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井工采煤地质力学

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内 容 提 要

本书阐述了巷道掘进时的岩石物理—力学性能，采煤时岩石移动和矿压变化规律，以及在采煤时保证采区准备巷道和主要采准巷道稳定性方法；说明了开采缓倾斜、倾斜和急倾斜薄及中厚煤层时的地质力学过程；揭示了在煤层中的地质动力过程，提出了预防煤、岩石和瓦斯突出与冲击地压的理论基础和技术手段。

本书可作为煤炭科研院所科研工作者，以及高等院校采矿、安全等专业师生的参考书，也可供煤矿工程技术人员参考。

译审者的话

《井工采煤地质力学》是乌克兰国立顿涅茨克技术大学出版的高等学校教科书，原著为俄文，共一、二、三卷，分别于2006、2007、2008年出版。第一卷、第二卷作者为M. П. 兹博尔希克，M. A. 伊利亚绍夫；第三卷作者为M. П. 兹博尔希克，M. A. 伊利亚绍夫，A. П. 斯塔里科夫。作者于2008年将原著赠送顿涅茨克技术大学校友、煤炭科学研究总院原建井研究所所长张永成教授。当时，中国老科学技术工作者协会煤炭工业分会在煤炭科学研究总院支持下，刚完成“国内外煤矿深部开采岩层控制技术”项目的调研，并准备出版专著。

矿井地质力学是矿井岩层控制的基础，《井工采煤地质力学》内容丰富，理论与实践相结合，全面系统地概括了顿涅茨克矿区岩层控制的经验。中国老科学技术工作者协会煤炭工业分会和煤炭工业出版社协商，将这三卷书翻译并成一本出版，供我国煤炭科技工作者参阅。

顿涅茨克矿区开发历史悠久，1916年产煤2860万t（我国1936年全国煤炭产量为2960万t），1976年产量最高达2.182亿t。矿区生产地质条件复杂，主要开采近距离的薄及极薄煤层群，煤层顶底板主要是中等强度和强度低、稳定性差的岩层，开采深度大，煤、岩石和瓦斯突出及冲击地压危险严重。原苏联及乌克兰、俄罗斯的科学家和工程师为顿涅茨克煤田的开采进行了长期、深入的科学研究工作，通过生产实践，积累了丰富经验。

本书对各种井工采煤地质力学理论、假说作了比较系统的剖析，根据地质力学的理论和实践经验，对合理进行采掘工作

布置，消除和减少采煤导致的岩层移动和矿山压力，尤其是集中压力的危害，防止煤、岩石、瓦斯突出和冲击地压，利用先开采上部或下部近距煤层形成卸压区，作了全面系统和翔实的阐述和探讨，并形成了许多行之有效的生产建设指导性规范，对保证在生产安全的条件下，实现高产、高效、低耗采煤，具有现实意义。

我国煤矿主要是井工开采，深部开采矿井日益增多，遇到的地质力学问题越来越多，给煤矿的安全、高效开采带来严重威胁，深部开采的岩层控制，尤其是煤、岩石、瓦斯突出和冲击地压等矿山压力动力现象，是生产建设中亟待解决的重大科学技术问题。本书在理论上，尤其在生产实践上对这些问题进行了详细阐述，对我国煤矿科技工作者研究解决这些问题，具有重大参考价值。

本书的出版得到了煤炭科学研究总院创新基金和煤炭工业出版社的大力支持，我们对此深表感谢。并且特别感谢乌克兰国立顿涅茨克技术大学授予我们在中国出版的权利。

书中对顿涅茨克煤田的开采技术和工艺作了非常详细的阐述，这些技术和工艺应用有其特有的地质生产技术条件，我国科技人员对其中一些技术和工艺，尤其是一些细节比较生疏，有些名词和术语在中文中还没有恰当的名词和词组与之对应，这会给读者阅读带来不便。我们认真译审了该书，但仍难免有不恰当之处，热忱欢迎专家、读者指正。

译审者

2010年6月

前 言

第 一 卷

煤炭工业是国家国民经济主要支柱之一。煤炭占乌克兰能源消费总量的 94% ~ 96%。乌克兰的全部煤炭都是井工开采的，大部分矿井在煤炭开采期间获得国家的补贴，以补偿亏损。

