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(Editors)
Progress in Landslide Science

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With 431 Images, 349 in Color

Springer

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Library of Congress Control Number: 2007920433

ISBN-13 978-3-540-70964-0 **Springer Berlin Heidelberg New York**

Springer is a part of Springer Science+Business Media
springeronline.com

Printed in Germany

Cover Photo: Guinsaugon landslide, Southern Leyte, Philippines

Cover design: deblik, Berlin
Typesetting: Stasch · Bayreuth (stasch@stasch.com)
Production: Almas Schimmel

Printed on acid-free paper 32/3141/as – 5 4 3 2 1 0

Foreword for the Publication of "Progress in Landslide Science" from UNESCO

Natural disasters are increasing in terms of frequency, complexity, scope and destructive capacity. They have been particularly severe during the last few years when the world has experienced several large-scale natural disasters: the Indian Ocean earthquake and tsunami, Hurricane Katrina and Hurricane Rita; the Kashmir earthquake in Pakistan; floods and forest fires in Europe, India and China; and drought in Africa. Images of these events have shocked us all and will remain with us for a long time. Numerous landslides and mudflows have also occurred, causing deaths, injuries and material losses. The most recent tragic ones were the large-scale landslides which struck the Philippines in 2006, hitting the Albay province on 02 December and the Leyte Island on 17 February respectively, resulting in terrible loss of life, suffering and damage. National authorities and the international community, of course, should continue to provide the practical support needed by the affected communities. At the same time, it is important to quickly learn appropriate lessons that may help individuals, families, communities and whole societies to be better prepared for other disasters, whether caused by natural forces or otherwise.

The time has come for putting more emphasis on pre-disaster action rather than remaining content with post-disaster reaction. We must mobilize scientific knowledge and technological know-how to assess natural hazards and to strengthen disaster mitigation measures. We should promote a better understanding of natural disasters. We must promote and enforce sound scientific, engineering and construction principles. And we must promote education and public awareness about natural disaster reduction.

Landslides pose considerable risks to people's livelihoods and to the environment. They cause great disruption and economic losses by the destruction of infrastructure works such as roads and other communications and utility lines and of cultural heritage and the environment. Today there is a need more than ever before to address the problem of landslides in an integrated and internationally concerted way. These are the purposes of the International Consortium on Landslides (ICL) and the International Programme on Landslides (IPL). Both initiatives encompass research, education and capacity-building in landslide risk reduction. They both enjoy the participation and support of numerous international, governmental and non-governmental organizations and entities. They contribute to the International Strategy for Disaster Reduction (ISDR) and to the implementation of the Hyogo Framework for Action 2005–2015 which was adopted at the World Conference on Disaster Reduction held in Kobe, Japan in January 2005. The 2006 Tokyo Action Plan on Landslides, which was adopted during the Tokyo Round Table Discussion on Landslides in January 2006, provides a roadmap for strengthening international collaboration and identifying focus areas for reducing landslide risk worldwide.

UNESCO had the privilege to accompany from the very beginning the establishment of the ICL and the launching of the IPL. In so doing, the Organization enjoys partnership with a large number of stakeholders including the World Meteorological Organization (WMO), the United Nations University (UNU), the Food and Agriculture Organization (FAO) of the United Nations, the UN/ISDR Secretariat and the In-

ternational Council for Science (ICSU) and its Unions. I am glad that the ICL and IPL have also been marked with the establishment of a UNITWIN Cooperation Programme on Landslide Risk Mitigation for Society and the Environment in the framework of the UNITWIN/UNESCO Chairs Programme, at Kyoto University (KU). This Programme is now hosted in the UNESCO-KU-ICL UNITWIN Headquarters at the Research Centre on Landslides of the Disaster Prevention Research Institute in Kyoto University. Furthermore UNESCO and ICL have established in August 2006 a Memorandum of Understanding for cooperation. Finally I am especially pleased that UNESCO will serve as co-organizer with ICL of the World Landslide Forum scheduled to take place in 2008. This Forum will constitute a milestone in our efforts to strengthen global risk preparedness.

The "Landslides" Journal of the International Consortium on Landslides plays a key role for the progress of landslide study as an integrated research field by putting together knowledge and technologies in many related fields of natural sciences, engineering, social sciences and culture. The present Publication "Progress in Landslide Science" comes in this context to provide an overview of the current status of this science. The diversity of subjects which are presented in this publication represents a rich collaborative work regarding landslides. I wish to commend the editors and the numerous authors involved in it. My particular greetings go to Professor Kyoji Sassa, Chairperson of ICL who continues to spare no effort in promoting ICL and IPL. It is with great pleasure that I praise the edition of this publication as a means of disseminating good knowledge in the area of landslide risk reduction.

Koïchiro Matsuura
Director-General of UNESCO

Foreword for the Publication of "Progress in Landslide Science" from UN/ISDR

A series of extremely high-profile disasters – the Indian Ocean tsunami of December in 2004, Atlantic hurricane season, the South Asian earthquake and the East African drought in 2005 underscored the importance of how better cooperation between Government authorities and the international community including scientific community would have played a critical role in helping people make life changing decisions about where and how they live before the disaster strikes, in particular high-risk urban areas.

Landslide, floods, drought, wildfire, storms, tsunami, earthquakes and other types of natural hazards are increasingly affecting the world. In the decade 1976–1985, close to billion people were affected by disasters. But by the most recent decade, 1996–2005, the decade total had more than doubled, to nearly two and a half billion people. In the last decade alone, disasters affected 3 billion people, killed over 750 000 people and cost around US$ 600 billion[1]. We cannot let this trend continue. Disaster risk concerns every person, every community, and every nation; indeed, disaster impacts are slowing down development, and their impact and actions in one region can have an impact on risks in another, and vice versa. Without taking into consideration the urgent need to reduce risk and vulnerability, the world simply cannot hope to move forward in its quest for sustainable development and reduction of poverty.

