Preface

In the last 100 years, a number of catastrophic events associated with rockslide dam formation and failure have occurred in the mountain regions of the world including the European Alps, the Himalayas, the mountains of Central Asia, the mountainous margin of the Tibetan Plateau in China, and the Andes of South America. These events illustrate the global importance of the process as a natural hazard and highlight the need for scientific and engineering knowledge concerning the characteristics and behaviour of rockslide dams and the hazards that they pose. The global importance of the formation of rockslide dams and their behaviour has been highlighted by the creation of many impoundments in the 2008 Wenchuan Earthquake, the most critical of which were successfully mitigated by Chinese authorities, and the formation of a massive rockslide-dammed lake in the Hunza valley (Northern Pakistan) in 2010. As of July 25, 2010 (200 days after impoundment) the Hunza Lake continues its stable overflow through an excavated spillway as Pakistan authorities consider engineering options to reduce the lake level.

Rockslide dams are a type of natural dam, and are created in bedrock landscapes when landslides resulting from rock slope failure block drainage leading to the formation of rockslide-dammed lakes upstream from the landslide site. As dramatically illustrated in the case of the 2010 Hunza rockslide-dammed lake, rising impounded waters flood areas upstream and form landslide-dammed lakes that vary in volume from <1 Mm^3 to >10 Gm^3. Lake Sarez, Tajikistan, formed in 1911 by the blockage of the Murgab River by the massive earthquake-triggered Usoi rockslide, has a volume of 17 km^3 and is the largest landslide-dammed lake presently in existence. Landslide-dammed lakes can be stable elements of the landscape that may persist for millennia. They can also fail within days, months, or years after their formation leaving remnant debris in the bottom of river valleys. If they breach suddenly the resulting outburst flood may devastate valley floors downstream. Thus outburst floods from rockslide-dammed lakes are a significant element of landslide hazard in mountain terrain and extend the area of potential damage by a rockslide (which we use in this book in a general sense to describe any mass movement involving a significant initial volume of rock) to beyond the debris of the landslide itself.

As the historical record shows, outburst floods from the failure of rockslide dams can cause destruction of linear infrastructure (roads, pipelines, railways, bridges) and communities in populated areas along the flood path causing a high loss of life. In fact, outbursts from rockslide dams have caused some of the most destructive (in terms of life loss) landslide-related natural disasters in recent history. In 1786, for example, an earthquake-triggered rockslide dammed the Dadu River in Sichuan, China. 10 days later, the dam breached releasing a flood of waters downstream; 100,000 people perished in the outburst flood and the eighteenth century Dadu event remains the most destructive single-event landslide disaster in history. Other notable rockslide dam outbursts occurred in 1841 on the Indus River, Pakistan and in 1933 on the Minjiang River, again in Sichuan, China. Together, these outburst floods took the lives of over 6,000 people. It is also noted that upstream flooding by rising waters during lake filling may submerge communities, infrastructure, and agricultural lands adjacent to river channels.

The formation of potentially unstable rockslide-dammed lakes may be an important secondary effect of major earthquakes and are a major component of the hazard associated with earthquake-triggered landslides. Because of this, lakes formed by earthquake-triggered rockslides are sometimes called "Quake Lakes". In 1959, for example, a large rockslide triggered by the M7.1 Hegben Lake earthquake, blocked the Madison River in Montana, USA, to form an extensive rockslide-dammed lake. The lake was stabilised by engineering works and today it is officially called Earthquake Lake. In 2008 the devastating M7.9 Wenchuan Earthquake struck eastern Sichuan Province, China resulting in over 85,000 fatalities. The major secondary effect of the earthquake was the formation of over two hundred "Quake Lakes" which blocked the narrow, deep valleys of rivers draining southeast off the Tibetan Plateau. Fortunately, the effective mitigation of these lakes resulted in controlled drainage or partial drainage of the impoundments and no catastrophic outburst ensued.

Generally, the failure of rockslide dams is initiated by overtopping which leads rapidly to the formation and enlargement of a breach in the debris dam leading to the catastrophic release of impounded lake waters. The engineering mitigation of rockslide-dammed lakes mainly consists of controlled overtopping, usually achieved by the excavation of a spillway across the debris dam. However, case histories show that this is not always successful and may result in triggering a catastrophic breach by initiating uncontrolled erosion of the debris dam. In other examples, however, controlled overflow has been successfully achieved through a constructed spillway, thus reducing the volume of impounded waters. Other engineering solutions include the construction of by-pass tunnels and high-capacity pumping. Where mitigation is not possible, and outburst is considered to be imminent, downstream warning and evacuation measures may be implemented to reduce life loss.

