

ITALIAN MINISTRY OF FOREIGN AFFAIRS
DIRECTORATE GENERAL FOR DEVELOPMENT COOPERATION

GEOLOGICAL DISASTERS IN THE PHILIPPINES

THE JULY 1990 EARTHQUAKE AND THE JUNE 1991 ERUPTION OF MOUNT PINATUBO

Description, effects and lessons learned

by Giovanni Rantucci

in cooperation with the Philippine Institute of
Volcanology and Seismology (PHIVOLCS)

PRESIDENZA DEL CONSIGLIO DEI MINISTRI
DIPARTIMENTO PER L'INFORMAZIONE E L'EDITORIA

To the People of the Philippines

Published under the aegis of

DIPARTIMENTO PER L'INFORMAZIONE
E L'EDITORIA - PRESIDENZA DEL CONSIGLIO
DEI MINISTRI

Figures, tables and short excerpts of this book may be reproduced if the source is correctly cited. This permission does not apply to figures, tables and text reprinted from other sources which are covered by copyright.

The book *Geological Disasters in the Philippines* has been presented to the World Conference on Natural Disaster Reduction, Yokohama (Japan) 23-27 May 1994, within the contribution of the Italian Ministry of Foreign Affairs to the International Decade for Natural Disaster Reduction (IDNDR).

The views expressed in this volume are solely those of the Author and do not necessarily reflect those of the Italian Ministry of Foreign Affairs.

Rome, October 1994

Cover: The July 1990 ground rupture (top) in Digdig (Nueva Ecija). The picture shows the surface faulting across the road to Carranglan. Mount Pinatubo (bottom) seen from the southeast, after the June 1991 eruption and the subsequent collapse of the crater.

FOREWORD

Geologic phenomena including earthquakes, volcanic eruptions, landslides and erosional processes are an essential aspect of the evolution of the environment in which we live. The exponential growth in the earth's population that occurred in this century and the associated development have progressively resulted in the overcrowding of several vulnerable areas of the planet. Thus, the occurrence of extreme natural phenomena increasingly entails disasters with loss of numerous lives, damage to infrastructure and property, and widespread human suffering. In this sense disasters, which more and more often result from the combined effect of human development and natural forces, substantially contribute to the global environmental crisis.

The book «Geological Disasters in the Philippines» is centered on these views and is designed to improve the understanding of the recent extreme geological events which affected the Archipelago in the early 1990s. A considerable part of the work is devoted to the description of disaster impacts on physical and human environments as well as on agriculture and the economy of the Philippines.

A great deal of knowledge about geological disasters in the Italian Peninsula (and more generally in the Mediterranean Region) was gathered as a result of the abundant literature from the Roman Times onward. It is worthwhile to mention the classic work of the latin writer Lucius Annaeus Seneca (5 B.C.-A.D. 65) «De terrae motu» (On the Motion of the Earth) inspired by the destructive earthquake which struck the town of Pompeii in A.D. 62 or 63. Pompeii and Herculaneum were buried by volcanic ashes in A.D. 79, that is about 17 years later, by the explosion of Mount Somma and Vesuvius. This disaster was described by the historian Pliny the Younger (A.D. 62 - 114) who wrote the first scientific report of a volcanic eruption.

The Italian experience with disasters was greatly enlarged in this century by the recurrence in the country of a number of calamities. Beyond the high-quality data which were gathered, these disasters triggered advanced research in various fields. The descriptions by historians during several centuries combined with the information from recent research constitute the best documented data bank on disasters during the last two millennia.

In view of the recurrent threat posed by extreme geological events, Italy has recently made considerable efforts in disaster preparedness, prevention and mitigation by adequately organizing the social response.

Italian Institutions are actively participating in the IDNDR initiatives for a worldwide reduction of disaster impacts, and contribute to alleviating the effects of calamities by sharing knowledge, available data and technical know-how.