The *Hyogo Framework for Action 2005–2015: Building the Resilience of Nations and Communities to Disasters*, adopted at the World Conference on Disaster Reduction (WCDR, Kobe, Hyogo, Japan, in January 2005), represents the most comprehensive action-oriented policy guidance in universal understanding of disasters induced by vulnerability to natural hazards and reflects a solid commitment to implementation of an effective disaster reduction agenda. In order to ensure effective implementation of the Hyogo Framework at all levels, tangible activities must be carried out. For the last two years as post WCDR, we have seen many activities and initiatives developed to implement the Hyogo Framework in various areas. As a concrete activity in the area of landslide risk reduction, the International Programme on Landslides has maintained the momentum created at the WCDR and has been moving forward, led by the International Consortium on Landslides.

This publication is a valuable contribution to the implementation of the priority area 2 of the HFA – "Identify, assess and monitor disaster risks and enhance early warning", by gearing landslide risk assessment, both hazard identification, monitoring and vulnerability analysis, as well as preparedness and landslide risk management. The combination of landslide scientific knowledge and risk reduction measures are essential to reduce the impact of landslides. The Hyogo Framework calls for the international coordination and collaboration among different actors dealing with disaster risk reduction. In this sense, the Global Cooperation Platform for research and investigation for landslide risk reduction in the 2006 Tokyo Action Plan consist of very

[1] Data derived from the EM-DAT: The OFDA/CRED International Disaster Database, *www.en-dat.net*, Universite Catholiqué de Louvain, Brussels, Belgium.

important activities to promote the thematic coordination to research and reduce impacts of landslides. This initiative also contributes to the priority area 3 of the HFA, which emphasizes the importance of education and public awareness of the disaster risk reduction. Education and public awareness about the hazards, in this case landslide, are also key for people to be able to reduce risks and their vulnerabilities.

I welcome the work of the Global Cooperation Platform for research and investigation for landslide risk reduction and the International Consortium on Landslides. I look forward to collaboration with them, in particular through the International Programme on Landslides (IPL) and its Global Promotion Committee.

Sálvano Briceño
Director of United Nations Secretariat
of the International Strategy for Disaster Reduction

UNESCO's Contribution to Landslide Risk Reduction

International scientific programmes provide a forum for an in-depth study of natural phenomena, their characteristics and their occurrence. This study is an essential prerequisite for a logical approach to the understanding of natural hazards. Furthermore the mitigation of risks arising from these hazards is based on the applied science and technology as well as on educational and information campaigns and programmes. The problem of risk reduction therefore requires a multidisciplinary approach, involving co-operation between specialists in several sectors of science, technology, education and culture.

The activities of the United Nations Educational, Scientific and Cultural Organization (UNESCO) in the study of natural disasters and the protection against them date from the beginning of the 1960s. Originally concerned with basic seismology, these activities were later extended to the reduction of earthquake hazards and still later to other categories of natural hazards including landslides and their socio-economic aspects. UNESCO has brought an interdisciplinary approach to the study of geohazards and the mitigation of their effects. Being at the crossroads of several sectors, UNESCO provides a unique intellectual setting, linking, within a single organization, the natural sciences with education, culture, communication and the social sciences. With its broad mandate and breadth of expertise, UNESCO is able to integrate many of the essential ingredients for disaster reduction.

The purposes of UNESCO in the field of disaster risk prevention can be described as follows:

- to promote a better understanding of the distribution in time and space of natural hazards and of their intensity;
- to help set up reliable early warning systems;
- to foster rational land use plans;
- to encourage the adoption of suitable building design;
- to provide policy advise on the protection of educational buildings and cultural monuments;
- to strengthen environmental protection for the prevention of natural disasters;
- to enhance preparedness and public awareness through education and training;
- and, when catastrophes do strike, to foster post-disaster investigation, recovery and rehabilitation.

Facing the increasing vulnerability of its Member States to natural hazards, UNESCO has constantly advocated that risk prevention policies, including warning systems related to natural hazards like landslides, must be established or improved. Hence the promotion of landslide risk reduction, environmental protection, and sustainable development has become among the objectives of UNESCO. Various studies have been conducted, and efforts supported by the Organization on the cause and prevention of landslides. In the 1970s, UNESCO books including guidelines on landslides hazards zonation have been published. As early as 1981 a joint project initiated jointly with the United Nations Environment Programme (UNEP), under the title "The Protection of

the Lithosphere as a Component of the Environment", resulted in significant research being carried out on landslide mitigation. Both the International Hydrological Programme (IHP) and the International Geoscience Programme (IGCP) have taken prominent roles in promoting activities related to landslides. The International Flood Initiative, which is led by UNESCO, addresses landslide risks as an integral part of hydrological extremes.

The foundation of the International Consortium on Landslides (ICL), in itself, lies within an IGCP project titled "Landslide Hazard Assessment and Mitigation for Cultural Heritage Sites and other Locations of High Societal Value". Approved in 1998, this project served as an initial platform for the establishment of a Memorandum of Understanding concerning cooperation in research for landslide risk mitigation and protection of the cultural and natural heritage between UNESCO and the Disaster Prevention Research Institute, Kyoto University, Japan.

