7	302.3	277.4
Beryl	6,687.5	44.2	-65.1
Sand	71.3	72.4	4.2
Limestone	78.4	3.6	18.2
Riolites	57.2	-9.6	5.8
Granites	1.2	-19.5	-3.4
Durmortiorite	-20.0	0.0	182.5
Natural gas	94.6	4.1	91,405.1
Total	**52.1**	**31.6**	**215.7**

Based on these data, the sectorial GDP per capita has raised from $30 in 2000 to over $60 in 2006, partly as a result of the World Bank (and others) investment in the sector at a cost equivalent of $0.32 per capita per annum.

Equivalent data for the DRC are more difficult to come by, but a recent report[10] by the Rights and Accountability in Development (RAID) organisation states that export earnings from mining have fallen from 25% of GDP in 1975 to about 2.5% of GDP in 2005, with GDP itself declining in real terms. Clearly, that fall cannot be attributed solely to the virtual absence of any sort of geological infrastructure, as political instability and other factors are primarily to blame, but it does show that the DRC remains unattractive to investors and operators for a variety of reasons.

Thus it seems that a cost (of geological infrastructure) to output (in the mining sector) ratio of 1:952 is found in South Africa's broadly stable and established system, with Mozambique experiencing an equivalent ratio of 1:188 by 2006. These results broadly match those of Reedman *et al.* who used a very different approach to conclude that the cost-benefit ratios in their studies were between 1:100 and 1:1000 over a longer period. Further work is required to examine the ratio of cost to output in other countries and regions.

ECONOMIC VALUE OF GEOLOGICAL INFORMATION IN THE OIL AND GAS SECTOR

Traditionally, the oil and gas sector is less dependent on state sponsored geological information and is more willing to carry out its own exploration work. However, there remains a need for regional scale geological data and for a licensing and regulatory infrastructure to be in place before the major oil companies are attracted to invest heavily in an area. This requirement was recognised by the Government of Papua New Guinea and the World Bank which, in the 1990s, provided funding for development and knowledge transfer of the (then) Petroleum Division (PD) of the Ministry of Mines and Energy to attract and facilitate growth in the hydrocarbons sector. The various costs of these developments, at around $11.5m over a decade, contributed to a value growth in oil and gas exports from PNG between 1990 and 2000 of some $228m[11]. Some of this sum is attributable to commodity price increases, however oil remained at a fairly consistent price level during the 1990s, and so much of the value growth was the result of greater production. The cost-benefit ratio of the investment put into the PD to the increase in export earnings over the decade stands at about 1:20. However, the extent to which there was cause and effect, or simply the coincidence of two loosely related events, is a matter for some debate.

ECONOMIC VALUE OF GEOLOGICAL UNDERSTANDING IN GEOHAZARD MITIGATION

The principal natural hazards that affect the world are weather and its consequences (including floods, mudslides), earthquakes, volcanoes, tsunami, landslips and subsidence, natural contaminations such as arsenic in groundwater and radon, and extra-terrestrial impacts[12]. Those attributable to geological, as opposed to meteorological, causes have, over historical times, had greater impact (Table 4) in terms of loss of life.

Table 4: Selected natural disasters 1200 AD to present

Year	Country	Deaths	Description
2004	Asia	260,000	tsunami
2003	Iran (Bam)	50,000	earthquake 6.3
1999	Venezuela	30,000	mudslides
1998	Armenia	100,000	earthquake 6.9
1998	California	11	earthquake 6.9
1998	Honduras / Nicaragua	10,000	hurricane (Mitch)
1976	China	750,000	earthquake 8.3
1970	Bangladesh	500,000	cyclone / floods
1970	Peru	18,000	landslide
1902	Martinique	30,000	volcano
1883	Indonesia	36,000	volcano / tsunami (Krakatoa)
1876	Japan	27,000	tsunami
1815	Indonesia	90,000	volcano
1815	Indonesia	90,000	volcano
1556	China	830,000	earthquake
1201	Egypt/Syria	1,100,000	earthquake

Whilst no amount of geological knowledge can prevent hazards from occurring, its value comes in mitigating their impacts by advising on vulnerability reduction. This is well illustrated in Table 4 by the almost identically sized earthquakes in Armenia and California, the former of which tragically caused some 100,000 deaths whereas the latter only 11. In California, the extensive understanding of the geology and physics of earthquakes has fed into planning controls, building regulations and civil defence which, because of sufficient wealth, are properly implemented. In Armenia, like so many other poor countries, the application of the inadequate geological knowledge is weak, leaving a highly vulnerable population.

Much has been written on the devastating tsunami that affected South East Asia on 26th December 2004. The damage cost has been estimated at $9.9 billion in addition to the loss of more than 260,000 lives. Loss prevention would have depended on far more than an effective early warning system; it would have required social programmes to move populations away from vulnerable areas and engineering solutions to provide some physical protection. Estimates for the installation and operation of an early warning system for the region are approximately $30m and it is pleasing to see that this initiative is underway, albeit some time after the main catastrophic events.

Volcano monitoring is a relatively cost effective way of mitigating damage, depending on the circumstances. In the British Overseas Territory island of Montserrat, in the Caribbean, the BGS has been involved in the monitoring of the Soufriere Hills Volcano almost since the start of its eruption in the mid 1990s. Montserrat is a small island, measuring 19kms by 11kms, whose economy was heavily dependent on sugar and tourism. Although nothing can be done to prevent the destruction of the former capital, Plymouth, and much of its surrounding countryside, careful monitoring of the volcano enables the authorities to adjust the extent of the exclusion zone according to levels of volcanic activity and risk, such that death and injury to the population is avoided. Furthermore, the presence of a competent volcano observatory instils confidence so that tourism, whilst reduced from previous levels, is still present to help sustain the island's economy.

The cost of monitoring is about £400,000 per year. The benefits are less easy to identify in financial terms as they include "losses avoided" - for example since formal monitoring began, there have been no deaths or serious injuries from volcanic activity, whereas before the current phase of monitoring, there were several fatalities. Putting a monetary value of this is impossible. However, if we assume that without the confidence generated by effective monitoring there would be little or no tourism, we estimate that the benefit to GDP is at least £6m per annum (although the economy as a whole still relies on some £20m per year of grant aid from the British Government)[13].

Insurance companies, of necessity, attribute monetary value to losses and damage. In recent years, UK insurers have calculated their losses on domestic property claims from ground movements to vary from £300m per year to over £800m per year. BGS now supplies geohazard susceptibility data to insurers at a ground resolution of tens of metres. These data feed directly into the premium calculations so that householders in higher risk areas are encouraged, by virtue of greater premiums, to take what mitigating action is possible, such as tree management. More importantly, fiscal pressures should in the future deter new development in areas of exceptional risk, where insurance premiums will become prohibitive.

SOCIETAL VALUE

It is difficult to measure in financial terms the various contributions made by the geosciences to societal welfare. These range from the health care and productivity losses of sick people avoided through the supply of potable groundwater that results from hydrogeological studies, to the economic contributions made by workers who learn their basic skills in mining or petroleum before going on to reapply them in other sectors such as manufacturing or commerce.

In an attempt to understand this further in the UK context, Roger Tym and Partners were commissioned to address the twin issues of how does BGS contribute to the economy and what is the value of this contribution. Their report[14] describes the use of the OXERA value-added method as a measure of the organisation's contribution to the national economy based on the total value of all goods and services which use the BGS's products and services as an input. They found that "the total value added of national outputs to which BGS contributed for 2001 lies in the range of £34 billion to £61 billion, representing around 5% - 8% of total UK output" and excluded intangible benefits or aspects of well-being that have no monetary price, such as improved health and safety and ecological and environmental benefits. The annual cost of running BGS was, at that time, approximately £40m per year, which interestingly is about one thousandth of the value of the benefit, a ratio consistent with previous discussions.

CONCLUSIONS

This paper has looked at various ways that geological information and infrastructure, usually embodied in a geological survey organisation, can benefit the "healthier, wealthier and safer" society. In so doing, attempts are made to compare costs with gains in monetary terms. The difficulties of doing this have been recognised but, nevertheless, this and various other more comprehensive studies have all pointed to a cost to benefit ratio that is in the orders of magnitude 10^2 to 10^3.

What has not been looked at is the optimal level of expenditure on geological infrastructures. There is no suggestion that the cost-benefit ratios would be sustained if costs were increased; doubling the size and scope of a geological survey organisation is unlikely to generate a doubling of benefit for the economy, although halving it might have a greater effect in the opposite direction. This then raises the interesting, and unaddressed, question of what is the right size for expenditure under different conditions and circumstances. There is a great deal of scope for further research towards understanding a methodological approach to deciding optimal investment in geoscience information and infrastructure.

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Climate Change Issues: Examples of Earth Science Solutions

Jean Claude Guillaneau
BRGM – Director - International Division of BRGM

Through the work of: D. Bonijoly, J. Casanova, I. Czernichowski, S. Chevrel, P. Guennoc, D. Guyonnet, J. Varet, J. Villeneuve, C. Fouillac, N. Lenotre, M. Garcin, C. Vinchon, D. Pennequin, P. Lachassagne, I. Thinon, W. Kloppmann

ABSTRACT

"The Norwegian Nobel Committee has decided that the Nobel Peace Prize for 2007 is to be shared, in two equal parts, between the Intergovernmental Panel on Climate Change (IPCC) and Albert Arnold (Al) Gore Jr. for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change.

Indications of changes in the earth's future climate must be treated with the utmost seriousness and with the precautionary principle uppermost in our minds. Extensive climate changes may alter and threaten the living conditions of much of mankind."

This citation from the press release of the Nobel Committee is illustrating the worldwide concern about climate change effects.

The Earth Sciences are offering some of the answers to this key issue for both mitigation of the problem sources and adaption to some of its effects.

Regarding the mitigation, examples will be presented on:

- *the development of geothermal energy uses,*
- *the practical development of CO_2 storage,*
- *the mineral sequestration of CO_2, and*
- *the clean waste management.*

In addition, examples of adaptation will be illustrated with coastal protection concerns and with the increased difficulty of protecting the underground water resources.

Do We Need a Permanent and Stronger ICOGS ?

Arne Bjørlykke
Member of Executive Committee of EuroGeoSurvey and President of 33IGC

ABSTRACT

The International Consortium of Geological Surveys (ICOGS) is a platform for exchange of information between and among the national geological surveys. ICOGS holds a symposium every four years at the International Geological Congress (IGC). The next symposium will be held in Oslo in 2008.

In the business meeting of ICOGS in IGC Florence in 2004, a committee was created to look into the future direction of ICOGS. Irwin Itzkowitch was appointed chairman of the committee and the minutes of this business were circulated.

There is increasing globalization in earth science, and the need for global databases and geological models is growing. The British Geological Survey (BGS) proposal for a 1:1,000,000 digital map of the world ('One Geology' project) is one important step in that direction. There is also a need for global databases on hydrocarbons, metallic and industrial minerals. Groundwater, natural hazards, and paleoclimate are other areas of concern. ICOGS could play an important part in bridging the gap between map and database owners (Geological Surveys) and users of global knowledge and data (Industry, UNESCO and other UN organizations).

In order to make good global databases, data from all countries are needed and participation of all geological surveys is required. It is important that this participation take place in an organized way. ICOGS may develop into an umbrella organization taking care of the geological surveys interested in the global cooperation. Rights and responsibilities related to development and maintenance of common databases should be taken into consideration.

ICOGS may also play a role in advising the UN-system within the field of earth science together with IUGS, IUSS and IUGG and work for an international union in earth science.

The first step is to vitalize the committee to prepare a proposal for a permanent ICOGS organization with a vision and a mission. A simple organization with a few regulations is proposed. One possibility is to formalize the present practice with an assembly meeting every four years during the IGC meeting, and every geological survey may be a member of ICOGS. During the assembly both business meeting and symposia of common interest between the surveys will be arranged. Between the assembly meetings, ICOGS will be led by a board with representatives of regions like EuroGeoSurveys and Asia, Africa, Russia with neighboring states, North America and, South America.

Activities of the Asian Disaster Reduction Center (ADRC) Concerning Awareness and Cooperation in the Geosciences

Takaaki Shiratori
Senior Researcher, Asian Disaster Reduction Center

ABSTRACT

The Asian Disaster Reduction Center (ADRC) was established in July 1998 with a mandate to facilitate multinational cooperation for disaster reduction in the Asian region. Along with 25 member countries, ADRC pursues activities leading to further prosperity and safe, peaceful, and comfortable lives for the people of Asia. ADRC also addresses issues of concern related to disaster reduction from a global perspective, in cooperation with international organizations and initiatives.

Along with its mandate, ADRC has proposed a unique GLobal disaster IDEntifier number (GLIDE) for disaster events as a tool for facilitating the sharing of disaster information archived by organizations around the world. The idea was shared with various organizations including OCHA/ReliefWeb, and was jointly launched as the new initiative, "GLIDE". (http://glidenumber.net/) Thus, the National Disaster Coordinating Council (NDCC), the Office of Civil Defense (OCD), the Government of the Philippines, and the ADRC conducted a cooperative project that was launched in August 2006 to develop a GLIDE-associated disaster database and website in the Philippines.

There are several other activities of ADRC. Among these were the proposed establishment of "Sentinel Asia" in 2004 by the Asia-Pacific Space Agency Forum (APRSAF) to showcase the value and impact of earth observation technologies, combined with near real-time internet dissemination methods and Web-GIS mapping tools. Moreover, ADRC and the Japan Aerospace Exploration Agency (JAXA) have been developing a new disaster image distribution system for ADRC member countries and, since 2004, have been creating a user-friendly GIS-based remote sensing database accessible via the web (http://dmss.tksc.jaxa.jp/sentinel).

ADRC also introduced the method called "Town Watching" in Galle District, Sri Lanka. With the collaboration of ADRC, the ultimate goal was to assist the notion of comprehensive and sustainable disaster prevention activities taking a firm hold in Sri Lanka. This project mainly consisted of three different categories of workshops, namely: District Workshop, Pilot Community Workshop and Community Workshop.

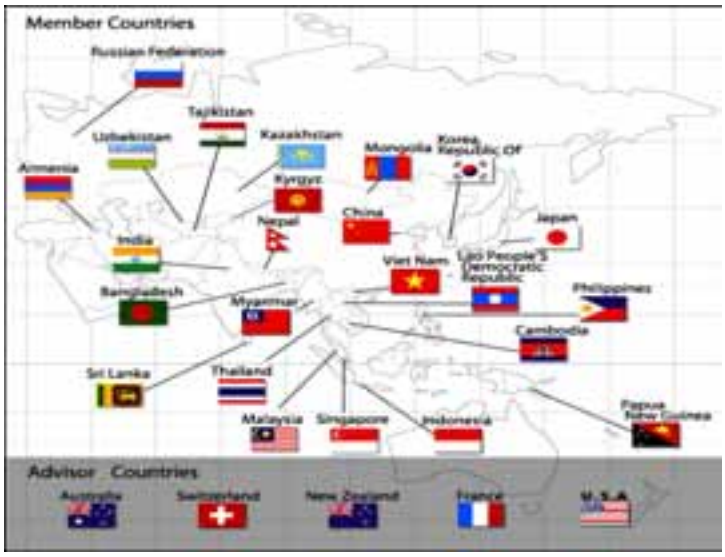
A field survey by questionnaire was also conducted from 15 to 17 January, 2007, in the areas affected by the mudflow that occurred in southern Luzon Island in the Philippines. The result of the survey indicated that there was a lack of evacuation sites at the time of the mudflow and imperfections in the early warning system. About 60% of the people responding to the survey expect another disaster of the same scale to occur here in the future.

1. INTRODUCTION TO ADRC

The Asian Disaster Reduction Center (ADRC) was established in July 1998 with a mandate to facilitate multinational cooperation for disaster reduction in the Asian region. Along with 25 member countries, ADRC pursues activities aimed at leading to further prosperity and safe, peaceful, and comfortable lives in Asia.

ADRC also addresses issues of concern related to disaster reduction worldwide in cooperation with international organizations and initiatives, such as the International Strategy for Disaster Reduction (UN/ISDR), the United Nations Office for the Coordination of Humanitarian Affairs (UN/OCHA), UNESCO, the United Nations University (UNU), the United Nations Economic and Social Commission for Asia and the Pacific (UN/ESCAP), World Meteorological Organization (WMO), United Nations Development Programme (UNDP) and the World Health Organization Regional Office for the Western Pacific (WHO/WPRO)) .

Main Activities of ADRC:
Information Sharing
Human Resource Development
Enhancement of Community Capabilities



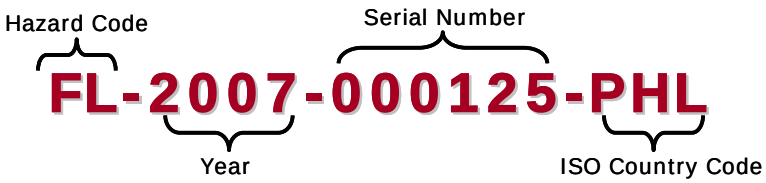
25 Member Countries,
5 Adviser Countries

2. SEVERAL EXAMPLES OF ACTIVITIES OF ADRC INVOLVING COOPERATION IN GEOSCIENCES

2.1 Development of the GLIDE-associated Disaster Database and Website in the Philippines

What is the GLIDE?

ADRC proposed a GLobal unique disaster IDEntifier number (GLIDE) for disaster events, as a tool for facilitating the sharing of disaster information archived by organizations around the world. The idea was shared by various organizations including OCHA/ReliefWeb, and was jointly launched as the new initiative, "GLIDE". *(http://glidenumber.net/)*



Contents of the Development

The National Disaster Coordinating Council (NDCC), the Office of Civil Defense (OCD), the Government of the Philippines, and the Asian Disaster Reduction Center (ADRC) conducted a cooperative project that was launched in August 2006 to develop a GLIDE-associated disaster database and website in the Philippines.

The importance of having a disaster database for disaster response and decision-making is recognized by the Philippine Government. The project will enable international access to disaster information by creating a disaster database and website that will chronicle disasters in the Philippines over the past 30 years and incorporate the relevant GLIDE numbers.

The use of these disaster data is also expected to facilitate rapid and efficient natural disaster response. This project is a leading opportunity to promote the GLIDE system, an effort in which the ADRC is playing a central role.

2.2 Promotion of "Sentinel Asia"; A Disaster Management Support System in the Asia-Pacific Region utilizing earth observation satellite data

"Sentinel Asia" was proposed in 2004 by the Asia-Pacific Space Agency Forum (APRSAF) to showcase the value and impact of earth observation technologies, combined with near real-time internet dissemination methods and Web-GIS mapping tools.

Since 2004, ADRC and Japan Aerospace Exploration Agency (JAXA) have been developing a new disaster image distribution system for ADRC member countries and creating user-friendly GIS-based a remote sensing database accessible via the web (*http://dmss.tksc.jaxa.jp/sentinel*). Operation was started in October 2006. Everyone can view information on website.

2.3 Community's Capacity Building for Natural Disaster Risk Management - Community Based Hazard Mapping in Galle District, Sri Lanka -

In Sri Lanka, the traumatic damage caused by the Indian Ocean Tsunami has resulted in enhanced public awareness of disaster mitigation. However, without much experience of natural disasters in the past, the country does not possess any effective and efficient measures to maintain and improve knowledge on disaster prevention. For enhancing the capacity for disaster prevention at the community level, it is a very practical approach to transfer Japanese knowledge and know-how gained through disaster experiences in Japan.

As one of the most effective ways to achieve this, ADRC introduced the method called "Town Watching". This method, used in Japan, involves groups of local residents, government officials and experts being involved in analysis and deep discussions for the purpose of sharing common understanding. This method has already been recognized for its favorable outcomes in Japan. With the collaboration of the Disaster Management Center in Sri Lanka, an institution newly established in 2005, the goal was to encourage comprehensive and sustainable disaster prevention activities taking a firm hold in Sri Lanka.

This project mainly consisted of three different categories of workshops.

The first category, "District Workshop" was designed to provide the local government officials with an opportunity to learn the town watching methodology. It was held from 18 to 20 April 2006 with 100 participants from local government offices in Galle District.

The second category, "Pilot Community Workshop" was held to train or enhance the skill of the district workshop participants.

