



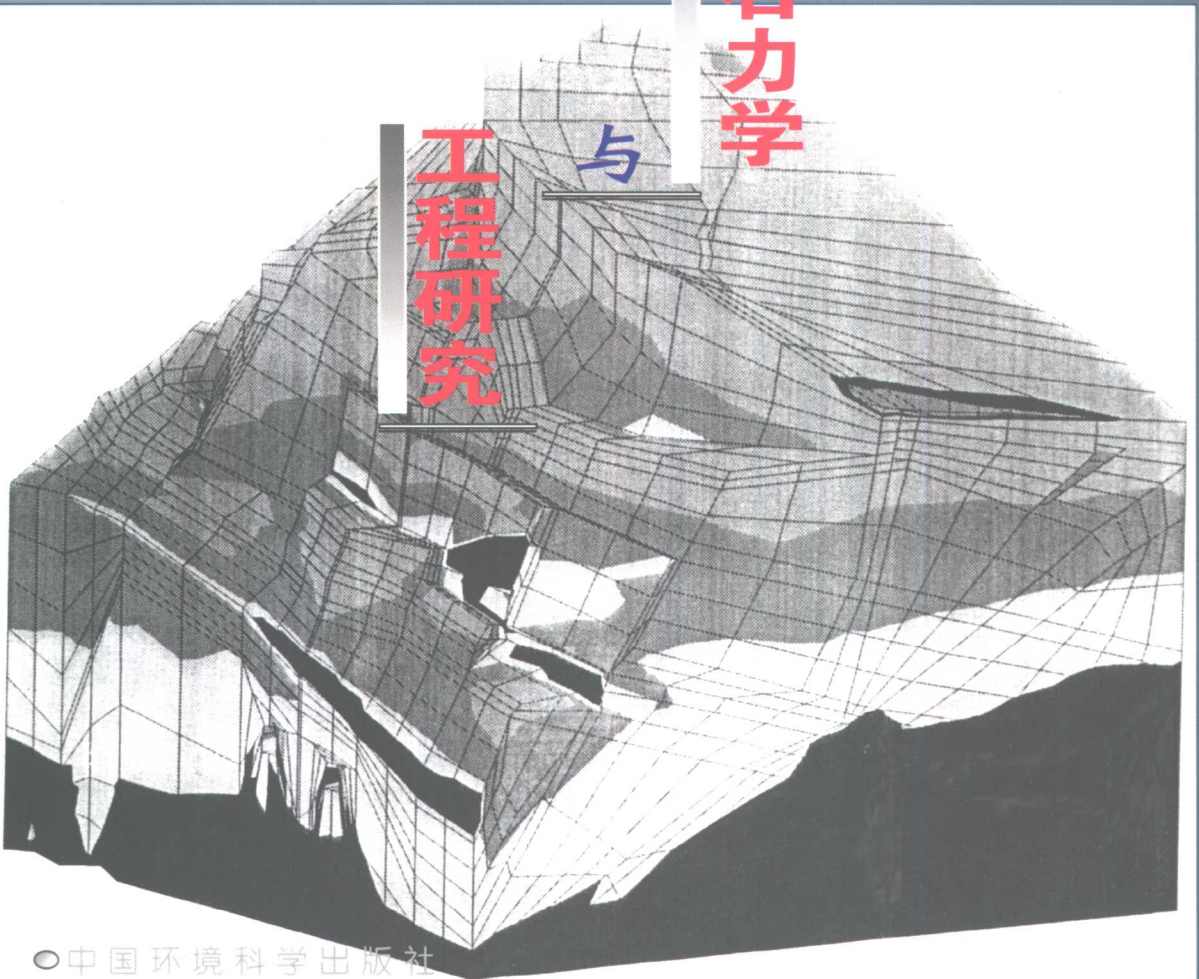
徐卫亚 著

边坡及滑坡

环境岩石力学

与

工程研究



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Related to Slope and Landslide Engineering



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作者简介



徐卫亚 理学博士，教授、博士生导师，国家级专家。男，1962年出生，江苏省张家港市人。

1982年本科毕业于华东水利学院（现河海大学）工程地质专业，1991年博士研究生毕业于中国科技大学研究生院、中国科学院地质研究所工程地质力学专业（Engineering Geomechanics），师从孙广忠教授、许兵教授及王思敬教授，获理学博士学位，并获中国科学院院长奖学金优秀奖。1994—1995学年在法国瓦朗谢纳大学做高级访问学者，从事计算机辅助工程设计研究。1994年经原电力工业部破格聘任为教授。