Investments by industrial countries are essential for the protection of efforts by developing countries towards economic growth and sustainable development. The Italian Development Cooperation has actively supported Developing World in the last 15 years, contributing also to disaster prevention and mitigation projects such as SEISMED, which was designed to reduce seismic risk in the Mediterranean Region.

The Author of the book, Dr. G. Rantucci, has worked for over ten years as a geologist in Asia, spending part of this period in the Philippines and a major part as Associate Professor at the Asian Institute of Technology in Bangkok. At present he is an Expert in the Technical Unit of the Italian Ministry of Foreign Affairs, Directorate for Development Cooperation. This book reflects the variety of his experience and the versatility of his expertise.

Antonio Catalano di Melilli
Deputy-Director General
Directorate General for Development
Cooperation
Italian Ministry of Foreign Affairs

PREFACE

Dr. Rantucci was one among many foreign scientists who were in the Philippines during the world class disasters that hit the Country in 1990 and 1991 - the July 16, 1990 Luzon earthquake and the 1991 eruption of the Pinatubo Volcano. He is also one of the few foreign scientists who were inspired by these two disasters to write and publish papers, but he is the only one who has produced a full monograph so far.

In the Philippines, we produced several compilations containing papers written on these two disasters by both local and foreign scientists including Dr. Rantucci. These compilations are:

- The July 16, 1990 Luzon Earthquake: a Technical Monograph;
- Proceedings of GEOCON '90, Quezon City, Philippines 5-7 December 1990;
- Proceedings of the International Scientific Conference on Mt. Pinatubo, Manila, Philippines 27-30 May 1992;
- Proceedings of GEOCON '91, Quezon City, Philippines, 4-6 December 1991.

However, only limited copies of these publications were printed and circulated locally. A technical monograph on the Pinatubo Volcano 1991-1992 eruptions and their aftermath is also in the making - a joint effort of the United States Geological Survey (USGS) and the Philippine Institute of Volcanology and Seismology (PHIVOLCS). This will have a wide international circulation but covers only the Pinatubo Volcano eruption. As a document integrating both disasters for international circulation, Dr. Rantucci's book is therefore a first.

Dr. Rantucci's book will certainly make our country famous internationally. We hope though that the image that will stick in the readers' mind will not be of a country prone to, and hard hit by disasters, where only the brave visitors and investors dare to tread. Rather, the image that should last in readers' memories is of a disaster-prone country whose leaders and citizens have learned their lessons well and taken steps toward effective disaster prevention and mitigation.

Raymundo S. Punongbayan
*Director of the Philippine Institute
of Volcanology and Seismology*

ACKNOWLEDGEMENTS

The publication of this book was sponsored by the «Dipartimento per l'Informazione e l'Editoria», a Government Institution attached to the Office of the Italian Prime Minister.

A particular thank is deserved to Senator Edmundo Mir, Undersecretary at the Department of Public Works and Highways of the Philippines for inviting the Author to Dagupan City, a town severely affected by the July 1990 earthquake, and on that occasion triggering his interest in the extreme geological phenomena hitting the Archipelago.

The Author feels deeply grateful to Dr. Raymundo Punongbayan, Director of the Philippine Institute of Volcanology and Seismology for his support to the work in terms of suggestions, data, published papers, information and pictures. Without the cooperation with PHIVOLCS and the excellent work of its scientists and researchers the publication of this book would not have been possible.

The Department of Public Works and Highways (DPWH) and the Bureau of Soils and Water Management (BSWM) of the Philippines were important sources of information and data.

Special thanks to Prof. Domenico Giardini and particularly to Dr. Laura Beranzoli of the Istituto Nazionale di Geofisica (ING), who kindly provided help, data and suggestions.

The author is very grateful to Dr. Robert Brinkman for his critical comments, the revision of the text and the invaluable enthusiasm which accompanied his work during several months.

Thanks are expressed to Organizations and Authors which kindly granted permission to use or reprint their material.