The third category, "Community Workshop", was held from June 2006 to March 2007.

The local government officials who had attended the "District Workshop" were to be the trainers of the "Community Workshop". Daily project management was operated by three local staff hired by ADRC, in concert with ADRC researchers visiting Sri Lanka from time to time throughout the project period. The latter could monitor the latest progress of the project implementation and provide appropriate advice in response to the local staff's needs.

This project was supported by Japan NGO Grant Aid and was completed on 30 March 2007. In total, a hundred community workshops were held in 19 divisions of Galle District and 3,350 residents participated in the project.

2.4 Investigation of the Liquid Mud Disaster at Mt. Mayon in the Philippines

From 15 to 17 January, 2007, Dr. Rolando P. Orense, Associate Professor at the Department of Civil Engineering at Yamaguchi University, and Mr. Makoto Ikeda, ADRC Researcher, conducted a field survey in the areas affected by the mudflow that occurred in southern Luzon Island in the Philippines.

Mayon Volcano, a strato-volcano known for its almost perfect cone, reaches to a height of 2,462 m and has a base circumference of 62.8 km. Its symmetric cone was formed through deposition from alternating pyroclastic and lava flows.

The upper slopes of Mayon are steep, reaching angles of 35-45 degrees. It has erupted 49 times since the first documented activity in 1616. Vulcanian eruptions in 1984, 1993, and 2000 resulted in large quantities of volcanic products which were re-deposited on the slopes of the volcano.

On 30 November 2006, the super-typhoon “Reming” (international code name: Durian) struck the southern part of Luzon Island where it caused widespread flooding, damaged property, and triggered landslides and mudflows in 11 provinces.

“Reming” had maximum sustained winds of 190 kmph near its center and gusts of up to 225 kmph. Camarines Sur was greatly affected by the strong winds and floodwater, while Catanduanes was isolated after being struck by strong winds. Thousands of passengers in Sorsogon ports were stranded. However, the province of Albay suffered the most damage, with the intense rainfall triggering flash floods and lahar flows from the slopes of Mayon Volcano.

The casualties caused by Typhoon Reming amounted to a total of 655 deaths, 2,437 injured and 445 missing (OCD-5, 2007).

A result of a questionnaire survey indicated that there was a lack of designated evacuation and of knowledge about such sites and also imperfections in the early warning system. About 60% of the people expect another disaster of the same scale to occur here in the future.

The Role of Geoscience Information Systems in Sustainable Regional Development Planning in Asia

Kimberley J. Patrick and Tom S. Loutit
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ABSTRACT

Global climate change, rapid population growth, and economic development will continue to put significant pressure on limited energy, mineral, and water resources, putting further stress over already strained ecological systems and worsening poverty in much of the developing world. This may inevitably lead people to fight over ever-dwindling supplies, with the potential to threaten regional peace and security.

Planning appropriate action on major water, energy, and related climate change issues requires better access to sufficient and relevant information on the systems considered. More than this, the knowledge base on our water and energy resources and waste disposal options, has to be continuously developed and updated. Geoscience information systems are critical to planning internally-funded development and estimating the amount and timing of external funding that will be required.

It is well known that geoscience information is critical to finding resources such as petroleum and minerals. The capital generated from these resources has fueled rapid development in many countries. However, very few countries have taken a big picture view of the life of these resources and factored this into developing a sustainable development plan for the country. Norway is the exception; having recognized the short life time of their petroleum resource, the government has put much of the profits into a fund for the future.

Ideally, a developing country would like to have an estimate of potential water, energy, and mineral resources early in the development so that the value of these resources can be factored into the development plan. However, the nature of geoscience exploration makes it difficult to estimate the total resource value of a country early in an exploration program. Generally, reliable estimates come when an exploration and development program is mature, and there has been considerable evaluation by drilling.

Experience shows that most countries have existing datasets that can be used to build a geosciences information system that will form the basis for sustainable regional development planning. Often these datasets have been in existence for 20-30 years but have not been fully utilized. Increases in computing power, increasingly sophisticated software and good geological interpretation can be used to turn existing datasets into rigorous information systems to plan exploration for petroleum, minerals, groundwater, and geothermal energy, and to locate natural hazards and sites for burial of wastes like CO_2. Using the SEEBASE™ workflow, it is possible to build geoscience information systems for countries within a 6-8 month period.*

This paper will focus on the building of geoscience information systems for sustainable regional development planning using groundwater as the key commodity. But the geological framework allows the user to lay the base for understanding the distribution of all resources in sedimentary basins and the underlying basement in both the onshore and offshore.

**SEEBASE™ Structurally Enhanced View of Economic Basement*

Sub-Theme 3 :

Geoscientific Researches and Studies

Assessment of Coastal Geo-Environmental Changes in the West of Bohai Bay, China

Wang Hong
Coastal Geo-Environmental Change Research Group (CGEC),
Tianjin Centre, China Geological Survey

ABSTRACT

As one of the most active groups dealing with coastal geological investigations and assessments in the China Geological Survey (CGS), the Coastal Geo-environmental Change Research Group (CGEC) has given many briefings concerning the coastal geology of Bohai Bay, China, to various regional and/or worldwide organizations. An updated summary of multidisciplinary studies in Bohai Bay by CGEC, focused mainly on the year 2006, is given in this paper.

INTRODUCTION

Bohai Bay is bordered by an extensive coastal area of considerable economic and geo-environmental significance (Figure 1).

Figure 1. A sketch map showing Bohai Bay and its economic activities, including three major parts. ***I. Tianjin Binhai New Area:*** (1) The Tianjin Binhai New Area, located at the west Bay head, is newly designed by the central government as the "Third Pole" for China economic blooming. (2) Tianjin New Port, the largest harbor in north China. (3) The reclamation area, filled completely on the original muddy intertidal flat and the upper part of the subtidal zone. (4) Different tourism parks or existing resorts. (5) Levees for oil drilling platforms. (6) Newly designed reclamation zone on the muddy tidal flat. ***II. Caofeidian Industr. Zone and Nanpu Oil Field*** and ***III. Huanghua Habour and Bohai New Area.***

In 2006, the Chinese central government designated the *Tianjin Binhai New Area*, along the Bohai Bay coast, east of Tianjin City, as the "Third Pole" for China's economic development after the "Pearl River Triangle" and the "Chanjiang River Triangle". The Pearl River Triangle is composed of its delta and Guangzhou-Shenzhou-Hong Gong Metropolitan Group; the Changjiang River Triangle consists of its delta and Shanghai-Suzhou-Wuxi-

Changzhou-Jiaxing Metropolitan Group. Both Economic Regions have been called the "first" and the "second" poles, respectively, driving the China's economic blooming in the past two decades. The Binhai New Area, situated at the western head of Bohai Bay, has coastal lowland of ~2,700 km^2 with ~150 km-shoreline and ~1,500 km^2 of shallow sea from 0 to -10 m in water depth (Figure 1).

Faced with global warming, sea level rise and other natural hazards as well as human impacts, CGEC is providing the information needed to support sustainable coastal development and management. A better understanding of coastal geo-environmental changes in the recent past together with present and future trends will allow relevant evaluations of the strategic policies for coastal development.

The following is a report on recent work towards this objective (CGEC, Tianjin Centre)

PRELIMINARY RESULTS

Sequential Mapping

During the recent years the CGS (Tianjin Centre) has continuously accumulated Eijkelkamp cores. Up to now, ~4,000 Eijkelkamp cores have been drilled along the Bohai Bay coast (Figure 2). As a result, sequential 3D mapping, shown as colour-insert, was undertaken based on the "sequential mapping" concept (Streif, 1978).

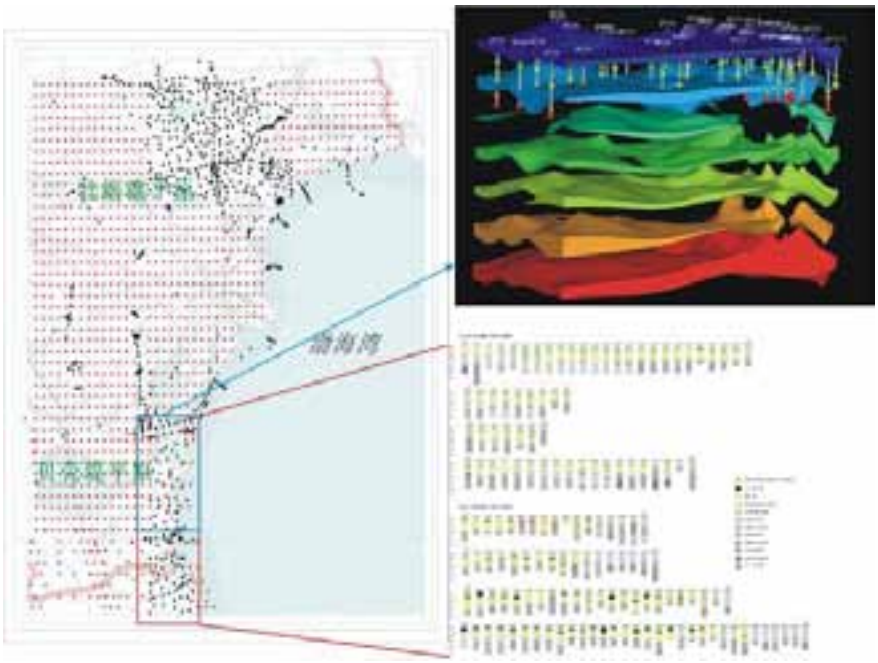


Figure 2. A 3D Visualization for the coastal shallow strata. 50 Eijkelkamp cores, distributed on the coastal lowland of ~150km^2, west Bohai Bay, revealed shallow strata of 6–8m and dating back to last ~4,000 yrs. Such strata are subdivided into 11 layers, attributed to the informal lithostratigraphic units: "Yellow Unit" in the upper, mainly lagoonal and salt-marsh, and "Gray Unit" in the lower, open tidal environment, with preliminarily chronostratigraphic framework, given by ^{14}C and OSL mainly. All the cores are leveled by Geodimeter based on the National Datum and Portable-GPS, or even DGPS, fixed. Consequently, such data are spatially-temporally characterized and represented as pseudo-3D diagram, by using C-Tech ware, shown at the upper right of the figure (Wang Hong et al., 2003, 2005).

Basal Shore Line

A 'Basal Shore Line' is an administrative landscape mark being legislatively fixed in many countries such as the Netherlands, USA, UK and Australia. However, there is not a legally designated basal line along the Bohai Bay, instead, a shoreline of the 1950s, is selected from a cluster of shorelines taken from various maps covering the shoreline changes for the last 130 years (Figure 3).

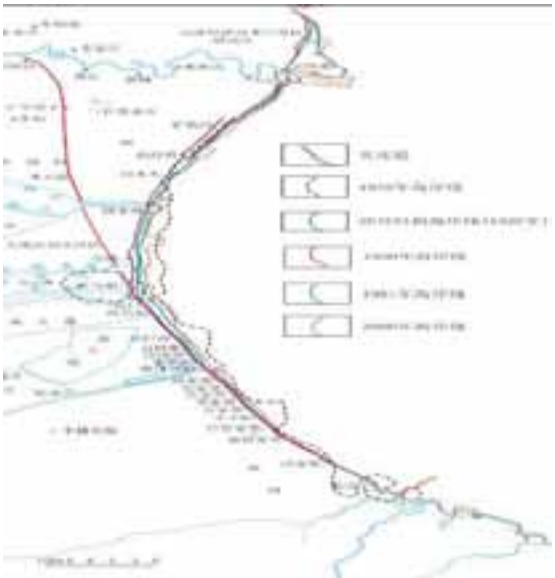


Figure 3. A schematic distribution map showing six shorelines of 1870, the beginning of 20c., 1950, 1981 and 2000, respectively. We select the 1950-line from such a cluster as a very preliminary "Basal Line" because it is more precise than the earlier ones and less human-influenced than the later ones. Compared to the length of ~130 km in 1870, the Line was only 92 km due, most probably, to shoreline erosion after the "LIA" (Little Ice Age): totally, 40 km of protruding sectors of the 1870-shore were eroded landward by 1-3 km, at max. ~40m/yr. However, this "Basal Line" is not the Basal Coast Line of the Netherlands neither National Baseline of Coastal Land, USA (Wang Hong et al., 2002, 2007).

Dating Young Sediments

Among ~100 sets of ^{210}Pb and/or ^{210}Pb/^{137}Cs data in the Circum Bohai Sea region, CGEC has contributed ~40 sets, among which ~25 sets have been dated in the Institute of Geography and Limnology, Chinese Academy of Sciences and Stony Brook University, Long Island. In 2006, CGEC cooperated with Dr. L. Robbins and Dr. C. Holmes, USGS Coastal Center, St. Petersburg, to date shallow sea modern sedimentation rates.

This enabled CGEC to summarize three essential models for ^{210}Pb distributions in the coastal sediments (Figure 4) and draw a very preliminary map showing distribution of the modern depositional rates in the west Bohai Bay and Huanghe River Delta (Figures 5 and 6).

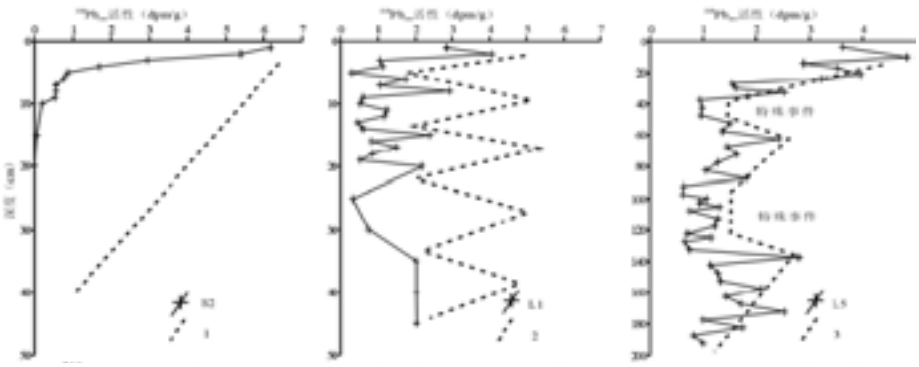


Figure 4. Three types of the measured vertical distributions of ^{210}Pb radioactivity, west Bohai Bay: (1) Ideal Decaying Type, (2) Wiggling with Approximate Equivalent Amplitude, (3) Episodic Event Influencing Type (Wang Fu et al., 2005).

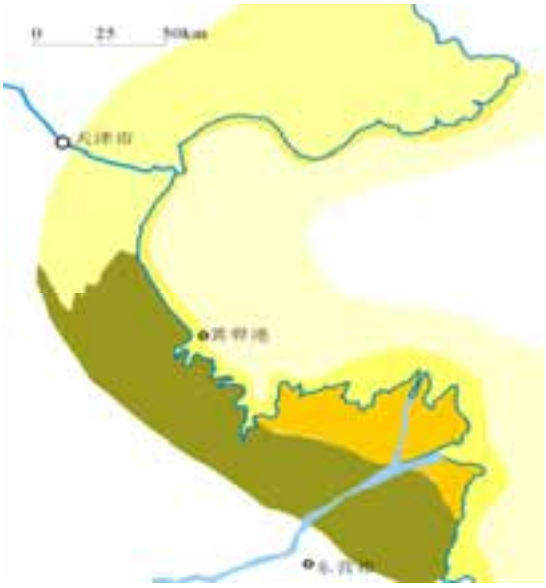


Figure 5. A schematic map showing the approximate modern sedimentary rates in the west coast of Bohai Bay. Rapid slumping accretion in the front of Huanghe R. Delta is in excess of 30cm/yr and even higher (Ye Yuguang et al., 1987, 1988). Coastal lowland behind the cheniers is as low as ~0.1cm/yr while open lowland is higher to ~0.5cm/yr. At the upper part of open tidal flat, the modern deposition is very active with rate of ~3–5cm/yr.

To better understanding the modern sedimentary process at the shallow sea bottom a systematic investigation is needed. This is a part of a modern sedimento-dynamic study and will be a linchpin to serve reclamation and other kinds of coastal engineering activities (Wang Hong et al., 2002).

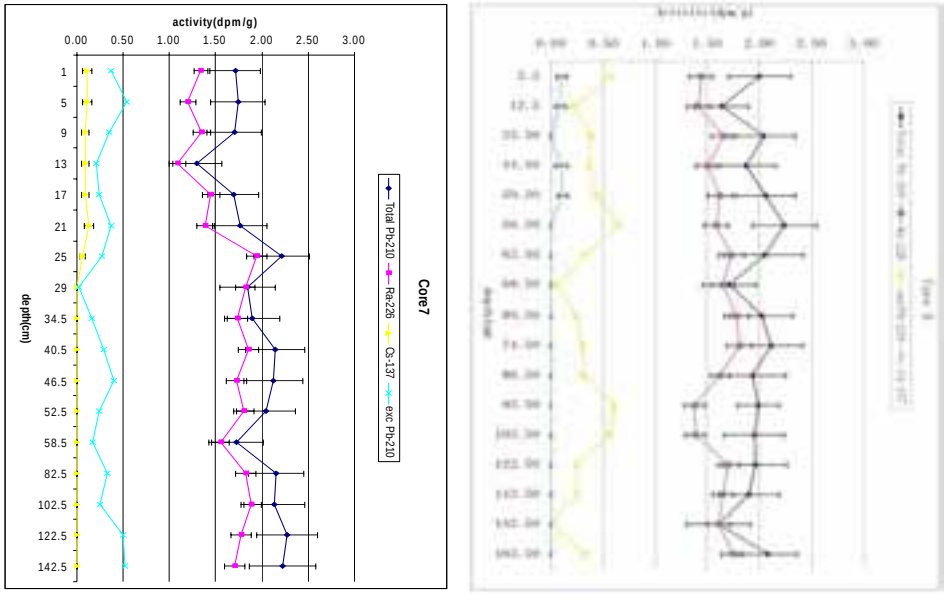
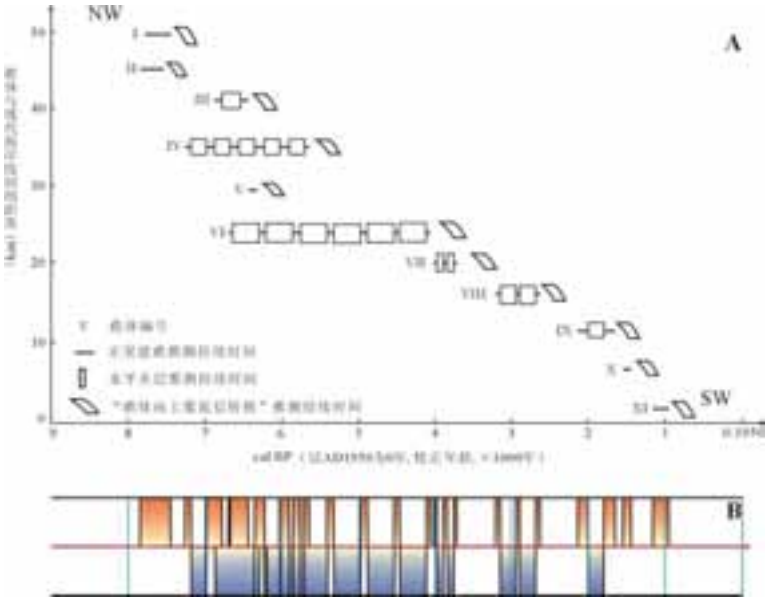


Figure 6. New ^{210}Pb and ^{137}Cs results measured in USGS Coastal Center, St. Petersburg in 2006 (Wang Fu and Pei Yandong, 2007, in prep.).

Comprehensive Studies of the Oyster Reefs

The local Holocene Oyster Reefs, consisting of *Crassostra gigas*, are very famous around world. In recent years, CGEC contributed a summary paper (Wang Hong et al., 2006) (Figure 7) concerning the reefs. An additional paper discusses the possible influence of the regional carbon reservoir for dating the local shells (Fan Changfu et al., 2006).

High resolution micro-sampling and isotope analysis for ^{87}Sr/^{86}Sr composition and palaeoenvironmental and palaeoclimatic reconstruction of the reefs is being carried out at North Carolina University by various colleagues and with the cooperation of Dr. D. Surge.