顿涅茨克煤田是煤炭主要供应地。该煤田所开采煤层的条件非常差：开采的煤层厚度薄（主要是 0.7m 的极薄到 0.7 ~ 1.2m 的薄煤层），煤层埋藏在中等强度和稳定性差的岩层中；煤层开采深度大，瓦斯含量高，并且有煤与瓦斯突出危险，井下温度高，煤炭有自然发火倾向，煤尘有爆炸危险等。

采煤是岩体中产生复杂地质力学过程的起因。这意味着，采煤改变了自然岩体中岩石的应力状态及其物理力学性能。作业场所周边的围岩在自然和技术工艺因素影响下，发生变形、位移和破坏。

讲授“岩体状态控制”和“井工采煤岩石力学”的目的是培养大学生——未来的采矿工程师具有岩体自然状态的基础知识，以及具有对井下作业引起的岩体地质力学变化过程的规律性的正确认识。在解决具体问题时未来的专家可以根据这些知识，选择防止或者降低矿山压力有害影响的最可行的措施、方法，以确保安全和低成本采煤。

要在综合考虑大量的矿山工作和生产技术因素的基础上，对整个井田、水平、区段、盘区和采区范围内井下作业进行设计。在这些因素中占主导地位的因素永远是进行采煤和掘进作业所采用的工艺、设备和预期的地质力学条件。例如，在采区

范围内采用的开采方法必须简单，并且从地质力学和技术工艺角度保证在采煤和掘进工作面的综合机械化装备能够高效工作。

在教材编写过程中，作者始终考虑所采取方法的自然条件、技术工艺和设备的相互关系，并借此避免或者在短时间内减少地质力学因素对采掘工作造成的负面影响。同时，作者力求以大学生易于理解的方式阐述地质力学的复杂问题。在本教材中引用了众多科学家在地质力学领域的研究成果。许多问题的论述是基于作者自身的科学研究成果，也采用了国立顿涅茨克技术大学多年的教学经验。

教材第一卷阐述了开采缓倾斜单一煤层或者煤系中第一层煤的地质力学综合性问题。本教材第二卷和第三卷的内容包括：开采煤系时煤体状态的控制、采煤工作面围岩状态的地质力学特性和开采单一煤层以及煤系时的瓦斯动态显现。

第5章由作者与科学技术副博士 Л. В. 拜萨罗维姆共同编写。

凡有助于改善教材第一卷内容和阐述的批评、建议，作者都将乐于接受并表示感谢。

第 二 卷

《井工采煤地质力学》教材首卷出版于2006年（由国立顿涅茨克技术大学出版）。书中阐述了乌克兰煤炭工业的现状与发展前景；煤体在自然状态下和采矿作业过程中的性质；开采煤系地层的第一层或单一煤层时，对围岩产生的地质力学过程特点和规律性的认识。在此基础上结合现代技术工艺，充分研究了开采缓倾斜和倾斜薄及中厚（平均厚度为2.0~2.5m）单一煤层时，为保证采区准备巷道和主要准备巷道稳定性可能采取的技术工艺解决办法。

第二卷教材论述了开采缓倾斜和急倾斜煤系煤层的地质力

学；保障采区准备巷道和主要准备巷道的稳定性；维护开采缓倾斜和急倾斜煤层时采煤工作面的稳定性。第二卷从两个地质力学体系（大体系和小体系）的相互作用角度出发，详细研究了煤层开采时，保障准备巷道和采煤工作面稳定性的问题。大体系是长壁工作面和受回采工作采动影响的周围岩体。小体系指的是巷道本身，包括技术工艺形成的设有支架的空间和煤层及其顶底板岩石。保证巷道稳定性的基本原则是，防止大地质力学体系对小地质力学体系的有害影响或者使其影响降到最低程度。在巷道内（小体系）所有可能产生的残余有害矿山压力显现，应通过采用先进的技术工艺措施和技术装备（支架）加以消除。本教材作者认为，这样编写教材，在一定程度上对大学生按授课计划理解和掌握在回采过程中产生围岩的复杂地质力学变化是比较合适的。

第二卷教材的编写目的仍然与第一卷类似，在于使大学生——未来的采矿工程师掌握在岩体自然状态下作业时的地质力学特点和规律性的基础知识。根据这些知识，未来的工程师必须能够选择最有用的措施、方法，防止或者减少矿山压力的有害显现，以保证煤炭的安全、低成本开采。