1982年7月至1999年11月期间在武汉水利电力大学（宜昌）（原葛洲坝水电工程学院）从事教学科研和行政管理工作，历任校环境与地质工程研究所（Institute of Geo'2E）所长，科研处处长，建筑工程系主任等职。现任河海大学土木工程学院教授，博士生导师，校长助理。兼任何梁何利基金科技进步奖提名人，高等学校电力工程专业教学指导委员会委员，高等学校水利水电类专业教学指导委员会委员，中国岩石力学与工程学会数值物理模拟专委会委员，测试技术专委会委员，湖北省岩石力学与工程学会常务理事，湖北省地震学会常务理事，中国地质学会工程地质专委会委员，中国地质教育学会理事，宜昌市青年联合会副主席等。1996—1999学年被连续聘任法国里尔科技大学（USTL）岩土—土木工程学科一级教授，法国国家科研中心里尔力学研究所（LML, URA1441, CNRS）研究员，在法从事岩石力学研究和讲学。

1994年被评为国家级有突出贡献中青年专家，1996年被评为湖北省有突出贡献中青年专家，1992年起经国务院批准享受政府特殊津贴。1995年被评为湖北省新长征突击手标兵，百名跨世纪优秀中青年专家，1996年确认为国家电力公司首批跨世纪学术带头人培养对象，1998年被评为湖北省高等学校学科带头人。

徐卫亚教授从事岩土工程、地质工程、灾害防御及水工结构工程等方面的教学与科研工作。在岩石力学与工程基本理论，坝基岩石工程、边坡工程、地下工程，滑坡等灾害防御，水工结构工程等领域的科学研究取得过一批具国际领先或国际先进水平的成果。参加过20余项以水利水电工程为主体的岩石力学、地质工程的工

程实践,主持完成30余项包括国家自然科学基金重大项目、国家重点科技攻关项目、国家重大科技专项、部委重大项目、中外科技合作先进项目、欧共体资助科技项目等科技项目,其中长江三峡链子崖危岩山体防治综合研究、长江三峡工程坝基岩石工程及高陡边坡工程研究等,岩石工程反馈设计施工理论与方法研究及实践,非线性岩石力学分析,岩石—水—热—化学耦合数学力学分析,地质灾害学研究等成果在国内外有一定的影响。获国家级奖励1次,以第一身份获省部级科技特等奖1次,一等奖2次,二等奖4次。1995年获中华电力教育基金会优秀教师奖,1998年获霍英东教育基金会青年教师奖(研究类)。1997年获电力工业部教学成果奖二等奖。

主要著作有:长江新滩滑坡研究(1986,科学出版社,第一著者),长江三峡工程地质力学研究(1997,中国三峡出版社,第一著者),清江水布垭库首及坝址若干重大滑坡稳定性分析(1997,中国环境科学出版社,第一著者),岩石高边坡的变形与稳定(1999,中国水利水电出版社,参著),三峡工程坝基岩体工程研究(1998,中国地质大学出版社,参著)等。

以第一著者身份发表论文110余篇,其中有部分论文被SCI, EI或ISTP索引。代表性的论文有:工程岩体结构类型定量划分问题研究,工程岩体质量评价研究,链子崖危岩体整治工程地质适应性,水布垭马崖高陡边坡三维数值模拟研究,三峡永久船闸高边坡变形预测人工神经网络分析,关于三峡永久船闸高边坡快速施工地质超前预报的几个问题,清江水布垭水电站地下厂房岩体质量评价及反馈设计研究,岩体力学尺寸效应研究,论滑坡预报,高陡岩体边坡工程反馈设计理论与方法研究,大城市不稳定性研究,崩塌冲击斜坡滑移联合运动分析,地质灾害系统的突变与失稳等。

序 一

地质环境是指以岩石圈为主在和大气、生物、水圈的相互作用中形成和演化的人类生活、生存和工程设施受其影响的周围岩土介质。地质环境应包括岩土物质组成、结构、特性、赋存状态、边界条件和运动特征等方面的综合特征。人类工程活动往往受到地质环境的制约，同时它作为活跃的因素，又积极地影响着地质环境，促进其次生演化，常会对人类工程活动产生次生制约。

面向 21 世纪的岩石力学与工程的研究应该是面向环境，面向可持续发展战略的。我高兴地看到边坡与滑坡的环境岩石力学研究命题的提出，其充分体现了把边坡与滑坡岩石工程与自然融合起来，或将岩石工程植入自然的环境地质工程生态准则，符合可持续发展战略需要，具有理论意义和实际价值。