UNESCO has been closely associated with the process that led to the establishment of ICL in January 2002. Subsequently the UNESCO UNITWIN Programme on Landslide Risk Mitigation for Society and the Environment came into effect in 2003, followed by the construction in 2004 of the headquarters building of the UNESCO/Kyoto University/ICL UNITWIN cooperation program within the Research Centre on Landslides, which hosts the secretariat of the International Programme on Landslides (IPL).

Under the above-mentioned cooperative mechanisms, a number of undertakings have been carried out, including the landslide investigation in the Inca's World Heritage Machu Picchu in Peru. Above all, UNESCO has fully participated in the adoption of the 2006 Tokyo Action Plan on Landslides which represents a global road map for the assessment and mitigation of landslides.

Much more recently an understanding has been reached between UNESCO and ICL in order to cooperate in the following areas:

1. The promotion of landslide research for the benefit of society and the environment, learning and capacity-building in landslide risk reduction, notably in developing countries;
2. the integration of earth sciences, water sciences, geophysical and geotechnical sciences, technology and disaster management within the appropriate cultural and social contexts in order to evaluate landslide risk in urban and rural areas, including cultural and natural heritage sites, as well as to contribute to the protection of the human and natural environment, including lifelines and buildings of high societal value;
3. the promotion of some or all of the global cooperation fields that have been agreed in 2006 Tokyo Action Plan.

UNESCO expects to enhance its contribution to the above-mentioned areas in shaping its participation in the preparations and follow-up of the First World Landslide Forum to take place in Tokyo from 18 to 21 November 2008. This participation will build on interdisciplinary scientific work through and among UNESCO's intergovernmental scientific programmes, and will capitalize further on the transdisciplinary activities between the programmes of the Organization in the sciences, education, culture and communication.

Badaoui Rouhban
Chief
Section for Disaster Reduction
Natural Sciences Sector
UNESCO, Paris

Establishment of the Technical Journal "Landslides" as the Successor to "Landslide News"

Landslides pose a hazard and threat in most countries. Worldwide, they annually cause billions of dollars in damages and thousands of casualties. To counter these losses, scientists and engineers are successfully conducting research that aims to investigate and mitigate landslide hazards. To sustain this research requires continuing communication among researchers and those who apply its results.

From 1987–2003 this goal of communication between researchers and practitioners was aided by the international newsletter "Landslide News," which was edited, published, and distributed by the Japan Landslide Society. Professor Sassa served as Editor-in-Chief of this comprehensive newsletter, which was a very successful technical news publication. It reported on landslide news, landslide research, the efforts of landslide research organizations, and news of landslide-related technical meetings.

At the first session of the Board of Representatives of the International Consortium on Landslides (ICL), which was held at UNESCO Headquarters in Paris on 19–21 November 2002, the Board decided to launch the International Programme on Landslides (IPL). As the first coordinating project of this new program, the Board conceived the concept of the new scientific journal "Landslides" as the successor to "Landslide News." This new journal was planned and activated by ICL as the international organ of scientific communication on landslides. Thereafter, extensive deliberation on the necessary financial resources, editorial board, editorial secretariat, and publishing firm was conducted. As a result of this deliberation, Professor Sassa was appointed Editor-in-Chief of this new journal and Kyoto University was named as the site of the secretariat.

The first issue of "Landslides" was published by Springer-Verlag in April 2004 as the successor to "Landslide News." This new quarterly journal with color illustrations was created by and for landslide researchers and practitioners as a means of communication to promote landslide research and to contribute to landslide disaster reduction.

"Landslides" is supported by the United Nations Educational, Scientific and Cultural Organization (UNESCO), the World Meteorological Organization (WMO), the Japan Ministry of Education, Culture, Sports, Science and Technology (MEXT) and Kyoto University. In addition to these organizations, ICL-supporting organizations and landslide experts worldwide are cooperating in writing, editing, and publishing this journal.

Publication of "Landslides" represents an important landmark in promoting research on landslide hazards worldwide, and thus in the mitigation of landslide hazards. The journal contributes to the development and continuance of landslide research by providing an international forum for the exchange and coordination of expertise in landslide risk assessment and mitigation.

We thank Professor Sassa for his efforts as Editor-in-Chief of "Landslide News" and its successor, the very successful technical journal "Landslides." We wish this new journal a long life in service of the international landslide research community.

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Preface – Aims of This Volume

Large and small landslides occur almost every year in nearly all regions of the world. However, the number of landslides is difficult to ascertain, and even the number of landslide-caused casualties is not correctly counted worldwide. Most casualties caused by rain-induced landslides are included in those tabulated for hurricane or storm disasters, and casualties caused by earthquake-induced landslides are often included in those for earthquake disasters. Thus, the casualties due to landslide disasters are often extremely underestimated. Japan has statistics of casualties by various types of landslides (small and large debris or rock slides, debris flows, rock falls, et al. since 1967), even though they occurred during typhoons, earthquakes, or volcanic activities. Figure 0.1 shows the statistics of casualties caused by landslides, earthquakes, and volcanic activities in Japan for the period of 1967–2004. Casualties by earthquake-induced landslides are included both in the landslide disasters and earthquake disasters. Landslide disasters in Japan for this period have occurred every year; the total number of deaths (3 285) due to landslides is about one half of the deaths (7 008) caused by earthquakes, including the catastrophic 1995 Kobe earthquake. Extensive landslide prevention works have been constructed in Japan. Thanks to those preventive works, the number of casualties has gradually decreased as seen in Fig. 0.1 in spite of progress of urban and mountain development all over Japan during those years. Although there are no reliable data for damages, or even for casualties due to landslides in many countries of the world, Fig. 0.1 provides a clear evidence of the strong negative impact of landslides to society. One clear difference of landslides, as compared to earthquakes and volcanic eruptions, is that humans can prevent or mitigate many landslide phenomena, while earthquakes and volcanic eruptions can not be prevented. The hazard assessment of landslides is very effective for disaster reduction because of relatively small affected area comparing to earthquakes and typhoons. Therefore, we can do much for landslide disaster mitigation. In addition to human damages, landslides often destroy cultural and natural heritage, and the natural environment, which cannot