Figire 7. Temporal-spatial distribution of the Oyster Reef Groups on the Oyster Plain, northwest coast of Bohai Bay. **(A)** Numbering of the normal building-up layers, intercalated horizontal layers and the durations, respectively, for each Group from NW to SE along the ~50km-wide coastal plain. **(B)** Temporal distribution of the normal building-up (red) and the horizontal intercalated layers and the transitional beds, overlying the reef bodies (blue). The Group XI is alive nowadays and is being restricted as patches on the upper part of the present-day subtidal zone due to human influence (see Figure 19 for details, Wang Hong et. al., 2006).

Diatom Assemblages of Bohai Bay

This year, CGEC investigated more than 15 samples, taken from the modern intertidal flat, sea bottom and cores for their diatom analysis. Preliminary results show the existence of three assemblages in the Bohai Bay region (Shang Zhiwen, 2006) (Figures 8 and 9).

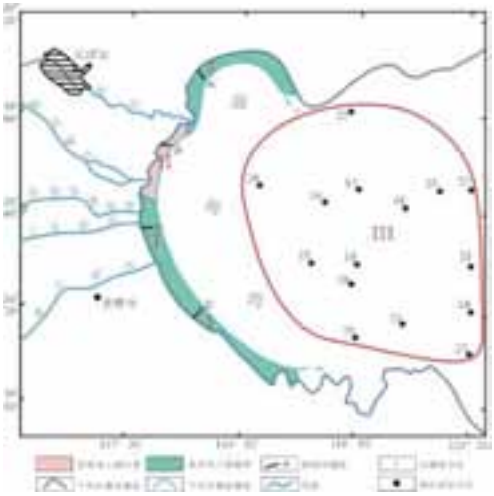


Figure 8. A total of 14 samples were taken from 14 stations, along the four sections perpendicular to the present shoreline, shown as A, B, C and D, for diatom study. Each section is 2–3km long in the intertidal zone. 46 species of 21 genera were found from the modern surficial sediments. Comparing with the previous results of the shallow sea assemblages, given by Jiang Hui (1987) and Cheng Guangfen and Cao Yuqiang (1991), three assemblages can be divided as I, II and III (Shang Zhiwen et al., 2006).

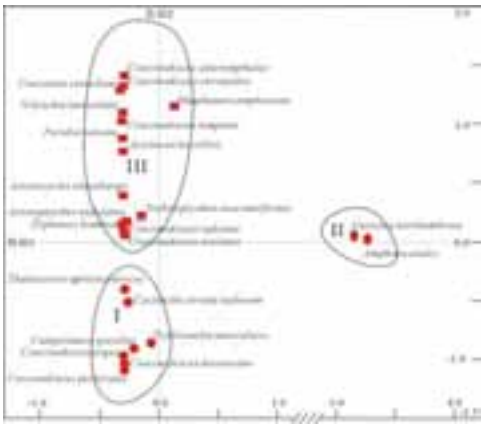


Figure 9. By using a Correspondence Analytical Method, the three assemblages are as follows. (I) *Cyclotella striata/ stylorum*– *Coscinodiscus* spp., distributed in the mud-dominated intertidal zone; (II) *Amphora* spp.–*Achnanthes* spp., stretches on the sand-dominated intertidal zone; (III) *Cyclotella stricta/stylorum*–*Nitzschia* spp.– *Coscinodiscus* spp.– *Palaria sulcata*, in the shallow sea. From the intertidal zone to the shallow sea, the percentage of *Cyclotella stricta/stylorum* reduces and the *Palaria sulcata* rises with increasing water depth (Shang Zhiwen et al., 2006).

Furthermore, four boreholes, 80m to 30m depth, in the intertidal flat and shallow sea area, have being analyzed for their diatom compositions.

Grain Size Distribution and Changing Trend in the Surficial Sediments

More than 200 bottom-samples of surficial sediments were collected at (1) the intertidal flat and (2) the upper part of the subtidal zone along nine sections perpendicular to the present shoreline, and (3) in the shallow sea area. Figure 10 indicates four selected sections in the north of Tianjin New Harbour.

Sixteen samples, taken from the four sections, were measured by the Fractional–Pipette and Laser granulometry methods, respectively, in order to make a comparison (Che Jiying et al., 2006) (Figures 10 and 11).

Figure 10. A map showing the four sections, located at the north of the Tianjin New Harbour and perpendicular to the modern shoreline, stretching onto the lower boundary of the intertidal zone. Solid circles indicate the sampling positions. Following the shoreline recession immediately after the LIA (Little Ice Age), the tidal flat becomes wider and stickier. Such a fining process is an essential fact of the Bohai Bay.

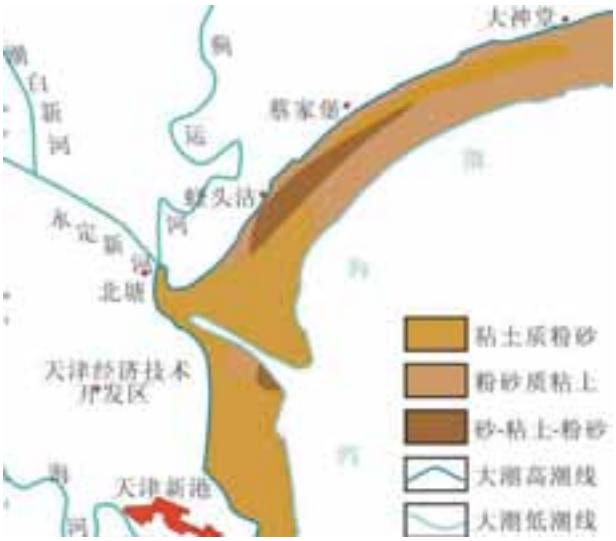


Figure 11. A map showing grain size distribution of the intertidal flat, north of Tianjin New Harbour, by using the Fractional–Pipette method.

The two methods gave different results. Compared with the traditional method, the average deviation of the 16 measured samples shows the part smaller than 4μm analyzed by the laser analysis decreases by ~7%, the part higher than 64μm decreases by ~5% and the part in between 4–64μm increases by ~12% (Che Jiying, 2006). Other results also testify to the clay-decreasing by using the laser method (Cheng Peng et al., 2001; Chen Xiufa et al., 2002). Efforts will be now be exerted for further detailed explanation. Comparing with previous data (Qin Yunshan and Liao Xiangui, 1962; Shi Jiantang, 1987), results indicate a gradually fining trend during the past four decades (Che Jiying, 2006).

Case Study: Comprehensive Investigation on Sanhedao Island

A unique island of the Tianjin Coast, Sanhedao Island, is located at the mouth of the junction of the Jiyunhe and Yongdingxinhe Rivers. Its geographical location renders it sensitive to both natural and human influences on the transitional belt between land and sea.

Based on ~310 points, measured with DGPS and Geodiameter leveling, a 3D map and a comprehensive map of the Island, incorporating its historical change, seasonal change of the landscape, remote sensing image, and shallow strata drilled by Eijkelkamp have been prepared (Liu Zhiguang et al., 2006, 2007a and b) (Figures 12 and 13).

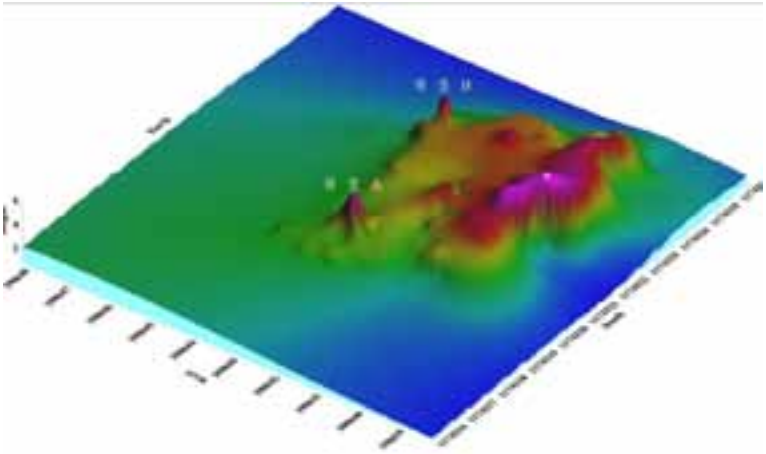


Figure 12. A 3D map of the Sanhedao Island and the surrounding tidal flat (Liu Zhiguang et al., 2007a).

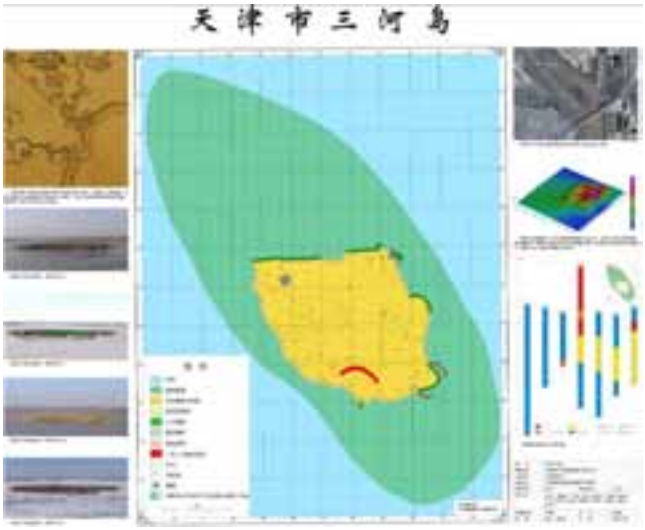


Figure 13. Map of Sanhedao Island. More than 300 sites were established inside the island and in the surrounding tidal flat, based on DGPS and Geodiameter measurements and Eijkelkamp augering and geomorphologic investigation. The inserts include a historical map, the seasonal landscape changes, remote sensing image, 3D illustration and the late Holocene strata revealed by Eijkelkamp cores (Liu Zhiguang et al., 2006).

Preliminary Division of the Muddy and Fine Sandy Tidal Flats

The modern tidal flat of Bohai Bay can be divided into two types: muddy flat and fine sandy flat, which have been called the “Mapengkou Bay Type” and “Lujuhe Type”, respectively (Wang Hong et al., 2005). More than 800 Eikelkamp cores (Figure 14) reveal that the buried Bohai Bay coastal lowland can be divided into the two types also (Figure 15).

Figure 14. Solid black circles indicate the Eijkelkamp hand-augering sites and the red ones are virtual sites. Yellow line demarcates approximately the range of the Tianjin Binhai New Area; blue line is the boundary of its shallow sea area (unpublished data, 2006).

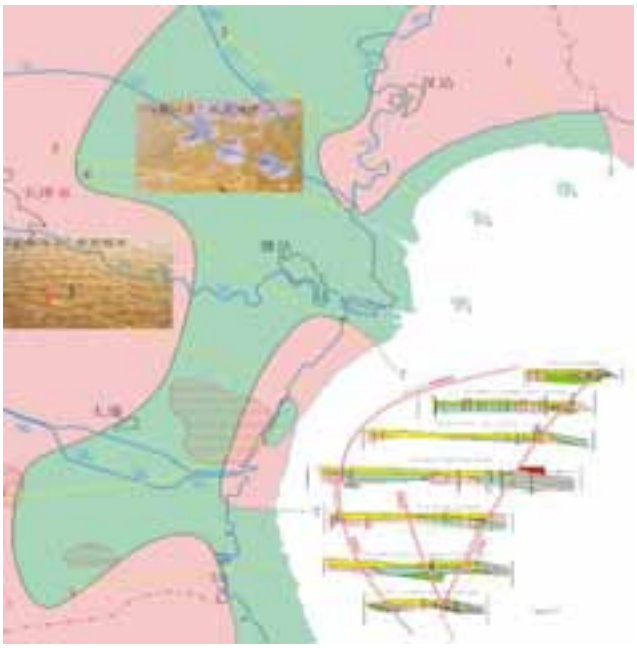


Figure 15. A schematic map showing distribution of two major types of buried Holocene intertidal sediments. The bluish part is soft mud shown by inset photo showing many small escaping depressions of methane and brownish diatom mat, existing on the surface of the modern muddy flat. A sample shows the composition of 35% is <3.8μm and ~95% is <23μm, according to the result given by laser granulometer analysis. This type of tidal flat sediment can be found from a great number of Eijkelkamp (unpublished data, 2005).

Geophysical Investigations in the Shallow Sea Area

Shallow sea bottom topography and shallow strata have been systematically surveyed by using EdgeTech 3100 Subbottom Profiler. For a key area of ~50km^2, the living oyster reefs and mounds, side scan investigation has been also provided by EdgeTech 4200 in recent years (Figures 16 and 17). This constitutes the first time for nonprofit-geological mapping in this shallow sea area by the Tianjin Centre, CGS (Tian Lizhu et al., 2006).

Figure 16. A map showing the navigation path of the subbottom profiling by acoustic investigation in the shallow sea area. Solid dark ellipse is an 80-m borehole in the intertidal zone while the red ellipse is a 30-m borehole drilled in shallow sea in 2006 while two 40-m boreholes were drilled in shallow sea in 2007. As verifying drilling for geophysical investigations, those cores have been the subject of detailed multidisciplinary studies, including grain size, diatom, form and molluscan analyses and MS ^{14}C and OSL dating, etc. Solid triangles are sampling stations for bottom sediments (Che Jiying, 2007; unpublished data, 2007).

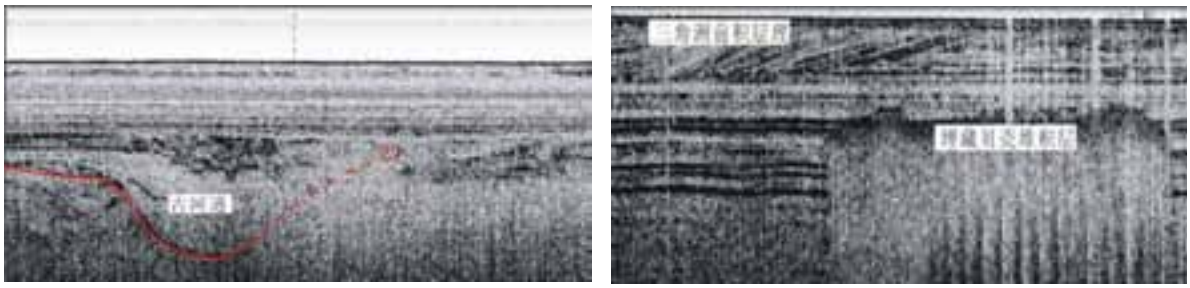


Figure 17. A set of subbottom profiles showing buried Holocene and late Pleistocene fluvial channel, foreset, and buried shelly layer (oyster mound) (unpublished data, 2006).

The Living Oyster Reefs

Living Oyster Reefs, *Crassostrea gigas*, exist on the shallow bottom, ~5km off the north shoreline and ~5m beneath the sea surface. EdgeTech 3100 for the shallow strata and EdgeTech 4200 for sea bottom topography were used focusing mainly on the undulated reef surface destroyed by the local fishermen (Fan Changfu, 2006) (Figure 18).

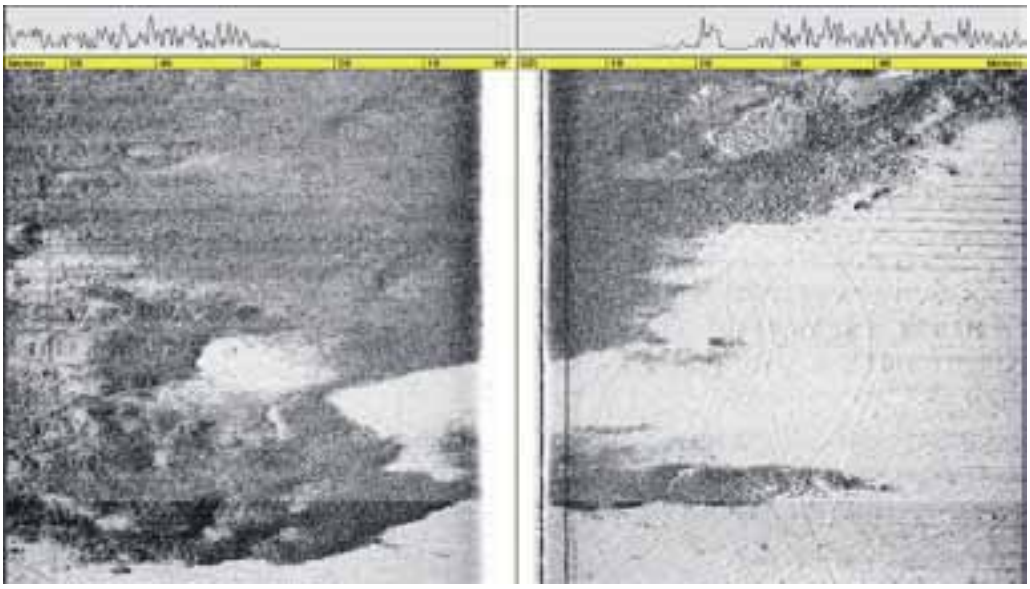


Figure 18. Side scanning image showing the destroyed reef: darkish part is reef body while the whitish is completely destroyed by over fishing during recent years. The reef body was several metres higher and reached to the msl (mean sea level) two decades ago (Fan Changfu et al., 2006).

CONCLUDING REMARKS

Based on the fundamental studies summarized above, this paper presents a preliminary submission to the discussion proposed by the CCOP Steering Committee for the 44th Annual Session: Coastal Erosion Problems on Deltaic Coasts. The major the coastal processes in the west of Bohai Bay relevant points from reflecting the relevant points from the current investigations and comprehensive research of CGS, in Bohai Bay are as follows:

Shoreline

(1) After the Little Ice Age (LIA), natural erosive process changed the shoreline from zigzag to straight and resulted in landward erosion for a few km in some sectors.

(2) After the 1960s, such a recession was partially arrested by human interference though some areas were still eroded landward.

(3) Since 1970-80s, the erosion of MHWST shoreline halted and some areas even moved seaward mainly by land reclamation and establishment of shrimp ponds.

Tidal Flat

Following the shoreline erosion after the LIA, the intertidal flat widened and became smoother. Particularly, rapid mud accretion has had an overwhelming impact on the tidal flat in the past three decades.

Recent Geological Studies and Age Dating of Ground Water in Jeju Island

Byoung-Woo Yum[1], Dong-Chan Koh[1], Ki-Hwa Park[1], Kyung-Sik Woo[2] and Yongje Kim[1]

ABSTRACT

Jeju Island is a volcanic island situated to the south of the Korean peninsula. For many years its striking volcanic landscape has attracted tourists and annual tourist arrivals are now ten times higher than its resident population of about five hundred and sixty thousand. The island is especially crowded during the summer season. Recently, several of the islands volcanic features were designated as "UNESCO World Heritage" sites.

Recent improvements in the geological modeling of the island and age dating of its groundwater will be presented in this paper. Various geological studies reveal that the tuffaceous rocks of the tuff rings and tuff cones that are common features of the island are influential in controlling the flow of groundwater. Detailed isotopic studies indicate that, with the exception of the eastern part of the island, old and slow-moving groundwater, controlled by the distribution of tuffaceous rocks, occurs all over the island. Young and fast-moving groundwater can be found in the spring waters that issue from the upper part of basaltic aquifers and from perched aquifers in the mountainous areas. Future work will focus on the basal groundwater in the high-altitude area, as this can contribute to considerable groundwater recharge, storage and recovery (ASR) in order to augment groundwater resources for the future water supply in the island.

***Keywords**: Jeju Island; groundwater; basaltic aquifer; tuffaceous rocks; age dating*
1: Groundwater & Geothermal Resources Division, KIGAM
2: Department of Geology, Kangwon National University

1. INTRODUCTION

In recent years much geological and hydrogeological work has been undertaken in order to solve the water supply problems of Jeju Island. Water supply on the island is completely dependent on rainfall and the exploitation of groundwater to provide an adequate supply needed for drinking, domestic and industrial purposes. In particular, the annual total of tourist arrivals is almost ten times higher than the island's permanent population of 560,000 inhabitants with the island especially crowded during the summer months. The Korea Institute of Geoscience and Mineral Resources (KIGAM) commenced geological and hydrogeological research for the Jeju Special Provincial Government in 2004 with funding of over one million US dollars each year. This paper focuses on the recent geological studies and age dating of groundwater in the island. Brief mention is also made of the granting of "UNESCO World Heritage" status to Jeju Island with the main designated areas being Mt. Halla Natural Reserve, the Geomunoreum lava tube system, and Seongsan Ilchulbong tuff cone.