Comments, remarks and suggestions were provided by Dr. Franco Maranzana, Dr. Domenico Bruzzone and Mr. Manuel Goseco.

A particular gratitude goes to my family, friends and colleagues for the support during more than two years of work.

ABOUT THE AUTHOR

Giovanni Rantucci received his Degree in Geology from the University of Rome (Italy) in 1964. During an assignment as a consultant in Central Luzon (Philippines), he witnessed the sequence of geological events described in the book: the July 1990 Luzon earthquake, the June 1991 eruption of Mount Pinatubo and the related primary and secondary effects.

During the period 1983-89 the Author served as Associate Professor at the Asian Institute of Technology in Bangkok (Thailand), Division of Geotechnical and Transportation Engineering, in a multilateral project financed by the Italian Cooperation (Ministry of Foreign Affairs) through the UNDP. Previously (1968-1983) he worked as a geotechnical engineer for a private Italian company, being involved in numerous projects in the Middle East, Far East, Africa and South America. At present he is a member of the technical staff of the Italian Ministry of Foreign Affairs (Rome) in the Directorate General for Development Cooperation.

AUTHOR'S NOTE

The phenomena described in the book 'Geological Disasters in the Philippines' are set within the framework of the theory of plate tectonics. The Author is aware of arguments for and against the theory and of questions as yet unanswered.

Each chapter deals with a well-defined topic and begins with an introductory paragraph. Thus, readers with a specific interest in one or more chapters can read the introductions of the others.

CONTENTS

Chapter 1 - Natural hazards and development	15
1.1 Introduction	15
1.2 Extreme phenomena and natural disasters	15
1.3 Disasters and developing countries	16
1.4 Human development and global hazard	18
1.5 Disaster distribution and effects during the last decades	19
1.6 International decade for the reduction of natural disasters	19
1.7 Conclusion remarks	20
Chapter 2 - Overview of past and recent disasters in the Philippines	22
2.1 Introduction	22
2.2 The framework of geological disasters in the Philippines	23
2.2.1 General	23
2.2.2 Earthquakes and tsunamis	24
2.2.3 Volcanic eruptions	25
2.2.4 Landslides and liquefaction	25
2.3 Climate-related disasters	26
2.4 The 1990-91 geological disasters in Luzon	29
Chapter 3 - Tectonics, seismicity and volcanism of Luzon	31
3.1 The Pacific Plate Region	31
3.2 Morpho-tectonic Units of Central and Northern Luzon	31
3.3 Tectonic setting of Luzon	33
3.3.1 Lineaments and bathymetry	33
3.3.2 Tectonics	34
3.4 Geologic history	36
3.5 Seismicity	37
3.6 Volcanism	38

3.6.1	Volcanic activity within the Pacific Plate	38
3.6.2	The volcanic environment of Mount Pinatubo	39
Chapter 4 - The July 16, 1990 Luzon Earthquake		40
4.1	Overview of the earthquake and its aftermath	40
4.2	Geotectonic framework of Luzon	41
4.3	Seismicity levels within the Pacific Region and the Philippines	42
4.4	Focal mechanisms	47
4.5	The 1990 Luzon Earthquake	47
4.6	The analysis of the earthquake	55
4.6.1	Data recording and processing	55
4.6.2	Seismic source analysis	55
4.7	Damage distribution and subsurface rearrangement	58
4.8	Recurrence period	58
4.9	Casualties, damage and environmental impact	58
4.9.1	General	58
4.9.2	Human losses	58
4.9.3	Damage to property and infrastructure	59
4.9.4	Environmental impact	63
Chapter 5 - Sand liquefaction in the Central Valley induced by the 1990 earthquake		64
5.1	The 1990 liquefaction and historical records	64
5.2	Liquefaction and related damage in the Central Plain	64
5.2.1	Damage in Dagupan City	66
5.2.2	Damage in Pura City	67
5.3	Evaluation of the liquefaction potential in Dagupan City	73
Chapter 6 - Landslides associated with the Luzon Earthquake		76
6.1	Introduction	76
6.2	Tectonic environment	77
6.3	Landslide distribution, volumes and geometry	77
6.4	Seismicity-related effects on slope failures	79