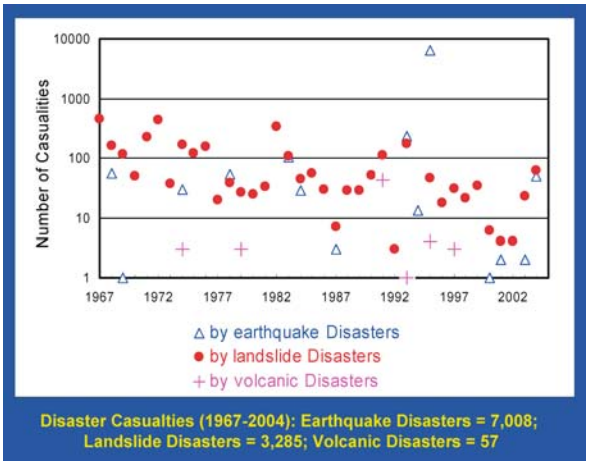

Fig. 0.1.
Comparison of the numbers of victims in Japan from 1967–2004 due to landslide disasters, earthquake disasters including deaths by earthquake-induced-landslides, and volcanic disasters including deaths due to volcanic gas (The data on victims due to landslide disasters since 1967 were published by the Sabo Technical Center)

be recovered. Landslide disaster reduction, protection of cultural and natural heritage sites, and the invaluable environment are vital factors for human society. However, studies of landslides have not been conducted in an integrated manner, although the phenomena are targets of many scientific and engineering fields. Landsides are a target of application of many technical fields, but they are not the major interest of any individual field. Therefore, no national landslide society has been established, except the Japan Landslide Society (JLS), and the very recent Nepal Landslide Society. No international society on landslides has been established because there are only one or two national societies.

The Japan Landslide Society was founded in 1963, and the society organized the first International Symposium on Landslides (ISL) in Kyoto in 1972, and the second International Symposium on Landslides in Tokyo in 1977. The Japan Landslide Society also initiated the International Conference and Field Workshop on Landslides (ICFL) in Tokyo, 1985. The society started to publish the International Newsletter "Landslide News" in 1987. Five thousand copies were printed in three colors and 2 000 copies were distributed free of charge over the world. Landslide News continued to be published until 2003 with supports from the United Nations Educational, Scientific and Cultural Organization (UNESCO), the Food and Agriculture Organization of the United Nations (FAO), the United Nations Secretariat for International Strategy for Disaster Reduction (UN/ISDR). This long-term activity gradually built up an infrastructure of international landslide community. It led to the formation of the International Consortium on Landslides (ICL) in 2002 and the new journal of ICL, "Landslides", in 2004. The publication of journal is the essential and necessary platform to create an independent field of science dealing with landslides. This book "Progress in Landslide Science" aims to present an overview of the current status of research by major landslide researchers worldwide. This volume can be a part of series of publications of ICL that may contribute to the education system of landslide science and landslide disaster management in the future.

The International Consortium on Landslides (ICL), United Nations Educational, Scientific and Cultural Organization (UNESCO), World Meteorological Organization (WMO), Food and Agriculture Organization of the United Nations (FAO), United Nations International Strategy for Disaster Risk Reduction (UN/ISDR), United Nations University (UNU), United Nations Environment Programme (UNEP), United Nations Development Programme (UNDP), World Bank (IBRD), International Council for Science (ICSU), World Federation of Engineering Organizations (WFEO), Kyoto University (KU), and the Japan Landslide Society (JLS) have jointly been organizing the First World Landslide Forum for Strengthening Research and Learning on Earth System Risk Analysis and Sustainable Disaster Management within the UN-ISDR as Regards "Landslides" which will be held in November 2008 in Tokyo. This forum will be a milestone in developing research and learning on landslide disaster reduction. Tangible progress in Landslide Science is foreseen during this process. It is hoped that this volume will be read by partners working for landslide risk mitigation and that further works will be published as increasingly wider support is obtained.

Kyoji Sassa
Kyoto, January 2007

Landslides and Cultural Heritage: the Common Thread from IGCP-425 to ICL/IPL

The protection of cultural heritage from natural hazards is an issue of worldwide concern that regards advanced nations and developing countries alike. The history and identity of every people is preserved in and portrayed by the unique monuments, art, literature, archeology and artefacts that have been created during its existence. The destruction of this wealth would represent an irreparable loss for the whole of humanity. The damage caused by natural disasters is increasing steadily as both the vulnerability of rapidly developing urban areas and the consequences of climate change tend to amplify the effects caused by their occurrence.

Within this framework landslides represent a major threat both for the safety of people and for the preservation of the built environment, including many important sites of renowned international cultural or natural value. For instance, the Mediterranean area is an excellent example of this situation as the immeasurable wealth of the entire region is often exposed to landslide hazard due to its particular topographic, geologic and climatic settings. Although the concept of preservation has already taken hold in many of the European nations bordering on the Mediterranean, much still has to be accomplished as the awareness of both the cultural and economic implications of loss is only just starting to be appreciated. The situation is rather more serious in developing countries, where even minimum levels of both the awareness of the unique value represented by cultural heritage and the economic, scientific and technical means for mitigating landslide hazard are often lacking.