2. GEOLOGICAL SETTING AND RECENT RESEARCH

Groundwater resources in Jeju Island can be divided generally into three types: basal groundwater, para-basal groundwater and upper (perched) groundwater. Auto breccias and/or lavas are the major aquifer rock types. Large quantities of groundwater are found in clinker formations (Figure 1) when fine and impermeable and/or low permeability rocks are located beneath them. It is very important therefore to know the distribution of these latter impermeable and/or low permeability rocks as they may underlie large reservoirs of groundwater. Relatively impermeable, hard and fine-grained rocks, tuff rings and tuff cones, and the sedimentary U-formation are therefore major targets for locating groundwater reservoirs in Jeju Island. KIGAM is now preparing 3-D distribution maps of such formations based on drilling data from 1,500 wells on the island.

Figure 1. Clinker at the surface (left) and in a drill-core (right).

2.1 The U-Formation

The U-formation (Figure 2) occurs at depths below mean sea-level of about 50 meters in the central part of the Island and 150 meters in the coastal area and offshore. It is mainly composed of muddy materials, and occasionally of fine quartz sands. The permeability of the U-formation is low and it acts as a barrier to the penetration of precipitation from the surface to deeper levels. Thus groundwater flow and resources are critically influenced by the distribution of U-formation. Three-dimensional modeling of the U-formation indicates that it is generally plateau-shaped towards the central part of the island (Figure 3). Its upper surface has been dissected by many narrow valleys containing lavas interpreted as lava flow infilling valleys that had been eroded in the exposed surface of the U-Formation during an earlier period of sea-level fluctuation.

Figure 2. Core samples from theU-formation.

Figure 3. Three-dimensional distribution of the U-formation with all overlying strata removed.eliminated.

2.2 Tuff Rings and Tuff Cones

Tuff rings and tuff cones are small volcanoes produced by explosive magma-water interactions and have been regarded as resulting from relatively dry and wet eruptions, respectively, which are related to low and high mixing ratios of water to magma. However, comparative work on four Pleistocene basaltic tuff rings and cones on Jeju Island, shows that there are dry and wet types in both tuff rings and tuff cones, and their variations are not satisfactorily explained by the prevailing model. Instead, it is inferred that the morphological variations are directly caused by depositional processes (pyroclastic surge-dominated in tuff rings, and fallout-dominated in tuff cones), irrespective of water-magma mixing ratios (Sohn, 1996). The depositional processes are interpreted as being controlled in turn by a number of fundamental factors, which include depositional settings, type, level, and lithology of aquifers, strength of country rocks, groundwater behavior, and properties and behavior of the magma. These controlling factors determine the explosion depth, conduit geometry, and mode of magma-water interaction, magnitude of explosion, eruption-column behavior, and subsequent depositional processes. The Suwolbong and Songaksan tuff rings on Jeju for example, which formed almost entirely on land above fragile and permeable sediments and granites with some aquiclude beds, were produced by contact-surface steam explosivity at depth because of the fragility of country rocks, insufficient and inhibited supply of shallow-level external water into the vents, and interaction of non-vesiculated magma with interstitial water. These conditions led to the generation of buoyancy-dominated eruption columns and pyroclastic surges, resulting in tuff rings. On the other hand, the Ilchulbong and Udo tuff cones were formed in shallow seas above extremely permeable but rigid basalt lavas. The explosions occurred at shallow depths mainly by bulk-interaction steam explosivity because of the rigidity of country rocks, sustained supply of shallow-level external water into the vents, and interaction of vesiculated magma with free water. This process resulted in the generation of dense, inertia-dominated jets and the formation of tuff cones mainly by fallout processes. It is believed that the morphological and sedimentological variations of these volcanoes are more clearly explained by the fundamental controls rather than solely by the water-magma ratio. It is suggested that the water-magma ratio can explain the evolution of a single volcano or a group of volcanoes under otherwise identical conditions, but cannot explain the variability of tuff rings and cones in different hydrogeological settings because the nature of hydroeruptions is governed by a number of fundamental controls (Sohn, 1996).

Conclusively, tuff rings and cones are very rigid, and their permeability is lower than other volcanic rocks. They are found above the U-formation and are correlated with the Seogwipo formation currently occurring at 150 meters below sea level. This indicates that they erupted in a shallow marine environment when sea level was much lower than the present. Tuff rings and cones were formed during several periods and show variations in altitude indicative of fluctuating sea-levels over time. It is also proposed that tuffaceous sediments were deposited through erosion and marine reworking of tuff deposits during sea level rise (Figure 4.).

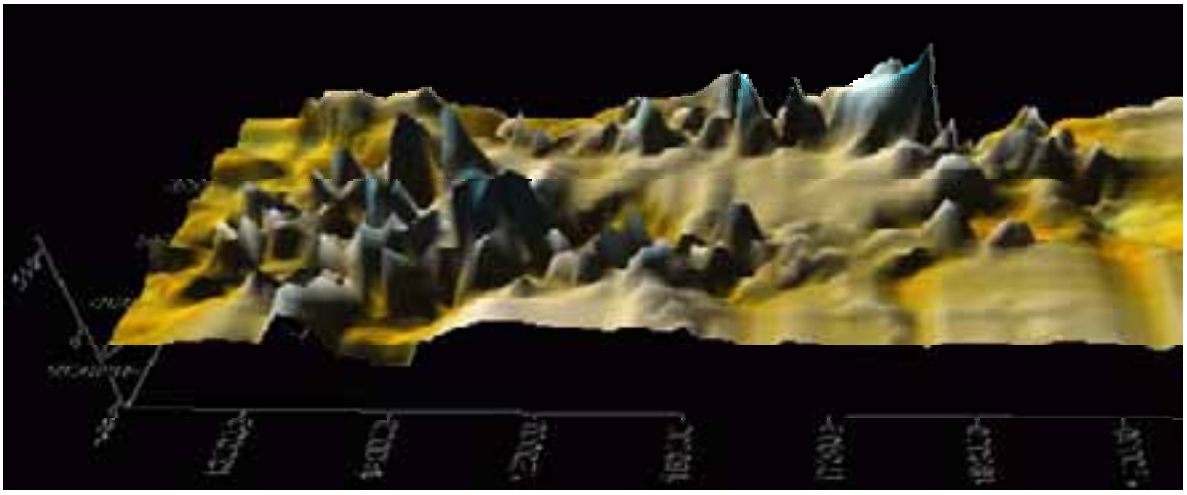


Figure 4. Distribution profile of tuffaceous (tuff-rings and tuff-cones) rocks in Jeju Island.

3. GROUNDWATER RESERVOIRS IN JEJU ISLAND

3.1 Distribution of Reservoirs

Figure 5 is a profile map showing the distribution of the U-formation and the tuffaceous rocks. The tuffaceous rock bodies have irregular shapes with high and low peaks, and with intercalated lava flows and clinkers. A groundwater reservoir with especially large amounts of groundwater is located within the wide valley-form seen in the distribution map (Figure 5). KIGAM has produced 3-D geologic profiles from surface and logging data, developing a unique basic method for indicating groundwater flow and groundwater reservoirs.

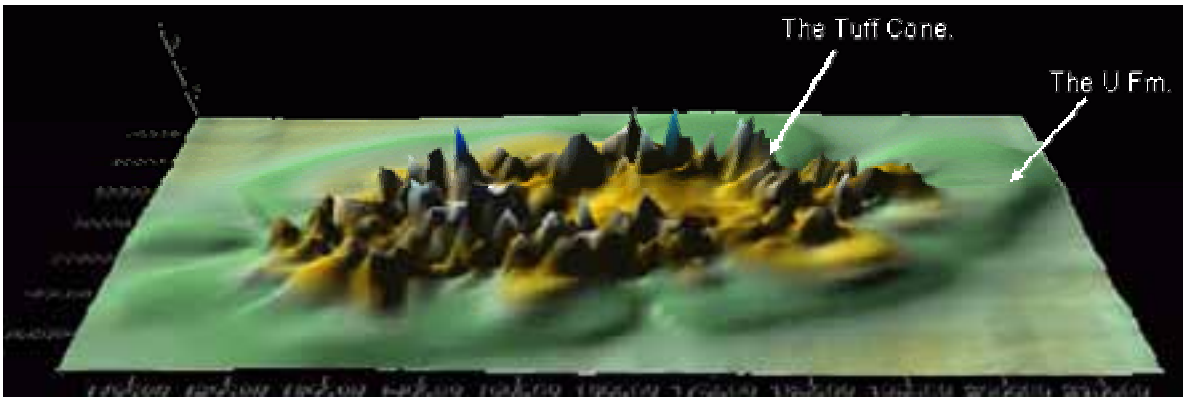


Figure 5. Distribution profile showing U-formation and overlying tuffs.

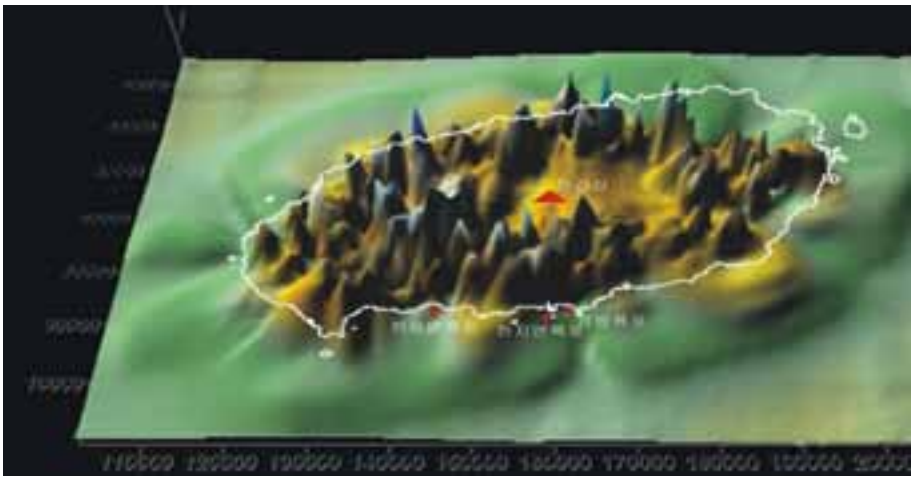


Figure 6. Location of perennial streams and waterfalls, and coinciding valley-forms in profile of tuffaceous rocks.

Perennial streams and water falls in Jeju Island coincide with the valley-forms defined by the profile of the tuffaceous rocks (Figure 6). Impermeable tuffaceous rocks both overlie and underlie the more permeable strata from which the outflowing springs and water falls originate. These features are the same as the underlying phenomena mentioned above. Both surface and ground water flows are strongly controlled by the tuffaceous rocks and there distribution relative to the permeable rocks and sediments.

3.2 Geophysical Logging

Various surveys, including monitoring and conventional geophysical well logging, were conducted in boreholes to identify basalt sequences and estimate the total porosity of aquifers related with the evaluation of groundwater resources. (Hwang et al., 2005). Radioactive logs (natural gamma log, dual neutron log and gamma-gamma log), electrical logs, caliper logs, fluid temperature and conductivity logs and heat-pulse flow meter logs were conducted in twenty-nine boreholes distributed in the eastern part of the Island. The aim was focused on the seawater intrusion phenomena along the coastal area. Neutron logs were very effective in identifying individual lava flows, flow breaks, and sedimentary interbeds in saturated formations. The results showed that porosity is high and resistivity is low in hyalocastite, which is the major flow pathway. Trachybasalt shows a wide range of porosity and high resistivity. Sedimentary interbeds, unconsolidated U formation, and Seogwipo formation illustrate high porosity and low resistivity. All these features with flow meter logs show that flow patterns of lava strongly control seawater intrusion phenomena.

4. GROUNDWATER AGE DATING

Many studies of hydrogeology and groundwater quality have been carried out on the groundwater resources of Jeju Island as compared to mainland Korea. Groundwater occurrence in Jeju Island is of three types (Won et al., 2005); 1) high-level groundwater, 2) parabasal groundwater, and 3) basal ground water. High-level groundwater from perched aquifers within basaltic rocks in mountainous areas either seeps out as springs or flows downwards to lower water bodies. Basal groundwater occurs in the coastal area and is in direct contact with seawater. Parabasal groundwater consists of extended bodies of basal groundwater in high-altitude areas.

The groundwater flow system in Jeju Island was investigated for spring water as early as the 1960s using environmental isotopes and resulted in a benchmark paper in the field of isotope hydrology (Davis, 1970). Using time-series data of tritium, it was estimated that the mean groundwater age was up to 20 years for coastal springs and much younger in high-altitude springs. The relatively younger age of groundwater was corroborated in highly permeable late Tertiary and Quaternary basaltic rocks. The relatively fast groundwater flow indicates that the basaltic aquifer is vulnerable to contamination from sources in the surface environment and requires a proper groundwater protection strategy.

However, this conceptual model cannot be applied to all the aquifers of Jeju Island. Koh et al. (2005) showed relatively old ground water exists below the hydrovolcanic tuff formation, also known as the Seogwipo Formation, in a study focused on the western coastal area using tritium. Although it was known it was known in outcrops at the seashore or as tuff-rings and tuff cones before this study, the widespread presence of the Seogwipo Formation in the subsurface was systematically identified by Koh (1997). The old groundwater appears to occur in the permeable zones below the low-permeable rocks, which have only a limited hydrologic connection with the upper basaltic aquifer (Figure 7). The old groundwater is unlikely to occur in the eastern coastal area because thick layers of permeable basaltic rocks supply sufficient water in the area and most of the wells are above the tuff formation, which can be inferred from the subsurface lithology (Oh et al., 2000). The old groundwater appears to have been recharged before the 1950s and has tritium content as low as 0.1 TU and to exist in confined condition. Mixture of the old water and younger water was significant in the well and this was caused by different screens in multiple aquifers. The occurrence of old groundwater resulted from the fact that the relatively thin basaltic rocks of the upper aquifer give less productivity and consequently the drillers installed the wells below the hydrovolcanic tuff formation in the western coastal area. The multi-tracer approach employing tritium and CFC-12 by Koh et al. (2006) reveals the occurrence of old groundwater. It also determines the quantity of the prevailing groundwater mixing (Figure 8). Three water groups were identified as 1) old water with negligible tritium and CFC-12, 2) young water with appreciable tritium and CFC-12 roughly matching a low-dispersion model, and 3) the binary mixture of the two waters.

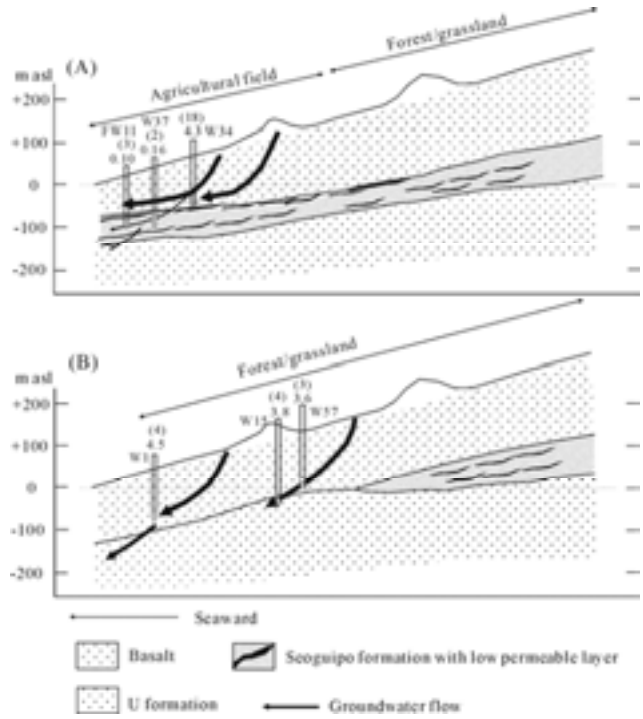


Figure 7. Schematic cross-section showing groundwater flow characteristics in the western and southern areas (A), and in the eastern area without Seogwipo formation in the subsurface (B) (Koh et al., 2005). The numbers above the well are ^{3}H values (TU) and nitrate concentrations (mg/L) in parenthesis. The thickness of the groundwater flow line indicates the relative groundwater velocity according to qualitative groundwater age by ^{3}H. The agricultural field and forest/grassland represent two major land uses in Jeju Island.

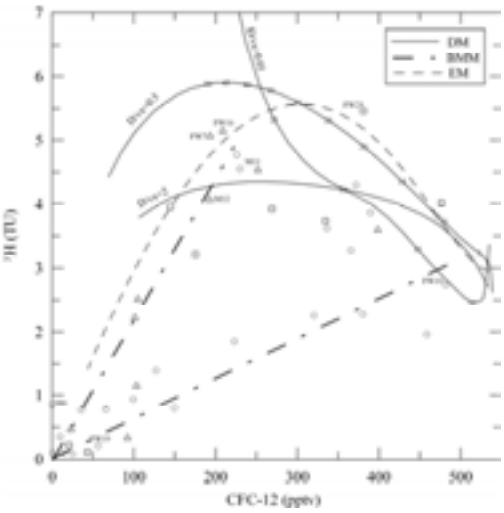


Figure 8. ^{3}H versus CFC-12 in groundwater samples. CFC-12 concentration is equivalent atmospheric concentration (pptv) (Koh et al., 2006). Theoretical curves are also shown for dispersion model (DM) with D/vx of 0.5 (a) and 0.05 (b), and exponential model (EM). The numbers on the DM lines are groundwater ages in years. For the binary mixing model (BMM), only two major mixing lines are shown although they are drawn for each sample respectively. Groundwater is classified by the altitude (above sea level) of the well site as, below 100 m (open circles), 100 to 200 m (open squares and above 200 m (open triangles).

5. DISCUSSION AND CONCLUSION

Most streams on Jeju Island are ephemeral and only have torrential flows after heavy rain, greatly reducing the availability of surface water. Groundwater is the most important freshwater resource and supplies almost all of the water demand for the island (Koh et al., 2005). The results summarized here came from the “Integrated Analysis of groundwater occurrence in Jeju (Park, et al., 2006)” which aimed to establish a hydrogeological conceptual model for the groundwater system and to obtain long-term data for interpreting or analyzing the hydrogeological characteristics of Jeju Island. The distribution of subsurface impermeable layers such as U-formation and tuff rings and cones is analyzed and it is found that the occurrence of groundwater springs are closely related to the distribution of the impermeable units. It is also found out that the precipitation pattern has a rough periodic cycle of 4~5 years in terms of total amount of precipitation. In case of Gasiri, the response time to a rainfall event is estimated to be about 2 days and the infiltration rate 21.2% based on the analysis of meteoric data automatically-collected from Gasiri AWS. Maximum potential evapotranspiration is estimated as 753.22 ~ 777.59mm by water budget analysis for the Gasiri area. Park et al. (2006) constructed a sliced geologic map for every 10 meters depth of Jeju Island, which is the first attempt to reveal the ideal groundwater flow system. Their future work will focus on the new ASR site to reserve huge amounts of groundwater in an unconsolidated aquifer. As a whole, these studies and their results are very promising to provide clean water to Jeju Islanders and tourists.

6. UNESCO WORLD HERITAGE – JEJU ISLAND

Jeju Island was finally designated as a World Natural Heritage on June 29, 2007. Several scientific teams had conducted basic and detailed research for the preparation of the proposal in the period from December 2001 to January 2006. Thereafter, the World Heritage Site proposal was submitted to UNESCO and on-site evaluation was carried out by the IUCN specialists. Jeju Volcanic Island and Lava Tubes comprises three sites that together make up 18,846 hectares and 10.3% of the surface area of Jeju Island. This includes: Geomunoreum (Figure 9.), regarded as the finest lava tube system of caves anywhere, with its multi-coloured carbonate roofs and floors, and dark-coloured lava walls; the 'fortress-like' Seongsan Ilchulbong tuff cone ("Sunrise Peak"), a dramatic landscape rising out of the ocean; and Mount Hallasan (Figure 10.), the highest mountain in the Republic of Korea, with its waterfalls, multi-shaped rock formations, and lake-filled crater (*http://whc.unesco.org/*).