本书汇集了著者十余年来开展的边坡与滑坡的环境岩石力学高水平研究成果，从边坡与滑坡的地质环境分析，工程地质适应性论证，到边坡与滑坡的变形破坏机理研究；从边坡与滑坡的稳定性评价，到边坡与滑坡的防治工程研究；从边坡与滑坡的监测，到边坡与滑坡的反分析和反馈设计；从岩石工程到灾害防御；全方位多侧面系统地研究了边坡与滑坡的环境岩石力学理论和实践。著作还涉及了长江三峡工程永久船闸高边坡岩体工程，三峡链子崖危岩体黄腊石滑坡防治地质工程，清江水布垭水电站坝区及库首重大滑坡，水布垭水电站马岩高边坡，长江新滩滑坡，小浪底工程库区滑坡，隔河岩水电站杨家槽滑坡等重大环境地质工程的实践，整个研究以上述案例分析为背景，各有特色，各有重点，然全书又构成系统，从理论到实践，体现了环境岩石力学研究的主要方面，不失为一本岩石力学与工程学科和地质工程学科的力作。

我十分欣喜地看到作为年轻一代的岩石力学专家和工程地质专家代表之一的徐卫亚教授的进步和成长。徐卫亚博士 1991 年在中国科学院地质研究所获得理学博士学位，并获中国科学院院长奖学金优秀奖，由于成绩突出，1994 年破格晋升教

授，并被评为国家级有突出贡献的中青年科技专家。十余年来他一直活跃在国内外岩石力学和地质工程的学术领域，以长江三峡工程和清江流域隔河岩，高坝洲及水布垭水电站等大型水电工程为背景，加强理论探索，更强调工程的应用。近年来他连续四年受聘为法国里尔科技大学邀请教授和法国里尔力学研究所研究员，在法从事岩石力学与工程的教学科研，也取得了可喜的进展。我感到他们这一代年轻学者精力旺盛，朝气蓬勃，坚持了岩石力学与工程的结合，坚持了地质工程与环境的协调。他们是充满希望的一代。

要建立环境岩石力学的系统理论体系，并服务于环境工程，还有很多的工作要做，还有大量的课题需要认真研究和探索。边坡与滑坡的环境岩石力学研究著作的出版正是环境岩石力学研究的一大进展，相信会受到岩石力学界，地质工程界和环境工程界同行学者和工程技术人员的欢迎。

中国岩石力学与工程学会理事长
国际工程地质与环境学会理事长
中国工程院院士 王思敬

王思敬

18/3/2000

PREFACE I

Geo - environment means the rock and soil, mainly in geo - sphere, that form and evolve from the reciprocity of atmosphere, creature and hydrosphere, and influence the life, existence, engineering equipment of human beings. It includes the material components of rock and soil, structure, characteristic, existence environment, boundary condition and dynamic characteristic etc. As an active factor, human engineering activity is always constricted by geo - environment, and it influences the geo - environment at the same time. It creates the secondary evolution that leads to the secondary constriction to the engineering activation.

The research of rock mechanics and engineering in 21st century should be based on environment and the stratagem of sustainable development. I' m glad to see the research topic of slope and landslide in environment rock mechanics is given. It merges the slope and landslide rock engineering with nature environment and based the rock engineering on environment ecology. It is consonant with the need of sustainable development. It is very important theoretically and practically.

This book has most of the author' s important research results on slope and landslide in environment rock mechanics in about 10 years. The result includes the geological environment analysis and engineering geology adaptability argumentation of slope and landslide, the mechanism of the slope and landslide deformation and failure, the stability assessment of slope and landslide, the research of slope and landslide protection, the monitoring of slope and landslide and the back analysis and feedback design of slope and landslide. This book comprehensively and scientifically discusses the theory and practice of slope and landslide in environment rock mechanics from rock engineering and disaster protection. The book also involves the practice of geology environment projects: the high slope engineering of permanent shiplock in Three Gorges Project, the Huangnashi landslide protection engineering, the serious landslide in dame site

and head of dame site in Qingjiang Shuibuya, Mayan high slope in Shuibuya hydropower station, Changjiang Xingtang landslide, landslide in Xiaolangdi project dame site and Yangjiachao landslide in Geheyan hydropower station. The research is based on the above practice cases which have their own features. This book, scientifically embodies the main substances in the research of environment rock mechanics, is one meaningful work on rock mechanics and engineering and engineering geology.