For these reasons, the International Geological Correlation Programme (IGCP) project 425 titled "Landslide hazard assessment and mitigation for cultural heritage sites and other locations of high societal value" was approved during the 26th Session of the IGCP Scientific Board. The main objectives of IGCP-425, proposed in 1998 by Kyoji Sassa, were to assess and mitigate the effects of natural hazards on the cultural heritage in countries from around the world and to propose reliable, cost-effective slope stabilization techniques suitable for use on a global scale, including developing countries.

Before ending in 2002, IGCP-425 strengthened previous projects for the preservation of cultural heritage sites carried out under the Safeguarding Campaigns of UNESCO, in which it played a key role in protecting 26 sites of global relevance. The IGCP-425 was set up to provide a framework for assembling the results of national projects carried out by the individual participants (over 50 national and regional institutions and universities were involved) concerning various aspects of landslide hazard that are still useful today for drawing up prevention and mitigation plans of general validity.

In particular, the specific aims of the IGCP-425 project were:

- to develop high precision and durable slope monitoring equipment for potential landslides in urban and rural areas, especially in relation to outstanding cultural heritage sites;
- to develop reliable, cost-effective techniques for assessing rapid landslide motion, delimit hazard areas and reduce damage to life, cultural heritage, infrastructures and property;

- to develop economical and effective slope stabilization works and disaster mitigation measures suitable for use on a global scale, including developing countries;
- to research reliable landslide hazard assessment and risk evaluation methods;
- to detect potential landslides and identify precursory phenomena.

To promote the project, UNESCO and the Disaster Prevention Research Institute of Kyoto University, Japan (DPRI/KU) exchanged in 1999 a Memorandum of Understanding concerning cooperation in research for landslide risk mitigation and protection of the cultural and natural heritage as a key contribution to environmental protection and sustainable development in the first quarter of the twenty-first century.

The Tokyo Declaration "Geoscientists tame landslides" was released in the 2001 UNESCO/IGCP Symposium on Landslide Risk Mitigation and Protection of Cultural and Natural Heritage to propose an initiative that led to the creation of the International Consortium on Landslides (ICL) for the worldwide promotion of landslide research.

This initiative derived from two observations: (*1*) that the specific points listed previously correspond to the main themes of landslide research in general and (*2*) that the specificity of the protection of cultural heritage from landslides must necessarily take into account not only landslide research methods but also those relative to the study of the vulnerability and worth of the cultural and natural artifact, which entails the involvement of other disciplines and professions. These factors led to a practical approach in which landslides are tackled comprehensively and cultural heritage is considered as a related, highly important field.

In 2002, during the International Symposium "Landslide Risk Mitigation and Protection of Cultural and Natural Heritage", co-organized by UNESCO and Kyoto University, international experts coming from different national, scientific, and governmental institutes, academic institutions, regional and international organizations, international non-governmental organizations and United Nations organizations unanimously agreed and declared to launch the ICL in the 2002 Kyoto Declaration. In the months following its launch, a great effort by the IGCP-425 leaders led to the definition of the objectives and the structure of the Consortium, and the results achieved during the projects were adopted as the basis for the construction of a world research program on landslides (International Programme on Landslides, IPL) as one of the main initiatives of the recently created ICL.

The IPL is today a pillar of the ICL and both are rooted in the initial endeavor: IGCP-425, the objectives of which are still the guiding principles. The IPL also gave birth to the journal Landslides, indeed one of its most important outcomes, which hosts many papers dedicated to the topic of landslides and cultural heritage.

Paolo Canuti
Firenze, January 2007

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Part I Progress in Landslide Science

Chapter 1

Landslide Science as a New Scientific Discipline

Kyoji Sassa

Abstract. Landslides cause great disasters and their impact to society is very great. Thus, they are studied in many scientific and engineering fields. However, studies on landslides from various fields have not been conducted in an integrated manner. There was neither international society, nor international journal, and the meaning of landslides was not defined internationally and interdisciplinary. During the United Nations International Decade for Natural Disaster Reduction (IDNDR) in 1990–2000, landslide researchers worldwide agreed the definition of landslides as "the movement of a mass of rock, debris or earth down a slope". This is a basis for the development of the study of landslides as a scientific field. This paper describes the progress in landslide science as an integrated discipline together with the development of international landslide community and a global cooperation platform as its infrastructure.

Keywords. Classification of landslides, landslide dynamics, landslide science, ISDR, IDNDR, ICL

1.1 Definition of Landslides

Landslides are studied in many countries because they occur almost worldwide, from high mountain areas to coastal areas and even in marine geologic units, from very wet or heavy rainfall areas to very dry areas, and from seismic or volcanic areas to tectonically non-active areas. Some landslides are triggered by human activities, such as road and railway construction, mining, and development in urban and mountain areas. The landslide phenomena have been studied in may countries and many areas. Landslide studies have been conducted in many fields of science and engineering. Landslide disasters have been dealt with many governments, ministries, and they are related to many other disasters. As shown in Fig. 1.1, landslides are phenomena that involve many disciplines, ministries, and individuals. However, landslide phenomena have not been studied in an integrated way. Even the definition of landslides, what is a "landslide", has been diverse in countries and disciplines worldwide.

