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冯梅梅　茅献彪　白海波　著

MECHANICS ANALYSIS OF WATER INSULATING EFFECT OF FLOOR IN COAL MINING ABOVE AQUIFER AND ITS APPLICATION

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内 容 提 要

带压开采面临的关键技术问题是如何预测和防治采场底板突水事故的发生，实现安全开采，而对煤层底板阻隔水性能的正确评价是预测和防治底板突水的主要依据。本书基于岩层控制的关键层理论，针对采场底板隔水岩层的构造及物理力学特征，综合应用理论分析、数值模拟、物理模拟等方法与手段，系统地研究了采场底板隔水岩层的隔水性能及突水机理，研究成果可为承压水上煤层的安全开采提供理论参考。

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前　言

中国是以煤为主要能源的国家，煤炭占中国能源生产的76%和能源消费的68.9%，其产量已经超过了世界总产量的三分之一，然而煤矿开采过程中的水害事故却制约着煤炭工业的快速发展。在我国煤矿重特大事故中，水害事故在死亡人数上仅次于瓦斯事故，居第2位；在发生次数上，也紧随瓦斯和顶板事故之后，居第3位。2000～2010年，共发生造成人员伤亡的各种煤矿水害事故521起，共死亡3 026人，给人民的生命与财产带来了极大的损失。矿井水害防治一直受到党和政府的高度重视。《国家中长期科学和技术发展规划纲要(2006—2020)》，在能源、水资源与矿产资源、公共安全等领域都涉及水害与水资源的问题，把重大生产事故预警与救援列入“公共安全”重点领域中的优先主题，重点研究开发矿井瓦斯、突水、动力性灾害预警与防控技术。在《煤矿安全生产“十二五”规划》中明确提出，要加强水害防治基础工作，加大水害综合防治技术研究。

目前，随着开采强度的增大，浅部煤层渐进枯竭，许多矿区转向开采较深部的下组煤，而面临煤层底部的高承压水的危害日趋加剧。据统计，有60%的煤矿不同程度地受到底板岩溶承压水的威胁，造成40%左右的煤炭资源不能正常开采，每年采出受水害威胁的煤炭还不到总产量的10%。带压开采具有开采成本低、对环境危害小、可实现对水资源保护等许多优点，是开采受底板突水威胁煤层的主要方法之一。带压开采面临的关键技术问题是如何预测和防治采场底板突水事故的发生，实现安全开采。本专著基于岩层控制的关键层理论，针对采场底板隔水岩层的构造及物理力学特征，综合应用理论分析、数值模拟、物理模拟等方法与手段，研究了承压开采工作面煤层底板隔水层的破坏过程，采动应力场和水压作用下的裂隙发育及扩展机制，探求底板突水可能的途径，分析了底板

岩层阻水性能及突水动态机理，对底板的隔水性能进行了综合评价，并将研究成果成功用于徐州矿区某工作面底板突水危险性评价及防治实践，取得了显著的经济和社会效益。

本书作者一直从事力学与岩土工程交叉学科的科学研究工作，主要研究方向为岩石力学及工程、渗流力学，在岩石断裂理论、岩体结构力学行为及破坏过程的仿真分析、煤矿水害发生机理及防治、多物理场耦合问题的数值模拟等方面取得较好的研究进展。参与完成了国家重点基础研究发展计划(973 项目)“煤矿突水机理与防治基础理论研究”(2007CB209400)、教育部科学技术研究重点项目“干旱半干旱地区煤炭开采中水资源保护与利用研究”(105024)，参与了国家自然科学基金重点项目“长壁综采矸石充填与岩层运动控制研究”(50834004)、国家重点基础研究发展计划(973 项目)“西部煤炭高强度开采下地质灾害防治与环境保护基础研究”(2013CB227900)，主持完成校青年基金项目“深部开采含水覆岩保水与防突水的基础研究”。本专著是作者及其课题组成员长期开展煤矿突水机理及防治技术研究的工作积累与总结，并广泛参考吸收前人相关研究成果而完成的。

在本书撰写过程中，得到了中国矿业大学王连国教授、马占国教授的热情指导和帮助，还有更多的研究人员、实验技师及研究生也为本书的研究成果做出了贡献，在此对他们的辛勤劳动表示诚挚谢意！

作　者

2013 年 1 月

Preface

Coal is the main energy of China, it accounts for 76% of energy production and 68.9% of energy consumption, and its output has already exceeded one-third of the world production. However, the water accident in the coal mining severely restricts the rapid development of coal industry. The death toll of water accident rank only second to gas accident in the main mine accidents of China and the deaths number frequency of water accident ranks the third next to gas and roof accidents. From 2000 to 2010 there were casualties caused by coal mine water injury accident 521 and a total of 3 026 people died, which brought great losses to people's lives and property. Mine Water Disaster Prevention has always been attached great importance by the party and government. National long-term science and technology development plan (2006—2020), involved in water damage and water issues in the field of energy, water and mineral resources, public safety, warning of the major production accidents and rescue in the "public priority themes in the security "key areas, focusing on research and development of coal mine gas, water inrush, disaster warning and prevention and control of dynamic technology. It is clearly stated in the coal mine production safety "12th Five-Year Plan" to strengthen the water hazard prevention and control foundation work, increase the water damage the integrated control technology.

