

МЕЖДУНАРОДНЫЙ



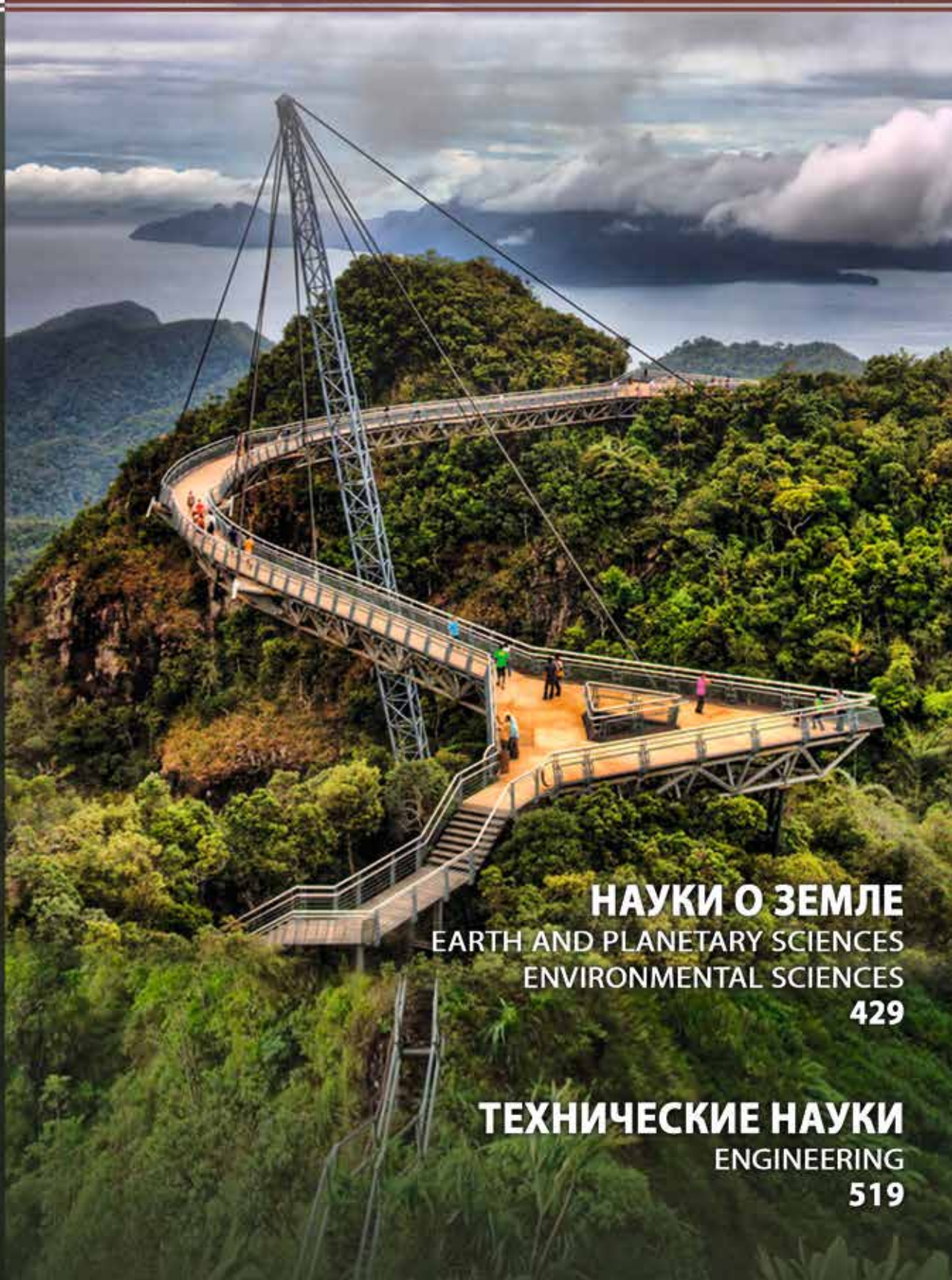
НАУЧНЫЙ ЖУРНАЛ

# УСТОЙЧИВОЕ РАЗВИТИЕ ГОРНЫХ ТЕРРИТОРИЙ

ISSN 1998-4502  
e-ISSN 2499-975X

Sustainable Development of Mountain Territories

*"Земля - планета не простая".  
А. де Сент-Экзюпери*



**НАУКИ О ЗЕМЛЕ**  
EARTH AND PLANETARY SCIENCES  
ENVIRONMENTAL SCIENCES  
**429**

**T.11**  
**№4(42)**  
**2019**

**ТЕХНИЧЕСКИЕ НАУКИ**  
ENGINEERING  
**519**



## НАУЧНЫЙ ЖУРНАЛ "УСТОЙЧИВОЕ РАЗВИТИЕ ГОРНЫХ ТЕРРИТОРИЙ"

Журнал входит в Перечень изданий, рекомендованных Высшей аттестационной комиссией (ВАК)

Журнал включен в международную реферативную базу данных и систему цитирования Scopus

### Адрес редакции, учредителя, издателя:

362021, РСО-Алания,  
г. Владикавказ, ул. Николаева, 44,  
Северо-Кавказский горно-металлургический институт  
(государственный технологический университет),  
редакция журнала «Устойчивое развитие горных территорий».

Тел.: 8(918) 707-39-25,  
8(8672) 40-73-60,  
8(8672) 40-72-28.

### Адрес в Интернете:

<http://www.naukagor.ru>

E-mail: [editor@naukagor.ru](mailto:editor@naukagor.ru)

Ответственность за содержание статей несут авторы.

Редакция не имеет возможности возвращать присылаемые материалы. За сведения в рекламных материалах редакция ответственности не несет. Перепечатка допускается только с разрешения редакции и с обязательной ссылкой на журнал «Устойчивое развитие горных территорий».

Журнал зарегистрирован в Федеральной службе по надзору за соблюдением законодательства в сфере массовых коммуникаций и охраны культурного наследия.