David Varnes presented "Classification of Landslides" by the type of material (bedrock and soils) and type of movement (falls, slides, flows) in "Landslides and Engineering Practice" (Eckel, ed.) in 1958 (Varnes 1958). This paper presented the concept of landslides in wider meaning, including debris flows, rock falls, debris avalanches, creep, etc. However, many opinions and criticism occurred whether land-SLIDE can include the phenomena of FLOW, FALL and other movements. Therefore, Varnes (1978) presented "Types of Slope Movements" in "Landslides-Analysis and Control" using the type of material (bed-

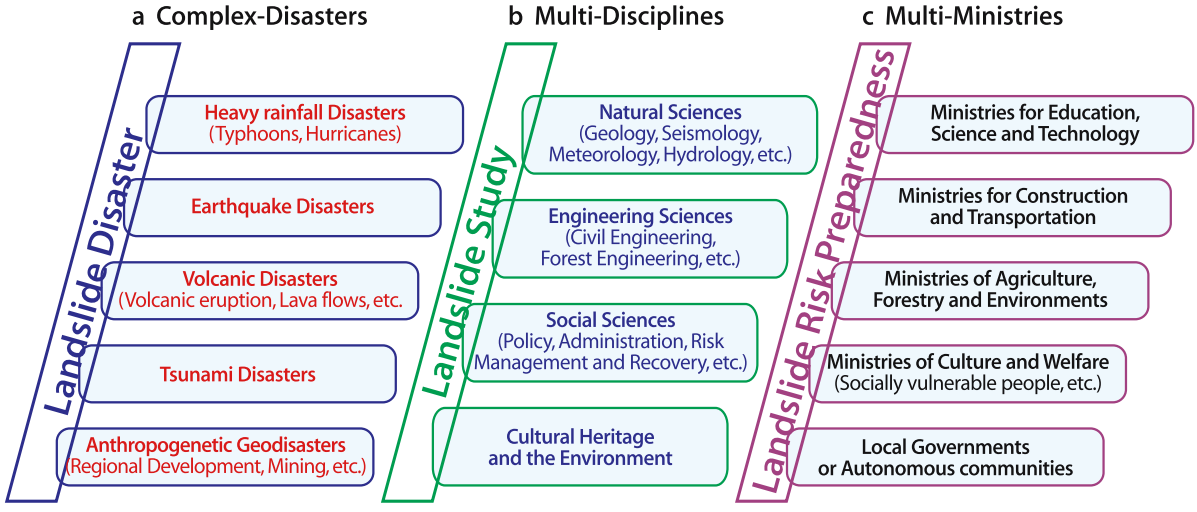

Fig. 1.1. Characteristics of landslide disasters (from 2006 Tokyo Action Plan; Sassa 2006)

rock, debris, earth) and the type of movement (falls, topples, slides, lateral spreads, flows; Fig. 1.2). The International Geotechnical Societies' UNESCO Working Party on World Landslide Inventory was established in conjunction with the United Nations International Decade for Natural Disaster Reduction (IDNDR). This Working Party was formed by the Commission on Landslides and other Mass Movements of the International Association of Engineering Geology and the Environment (IAEG), the Technical Committee on Landslides of the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE) and the International Society for Rock Mechanics (ISRM). This working party defined various terms of landslide features, landslide velocities, landslide dimensions, and state of activities (Cruden and Varnes 1996). The most important of these factors is the definition of landslides by the Working Parties as "the movement of a mass of rock, debris or earth down a slope". Namely various types of gravitational mass movements were integrated in the category of "Landslides". Even some movements are not "Slide". Cruden (1991) explained that an English word combining two words can express something different from original two words. Thus, landslide is not always necessary to be "*Slide of Land*".

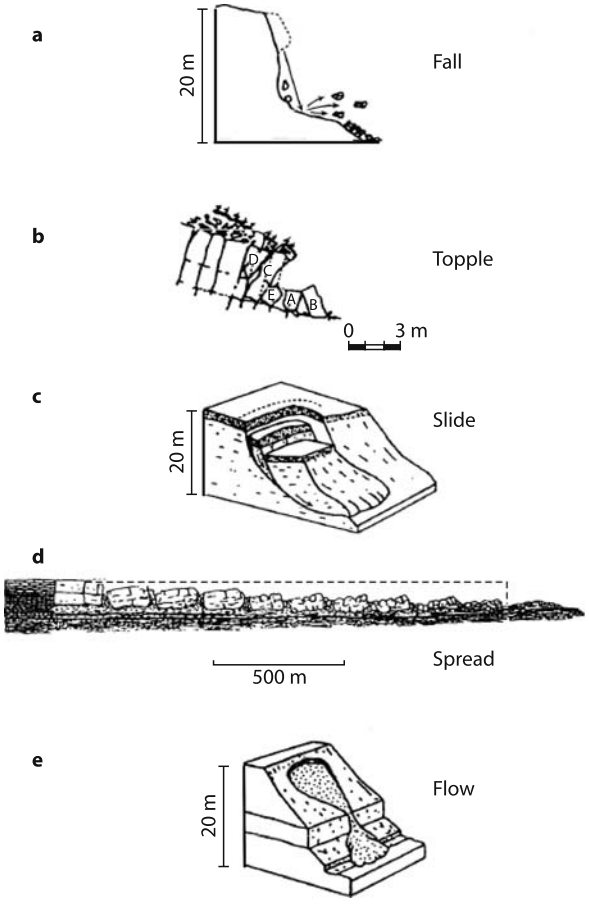

Fig. 1.2. Types of landslides (modified from Cruden and Varnes 1996)

Landslides were classified by the Working Party by the type of material (rock, debris: predominantly coarse soils, and earth: predominantly fine soils) and the type of movement (fall, topple, slide, spread, flow). Basically the idea was to return to the Varnes' Classification of Landslides (Varnes 1958). It was introduced by Cruden and Varnes (1996) in "Landslides – Investigation and Mitigation". The definition of landslides as the "the movement of a mass of rock, debris or earth down a slope" was widely accepted. It is the very important basis for the development of Landslide Science.