第 三 卷

教科书《井工采煤地质力学》是针对“岩体状态控制”或“井工采煤岩石力学”教学课程编写的。

该教科书第一卷于2006年出版。第一卷充分阐述了在开采单一缓倾斜、倾斜薄及中厚煤层时，可以确保采区及主要采准巷道稳定性的先进工艺和技术方案。

教科书第二卷于2007年出版。该卷阐述了开采缓倾斜及急倾斜煤系的地质力学问题，采区及主要采准巷道稳定性及其维护问题，开采缓倾斜及急倾斜煤层时采煤工作面稳定性问题。

本卷（第三卷）阐述了在进行采掘工作时在煤系地层中发生的气体动力过程和地质动力过程。着重阐述了煤、岩及瓦斯突出以及冲击地压的假说的有效性及理论实质，预测这些危险的方法的应用；采用先进的区域性方法，预防井下采煤时煤、岩石和瓦斯突出及冲击地压。在编写此卷时作者认为，学生通过学习以前的专业课程，已经具备了学习本卷的基础知识。

编写本卷还有一个目的，就是让学生——未来采矿工程师掌握有关岩体处于自然状态时的基础知识，和在进行采矿工作时发生在岩体中的地质力学过程的本质特点及发展规律的基础知识。在解决具体问题时，未来的采矿工程师依据这些知识应当能选择最适当的措施、方法，来预防或减少有害及危险的矿压显现，以确保安全、低成本采煤。

凡有助于改善教材第三卷内容和阐述的批评、建议，作者都将乐于接受并表示感谢。

INTRODUCTION

Volume One

The coal industry is one of the main sectors for the national economy. Coal is taken 94% ~ 96% of the national energy total consumption. The national coal production mined in Ukraine actually is all came from underground mines. The products of the coal industry are precious. During the coal mining period, a large number of the mines in Ukraine are subsidized by the State in order to compensate the deficits of the mines.

The Donetsk Coalfield Company is the main coal supplier. Under the conditions of the coalfield, the seams to be mined would be very difficult. The difficulties are as followings: The seams to be mined are thin (and are mainly 0.7 m thick and 0.7 m to 1.2 m thick) . The seams in between the underground strata would not be over in the medium strength and in the medium stability. The depth of the seam mining would be high. The seams would be high gassy and have coal and gas outburst dangers. There would be a high air temperature in the mine roadways. The seams in the mine would have a spontaneous combustion tendency and coal dust explosion dangers. The operations in the underground mine would be very complicated.

During the mine operation period, the coal mining would be the cause to occur a complicated geological mechanics process in the mineral body. This means that the rock stress status and its physical mechanical properties would be changed in the natural mineral mass. Under

the factors influences of the nature and technological technique, the mine roadway and the surroundings would have the strata deformation, displacement and failure.

The purposes of the teaching course – “Control of Rock Status” or “Rock Mechanics of Underground Coal Mining” is to train the college students – future mining engineers with the basic knowledge of the rock natural (natural world) status as well as the basic knowledge of the geological mechanics process law and features occurred in the minerals during the mine operations. Base on the those knowledge to solve certain problems, the future experts shall select most feasible access, measures, methods, technology and equipment to prevent or reduce the harmful influences of the mine strata pressure in order to ensure the mining safety and lower consumption in the coalfield.

Base on the comprehensive considerations on the factors of the great mine geological and production technology, the design on the mine operations in the completed minefield, mine levels, mine sections, mining panel and mining districts were conducted. In those factors, the major position (or main) factors would always be the production equipment (including the machinery as well as the fully mechanized units, devices, equipment and others) applied to the coal mining and the gateway driving and the predicted geological mechanics conditions. For example, the mining method applied to the mining district shall be simple. From the geological mechanics and technical technique, the mining method applied shall ensure the high efficient operation of the modern fully mechanized unit in the coal mining face and in the gateway driving face.

In the statement of the teaching material, the authors always considered the mutual relationship between the natural conditions, technical technique and equipment for the methods to be taken. With those

measures, the geological mechanics factors to cause the negative influences to the coal mining and preparation work could be overcome or seriously reduced. Meanwhile, the authors tried to use a way to state the complicated issues of the geological mechanics for the college students to easily understand. In this teaching material, many research achievements of the geological mechanics by the scientists were adopted. The authors also base on themselves actual researches, stated a series of issues with the many years teaching experiences in the State Donetsk University of Technology.

This teaching material stated the comprehensive issues of the geological mechanics in the mining of the gently inclined single seam or the first seam of the coal measures. The contents of the No. 2 and No. 3 Volumes of the teaching material published later would be including the control of the coal measures status during the coal mining period, the active geological mechanics of the surrounding rocks of the coal mining face and the gas dynamics behaviors in the mining of the single seam or the coal measures.