At present, with the increase of mining scale and depth, the shallow coal seam have been almost exhausted, so many coal mines will be transferred to the lower coal group. Many coal mines go into deep mining, and the confined water Karst aquifer at the bottom of coal groups is a serious threat to coal mines during the mining, According to statistics, 60% of the coal mine is threatened by the karst confined water of coal seam floor in different degrees, cause about 40% of the coal resources can't be mined normally, the production of the coal threatened by water hazards is less than 10% of the total output of each year. Mining above aquifer is one of the main effective methods to explore

the coal threatened by water inrush in floor because of the merits, such as low mining costs, less environmental hazards, and the easy realization of the water resources protection. In order to mining safely, the forecast and prevention of the water inrush from floor in working face has been the key technique problem in mining above aquifer. In this book, based on the key strata in rock's control, aimed at the construct features and the mechanics properties of the water-resisting strata of floor in working face, A synthetically study means combined with theoretical analysis, numerical simulation, physical modeling, and practical application is applied to study the failure process of the water-resisting strata in working face floor above aquifer, the mechanics mechanism of fracture developing and extending with the effect of mining stress and water pressure, explore a possible way of water inrush from floor, analyze the water insulating effect of floor strata and the dynamic mechanism of water inrush. Then, the insulating effect of the floor is integrated evaluation and the study results are successfully applied to the risk assessment for water-inrush from floor in working face and preventing practice in Xuzhou coal mine, which have achieved significant economical and social benefits.

The author has been engaged in interdisciplinary research work of the Mechanics and Geotechnical Engineering, the main research directions are rock mechanics and engineering, seepage mechanics. Good progresses have been made in the structural mechanics of rock mass behavior and the failure process simulation analysis, the mechanism of coal mine water disaster and control, numerical simulation of multi-physics coupling. The author has participated in the National Basic Research Program of China(973 Program)"Research on basic theory about the mechanism of water inrush and its prevention in coal mines"(2007CB209400), and Science and Technology Key Project of Ministry of Education "Research on the water resources protection and utilization in arid and semi-arid areas of coal mining" (105024). Now, have being participated in the National Natural Science Foundation of China "longwall control of waste filling and rock movement" (50834004). The author finished a school youth fund "Research on the water preventing and protecting of aquifer overlying rock in deep mining". The book is the author and his group members to carry out long-term coal mine water inrush mechanism and control techniques of accumulation and summary of previous related research and extensive reference

to the absorption.

In the book writing process, professor Wang Lianguo and professor Ma Zhanguo of China University of Mining and Technology, have given much enthusiastic guidance and help. In addition, there are many more researchers, laboratory technicians and graduate students made contributions to the research of the book. Here, sincere thanks are owed to their hard working on this!

目　录

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1 绪 论

1 Introduction

我国能源结构以传统燃煤为主，目前煤炭在一次能源消费结构中的比重仍然维持在七成左右。煤炭企业的安全高效生产是关系国计民生的大事。随着国民经济的发展，煤炭消耗量日益增加，煤炭开采量也随之加大，浅埋煤炭资源渐趋匮乏，为了满足社会对能源不断增加的需求，煤炭开采逐渐向深部发展。同时，与之伴生的地质灾害问题也日趋严重，如瓦斯爆炸、矿井突水、冲击矿压、巷道围岩变形失稳等等，给深部煤炭资源的安全高效开采造成了巨大威胁。其中，灾害性突水仅次于瓦斯爆炸，成为危及煤矿安全生产最为严重的问题之一。

1.1 研究的目的和意义(Research Objective and Significance)

我国煤矿群死群伤特大事故主要由瓦斯和突水灾害造成，遏制瓦斯和突水事故是我国煤矿安全控制的主攻目标，并且突水造成的直接经济损失一直排在各类煤矿灾害之首。目前，全国煤矿遭受水害威胁的储量高达 250 亿 t，主要分布在约占全国产量 50%的华北地区石炭二叠纪煤田。该煤田位于复杂的岩溶水文地质类型区，主要受煤系底部灰岩强岩溶含水层的威胁，突水事故频繁发生，且突水量大。据不完全统计，自 1956 年到 1994 年内，我国北方开采山西组与太原组煤层时，来自煤层夹层灰岩和基底中奥陶系灰岩岩溶水的底板突水 1 300余次，其中淹井 200 余次，造成的经济损失达几十亿元，人员伤亡达几千人。例如：河北开滦范各庄矿于 1984 年 6 月 2 日发生了称之为“举世罕见”的特大突水灾害，仅 20 小时 55 分就淹没了整个矿井，而后涌水又冲破井田边界煤柱溃入相邻的一个矿井，使之被淹，进而涌水渗入另一个矿井，迫使该矿井停产；同时还威胁其他两矿的安全，使之处于半停产状态，造成直接经济损失达 5 亿元以上。

过去 20 年间，有 250 多对矿井被水淹没，直接经济损失高达 350 多亿元。近几年来，随着煤矿开采深度的不断增加，矿井底板突水日趋严重，淹井伤人事故频繁发生，近 5 年所发生的矿井突水事故比前 10 年的总和还多，对人民的生命和财产造成了极大的损失。表 1-1 是 2000～2006 年间煤矿重、特大突水事故