Свидетельство о регистрации  
ПИ №ФС77-27831 от 19.04.2007 г.

Издается с 2009 г.

Редактор МИСИКОВА И.А.

Технический перевод ПЕЙКАРОВА Н.И.

Компьютерный дизайн

и верстка ПРОВОТОВА Н.М.

Тираж 50 экз. Заказ №206  
Подписано в печать: 20.12.2019 г.  
Дата фактического выхода:  
30.12.2019 г.

Отпечатано в типографии  
ИП Харченко Т.В.  
344013, г. Ростов-на-Дону,  
ул. Мечникова, 112 А.

### УЧРЕДИТЕЛЬ:

СЕВЕРО-КАВКАЗСКИЙ ГОРНО-МЕТАЛЛУРГИЧЕСКИЙ ИНСТИТУТ (ГОСУДАРСТВЕННЫЙ ТЕХНОЛОГИЧЕСКИЙ УНИВЕРСИТЕТ)

### РЕДАКЦИОННАЯ КОЛЛЕГИЯ:

**Главный редактор – Дмитрак Ю.В.** – доктор технических наук, профессор, ректор Северо-Кавказского горно-металлургического института (государственного технологического университета), (Владикавказ, Россия).

### ПЕРВЫЙ ЗАМЕСТИТЕЛЬ ГЛАВНОГО РЕДАКТОРА:

**Хадзарагова Е.А.** – доктор технических наук, профессор, проректор по научной работе и инновационной деятельности Северо-Кавказского горно-металлургического института (государственного технологического университета), (Владикавказ, Россия).

### ЗАМЕСТИТЕЛИ ГЛАВНОГО РЕДАКТОРА:

**Клюев Р.В.** – доктор технических наук, профессор, заведующий кафедрой «Электроснабжение промышленных предприятий» Северо-Кавказского горно-металлургического института (государственного технологического университета), ответственный за выпуск номеров журнала, (Владикавказ, Россия).

**Гуля А.Н.** – доктор географических наук, профессор, руководитель горной группы МАВ-6 программы ЮНЕСКО «Человек и биосфера» в Институте географии Российской Академии наук, старший научный сотрудник ИГ РАН, (Москва, Россия).