The Chapter Five was jointly written by Author and Deputy Dr. Л. В. Байсаровым.

The authors will be glad to accept any comments, proposals and wishes to improve the first volume of the teaching book and will highly appreciate.

Volume Two

This book could be applied to the course of “Rock Mass Status Control” or “Rock Mechanics of Underground Mining in Coalfield”. The first volume of the teaching Material of “Geological Mechanics of Underground Mining coal Seam” was published in the year of 2006 (by

State Donetsk University of Technology with 256 Pages). The book stated the status and function prospects of Ukraine Coal Departments and introduced the coal properties under the natural conditions and during the coal mining operation process. During coal mining in the first seam of the seam group or a single seam, the geological mechanics process features and law occurred from the surrounding rocks shall be understood to the update. Base on the circumstances and in combined with the modern technical technique, it could be completely in detail to study the possible adopted technical technique solution method to ensure the stability of the prepared gateways and main prepared gateway in the mining district during the mining in the gently inclined and inclined thin and medium thick seams (average thickness 2.0 ~ 2.5 m).

The second volume of the teaching material stated the geological mechanics of coal mining in gently inclined and steep inclined seams, the protection or guarantee of the stability for the prepared gateway and main prepared gateway in the mining district and the stability maintenance of the mining gateway (of the coal mining face) during the mining in the gently inclined and steep inclined seams. From the closed mutual functions of the two geological mechanics systems (a large system and a small system), the second volume also in detail studied the all problems in the protection and guarantee of the stability for the prepared gateway and coal mining face during the mining in seams. The large system meant the long coal mining face (longwall coal mining face) and the mine matters around the coal mining face affected by the coal mining. The small system meant the mining gateway, such as the technique technology chamber formed with the supports and the floor and roof strata around the coal mining face. The basic principle to ensure the stability of the supported gateway was to prevent the harmful influence of the large geological mechanics system to the small geological mechanics system or to reduce the influence to minimal. In the supported gateway (small system), all residual harmful mine strata

pressure behaviors possibly occurred shall be compensated with the advanced technical technique measures and technical equipment (supports). The authors hold that such access to introduce the teaching material would be successful and benefit on certain degree for the students in schedule to understand and master the complicated geological mechanics of the surrounding rocks occurred from the mining process.

The purposes of the second volume teaching material also are similar to the above mentioned and are to let the college students – future engineers have the basic knowledge of the geological mechanics process, essential features and law of the mine body natural status and mine body during the mine operation. With those knowledge, the future engineers shall select most applicable access, measures, methods, technique and equipment to prevent and reduce the harmful behaviors of the mine strata pressure in order to ensure the safety degree and a economic cost during the coalfield mining.

Volume Three

This teaching book – 《Geological Mechanics of Underground Coal Mining》 was written for the the teaching course of “Control of Rock Mass” or “Rock Mechanics of Underground Coal Mining”.

The First Volume of the teaching book was published in 2006. In the First Volume, the advanced technique technology plan to ensure the stability of main prepared mining gateway in the mining district during the mining in the gently inclined or inclined thin and thick seams was fully analyzed.

The Second Volume of the teaching book was published in 2007. The volume stated the geological mechanics issues during the mining in the gently inclined or steep inclined seams, the keeping and mainta-

nence of the main mining prepared gateway stability in the mining district, and the stability keeping of the coal mining face during the mining in the gently inclined and steep inclined seams.

This volume stated the gas dynamic process and geological dynamic process occurred in the coal measure strata during the mining and excavation. This volume emphasized to show the available work assumption or theoretical substances of the coal, rock and gas outburst as well as the pressure bumping. The volume introduced the application of the prediction methods of those dangerous phenomenon. The advanced area and local methods were applied to prevent the outburst and mine pressure bumping occurred in the underground mining. During the writing and preparing the volume, the considerations of the authors were that the students should have the base to study this volume before they had learned professional courses.

The purpose of the volume is to let the students – the future mining engineers master the basic knowledges of rock mass in nature conditions and the basic knowledges of the essential features and development law in the geological mechanics process occurred in the mining operation. In the solution of certain problems, the future engineers shall based on those knowledges to select most suitable access, measures, methods, technology and equipment to prevent and reduce the harmful and dangerous mine strata pressure behaviors in order to ensure the safety of the coal resources and the mining with a low cost.

The authors will be glad to accept any comments, proposals and wishes to improve the third volume of the teaching book and will highly appreciate.

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