The International Consortium on Landslides (ICL) which was established in 2002 as the first and unique international organization dedicated to landslide research, created a new award called the "Varnes Medal", which recognizes professional excellence in landslide research and education, the basis for David Varnes definition of the area of landslide study. The first Varnes Medal was bestowed to Robert Schuster of the U.S. Geological Survey (Canuti 2004).

1.2 Landslide Science as a New Scientific Discipline and Landslide Dynamics as its Core

The International Strategy for Disaster Risk Reduction of the United Nations (UN-ISDR) was initiated in 2000 following the International Decade for Natural Disaster Reduction (IDNDR) for 1990–2000. Landslide disaster risk reduction is one of major task of this strategy. Landslide

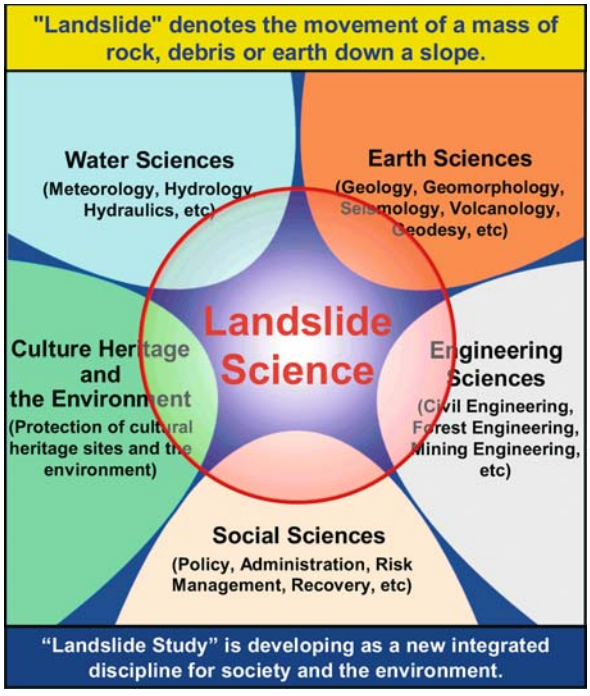

Fig. 1.3. Landslide Science as a new integrated discipline

study by integrating knowledge obtained in many fields of science and engineering related to landslides is imperative to effectively mitigate landslide risk. Figure 1.3 presents an illustration of landslide study as a possible integrated discipline. However, It necessitates at least two factors to be an independent discipline, namely its own core study in research and an international journal to bring together common scientific knowledge.

1.2.1 Core Study of Landslide Science

The core study in landslide research may develop as an integrated and independent discipline, namely landslide science. One of the initial core studies in landslide science can be landslide dynamics because landslides have been defined as "the *Movement of a Mass* of rock, debris or earth down a slope". Dynamics are studied in the field of sciences dealing fluids: air, water, and other liquids. Geology, geomorphology, and geotechnology dealing with solids on earth do not include dynamics, at least as their central interests. The stability analysis for the failure of slopes is a major task for geotechnology, but post-failure motion is not a concern because major interests are to design construction works, such as roads, dams, and others, in a state that does not allow failure. The tools to study dynamics of soil masses have not been fully developed. Sassa (1992) developed an apparatus to simulate the initiation and post-failure motion of earthquake induced landslides. This apparatus was not well functioned to monitor pore-pressure generation in the shear zone and to keep a shear box in the undrained condition during tests. The apparatus was later improved in its capability to maintain an undrained state in the soil sample and to monitor pore-pressure generation near the sliding surface. It was applied to the Nikawa landslide triggered by the 1995 Kobe earthquake, which killed 34 residents by its rapid and long travel movement (Sassa 1996). By obtaining a special budget to investigate the 1995 Kobe earthquake disaster and to prevent further similar disasters, a new advanced undrained dynamic loading ring shear apparatus (DPRI-5 and 6) was developed (Sassa 2000). The apparatus is called as a "ring-shear simulator of earthquake-induced landslides", with capability to reproduce 5 Hz real seismic wave loading, to maintain undrained condition in the soil sample during a maximum 224 cm s^{-1} velocity at the center of ring shear sample box (250 mm inside diameter, 350 mm outside diameter for DPRI-6). The latest version is the ring shear apparatus (DPRI-7) which has a transparent shear box enabling the direct observation of shearing and crushing of grains at high speed under a high normal stress at a maximum speed of 300 cm s^{-1} (Sassa et al. 2004). These apparatuses, DPRI-5,6,7, can reproduce the stress in the slope during ground-water rise (pore-pressure increase) or during earthquakes (seismic wave loading up to 5 Hz in both normal stress and shear stress). Therefore, the apparatuses can study pore-pressure generation and mobilized shear resistance during sliding-surface formation and post-failure motion in various types of landslides; such as rain-induced landslides, earthquake-induced landslides, transformation of debris slides to debris flows, and enlargement of landslide masses during the process of downslope movement. Those applications were introduced in the initial issue of the new international journal *Landslides* (Sassa et al. 2004). This study is one of core studies in landslide science as a new discipline on landslides. Within this initial issue of *Landslides,* a new monitoring technology for landslides, the ground-based Synthetic Aperture Radar system (GB-SAR), was also reported on. SAR was originally developed as a satellite monitoring method; however, this new system is installed on a short rail on the ground in front of landslides. The radar antenna is repeatedly moved on the short rail. Therefore, monitoring for a short time span is possible (Antonello et al. 2004). Application of GIS and geophysical technology for landslide mapping and investigation, and application of stability technology to protect the Bamiyan Budda niches in Afghanistan were also reported in this initial issue.