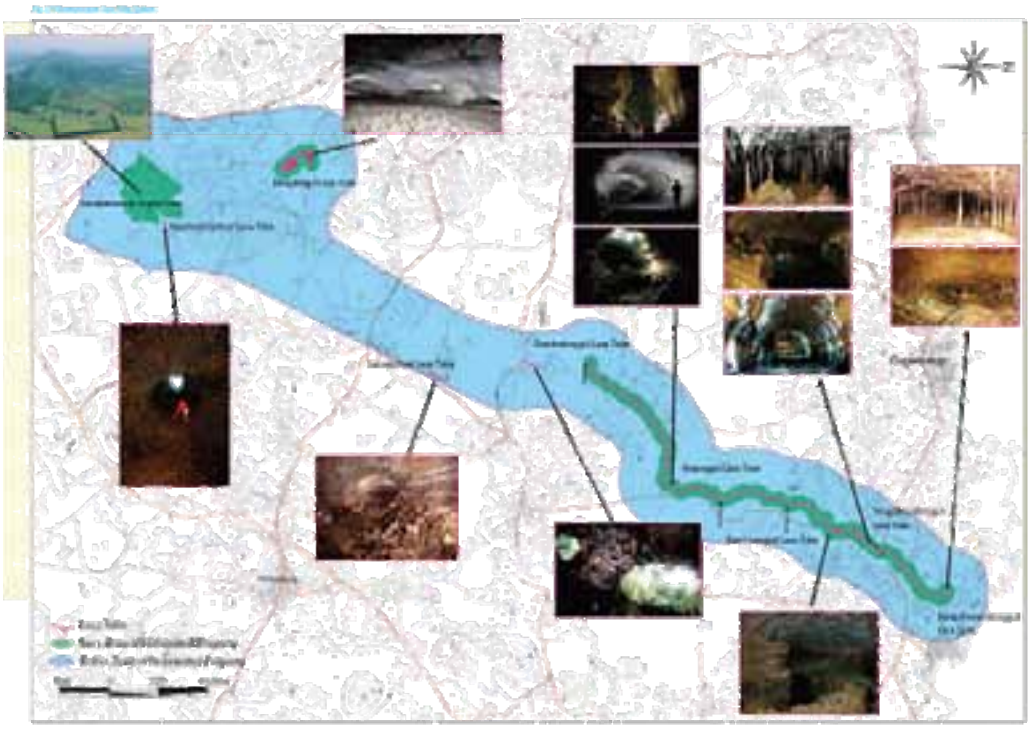


Figure 9. Geomunoreum lava tube system and its beautiful mineral formations (modified by Woo)

Figure 10. Landscapes of Jeju Island (Mount Hallasan & Seongsan Ilchulbong)

ACKNOWLEDGEMENT

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Implementing Geological Information on Natural Hazards in Urban Planning – Reconstruction of Banda Aceh, Indonesia

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ABSTRACT

The Tsunami catastrophe on December 26, 2004 in the Indian Ocean claimed more than 250,000 lives, most of them in the Indonesian Aceh Province. It made thousands homeless and completely destroyed large city areas of Banda Aceh, Meulaboh and Calang as well as villages along the coast of the Aceh Province, Northern Sumatra. The housing situation of thousands of people was dramatic; life-support infra-structure was largely damaged and the daily demands were difficult to supply.

A sustainable reconstruction of the Aceh Province required a rehabilitation of the affected cities and villages often from scratch. Schools, hospitals and communication centres had to be rebuilt; lifelines to provide electricity and hygienic safe drinking water had to be established again.

Any reconstruction has to consider the natural conditions already in the planning phase; i.e. the area's susceptibility to the impact of all kind of natural disasters. Therefore the national authorities for the reconstruction of the Aceh Province (BRR and BAPPENAS) have initiated the technical cooperation project "Management of Georisks, Province Aceh" with Germany.

The project focuses on: "Regional planners / town planners are using geological background information and guidelines for sustainable local disaster reduction". The purpose of all project activities is to reduce the impact of further natural disasters on the population still suffering from the destruction caused by the Tsunami and earthquake of December 26, 2004.

The Tsunami was triggered by one of the most powerful earthquakes mankind has ever been exposed to. The Aceh Province is one of Indonesia's most earthquake prone areas. Prevention measures have to be considered to make the houses earthquake safe. Based on seismological analysis and engineering-geological investigations, recommendations for the suitability of safe building grounds will be given. Other aspects of the project are: georisk assessment (floods, volcanic eruptions, landslides, earthquakes and Tsunami) including community based disaster risk assessment, construction raw materials (identification of suitable building materials) and hydrogeology (identification of freshwater resources). Due to the Tsunami flooding, the entire near-coast aquifers were contaminated with salt water and by anthropogenic waste.

The participation of the population in evaluating the communities' risks and vulnerabilities ensures that the specific local needs of the communities are taken into consideration in governmental mitigation measures – Community Based Disaster Risk Management. So called Community Action Planning Workshops (CAP) involve the communities in the disaster resilient reconstruction of their villages in Banda Aceh. Local knowledge on the socio-economic environment thus finds its way into the planning

processes. The more the local population is informed about the georisks of their living environment and about the measures to take in case of a natural catastrophe event, the smaller are losses of life and property.

Besides these Community Action Planning Workshops, a GEOmobile tours schools in the Aceh Province with information material on natural hazards. School children are expected to convey the knowledge into their families and thereby help to build awareness towards Georisks.

The project is carried out by the Geological Agency of Indonesia, the Authority of Mining and Energy of Province Aceh and the Federal Institute for Geosciences and Natural Resources, Germany (BGR). The project has a four-year duration and is funded by the Federal Ministry for Economic Cooperation and Development (BMZ) of Germany.

Characteristic Seafloor Morphology and Geology of a Tropical Lagoon

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ABSTRACT

In Samoa, the seafloor morphology and geology of a tropical lagoon has been studied by the Korea Institute of Geoscience and Mineral Resources as a part of international collaboration study initiated through the United Nations Development Programme. The main aims of the study were to investigate any potential geologic hazards and to assess economic resources (especially sand and gravel) in the coastal area. This brief paper reports on the geological and geomorphological aspects of the study. The surveyed lagoon is located on the southeastern coast of Savai'i Island, Samoa. Various survey techniques were used such as interpretation of aerial photographs and satellite images, single-beam echo-sounding, ground-truthing with a video camera, underwater video photographing, surface sediment sampling and grain size analysis

Characteristic morphologic features, from shore to sea, include beaches, mudflat, delta, reef flat, blue holes, tidal inlets, barrier reef, back-barrier beaches, and submarine terraces. The water depth in the lagoon is generally only a few meters, whereas the blue holes and submarine terraces reach depths of a few tens of meters.

The surface sediments of the lagoon are dominated by coral-algal debris ranging from mud to gravel in grain-size. Locally volcaniclastic sediment covers the river mouth area. Near the seaward margin of basement outcrops or sea cliffs coral rubble and large boulders are either scattered or accumulate as pockets of gravel beach. Live coral colonies are also recognized in the lagoon. In the southern par, large blue holes are dominant. In the back-barrier areas lineation structures were seen on the aerial photographs. At the reef breaks, where tidal inlets are developed, high energy currents have caused submarine exposure of volcanic basement or old reef flat.

During this survey modern tropical lagoon morphology and geology could be evaluated in detail. Additionally, some geological evidence for the influence of global environmental change was evaluated in coastal areas. The survey results are expected to provide useful information for the sustainable development of Samoa as well as a useful modern analog to help in understanding ancient carbonate environments.

Keywords: *coastal geology, morphology, lagoon, Samoa, carbonate.*

INTRODUCTION

As global warming continues its upward trend (Figure 1) due to increasing fossil fuel consumption, sea level rise is no longer only a long-term hazard, especially to the people living in low-elevation coastal areas or small ocean island countries. It is becoming a persistent controlling factor of *hazard mitigation* or *adaptation planning* in the present time domain or at least in the very near future (Figure 2). In this regard, it is not only important to understand the significance of the sea level rise itself, but also its interaction with other factors, such as. geology, geomorphology, vegetation, meteorology, population density and human activity.

Tropical lagoons in small oceanic islands are generally formed behind a barrier reef and are generally well-protected from strong inward currents and waves. Owing to their ecologically favorable condition, biologic activity, including anthropogenic activity, is comparatively intense both in magnitude and in diversity. Especially, tropical corals and algae are dominant species which maintain the lagoon frameworks and will eventually form characteristic geology and geomorphology.

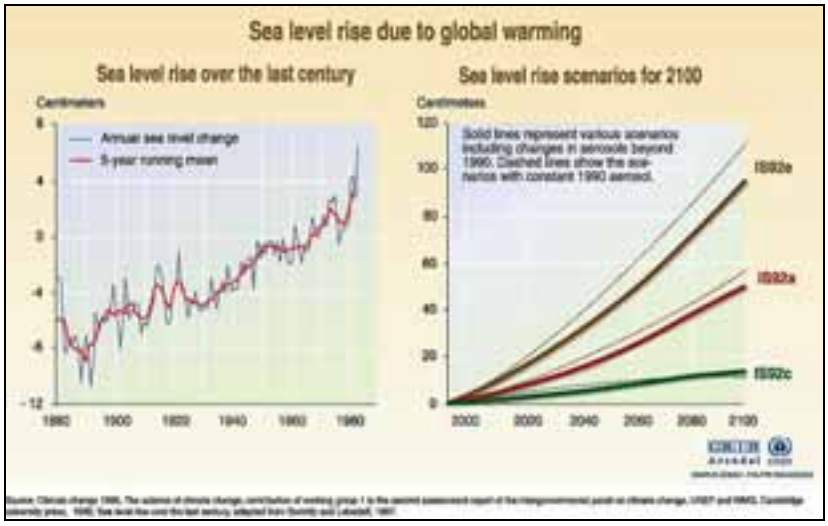

Figure 1. Sea level rise model due to global warming published by the first working group of IPCC in 1995.

Recently, several coastal areas have experienced abrupt geologic or meteorological events, showing how human life is vulnerable to these unexpected phenomena (e.g. Rearic, 1990; Szczucinski et al., 2006). The tropical lagoons and their surrounding coastal areas could be examples of disasters-waiting-to-happen, because of their heavy population density, comparatively low energy environment inducing negligence, and high degree of utilization. Moreover, disasters along coastal areas are expected to be augmented as sea level rise continues and geologic and geomorphologic features interact.

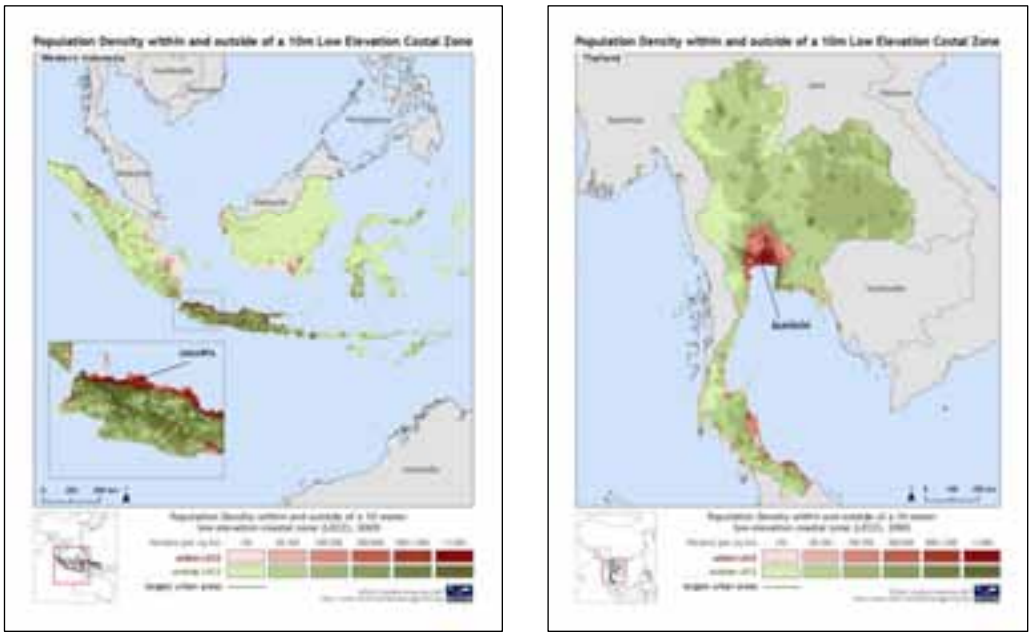

Figure 2. Population density in and outside of a 10-m low elevation zone (left: Indonesia, right: Thailand).

This paper focuses on the geologic and geomorphologic characters of a tropical lagoon formed by a barrier reef bordering a Pacific volcanic island. The seafloor of the lagoon and its adjacent land area were surveyed as a partial work of a UNDP-KIGAM project which has been implemented for three years. The main objectives of the project are mapping the coastal area of the Savai'i Island in Samoa, developing human resources of the Samoan government, and exchanging scientists and knowledge-based opinions through international meetings.

STUDY AREA

The study area is a lagoon geographically located in the southeastern part of the Savai'i Island, Samoa (13° 34′ S – 13° 44′ S, 172° 09′ W – 172° 48′ W; Figure 3). It is delineated seaward by a barrier reef of approximately 20-km length and landward by a fairly straight coastline. The coastal area is well-vegetated with a predominantly sandy or muddy shoreline. At some locations, volcanic basement crops out along the coastline forming a cape or a point. Major villages occupying the eastern coastal area of Savai'i island are Salelologa, Tuasivi, and Pu'apu'a (Figure 4). (Ward and Ashcroft, 1998). These villages have experienced heavy damage caused by cyclones Ofa and Val in February, 1990 and December, 1991, respectively (Ward and Ashcroft, 1998; Elmqvist et al., 1998).

Figure 3. Location of the Savai'i Island of Samoa. Samoa is located in the western South Pacific region north of Fiji and New Zealand.

Figure 4. Aerial photographs of the surveyed tropical lagoon in Savai'i Island, Samoa. The picture on the left is an enlarged part of the delta. Note the distinct color change in the southern part of the lagoon showing a change in water depth.

The tidal range of the lagoon belongs to a micro-tidal regime and the tide is semidiurnal. Local currents are not prominent but recognizable at several locations with indicative morphologic features. The wave parameters inside the lagoon have not yet been reported in any systematic way.

According to the geologic map of the Savai'i island (New Zealand Geological Survey, 1958; Figure 5), the study area is covered with Middle to Late Pleistocene Mulifanua volcanic deposits, with the exception of small areas around the wharf in Salelologa and around the Lesolo Point which are composed of the Holocene Pu'apu'a volcanic deposits. From Mt. Asi to Pu'apu'a village, the Holocene Tafagamanu sand strips, consisting dominantly of coral sands, cover the coastal area to about 5 ft. above sea level. Small creeks, inland springs and lithified sands (beach rock) near sea level can be observed at several locations.

Figure 4. Geologic Map of Savai'i Island (New Zealand Geological Survey, 1958).

STUDY MATERIALS AND METHODS

In order to overview the study area, high-resolution aerial photographs taken in 1999 and satellite images were interpreted in a MapInfo™ geographic information system. A geologic map (1:100,000 scale), topographic maps (1:20,000; New Zealand Mapping Agency), and a tourist guide map were also used for reference. For ground-checking, the water depth was measured with a single-beam echo-sounder. The depth value was calibrated with respect to local mean sea level based on the tide table (*http://www.pacificsealevel.org*). An underwater video camera was operated for investigating the sea floor sediments and vegetation. At more than forty locations, sea floor sediments were acquired after taking underwater photographs. In the laboratory, the lagoon sediments were dried and sieved, and grain size parameters were obtained. The sieved samples were also photographed under a stereo-microscope at each size interval.

RESULTS

Seafloor Morphology

The lagoon could be delineated seaward by barrier reefs and landward by a sandy or muddy shoreline partly penetrated by the volcanic basement. Major seafloor morphologic features are, from shore to sea, mudflats, sand and gravel beaches, reef flat, delta, blue holes, reef breaks, tidal inlets, back-barrier beaches, barrier reefs and submarine terraces (Figure 6).

Figure 5. Characteristic coastline features. Mud flat, beach with beach rock, pocket sand beach with gravels at the foot of basement cliff, and basement outcrop with freshwater spring (from top left clockwise).

Most of the features reside in inter-tidal or sub-tidal zones of less than a few meters water depth. Exceptions are the blue holes and submarine terraces that fall abruptly to a few tens of meters of water depth.

Based on the survey results, the seafloor of the lagoon could be divided into two parts; the southern part from Salelologa to Tuasivi and the northern part from Tuasivi to Pu'apu'a. The prominent features of the southern part are mud flats, volcanic basement outcrops, delta, and blue holes. The sea floor of the southern part is characterized by seaward stepwise change in water depth which presumably originated from reef collapse. This water depth change is easily noticed by distinct color change on the aerial photographs (Figure 4). The northern part is characterized by relatively straight sand beaches developed along the cuspate-shaped shoreline. The seafloor is generally planar with gentle slope, except the areas breached by tidal inlets. In some locations reef lineation can be recognized.

Seafloor Geology

The seafloor sediments of the lagoon are mostly biogenic in origin, being composed of coral-algal (calcium carbonate) debris (Figure 7). The grain size generally ranges from mud to gravel according to the Folk and Ward scheme (1958). At the river mouth, where a delta is developed, volcaniclastic sediments cover the seafloor being diluted seaward by biogenic sediments, which could be recognized in the aerial photographs as a dark brown zone (Figure 8). Adjacent to basement outcrops or sea cliffs, large volcaniclastic boulders and coral fragments several tens of centimeters in diameter are found in the mud flat. Live coral colonies and sea weed also cover the lagoon sea floor at some locations.

Figure 6. Characteristic coastline features. Delta, tidal inlet and submarine terrace, reef lineation, and blue holes (from top left clockwise).

At the reef breaks, where tidal inlets develop, volcanic basement or old reef flat are exposed on the sea floor. Along the coastline, lithified sand (beach rock) in the northern part is a characteristic feature in the coral beach. Freshwater springs are found at some locations and sand spits may be found at the mouths of small creeks.

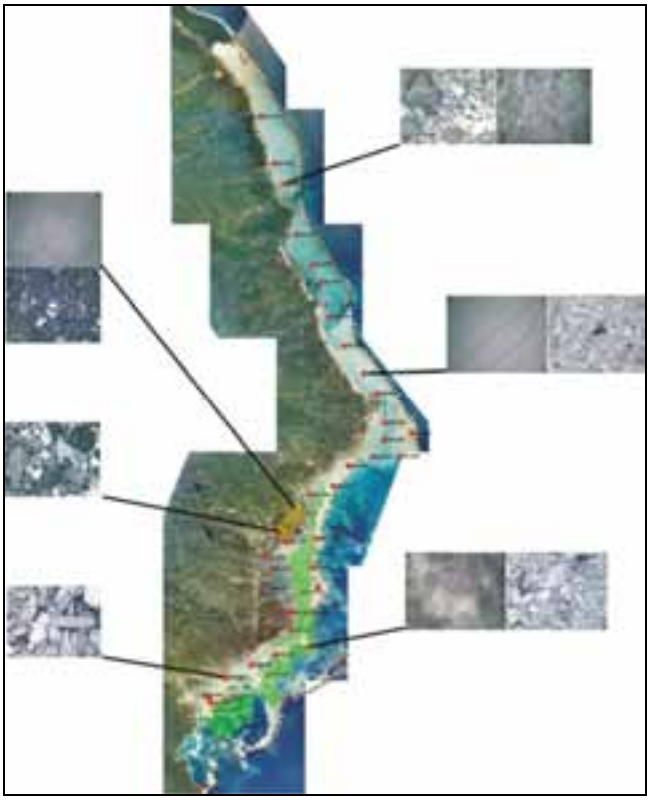

Figure 7. Sampling and underwater photograph locations for sea floor sediment investigation.

CONCLUSIONS

Based on the survey results, the geomorphology and sea floor geology of the tropical lagoon in Savai'i Island could be understood in detail.

The major morphologic features are delta, mud flat, beaches, reef flat, blue holes, reef breaks, tidal inlets, back-barrier beaches, barrier reefs and submarine terraces. The internal boundary indicating stepwise water depth changes is presumably due to the Holocene sea level change and closely related to blue whole formation (Richmond, 1991; Kennedy and Woodroffe, 2000).