Rockslide debris has similar geotechnical properties to engineered rockfill used to construct conventional dams. As a result, stable rockslide dams have been utilised as foundations for conventional artificial dams in mountainous areas of the world including Canada, USA, New Zealand, at several locations in the European Alps, the Himalayas, and in the Andes. Constructed artificial dams increase the storage capacity of a landslide-dammed lake by increasing the natural dam height. In addition, the emplacement of artificial valley-blocking rockslides by the explosive initiation of massive rock slope failure has been utilised to form stable rockfill dams (so-called blast-fill dams) for water storage and debris flow defence. The technology was developed in the former Soviet Union and its most recent utilisation was in Kyrgyzstan in late 2009.

This book examines the subjects noted above, investigates the characteristics and behaviour of natural and artificial rockslide dams, presents a detailed verified database of major rockslide dams that have formed and/or failed since 1840, reports new data on important rockslide dam case histories (including the 2010 Hunza event), examines mitigation strategies, and reviews the impact of rockslide-damming on the landscape. To begin, Evans et al. present a comprehensive state-of-the-art review of our global understanding of the formation, characteristics, and behaviour of natural and artificial rockslide dams up to July 2010 (including a short review of the rockslide dams emplaced by the 2008 Wenchuan Earthquake, Sichuan, China, and the 2010 Hunza rockslide dam noted above). Evans et al. also examine the mitigation of rockslide-dammed lakes. Davies and McSaveney explore ideas of hazard assessment whilst overviews of approaches to rockslide dam risk mitigation, illustrated with case histories from around the world, are provided in two papers by Schuster and Evans, and Bonnard. The book contains detailed regional studies of rockslide dams in India, Nepal and China (Weidinger), the Upper Indus region of Pakistan (Hewitt), the northwest Himalayas and adjacent Pamirs (Delaney and Evans), Southern Alps of New Zealand (Korup), and the southern Andes of Argentina (Hermanns et al.). Capra reviews the occurrence and behaviour of rockslide dams associated with large-scale instability of volcanoes in the volcanic belts of the world. The formation and behaviour of rockslide-dammed lakes ("Quake Lakes") formed during the 2008 Wenchuan Earthquake (East Sichuan, China) are summarised in an extensive paper by Cui et al. Detailed case histories of well-known historic and prehistoric rockslide dams provide examples of investigations of rockslide dam behaviour, stability, and characteristics; these form chapters on the Scanno, Italy (Bianchi-Fasani et al.), Val Pola, Italy (Crosta et al.), Usoi, Tajikistan (Ischuk), Dadu, China (Lee and Dai), La Josefina, Ecuador (Plaza et al.), Tsao-Ling, Taiwan (Chang et al.) and Flims, Switzerland (Poschinger) rockslide dams. The formation and stability of rockslide dams is examined in analytical papers by Hungr, Eberhardt and Stead, and Dunning and Armitage. Dunning and Armitage also investigate the sedimentology of dam-forming rockslide debris as do Davies and McSaveney. Manville and Hodgson analyse break-out floods from volcanogenic lakes and review hydrological methods of estimating break-out flood magnitude and behaviour from natural dams. Several papers illustrate the use of remote sensing data (including satellite imagery and digital data from the Shuttle Radar Topography Mission (SRTM)) in the characterisation of rockslide-dammed lakes. This is examined with specific reference to the 2000 Yigong Zangbo rockslide dam (Tibet, China) in a paper by Evans and Delaney and a new approach to the classification of rockslide dams is introduced by Hermanns et al. Finally, a unique section of the book summarises Russian and Kyrgyz experience with blast-fill dam construction in two papers by leading authorities on the technology (Adushkin and Korchevskiy et al.).

This book is the first published on the general topic of rockslide dams and is the first book in English that encompasses a treatment of both natural and artificial rockslide dams. The volume contains 26 papers by 56 authors from 17 countries including most of the recognised world authorities on the subject. The volume will be of interest to geologists, geographers, geomorphologists, hydrologists, and engineers involved in the hazard assessment and mitigation of rockslide dams, to emergency preparedness personnel in the management of rockslide dam emergencies, to natural disaster specialists, and to earth scientists in general who require a detailed outline of the occurrence and behaviour of natural and artificial rockslide dams.

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