I'm very happy to see the advancement and growing up of Professor XU Weiya who can be said as one of the representations of the young experts on rock mechanics and engineering geology. Professor XU got his doctoral degree at Institute of Geology, Chinese academy of science in 1991, and got the excellent scholarship of Chinese academy of science. He was promoted as professor in 1994 and was selected as the State Distinguished Scientist named by state council of P. R. China. He have done much excellent work in the research field of rock mechanics and geology engineering for more than 10 years based on the large hydro - projects such as Three Gorges Project, Qingjiang Geheyan project, Gaobazhou project and Shuibuya project. He has been engaged as invited professor of USTL in France and invited Professor of LML in France. He also got felicitous research result in abroad. I think the young generation is activity and insists the emergence of rock mechanics and engineering and the concert between geology and environment. They are hopeful.

To construct the theoretical system of environment rock mechanics, there still is much work needed to do, many projects need to research carefully. The publishing of slope and landslide in environment rock mechanics is one large progress on the study of environment rock mechanics. It's sure that the colleague and technician of rock mechanics and engineering geology and environment engineering will welcome it.

President of Chinese Association Rock Mechanics and Engineering

President of International Association Engineering Geology and Environment /IAEG

Member of Chinese Academy of Engineering

Professor of Chinese Academy of Science



Prof. Dr. WANG Sijing

18/3/2000, Beijing

序 二

边坡和滑坡工程是重要的地质工程，岩石力学是其理论基础。地质工程是改造（稳定）地质体和调节（控制）地质作用以合理利用和保护地质环境的工程。开展边坡和滑坡工程的环境岩石力学研究具有重要的理论意义和工程实用价值。

作为徐卫亚教授十余年来进行边坡和滑坡工程理论和应用研究工作的总结，以环境岩石力学的命题提出，本著作在岩石力学与地质工程领域开展了有许多特色的高水平研究。其中包括边坡和滑坡工程的地质环境研究，边坡和滑坡的变形破坏机制和稳定性评价方法及应用的研究，边坡和滑坡减灾防灾工程研究，边坡和滑坡工程监测和反馈设计研究。著作既有理论上的深入探讨，更有工程实践的实际应用，以长江三峡工程永久船闸高陡边坡岩体工程，清江水布垭水电站马崖高陡边坡，长江三峡链子崖危岩体，黄河小浪底坝址区边坡，清江隔河岩库区扬家槽滑坡，长江三峡黄腊石滑坡、新滩滑坡、雷劈石古滑坡、盐关滑坡，水布垭坝址鱼洞河滑坡、大岩淌滑坡、马岩湾滑坡等工程实践案例为背景，系统进行了边坡和滑坡工程环境岩石力学基本理论和方法研究。可以认为，本著作是岩石力学和地质工程学科的高水平著作。

我熟识徐卫亚教授。从1988年起在我兼任国家长江三峡链子崖危岩体和黄腊石滑坡防治工程指挥部副指挥长期间，徐卫亚作为中国科学院的博士生，参加了国家重大防灾减灾项目长江三峡链子崖危岩体和黄腊石滑坡防治的研究工作，我也参与了对他的指导。他勤奋努力的研究作风给我留下了深刻的印象，1995年因在长江三峡链子崖危岩体和黄腊石滑坡防治的研究工作中成绩突出，他曾受到原国家科委的表彰。看到本著作中有关此工程的环境岩石力学与工程应用研究，使我又看到了徐卫亚当年初生牛犊的身影。徐卫亚的成长，贯穿了一个地质工程工作者和岩石力学学者所应坚持的地质、力学、工程和环境的有机结合的学术方向。

徐卫亚教授请我为本著作作序，我欣然提笔，是为序。

中国工程院院士 刘广润

刘广润

16/3/2000



PREFACE 二

Landslide and Slope engineering are important geological engineering which are theoretically based on rock mechanics. Geological engineering involves reconstructing / stable geological body and adjusting/control geological function to reasonably use and protect geological environment. It's very important theoretically and practically to start the study of slope and landslide in environment rock mechanics.