The seafloor sediments are dominated by biogenic sediments mostly originating from corals and algae. At the river mouth, where deltaic deposition occurs, volcaniclastic sediments are dominant. Outsized clasts in mud flat are possibly transported by strong waves or surges during storm or cyclone periods. In the tidal inlet, where high-energy currents are expected, sediment-barren sea floor is observed.

The survey results will be compiled and input to a geographic information system in order for the Samoan government to use them as basic information for managing (e.g. reclaiming or protecting) coastal areas of Savai'i Island. It is also expected that the surveyed features could be used as well-defined modern analogs to ancient carbonate environments of a tropical lagoon. The UNDP-KIGAM program has extended its scope and study area further into the Asia-Pacific area so that the survey results would lead to future collaborative studies.

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Offshore Fault Assessment: Implication to Predict Earthquake and Tsunamigenic Potential along the Coastal Area of Muria Peninsula, Central Java *

Subaktian Lubis**

ABSTRACT

The purpose of the assessment is to present the analyzed offshore fault characteristics (type and style, direction, length, age and possibility) necessary for estimating the offshore earthquake and tsunami hazard which may have an impact to the coastal area.

Interpretation results of the seismic profiles found indication of some typical faults such as normal fault, strike-slip fault and thrust fault. An unusual long fault was also found in this region. The total length of the fault is approximately 160 Km oriented northeast-southwest direction and it comprises at least seven fault segments.

According to the consideration of assumed vertical offset, fault displacement, average of the water depth, and the length of each segment fault, these long faults would cause earthquakes with relatively low energy release (low magnitude). Furthermore, there is no significant tsunami will occur and propagate to the coastal area. However, the coastal area has a low tsunamigenic potential.

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INTRODUCTION

Coastal area of Muria peninsula, northern coast of Central Java (Figure 1), was established to be a most proper site for the first Indonesian Nuclear Power Plant (INPP) construction. Based on the seismicity data, this coastal area is geologically more secure than other selected sites. The main purpose of the assessment is to present the analyzed offshore fault characteristics (type and style, direction, length, age and possibility of reactive fault) necessary for estimating the offshore hazards such as earthquake and tsunami which may have an impact to the coastal area. The seismic data were obtained from the existing data of NIRA (1982), Pertamina-Bicep (1985), Conoco (1983), Sceptre (1984), Newjec (1993) and MGI (1991, 1992, 2006, 2007).

Interpretation results of the seismic records show indication of some typical faults such as normal fault, strike-slip fault and thrust fault. Lineations of each fault also indicate an unusual long fault found in this region. The total length of the fault is approximately 160 km oriented northeast-southwest direction. This fault comprises at least seven fault segments which are various in their length of 20-40 km long. Most of the faults penetrated upward into the Quaternary layer, but had never reached the top of the sediment. It is suggested, that no fault activity occurs recently.

Figure 1. Location of offshore area of the Muria Peninsula, Central Java

REGIONAL TECTONIC SETTING

The tectonic setting of Central Java are dominated by the northward motion of the oceanic crust of Indo-Australian plate to the Eurasian continental plate with the approximately movement rate of 6-7 cm/yr (Hamilton, 1979). The perpendicular plate motion is mostly accommodated normal faulting in the fore-arc basin, and substantially accommodated strike-slip faulting in the back-arc basin area.

Back-arc basin off northern Central Java is characterized by thick layer of sediments. The maximum thickness of the basin sediment is approximately 2-3 km. The basin which is characterized by a fault border, probably associated with the Tayu strike-slip fault system, could be described as an extreme long fault which several fault segments.

SEISMIC INTERPRETATION

The single channel seismic profiles from the Marine Geological Institute, MGI (2006, 2007) provide new information of faults at the offshore area of Muria Peninsula. Faults within 5 km off the coastal area is interpreted as post Tertiary activity (Figure 2), although some faults within 25 km of the coastline may still be active as growth-type faults.

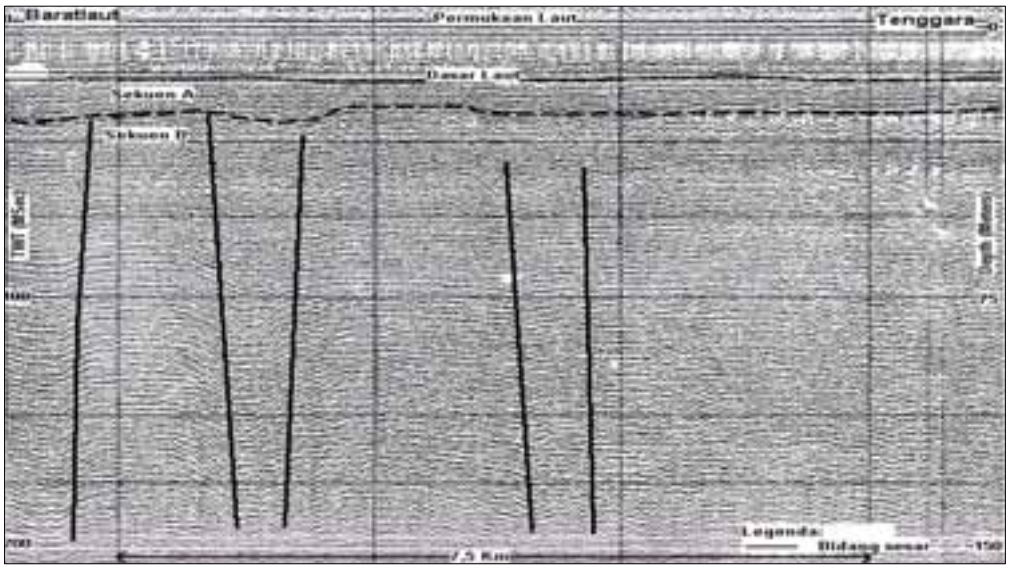

Figure 2. Seismic interpretation showing the Tertiary growth fault

In the eastern part of offshore Muria exhibits two prominent fault sets, a normal fault as indicated by a half graben fault or growth fault set, and strike-slip fault set. Previous reports by Newjec (1993) suggested that the former was Quaternary in age, but new interpretation suggests that both fault sets have been active through the present time. According to the IAEA safety guide, these faults are classified into capable fault type as shown in the table below.

Table 1. Fault characteristics interpreted from seismic data of MGI (2006, 2007)

Fault Identification	*Length (km)*	*Age*	*Estimate of Activity*	*Distance to INPP Site (km)*	*Fault Type*
MGI-1	13.5	Quaternary	Capable	58	Strike-Slip
MGI-2	13.8	Quaternary	Capable	60	Strike-Slip
MGI-3	160.3	Quaternary	Capable	60	Strike-Slip
MGI-4	7.5	Quaternary	Capable	23	Strike-Slip
MGI-5	38.2	Quaternary	Capable	105	Normal
MGI-6	36.7	Quaternary	Capable	105	Normal

Capable fault is defined as a hazardous geological phenomenon and probably will re-active again due to tectonic activity in this area. Seismic interpretation results show that the faults also are composed of growth faults. These faults indicated by several step faults which were occurred since the Tertiary until present time.

Seismic analyses of the internal seismic pattern of the records (Ringis, 1993) indicate that the growth faults seem to occur continuously to the Quaternary sequence which is shown as great deformation and highly faulted of the seafloor, and in some part forming half graben structures.

According to the consideration of assumed distance to INPP site (more than 50 km), vertical offset, fault displacement, the average of the water depth, and the length of each segment fault, these long faults would cause earthquakes with relatively low energy release (Godoy, 2006). Furthermore, there is no significant tsunami will occur and propagate to the INPP coastal area. However, the coastal area has a low tsunamigenic potential.

RESULTS

A regional map covering the offshore area from 110° E to 112° E was constructed at a scale 1:100.000. It shows faults mapped from all of the seismic interpretation results including the respective survey lines.

This map confirms the structural style of the major offshore faults. In particular, the northeast trending left-lateral strike-slip fault is shown to extend offshore from Tayu for over 160 km (Figure 3). This is about two times the distance reported in the recent seismotectonic models of Newjec (1993).

Figure 4. Simplified map of the offshore faults in Muria peninsula and its vicinity

The significant finding of this assessment is suggested that the offshore fault in the northeastern of Muria Peninsula was fragmented into at least seven fault fragments with the length of 20 up to 40 km long. This phenomenon shows that the tectonic activity of this region is greater than at surrounding area, but, therefore, the fault had only released a relatively lower energy than the expected.

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Sub-Theme 4 :

New Methods and Technologies

Landslide Susceptibility Mapping Using an Efficient Artificial Neural Network Computing Method, Satellite Images, and GIS

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ABSTRACT

This study focuses on the generation of landslide susceptibility maps using a new artificial computing method. The research also uses satellite images to generate vegetation cover information and geomorphic parameters like altitude, slope, and aspect which are very important factors affecting landslide occurrence. Geologic parameters such as rock type, distance from geologic boundary, and geologic dip-strike angle are other landslide occurrence factors used in the study. The study area is located in the southern Japanese Alps with several sites that sustained damage due to the occurrence of landslides. The artificial neural network structure and training scheme is formulated to generate landslide susceptibility maps. The aforementioned factors are used as inputs to the artificial neural network. Inhibited Brain Learning, a new and efficient artificial neural network computing method, is used. The network is trained to output 1 when the input data are obtained from areas with landslides and 0 when the input data are obtained from sites without landslides. The trained network generates an output ranging from 0 to 1, reflecting the susceptibility of the area to landslide occurrence. Output values nearer to 1 mean higher susceptibility to landslide occurrence. The study successfully generated a landslide susceptibility map of the study area.

Keywords: *artificial neural networks, landslides, satellite images*

INTRODUCTION

Recent research on landslides has shown that defining the relationship between landslide occurrence and the diverse environmental factors affecting landslides is very difficult. Several factors affecting landslide occurrence have been identified. These include geomorphic and geologic features, rock types, and vegetation cover. However, using these factors to generate landslide susceptibility maps using conventional mathematical and statistical method is difficult and inaccurate.

The artificial neural network (ANN) has recently been included in the list of analytical tools used in a wide range of applications in the fields of natural science research. One of the advantages of using ANN for pattern recognition is that it can handle data at any measurement scale ranging from nominal, ordinal to linear and ratio, and any form of data distribution (Wang et al., 1995). In addition, it can easily handle qualitative variables making it widely used in integrated analysis of spatial data from multiple sources for prediction and classification.

One of the most important constraints of using ANN in a wide range of applications is its training efficiency. Training artificial neural networks is computationally expensive. For this reason, the newly-developed ANN training method, the Inhibited Brain Learning (IBL), is used

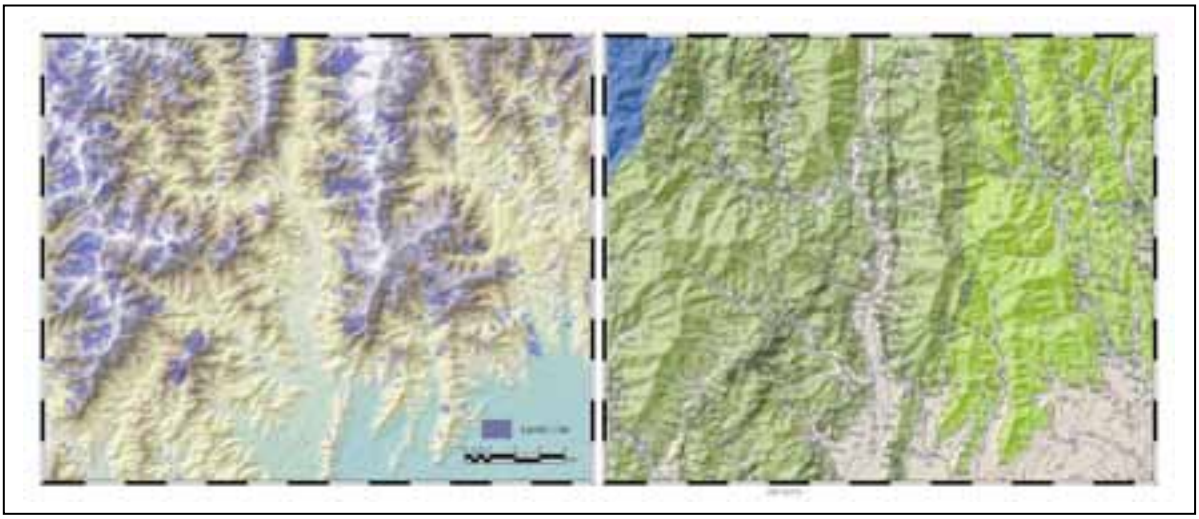
in this study. IBL has been found to be very efficient in training ANN. For more details about the training method, refer to the work of Bandibas and Khoyama (2001).

This study focuses on developing a method to generate landslide susceptibility maps using ANN. The IBL computing method was used during ANN training. The ANN software developed at the Geological Survey of Japan was used to implement the experiment. Satellite images were also used to generate important inputs to the ANN, such as vegetation data, slope, aspect and elevation. A landslide susceptibility map of the study area was successfully generated using the developed method.

BACKGROUND OF THE STUDY AREA AND DATA USED

The study area is located at the mountainous region in the central part of Japan. The highest peak of the area is 1450 meters above sea level. The geology of the site is characterized by sedimentary and metamorphic rocks from Paleogene to Quaternary age (Figure 1.). A 15-meter digital elevation model (DEM) of the area was generated using the Advanced Spaceborne Thermal Emission Radiometer (ASTER) satellite images obtained during the winters of 2001 and 2003 and the summer of 2004. ArcView software was used for the topographic measurements. Slope angle and aspects for each grid point were calculated from the altitudes of the surrounding eight DEM points (Horn, 1981). The plane and profile curvatures were calculated using the spatial analyst command of ArcView.

The digital geological map was generated by digitizing the 1:50,000 geological map of Shimizu (Sugiyama and Shimokawa, 1990). Maps of strike and dip angles were calculated using the thiessen subdivision, from the points of dip-strike angle of the source map. The buffer region map was calculated from polyline data of the geological boundary. Areas with and without landslide occurrence were digitized using the landslide map of Shimizu, courtesy of the National Research Institute for Earth Science and Disaster Prevention.



A. B

Figure 1. A. Landforms including sites with landslide occurrence in the study area.
B. Geological map of the study area.

DATA ANALYSIS

Analysis of the data shows that landslides are more prevalent in some rock types as shown in Figure 2. It is also observed that many landslides occur in areas with south-southwest strike angles. However, the relationship between landslide and dip angle is not very clear. The result also shows that half of the landslides that happened in the area occurred within a 50-meter distance from a geological boundary.

The result further shows the relationship between altitude, slope, aspect (slope direction) and curvature, and landslide occurrence. Landslide incidence increases with altitude (Figure 3B). It can be observed that the mean slope in areas without landslides is higher compared to the mean slopes in areas where landslides occurred. It is also evident that more landslides occurred in slopes facing west (Figure 3A), correlating with the dominant west to northwest dip direction. This observation shows that there is higher probability for landslides to occur when the slope and the dip directions are the same. The results of the curvature analysis also show that there is no clear relationship between landslide occurrence and terrain types.

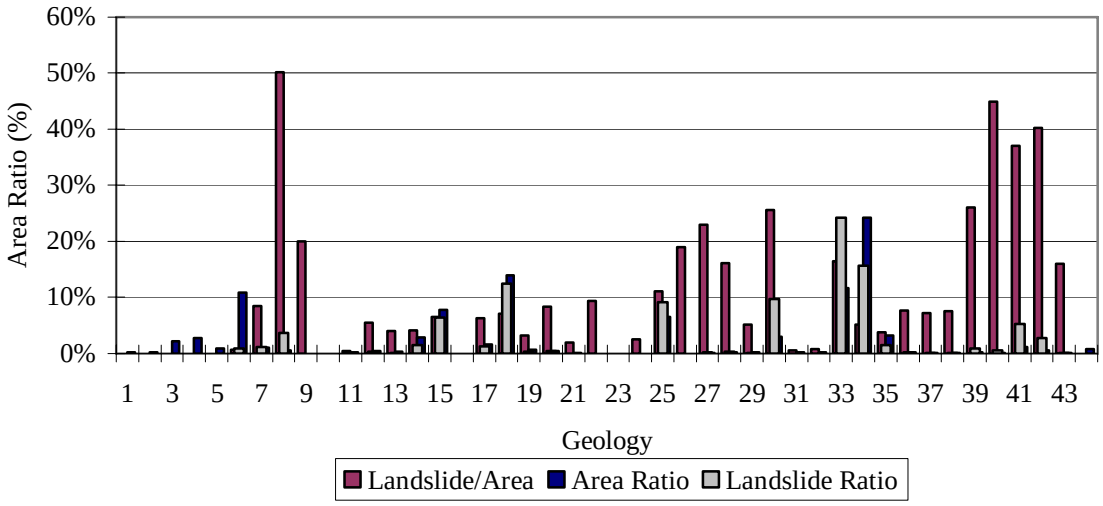


Figure 2. Graph of landslide occurrence in each geological type in the area. The numbers used are the geologic code used for the area.

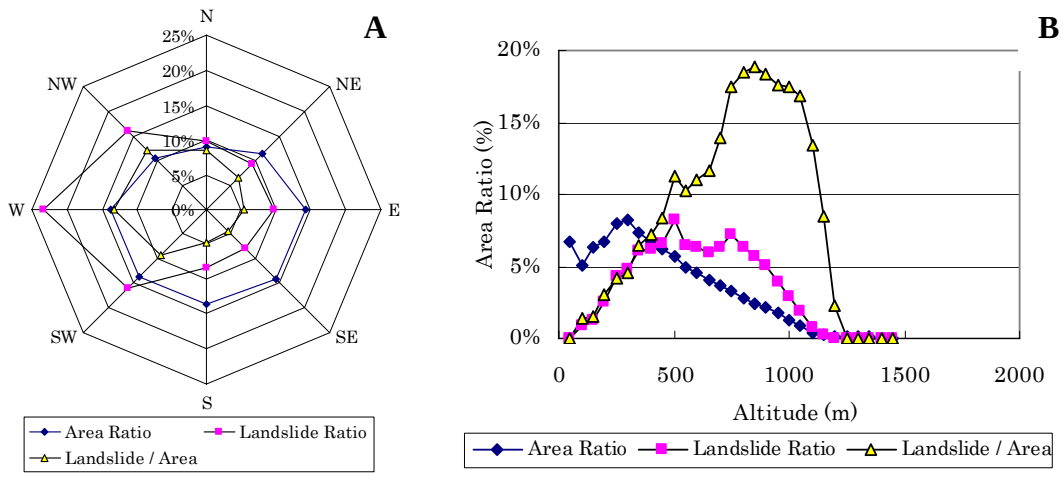


Figure 3. **A**. Aspect of Landslides. **B**. Altitude distribution of landslides.

LANDSLIDE SUSCEPTIBILITY INFORMATION USING ARTIFICIAL NEURAL NETWORK (ANN)

A multi-layer perceptron ANN trained by the back-propagation algorithm (Rumelhart et al., 1986) using the gradient descent training method was used in this experiment. The efficient IBL training method (Bandibas and Khoyama, 2001) was also used. The ANN has one hidden layer with 40 nodes. The number of nodes in the input layer ranged from 4 to 23 depending on the number of factors considered for training (Figure 4.). The ANN has one node in the output layer. The JasGB-Net software developed at the Geological Survey of Japan, AIST, was used to implement the experiment. This is artificial neural network software designed to generate landslide susceptibility maps using GIS based data inputs. Figure 4 shows the scheme in the presentation of the input and output pairs during the ANN training. Training pairs were extracted from the GIS-based database. Sample sites with landslide occurrences were identified in the study area. The corresponding information (slope, aspect, geology, vegetation etc.) were fed into the ANN with a training output of 1. Sites with no landslide occurrence were also randomly selected. The ANN was trained to output 0 using the data in these sites. Through this training scheme, a trained ANN will output nearer to 1 when the area's susceptibility to landslide occurrence is high and nearer to 0 when the landslide occurrence susceptibility is low.