1.2.2 A New International Journal, *Landslides*

The publication of an international journal is imperative for an independent discipline. Such publication requires a stable financial background and a strong involvement of the international scientific community to contribute quality articles. It is not easy to create a new international journal. The number of individuals, organizations, and entities that are involved in landslide research are many, as is shown in Fig. 1.1. However, the total number of professionals studying landslides as their main interest is small. The target of readers of new landslide journal must be the wide variety of groups and disciplines shown in Fig. 1.1. Therefore, the articles of the journal must be enjoyed by those people who have not professionally studied and those who have no time to read in detail, but have time to glance at the articles. Thus, articles in the new journal must be something understood by a glance, and enjoyed by looking over pages of the journal. Ideally, the journal should be printed in full color. Mono-color landslide photos can neither be fully understood nor attractive. Figures must be drawn in color to present their meaning immediately in an understandable way. However, publication of a full color journal is very expensive. As far as the author knows, no full-color scientific journal has been published without advertising, or without additional charges for the color figures. Sassa proposed publication of the journal "Landslides" as the initial and the life-time

project of the International Programme on Landslides (IPL) at the first session of Board of Representatives of ICL held at UNESCO Headquarters on November 19–21, 2002. Publication of "Landslides" was decided to begin as the IPL C100 project. Sassa surveyed and negotiated with major international publication companies. Agreement was reached with Springer-Verlag at Heidelberg, Germany. Dr. Wolfgang Engel, the Executive Editor of Geosciences of Springer-Verlag, was the main partner. "Landslides" began publication in April 2004 as a quarterly journal. The journal was accepted at Thompson ISI for coverage in Science Citation Index Expanded from 2005. It is extremely fast to be accepted in this index after only one year of publication. The journal is distributed through the web at most of universities, institutes, and other organizations that have contracts to purchase web journals with Springer-Verlag. The printed version of the journal is distributed to ICL member organizations and others through Springer-Verlag sales worldwide. It is said that the journal is fulfilling the initial purpose to attract groups, organizations, and individuals in many fields in both contribution and reading. The number of pages submitted and the quality of papers are constantly increasing.

1.3 Foundation of the International Consortium on Landslides

Landslide science as an integrated discipline is developing through the journal publication and progress of core studies. As its background for the development, the International Consortium on Landslide (ICL) and the recent development of the international landslide community under the initiative of ICL are introduced in this and the next section.

As a part of the Japanese contribution to the IDNDR (International Decade for Natural Disaster Reduction) in the last decade of the 20th century, the Ministry of Education, Culture, Sports, Science and Technology of the Government of Japan (MEXT) conducted international joint research projects. The projects included the Japan-China Joint Project "Assessment of Landslide Hazards in Lishan (Yang-Que-Fe Palace), Xian, China", which was proposed by Kyoji Sassa, Disaster Prevention Research Institute, Kyoto University. The Palace is an important Cultural Heritage site, attracting more than three million visitors per year. The report of the joint research clearly demonstrated evidence of the risk of large-scale rock slide, based on detailed monitoring and observation of two investigation tunnels. The Secretary-General of the Communist Party of the Shaanxi Provincial Government, the former director of the Chinese Seismological Bureau, and the honorary chairperson of the International Symposium on Landslide Hazard Assessment, Xian, China organized by this group understood the landslide risk at the Lishan Palace. An extensive landslide prevention work was conducted to stabilize the slope. This work was funded at a level of three million U.S. dollars by municipal, regional, and national governments of China. Probably this is the first case of the initiation of extensive landslide remedial measures at a cultural heritage site for mitigation of potential landslides at the precursor stage in the world. This investigation of landslides at the precursor stage was evaluated as a contribution of geoscientists to protection of Cultural Heritage.

Based on the invitation by Edward Derbyshire, Chairman of the Scientific Board of International Geological Correlation Programme (IGCP), which is a joint program funded by UNESCO and the International Union of Geological Sciences (IUGS), and encouragement by Hideo Noguchi (Programme specialist of the Division of Cultural Heritage of UNESCO), Kyoji Sassa proposed an IGCP project in 1998. Then, the UNESCO–IUGS joint project, International Geological Correlation Programme (IGCP) No. 425, "Landslide hazard assessment and mitigation for cultural heritage sites and other locations of high societal value" began. Thirty-one subprojects were proposed to join this IGCP-425 project worldwide. This project obtained about 4000 US dollars from UNESCO and IUGS. The budget was shared to 31 subproject leaders as a part of their travel fees to attend the IGCP-425 meeting. This small amount of budget was very effective in promoting subproject leaders and in raising fund in their countries. Because IGCP projects have to be terminated within 5 years, the IGCP-425 group wished to establish its own international program on landslides by creating an international organization on landslides similar to the IUGS in IGCP program.

As a first step, a cooperative agreement was proposed between UNESCO and the institute of the IGCP-425 leader, the Disaster Prevention Research Institute, Kyoto University. This proposal was made at the International Conference "Cultural Heritage at Risk", which was organized by UNESCO and the IGCP-425 group at UNESCO Headquarters, Paris on 20–24 September 1999. Then, the Memorandum of Understanding (MoU) between the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the Disaster Prevention Research Institute (DPRI), Kyoto University concerning "Cooperation in Research for Landslide Risk Mitigation and Protection of the Cultural and Natural Heritage as a Key Contribution to Environmental Protection and Sustainable Development in the First Quarter of the Twenty-First Century" was signed by Koichiro Matsuura, Director General of UNESCO, on 26 November and by Shuichi Ikebuchi, Director of the Disaster Prevention Research Institute, Kyoto University, on 3 December 1999. Based on this MoU, UNESCO and Kyoto University jointly organized the international symposium "Landslide Risk Mitigation and Protection of Cultural and Natural Heritage" in Kyoto.