As the conclusion of Professor XU's work on slope and landslide engineering in 10 years, this book has many characteristic research result in the field of rock mechanics and geological engineering. The result includes the geo - environment analysis and engineering geology adaptability argumentation of slope and landslide engineering, the mechanism of the slope and landslide deformation and failure, the stability assessment of slope and landslide, the research of slope and landslide protection and control, the monitoring of slope and landslide and the back analysis and feedback analysis of slope and landslide. This book has not only the research of theory but also the study of practical engineering. This book involves the practice of many geo - environment engineering projects: the high and deep slope engineering of permanent shiplock in Three Gorges Project, the serious landslide in dame site and head of dame site in Qingjiang Shuibuya Hydropower project, Mayan high slope in Shuibuya hydropower station, landslide in Xiaolangdi project dame site, Yangjiachao landslide in Geheyan hydropower station, the Huangnashi landslide protection engineering, Changjiang Xingtan landslide, Leipishi ancient landslide, Yanguan landslide, Yudonghe landslide, Dayantang landslide and Mayanwan landslide. Based on the above projects, the basic theory and method of slope and landslide in environment rock mechanics are systemically studied. This book can be said as one of the high level work in the field of rock mechanics and geological engineering.

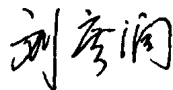
I know well Professor XU Weiya. When I was holding a concurrent post as the vice chair-

man of the headquarters of the State Changjiang Lianzhiyan and Huanglashi landslide – control project, he take part in the research work of the project as a doctoral candidate of Chinese academy of science. I was his instructor too. I have a deep impression of his hardworking. He got the commendation of the prior national science committee for his outstanding work in the landslide – protecting project. I see his young silhouette again when I see the study work of environment rock mechanics and engineering in this book. Dr. XU Weiya grows up as the representation of young generation of geologic engineering and rock mechanics scholars and experts.

Professor ask me to write the recommendation and introduction of the book. It' s my pleasure to do that.

Member of Chinese Academy of Engineering

Professor LIU Guangrun



2000/3/18 Wuhan, China

前 言

岩石力学是研究在环境应力改变时经受过变形、遭受过破坏的地质体再变形再破坏的力学理论、力学规律和力学应用的一门应用性科学。

关于岩石力学的学科性质和学科地位，近来多有讨论。有人认为它是一门有关力学的科学 (SCIENCE)，也有众多的专家认为其应该是一门有关岩石材料和岩石工程的力学规律的实用的工艺技术 (ART)。

岩石力学以地质为基础，力学为手段，工程为对象，实用为目的，以合理利用和保护地质环境为宗旨的学科方向和学科性质应该得到重视和体现。作为一门交叉性和边缘性的科学，岩石力学融汇了地质学、工程学和力学的科学理论、技术和方法，进入 21 世纪的岩石力学还应该交叉环境科学理论、技术和方法，这是历史的必然。可以认为，岩石力学不仅是开发资源和能源的奠基石，同时，也是地球环境保护和灾害防御的一把金钥匙。

综观岩石力学的发展里程，从岩块材料力学起步，经历了裂隙岩石力学和岩体结构力学后，21 世纪的今天，岩石力学已进入了信息环境岩石力学的新阶段。

环境岩石力学是应用岩石力学及环境科学的基本理论和方法，研究岩石工程中存在的各种环境工程问题，分析其力学性质，研究其力学作用和规律，探讨人类岩石工程活动与地质环境之间相互作用、相互协调、相互适应的途径，基于力学的分析和综合的研究，提出符合于可持续发展的环境岩石力学预测和调控对策。

环境岩石力学的提出和系统研究，从理论体系而言是近几年来随着可持续发展的要求应运而生的。环境岩石力学研究作为一个新的命题出现，主要基于如下三个基本内涵：其一是指用岩石力学理论解决环境工程问题；其二是指研究岩石力学理论及技术方法时必须考虑到环境；其三是指环境科学理论应用于岩石力学。其核心思想体现了把岩石工程与环境保护融合起来。

基于上述想法，著者总结了从事教学科研工作以来有关研究成果，以边坡及滑

坡工程作为对象主体的环境岩石力学研究为主线，出版著作。书中汇集了著者十余年来开展的边坡及滑坡环境岩石力学研究基本成果，以长江三峡工程永久船闸高陡边坡岩体工程、清江水布垭水电站马崖高陡边坡、长江三峡链子崖危岩山体、黄河小浪底坝址区边坡，清江隔河岩库区扬家槽滑坡、长江三峡黄腊石滑坡、新滩滑坡、雷劈石古滑坡、盐关滑坡、水布垭坝址鱼洞河滑坡、大岩淌滑坡、马岩湾滑坡等工程实践案例为背景，涉及边坡及滑坡的环境工程地质适应性分析，地质模型及地质结构研究，变形破坏机理研究，物理模拟及数值模拟研究，稳定性评价理论研究，治理改造技术方法研究，反馈设计研究，减灾防灾环境工程等环境岩石力学基本理论和方法。