A series of training runs were implemented using different combinations of factors. The aim of the experiments was to determine the combination of factors that has the highest degree of correlation to landslide occurrence. The following are some of the combinations that were tried in this study:

1. Slope, Aspect, Elevation, Geology, Buffer, Strike, Profile Curvature, Plan Curvature, Dip and Vegetation Cover (using all data from 2001 to 2004).
2. Slope, Aspect, Elevation, Geology, Buffer, Strike, Profile Curvature, Plan Curvature , Dip and strike (using only 2004 data), and vegetation cover from 2001 to 2004.
3. Slope, Aspect, Elevation, Geology, Buffer, Profile Curvature, Plan Curvature (using only 2004 data), and vegetation cover from 2001 to 2004.

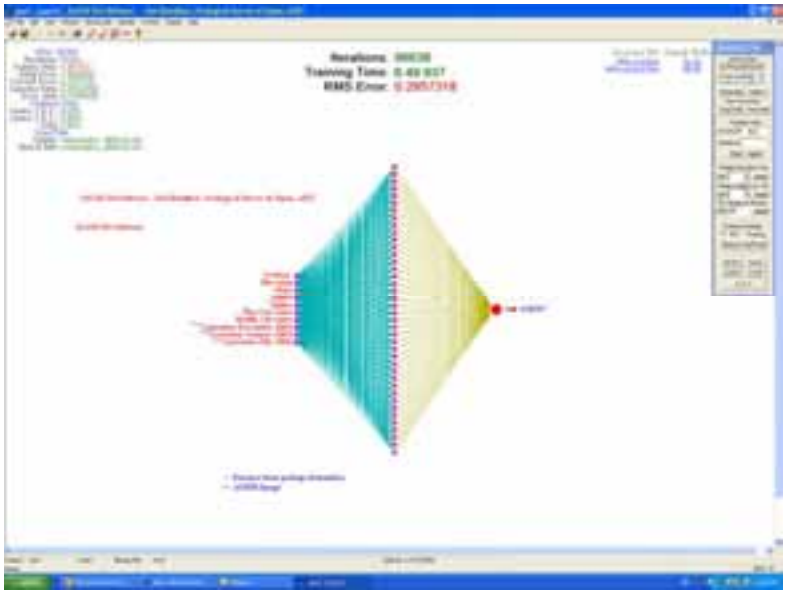


Figure 4. JasGB-Net Software in ANN Training mode. It shows the JasGB-Net software training the ANN using combination 3. The ANN network training run is stopped when the RMS error reaches 0.25.

DISCUSSION

This study is still ongoing but the initial results of the research are very promising. Figures 5A and 5B show the landslide susceptibility maps generated using the trained ANN using combinations 1 and 3, respectively. Training the ANN using all the available data in this experiment (combination 1) does not result in an accurate landslide susceptibility map as shown in Figure 5A. In this, flat areas and water surfaces are shown to have high susceptibility to landslides which indicates that some input data are not correlated to landslide occurrence and just confuse the ANN. On the other hand, combination 3 generated promising results as shown in figure 5B. This is consistent with the initial spatial analysis showing high correlation between landslide occurrence and the factors in combination 3. The result showed that landslide susceptibility values in the generated map are highly correlated to the landslide occurrences observed in the area. Based on these results, it will be efficient that the factors to be used as ANN inputs will be determined first using geomorphological and geological analysis. Presently, the accuracy assessment for the generated landslide susceptibility maps is still ongoing.

A. **B.**

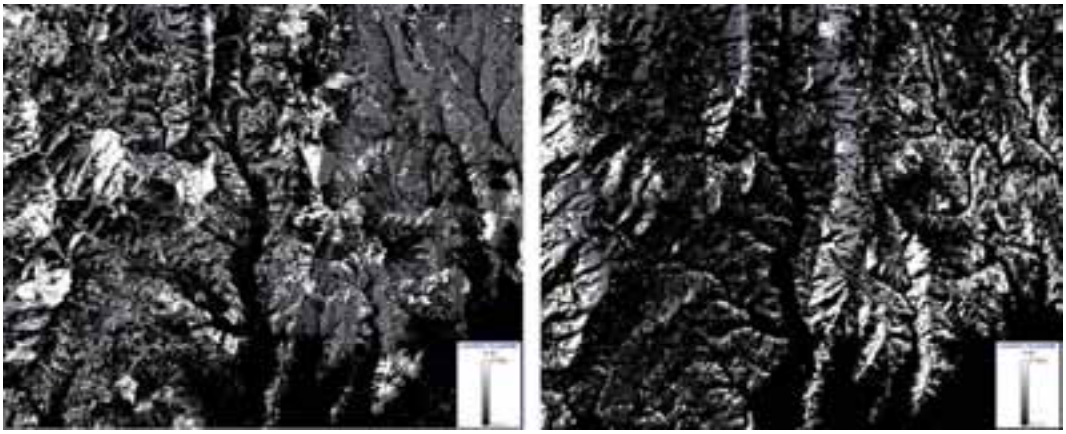


Figure 5. A. Landslide susceptibility map generated using combination 1.
B. Landslide susceptibility map generated using combination 3.

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Assessment of Runout Distance of Debris Flows Using an Artificial Neural Network Method

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ABSTRACT

A method to assess the runout distance of debris flows through natural terrain is described. The runout distance of debris flows in three pilot sites underlain by different lithologies were measured in the field. Only debris flows that were not interfered with by other nearby debris flows were selected for the study in order to accurately quantify the distance of travel of a single landslide/debris flow. Based on the results of field surveys and the laboratory tests, artificial intelligence methods were applied to develop models for assessment of the runout distance of debris flows. Because the factors influencing runout distance are too complex to analyze individually in a deterministic manner, an artificial neural network method was used to characterize runout distance relative to topographic and geologic properties. Input factors were determined as follows: slope gradient, length of landslide, permeability, dry density and porosity of soils. These parameters were selected by logistic regression analysis that had been used to predict landslide probability. From the analyses of results of assessment of runout distance using the artificial neural network method, it was possible to determine two models with the inference accuracy lower than 5% and 2% respectively.

Keywords*: runout distance, natural terrain, debris flows, artificial neural network.*

INTRODUCTION

Most landslides in Korea are closely related to intense rainfall during the summer rainy and typhoon seasons. The precipitation in the summer season reaches as much as 1,200mm, more than half of the mean annual precipitation. Ninety percent (90%) of landslides that occur in Korea are debris flows (Kim *et al.*, 2003; Chae *et al.*, 2004a).

An accurate prediction of landslides is necessary to aid mitigation and prevention of landslide damage. However, landslides do not always cause significant damage. The runout distances of debris from similar sizes of landslides can have different values dependent on geomorphology of slopes and geologic conditions of the materials. Because the runout distance of debris is directly related to magnitudes of damage, it is necessary to assess the runout distance of debris for prediction of landslide risk.

Previous research projects concerning the runout distance and the characteristics of debris flows are largely comprise two approaches: a) field survey or observation and, b) laboratory model testing. Most studies include measurements of rainfall, pore water pressure, displacement of foundation and runout distance of debris and classification of materials. They try establishing the relationships between geomorphologic characteristics, sliding material and runout distance based on analyses of the transportation mechanism, velocity and energy of debris (Suwa, 1988; Suwa and Sumaryono, 1995; Iverson, 1997; Sassa, 1998). However, field

observations and measurements have difficulties in identifying the weighting value and the role of each factor related to the transportation of debris because the factors may be mixed in the field. In order to complement field surveys, research on the characteristics and distance of debris transportation are performed by laboratory tests. The laboratory tests usually use large or intermediate sized flumes filled with various conditions of soil and they analyze flow characteristics of debris as a function of rainfall intensity and slope angles (Moriwaki, 1987; Okura *et al.*, 2002; Wang and Sassa, 2003; Moriwaki *et al.*, 2004).

The present study resulted in the development of a method to assess the runout distance of debris on natural terrain. The runout distances of debris flows in three pilot sites composed of different lithologies were measured in the field. Isolated debris flows that were not interfered with by other nearby debris flows were selected in order to measure accurately the distance of debris transportation on single landslide. The results of field measurements were analyzed using geomorphological factors and geotechnical properties of debris. The results were used to determine optimal models for assessment of runout distance of debris by an artificial neural network.

METHODS

Study Area

Sites selected for this study were based on recent occurrences of debris flows that showed evidence of debris movement. The sites were composed of materials with different physical properties. Three pilot sites, Sacheon, Macheon and Gabuk, were chosen for the study.

The Sacheon area was selected for this study to determine the characteristics of flows and runout distance over gentle slopes composed of sandy materials. Here the top soil and weathered soil are typically composed of equigranular sand derived from granite. The area experienced intensive debris flows during the Typhoon ‘Rusa’ in 2002 and had been damaged by a large mountain fire in the spring of 2000.

The Macheon area was chosen to analyze the characteristics of flows and transportation of debris composed of various sizes such as large corestones, sand and silt on steeply inclined slopes. The area is composed of gabbros that form steep and long mountain slopes. Corestones are well developed in the weathered soil layers. The area experienced large debris flows during the Typhoon ‘Maemi’ in 2003.

The Gabuk area is composed of gneisses and experienced intensive debris flows during the Typhoon ‘Maemi’ in 2003. The area still has the traces of debris deposition at the bottom of mountain slopes.

Data Acquisition

The authors established a procedure to select debris flows for detailed field survey. The debris flow should have initiated from a single landslide without interference of the adjacent debris flows and converging into other debris flows. In order to accurately measure runout distance and to analyze transportation of debris from the head of a debris flow, it is necessary to trace one debris flow without interference of other debris flows.

Detailed field surveys were conducted for the three pilot sites (total area 99 km^2) to investigate geology, geometry of debris flow, track of debris transportation, runout distance of debris and to collect debris soil samples. The measurement of the geometry of a debris flow was performed for the whole path of a debris flow from the head to the toe. The measurement items are changes of slope angles, path widths, orientations, and erosion depth or deposition thickness along longitudinal and lateral cross-sections.

Laboratory tests were performed on thirteen soil samples to determine the relationship between geotechnical properties of debris and runout distances of debris flows. Soil samples were collected as undisturbed samples in the soil layer that had not failed and as disturbed samples from the materials deposited near the toe of the debris flow. *In-situ* density tests were also conducted on the soil layers composed of larger rock fragments and boulders (Kim et al., 2004).

Deterministic methods cannot be used thus far to evaluate relations between the fluid measurements, laboratory data and debris flow runout distance because the relations among these data are very complex. Therefore, this study applied an artificial neural network method to assess the runout distance of debris flows. This method is one of the useful methods to identify a relationship among manifold data and factors. The data from the detailed field surveys and the laboratory tests were analyzed to find inter-relationships of the transportation characteristics, the runout distance of debris, geomorphology and geologic conditions using the artificial neural network.

ASSESSMENT OF RUNOUT DISTANCE OF DEBRIS FLOWS BY AN ARTIFICIAL NEURAL NETWORK

Determination of Optimal Neural Network Models

In order to select optimal models for the assessment of runout distance of debris flows, a total of twenty four debris flows were used for the inference simulation by the artificial neural network. The analyses to select optimal artificial neural network models were performed using six input factors that are known to influence the transportation of debris. The six input factors consist of gradient of changes in slope angle, permeability coefficient, dry density, porosity, sand proportion and volume of debris. The output factor is the runout distance of debris. The evaluation computations were performed with the following four groups.

Group A: gradient of changes in slope angle, permeability coefficient, dry density, porosity, volume of debris.

Group B: gradient of changes in slope angle, permeability coefficient, dry density, porosity, volume of debris, sand proportion.

Group C: gradient of changes in slope angle, permeability coefficient, dry density, porosity, sand proportion.

Group D: gradient of changes in slope angle, permeability coefficient, dry density, porosity.

The learning theory is a multi-layer back propagation theory which is composed of an input layer, a hidden layer and an output layer. The artificial neural network has large changes of learning reliability and inference capacity dependent on the structure of the input layer, output layer and hidden layer. It is also influenced by the learning factors such as learning constant, momentum constant and the number of learning. Therefore, this study performed the learning with changes of the learning constant as 0.6 and 0.9 and fixing the momentum constant at 0.7. The model structure changes with the number of hidden layers and the number of layer items from two to four.

Table 1 shows the simulation models to find optimal artificial neural networks. The number of items of input layer was changed from four to six on each group. The output layer, the runout distance of debris, was fixed as one. The structure of the hidden layer was set up as two layers and three layers.

Table 1. Structures of test models and learning constants

GROUP	Model No.	Input layer	Hidden layer	Output layer	Learning constant	Momentum constant	System error
A	1	5	2-2-2	1	0.6	0.7	0.94
	2	5	3-3	1	0.6	0.7	0.79
	3	5	3-3-3	1	0.6	0.7	0.54
	4	5	4-4	1	0.6	0.7	0.14
	5	5	4-4-4	1	0.6	0.7	0.27
B	6	6	2-2-2	1	0.6	0.7	2.14
	7	6	3-3	1	0.6	0.7	0.59
	8	6	3-3-3	1	0.6	0.7	0.92
	9	6	4-4	1	0.6	0.7	0.89
	10	6	4-4-4	1	0.6	0.7	0.19
C	11	5	3-3	1	0.6	0.7	0.97
	12	5	2-2-2	1	0.6	0.7	2.64
	13	5	4-4	1	0.6	0.7	1.36
	14	5	4-4-4	1	0.6	0.7	4.22
	15	5	2-2	1	0.6	0.7	2.04
	16	5	3-3-3	1	0.9	0.7	1.53
	17	5	2-2	1	0.9	0.7	2.98
	18	5	4-4	1	0.9	0.7	1.14
	19	5	3-3	1	0.9	0.7	0.99
D	20	4	3-3-3	1	0.6	0.7	2.54
	21	4	3-3	1	0.6	0.7	1.48
	22	4	2-2-2	1	0.6	0.7	2.07
	23	4	4-4	1	0.6	0.7	0.51
	24	4	3-3	1	0.9	0.7	1.48
	25	4	2-2-2	1	0.9	0.7	1.63
	26	4	2-2	1	0.9	0.7	1.91
	27	4	4-4	1	0.9	0.7	0.67
	28	4	3-3-3	1	0.9	0.7	2.57

Computation Results Using the Models

In order to verify the learning reliability, the convergence trends of the test models which were completed, the learning and the runout distance of debris were inferred once more for the twenty four debris flows. The average error rate of inference, $P_{avr.}$, was calculated as:

$$P_{ave} = \frac{1}{n}\sum_{i=1}^{n} P_i$$

$$P_i = \frac{|R_m - R_i|}{R_m} \times 100$$

where, R_m is the measured runout distance, R_i is the inferred runout distance, and *n* is the number of data for the inference. The trend of convergence was classified as "good" if the average error rate of inference is lower than 20%, "poor" if between 20-50%, and "divergence" if higher than 50%.

The learning results of the twenty eight artificial neural network models are shown in Table 2. For group A, model numbers 4 and 5 have good inference results with low average error rate of inference. Model number 10 of group B also shows good inference results with the average error rate of inference of 3.7%. For the groups C and D, model numbers 18, 23 and 27 have relatively good inference results. The results reveal that the good models have two and three hidden layers and four items of each hidden layer. The higher average error rates of inferences for the groups C and D than those of the Groups A and B imply that the volume of debris influences on the runout distance of debris flows.

Tables 3 and 4 show the inference results of model numbers 4 and 5 that have the average error rates of inferences lower than 10% among the ten models of good inference results. Because the error rate of inference on each debris flow also has lower value as much as 10%, the models are evaluated as excellent models to predict the runout distance of debris. However, in the case of model numbers 18, 23 and 27, they have large differences of error rates of inferences on the debris flows, although the average error rates of inferences are lower than 20%. This is thought to be due to few data from the analyzed debris flows. Therefore, more debris flows and various test models are needed to draw more accurate inference models in future studies.

DISCUSSION AND CONCLUSIONS

This study developed a method to assess the runout distance of debris flow through natural terrain using artificial neural network. The analysis was performed using data from twenty four debris flows. The input data were gradient of changes in slope angle, permeability coefficient, dry density, porosity, volume of debris, and sand proportion from each debris flow.

The results of analysis were determined using insufficient number of data because this study had a premise to select debris flows without interference of other debris flows. However, considering limited data, most of the error rates of inferences were lower than 10%, which can be considered as good learning reliabilities. It is therefore emphasized that a greater number of debris flows and various test models are needed to draw more accurate inference models in future studies.

Table 2. Learning Results of the Test Models

GROUP	Model No.	No. of learning iteration	Trend of convergence	Average error rate of inference (%)
A	1	146094	Poor	22.8
	2	304276	Poor	20.4
	3	49420	Good	15.4
	4	518334	Good	2.6
	5	391032	Good	6.9
B	6	192089	Divergence	62.4
	7	127215	Good	13.9
	8	112186	Good	13.9
	9	361525	Good	12.0
	10	149333	Good	3.7
C	11	261637	Poor	24.9
	12	124617	Divergence	77.9
	13	74507	Poor	29.8
	14	127788	Divergence	111.9
	15	17761	Divergence	57.9
	16	63566	Poor	39.6
	17	80564	Divergence	52.7
	18	101319	Good	18.6
	19	266463	Poor	25.4
D	20	121016	Divergence	71.7
	21	85015	Poor	36.4
	22	24445	Poor	48.3
	23	293607	Good	15.9
	24	69300	Poor	34.4
	25	196809	Poor	23.1
	26	207457	Poor	48.0
	27	323226	Good	14.3
	28	64818	Divergence	72.3

Table 3. Inference Results of the Model 4

Landslide ID	Gradient of slope angle changes	Permeability coefficient (cm/sec)	Dry density (g/㎤)	Porosity (%)	Volume (㎥)	Length (m) *measured	Length (m) *inferred	Error rate of inference (%)
KR-73-18	0.278	0.0210	1.38	81.00	245.2	100	101.46	1.46
KR-73-20	0.452	0.0240	1.35	74.80	103.2	47	47.12	0.26
KR-84-01	0.321	0.0224	1.39	85.00	130.6	43	43.82	1.90
KR-84-02	0.364	0.0138	1.52	74.70	16.6	39	36.94	5.29
GY-72-01	0.581	0.0053	1.31	68.62	252.0	74	80.00	8.11
GY-72-02	0.490	0.0135	1.41	69.62	323.4	132	129.46	1.92
GY-72-03	0.496	0.0155	1.33	67.03	256.7	139	141.18	1.57
GY-81-01	0.438	0.0035	1.49	74.52	653.1	305	297.88	2.33
GY-81-02	0.369	0.0076	1.41	76.77	153.2	270.5	269.16	0.49
MP-79-02	0.481	0.0034	1.25	83.17	1320.5	168	181.97	8.32
WB-27-01	0.587	0.0337	1.51	73.71	301.5	270	270.76	0.28
WB-36-01	0.362	0.0136	1.38	61.45	1401.0	168	175.75	4.62
WB-36-02	0.445	0.0053	1.16	64.72	1400.2	197	200.26	1.65
WB-37-01	0.547	0.0400	1.26	69.72	1238.7	322	318.21	1.18
WB-37-02	0.475	0.0030	1.22	68.65	3012.6	175	173.47	0.87
WB-46-01	0.528	0.1208	1.07	71.84	4003.7	483	488.72	1.19
WB-46-02	0.371	0.0504	1.07	69.52	1690.5	297	299.53	0.85
WB-46-03	0.402	0.0146	1.19	65.46	666.6	299	303.21	1.41
WB-46-04	0.402	0.0406	1.28	67.73	485.9	64	67.11	4.85
WB-46-05	0.544	0.0474	1.25	69.91	2240.5	491	491.32	0.07
WB-46-06	0.367	0.0390	1.28	70.58	426.5	56.5	49.62	12.18
WB-47-01	0.370	0.0075	1.29	64.77	870.9	244	240.33	1.50
WB-47-02	0.318	0.0152	1.26	64.17	5822.9	333	335.11	0.63
WB-47-03	0.582	0.0337	1.02	71.15	630.4	223	223.19	0.09