6.5	Shallow and deep-seated slides	79
6.6	Landscape evolution and environmental impact	82
6.7	Casualties, property and infrastructure damage	82
6.7.1	Death Toll	82
6.7.2	Damage to property and roads	83
6.8	Landslides in the Cordillera Central and Caraballo Mountains	84
6.8.1	General	84
6.8.2	Types of slope failure in the Southern Cordillera	85
6.8.3	Types of slope failure in the Caraballo Mountains	87
Chapter 7 - Pre-earthquake seismicity and the 1990-91 aftershock swarm		90
7.1	The July 1990 earthquake and aftershocks	90
7.2	Seismicity trends between 1985 and 1991 in the Philippines	90
7.3	Aftershock swarm	93
7.4	Concluding remarks	96
Chapter 8 - The eruption of Mount Pinatubo in 1991		97
8.1	Introduction	97
8.2	Geo-tectonic setting	97
8.3	Mount Pinatubo eruption	102
8.3.1	Pre-eruption signs and major explosive episodes	102
8.3.2	Some considerations on the eruption and related effects	104
8.4	Volcanic ejecta and their mobilization	105
8.4.1	Pyroclastics, sediment delivery in 1991-93 and gases	105
8.4.2	Composition of the ash blanket and its effects on agriculture	107
8.5	The global effect of the eruption	107
8.6	Lahars	109
8.6.1	Lahar initiation and development	109
8.6.2	Hot and cold lahars and their distribution	110
8.6.3	Some observations on Mt. Mayon and Mt. Pinatubo lahars	112
8.7	Casualties and injuries	113
8.8	Damage assessment	113

8.8.1	General	113
8.8.2	Damage to buildings and city services	115
8.8.3	Damage to roads and bridges	115
8.8.4	Damage to agriculture and related activities	120
8.9	Environmental impact	120
8.10	Social impact	122
Chapter 9 - The damage to the economy of the Philippines		123
9.1	The trend of the economy and the impact of disasters during the period 1987-1991	123
9.2	The damage caused by the 1990 Luzon earthquake	124
9.3	The damage induced by the 1991 eruption of Pinatubo	125
9.4	Overall economic losses caused by earthquake and eruption	126
Chapter 10 - Lessons learned from the 1990-1991 disasters		128
10.1	Introduction	128
10.2	Disaster proneness of the Philippine archipelago and social response	128
10.3	Problems related to specific aspects of disasters	129
10.3.1	Landform evolution and the formation of a new regolith	129
10.3.2	Agricultural development and future perspectives	130
10.4	Recommendations and suggestions	131
10.4.1	Maps and data banks	131
10.4.2	Building codes and liquefaction-prone areas	131
10.4.3	The performance of the rigid pavement of the road network during the quake	132
References		133
List of Figures and Tables		140
Acronyms and abbreviations		143
Glossary		144
Summary of the book in Italian		148
APPENDIX A: The geological time-scale		150
APPENDIX B: Earthquake source zones		151
APPENDIX C: The Rossi-Forel Scale of Seismic Intensities		154

Baguio City was isolated from the rest of the Philippines for the first 48 hours after the quake. Damage at Loakan Airport rendered access to the city by air limited to helicopters.[12] American and Philippine Air Force C-130s evacuated many residents from this airport. Many city residents, as well as patients confined in hospital buildings damaged by the quake, were forced to stay inside tents set up in public places, such as in Burnham Park and in the streets.Â Geological Disasters In The Philippines: The July 1990 Earthquake And The June 1991 Eruption of Mount Pinatubo.