著作中的大部分内容是著者在武汉水利电力大学（宜昌）工作期间完成的，部分内容在河海大学完成。研究成果主要取自于著者主持和参加的国家重大科技项目，国家自然科学基金重大项目，湖北省高等学校科学研究指导性项目，国家电力公司重大项目，中国科学院工程地质力学开放研究实验室学术基金项目，以及长江三峡工程施工科研和清江水布垭水电站勘测设计科研项目等科学研究工作。著作的出版得到了武汉水利电力大学“211”工程重点学科建设资助。

著作中的许多研究工作得到了著者的老师孙广忠教授、王思敬教授、许兵教授的指导，得到了徐瑞春教授级高工、刘广润教授级高工、周维垣教授、邵建富教授的指导和帮助，著者所指导的博士研究生谢守益博士、蒋晗博士在部分工作中协助进行了大量的研究，谨此致谢。

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由于著作中涉及研究工作的时间跨度较长，研究时的针对性不完全一致，因此不可避免的存在研究内容的系统性不强等问题。不足之处，敬请同行专家批评指正。

作者
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INTRODUCTION

Rock mechanics, an application science of the mechanics theory, mechanics rule and application, is focus on the re – deformation and re – failure of geologic body, which had undergone deformation and failure, while environment stress changes.

There are many discussions about the position and nature of rock mechanics recently. It is said that it is a SCIENCE on mechanics. It is also said that it is and practical ART on the mechanics rule of rock material and engineering.

Based on the geologic, the nature and aspect of rock mechanics, whose means is mechanics, object is engineering, goal is practices, purpose is reasonably using and protecting geo – environment, should be paid attention to and embodied. As one cross and fringe science, rock mechanics includes the scientific theory, technique and method of geologic, engineering, mechanics. It is natural for it to include the same things of ecology in the 21st century. It can be said that rock mechanics is the cornerstone of resource and power exploitation and the golden key of environment protection and disaster prevention.

In whole the development of rock mechanics, from the rock block material mechanics to fracture rock mechanics and rock mass structure mechanics, the rock mechanics has gone to the new stage of Informative Environmental Rock Mechanics in the 21st century.

The basic theories and methods of rock mechanics and environment science are used in the environment engineering questions of geo – engineering to analysis its mechanics characters, to study its application and rules and to discuss the way of action, harmony and adaptation between the geo – engineering and environment. Based on the mechanics analysis and comprehensive research, the prediction and control countermeasure of environment mechanics according to the substantial development will be given.

Theoretically, the emergence and research of environmental rock mechanics are happened

with the demand of the substantial development. Emerged as one new topic, environmental rock mechanics is mainly based on the following connotations: using the theory of rock mechanics to solve the questions in environment engineering, considering the environment question during studying the theory and technological method of rock mechanics and applying the theory of environment science to rock mechanics. Its core idea is the criteria of environmental geology engineering, which merges the geo - engineering with, or in another word, bases it on ecology.

According the above ideas, this book is written to conclude the author' s achievement on environmental rock mechanics related to slope and landslide engineering during more than ten years. Base on the following engineering such as the permanent shiplock slope engineering in Three Gorges Project, Mayan high slope in Shuibuya project, Lianzhiya hazardous rock mountain in the area of Changjiang, landslide in Xiaolangdi dams site Yellow river, Yangjiachao landslide in dams site Geheyan, Huanglashi landslide in the area of Changjiang, Xintan landslide, Leipishi ancient landslide, Yanguan landslide, Yudonghe landslide in Shuibuya project, Dayantang landslide and Mayanwan landslide. Its content includes the basic theories and methods in environmental rock mechanics: environment engineering geology analysis of slope and landslide, the studying of geological model and structure, the research of failure mechanism, physical and numerical simulation, theory discussion of stability assessment, the studying of control methods, back analysis, reducing and protecting hazard environment engineering.

Most of the work was done by author in Wuhan University of Hydraulic and Electric Engineering, part of the work was done in HoHai University. The research achievement is mainly from the National key project, National Science foundation of China project, Hubei province academic science research project, State Power Corporation key scientific research project, Engineering geomechanics Laboratory, Institute of Geology Chinese Academy of Science fund project, Three Gorges Project fund project and Shuibuya project fund, in which the author led or attended. The Publishing of this book is funded by the "211" project of WUHEE.

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Because of the long period of studying and the difference between research objects, the