Table 4. Inference Results of the Model 5

Landslide ID	Gradient of slope angle changes	Permeability coefficient (cm/sec)	Dry density (g/㎤)	Porosity (%)	Volume (㎥)	Length (m) *measured	Length (m) *inferred	Error rate of inference (%)
KR-73-18	0.278	0.0210	1.38	81.00	245.2	100	88.81	11.19
KR-73-20	0.452	0.0240	1.35	74.80	103.2	47	44.48	5.36
KR-84-01	0.321	0.0224	1.39	85.00	130.6	43	47.05	9.43
KR-84-02	0.364	0.0138	1.52	74.70	16.6	39	45.26	16.06
GY-72-01	0.581	0.0053	1.31	68.62	252.0	74	63.09	14.74
GY-72-02	0.490	0.0135	1.41	69.62	323.4	132	118.87	9.95
GY-72-03	0.496	0.0155	1.33	67.03	256.7	139	126.30	9.14
GY-81-01	0.438	0.0035	1.49	74.52	653.1	305	276.71	9.27
GY-81-02	0.369	0.0076	1.41	76.77	153.2	270.5	276.77	2.32
MP-79-02	0.481	0.0034	1.25	83.17	1320.5	168	149.29	11.14
WB-27-01	0.587	0.0337	1.51	73.71	301.5	270	272.03	0.75
WB-36-01	0.362	0.0136	1.38	61.45	1401.0	168	154.12	8.26
WB-36-02	0.445	0.0053	1.16	64.72	1400.2	197	181.73	7.75
WB-37-01	0.547	0.0400	1.26	69.72	1238.7	322	319.29	0.84
WB-37-02	0.475	0.0030	1.22	68.65	3012.6	175	174.68	0.18
WB-46-01	0.528	0.1208	1.07	71.84	4003.7	483	482.21	0.16
WB-46-02	0.371	0.0504	1.07	69.52	1690.5	297	293.30	1.25
WB-46-03	0.402	0.0146	1.19	65.46	666.6	299	276.57	7.50
WB-46-04	0.402	0.0406	1.28	67.73	485.9	64	67.13	4.88
WB-46-05	0.544	0.0474	1.25	69.91	2240.5	491	490.93	0.01
WB-46-06	0.367	0.0390	1.28	70.58	426.5	56.5	50.52	10.58
WB-47-01	0.370	0.0075	1.29	64.77	870.9	244	276.78	13.43
WB-47-02	0.318	0.0152	1.26	64.17	5822.9	333	332.79	0.06
WB-47-03	0.582	0.0337	1.02	71.15	630.4	223	247.32	10.91

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Reduction of Acid Rock Drainage Using a Phosphate Coating Technology

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ABSTRACT

Acid rock drainage (ARD) is an environmental problem causing concern at certain construction sites in Korea. Sulfide minerals are commonly present in many rocks, sediment and soils where they are stable under reducing conditions. When sulfide is exposed to oxidizing conditions by excavation, drainage and groundwater withdrawal, ARD may develop. About 20% of the surface area of South Korea is covered by potential ARD generating rocks. Paleozoic coal bed (Peongan group), slope For the reduction of ARD generation, the Korea Institute of Geoscience and Mineral Resources (KIGAM) has developed a coating technology using a solution containing phosphate, an oxidizing agent and a buffer. The solution was tested in the laboratory and was also applied on a cut slope in the field. The treatment of potential ARD generating rock and pyrite with the coating solution reduced ARD generation and rock weathering by about 80%. It also increased plant growth in acid sulfate soil by about three times compared with untreated soil.

***Keywords**: Acid rock drainage, phosphate coating, plant growth, surface analysis.*

INTRODUCTION

Sulfide is a common mineral in rock, sediment and soil and is stable under reducing conditions. When it is exposed to oxidizing conditions by excavation, drainage and groundwater withdrawal, it produces acid rock drainage (ARD) by its oxidation (Stum and Morgan, 1995):

$$FeS_2 + 3.5O_2 + H_2O \rightarrow Fe^{2+} + 2SO_4^{2-} + 2H^+$$

$$Fe^{2+} + 0.25O_2 + H^+ \rightarrow Fe^{3+} + 0.5H_2O$$

$$Fe^{3+} + 3H_2O \rightarrow Fe(OH)_3 + 3H^+$$

$$FeS_2 + 14Fe^{3+} \rightarrow 15Fe^{2+} + 2SO_4^{2-} + 16H^+$$

In Korea, Paleozoic coal beds (Pyeongan group), Paleozoic meta sedimentary rocks (Okcheon group), Mesozoic volcanic rocks and Cenozoic sedimentary and volcanic rocks are all known as ARD generating rocks in Korea and together they underlie about 20% of the surface area (Figure 1). Recently, the negative effects of ARD on the environment and on structural stability in construction sites are recognized as problems in Korea. The ARD acidifies and contaminates soil, surface water and groundwater with heavy metals. It accelerates rock weathering and deteriorates concrete and metal structures resulting in a reduction in slope stability. Millions of dollars of additional construction cost was paid to remediate its negative impacts during the last year.

Damage reduction strategies for ARD involve ARD treatment and prevention. The ARD treatment technology can be classified into active and passive treatments. Underground storage, underwater storage, surface containment, blending, application of bactericide, and micro-encapsulation are the commonly applied technologies for ARD prevention (Evangelou, 1995). This paper will report a micro-encapsulation technique for the formation of a nano-scale coating on the surface of pyrite.

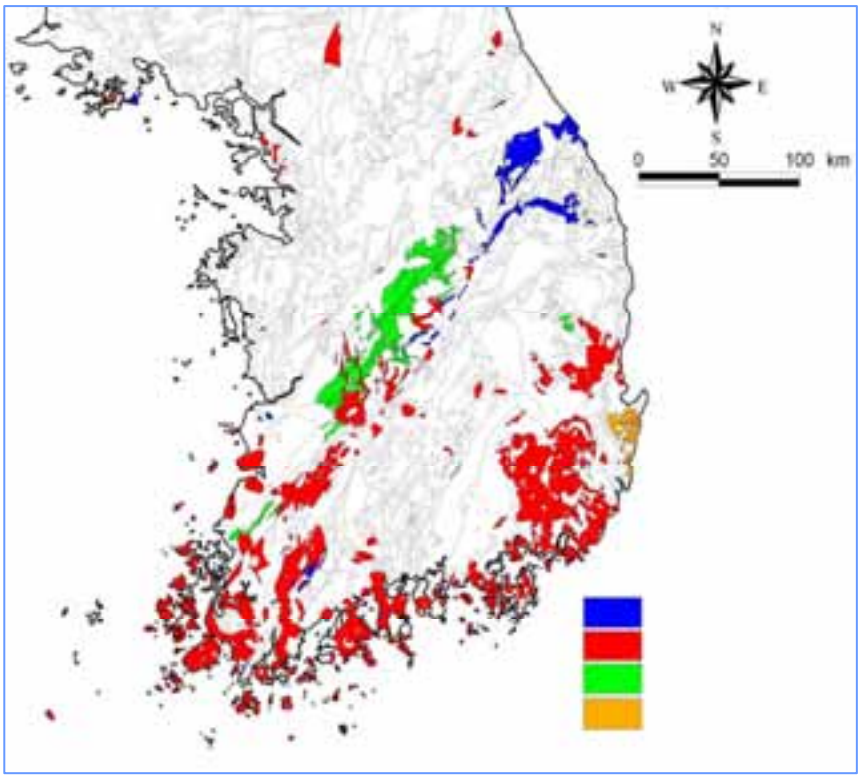

Figure 1. Distribution of ARD generating rocks in Korea.

MATERIALS AND METHODS

A variety of coating solutions containing H_2O_2, KH_2PO_4 and 0.01M Na_2CO_3 was reacted with standard pyrite or a pyrite-rich rock for 24 hours. The pH and concentrations of Fe and SO_4^{2-} of the solution were then determined for the optimum coating solution. The pyrite surface that reacted with the optimum coating solution was examined with a light microscope, a scanning electron microscope (SEM) and by X-ray photoelectron spectroscopy (XPS) to see the formation and the thickness of coating. The effect of the coating treatment on ARD reduction was tested with an oxidation experiment using distilled water and H_2O_2 solutions. The technology was also applied on a sectioned cut slope for the reduction of ARD generation and rock weathering in the field. The chemistry of the drainage and rock weathering were monitored for 4 months. A greenhouse experiment was also conducted in order to examine the effect of coating on plant growth in an acid sulfate soil. Acid sulfate soil was coated by flooding a plastic pot with the optimum coating solution and spreading ryegrass seeds on the surface. The plant growth and the leachate chemistry were monitored for 2 months in a greenhouse. After 2 months, the plants were carefully collected and dried and the soil samples were collected at 1 cm depth interval for chemical analysis. The biomass and the pH, electrical conductivity (EC), and concentration of water soluble captions and anions of the soil were determined.

RESULTS AND DISCUSSION

The optimum coating solution was 0.01M H_2O_2_0.01M KH_2PO_4_0.01M Na_2CO_3. The surface examination using microscopes and XPS confirmed the formation of the coating and the reduction of pyrite oxidation. The surface coating treatment reduced the oxidation of pyrite even under strong oxidizing conditions (Figure 2). The formation of phosphate compound on the coated pyrite surface was confirmed with EDX of SEM (Figure 3).

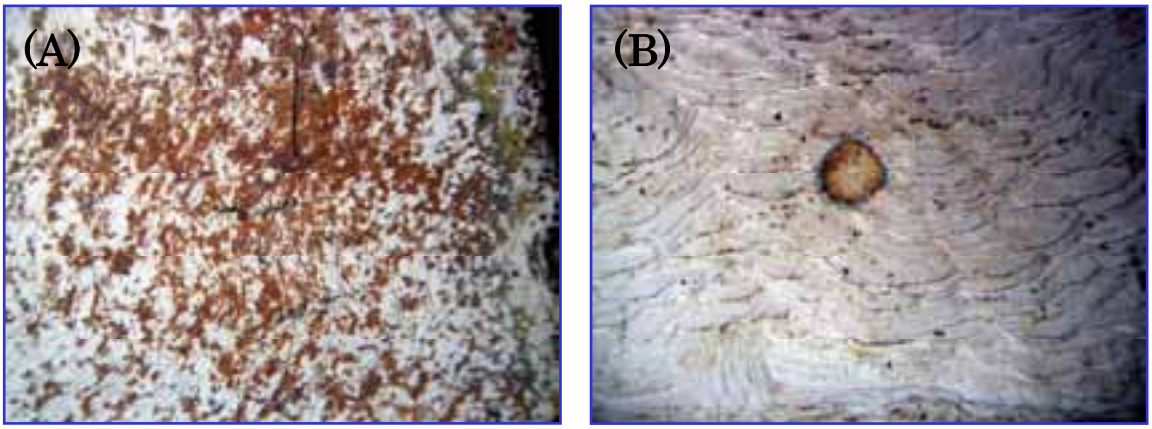

Figure 2. The surface images of uncoated (A) and coated (B) pyrites after oxidation with 0.01M H_2O_2.

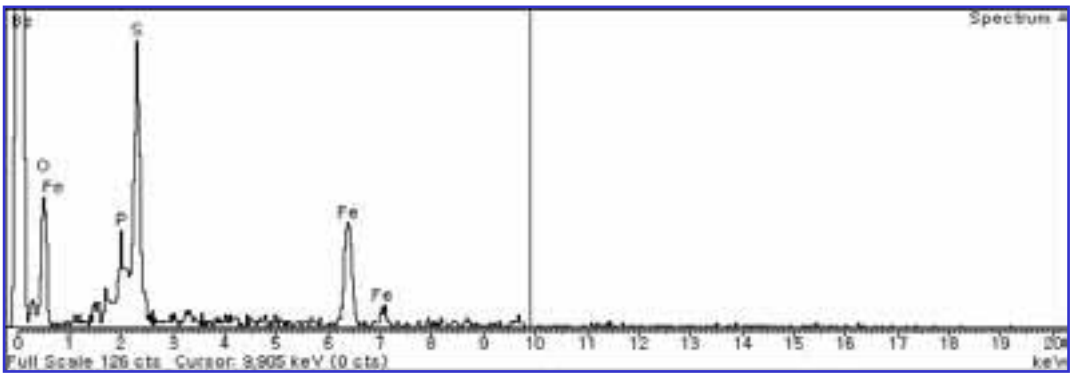

Figure 3. The EDX data of the surface coated pyrite.

According to the XPS data, the coating was a mixture of iron phosphate and iron oxide and was 5μ in thickness (Figure 4). The vertical section of the coated pyrite showed an iron phosphate and oxide dominant layer (5μ in thickness), a mixed layer of iron phosphate, sulfate, iron oxide and pyrite (25μ in thickness), and pyrite (Figure 5).

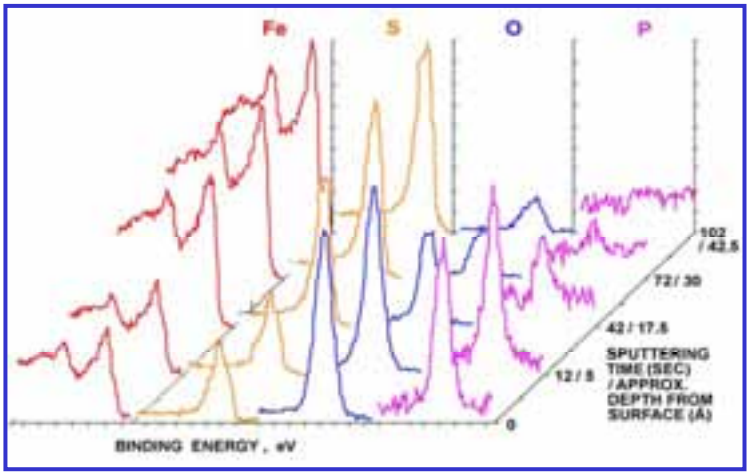

Figure 4. The XPS data of the treated pyrite surface with the coating solution.

Figure 5. A schematic vertical presentation of coated pyrite based on the XPS data.

The coating was stable in both acidic and alkaline conditions. Treatment of pyrite and pyrite-rich rock with the coating solution decreased ARD generation under normal conditions by about 80% of (Table 1). Even under strongly oxidizing conditions (0.01M H_2O_2), the coating treatment reduced ARD generation by about 50% conditions. The coating technology was also successfully applied in the field resulting in a decrease of ARD from cut slope and a reduction in rock weathering. The drainage from the coated section had a similar pH with the rainfall of the study site (Figure 6). However, the drainage from an uncoated section was strongly acidic (pH 3).

Table 1. Reduction of ARD generation from a pyrite rich rock by the coating treatment.

Reacting solution	Treatment	H^+ concentration in solution	ARD reduction rate (%)	Experimental condition
Distilled water	Coated	0.19	80.9	◦ Reaction of coated or uncoated sample and reacting solution for 24 hours ◦ Determination of H^+ concentration in solution
	Uncoated	1.01		
0.0001M H_2O_2	Coated	0.21	80.9	
	Uncoated	1.10		
0.001M H_2O_2	Coated	0.40	72.2	
	Uncoated	1.44		
0.01M H_2O_2	Coated	1.08	51.8	
	Uncoated	2.24		

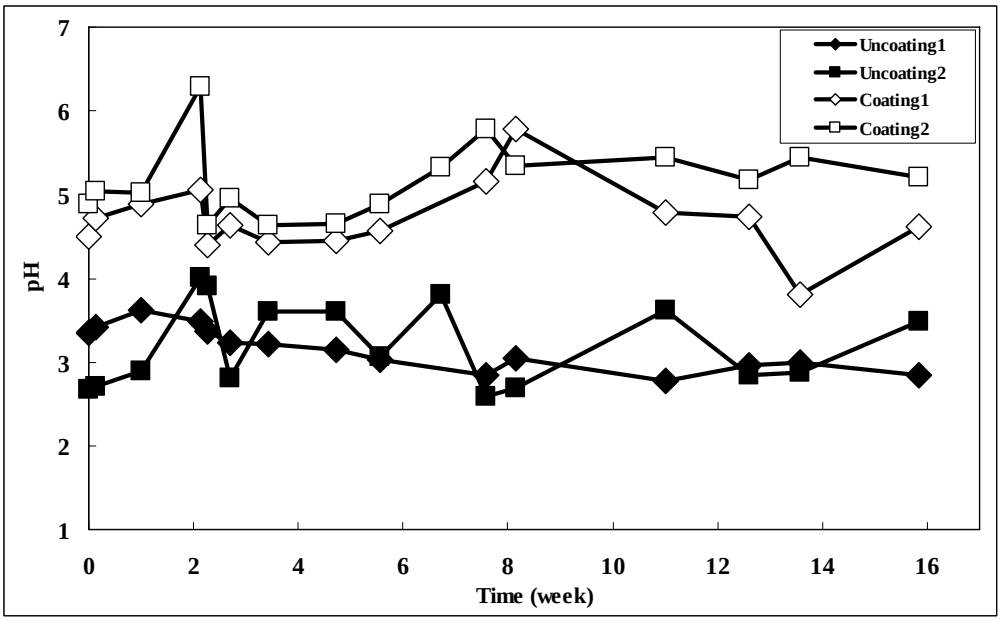

Figure 6. The pH of the respective drainage from coated and uncoated sections. The average pH of the rainfall of the study site was 5.4 during the field experiment.

The coating treatment also increased plant (ryegrass) growth in an acid sulfate soil by about 3 times compared with untreated soil. The pH of leachate from the coated soil was about 6 but the pH of leachate from the uncoated soil was about 3.5. The EC and the concentration of cations and anions of the leachate from the uncoated soil were much higher than those of the leachate from the coated soil. The uncoated soil was more acidic and had higher EC and higher concentrations of water soluble cations and anions than the treated soil. The chemistry of the leachate and the soil indicated that the coating treatment reduced ARD generation. The reduced ARD generation by the coating also increased plant growth.

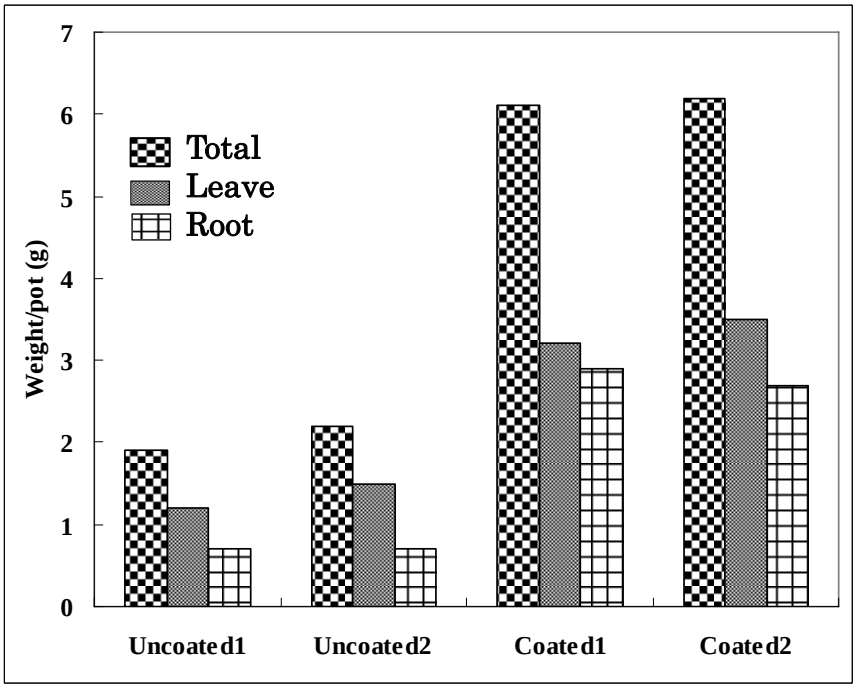

Figure 7. Ryegrass growth in coated and uncoated acid sulfate soils after 60 days growing.

CONCLUSIONS

The optimum coating solution for the reduction of ARD from pyrite and pyrite-rich rock was 0.01M H_2O_2_0.01M KH_2PO_4_0.01M Na_2CO_3. The pyrite surface was observed to be coated with iron phosphate and iron oxide by the treatment with the solution. The thickness of the coating was about 5μ as confirmed by XPS analysis. The phosphate coating was also confirmed with SEM. The coating treatment of rock and pyrite reduced ARD generation by about 80%. The prevention of pyrite oxidation by the coating treatment was observed under a light microscope. The coating treatment of an acid sulfate soil increased plant growth by about 3 times and reduced the pyrite oxidation. The application of the coating technology on a cut slope producing ARD reduced the acidity of the drainage and the rock weathering.

REFERENCES

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