**Хетагуров В.Н.** – доктор технических наук, профессор, руководитель рабочей группы по подготовке журнала к изданию, профессор кафедры «Технологические машины и оборудование» Северо-Кавказского горно-металлургического института (государственного технологического университета), (Владикавказ, Россия).

### ОТВЕТСТВЕННЫЕ СЕКРЕТАРИ (по направлениям):

**Науки о Земле – Керимов И.А.** – доктор физико-математических наук, профессор, вице-президент Академии наук Чеченской Республики (Грозный, Россия).

**Технические науки – Кондратьев Ю.И.** – доктор технических наук, профессор Северо-Кавказского горно-металлургического института (государственного технологического университета), (Владикавказ, Россия).

.

### РЕДАКТОРЫ:

**Караев Ю.И.** – директор Международного инновационного научно-технологического центра «Устойчивое развитие горных территорий» (МИНТЦ «Горы») Северо-Кавказского горно-металлургического института (государственного технологического университета), (Владикавказ, Россия).

**Мисикова И.А.** – начальник редакционно-издательского отдела Северо-Кавказского горно-металлургического института (государственного технологического университета), (Владикавказ, Россия).

### РЕДАКЦИОННЫЙ СОВЕТ:

#### Председатель редакционного совета:

**Котляков В.М.** – доктор географических наук, академик РАН, Почётный президент Русского географического общества, председатель экспертного совета Национальной премии «Хрустальный компас», член Межправительственной группы экспертов по проблеме изменения климата, (Москва, Россия).

#### СОПРЕДСЕДАТЕЛИ РЕДАКЦИОННОГО СОВЕТА:

**Вейнгартнер Р.** – доктор наук, профессор Университета г. Берн (Швейцария), заведующий кафедрой гидрологии Географического института Университета г. Берн. Руководитель Международной Исследовательской Инициативы (MRI), (г. Берн, Швейцария).

**Дзасохов А.С.** – доктор политических наук, заместитель председателя Комиссии Российской Федерации по делам ЮНЕСКО, (Москва, Россия).

**Кавалла Р.** – кандидат технических наук, профессор, директор института обработки металлов давлением Фрайбергской Горной Академии, (Фрайберг, Германия).

**Пучков Л.А.** – доктор технических наук, профессор, член корр. РАН, профессор кафедры «Безопасность и экология горного производства» Горного института Национального исследовательского технологического университета «Московский институт стали и сплавов», (Москва, Россия).

#### СОСТАВ РЕДАКЦИОННОГО СОВЕТА:

**Айдаралиев А.А.** – доктор медицинских наук, академик Национальной Академии наук Республики Кыргызстан, Председатель попечительского Совета УНПК «Международный университет Кыргызстана», (Бишкек, Кыргызская Республика).

**Бабаян Г.А.** – кандидат физико-математических наук, заведующий отделом мониторинга и инноваций Института геологических наук Национальной Академии наук Армении, (Ереван, Республика Армения).

**Баденков Ю.П.** – кандидат геолого-минералогических наук, ведущий научный сотрудник Института географии РАН, научный руководитель горной группы МАВ-6 программы ЮНЕСКО «Человек и биосфера» в Институте географии РАН, (Москва, Россия).

**Большаков В.Н.** – доктор биологических наук, профессор, академик Российской академии наук, Советник РАН, главный научный сотрудник, заведующий лабораторией эволюционной экологии Института экологии растений и животных УрО РАН, (Москва-Екатеринбург, Россия).

**Вагин В.С.** – доктор экономических наук, профессор, директор Института международного образования Южно-Российского государственного политехнического университета (Новочеркасского политехнического института), (Новочеркасск, Россия).

**Викторов С.Д.** – доктор технических наук, профессор, заместитель директора по научной работе Института проблем комплексного освоения недр РАН, (Москва, Россия).

**Винчигуэрра С.** – доцент кафедры наук о Земле Университета Турина, (Турин, Италия).

**Глазырина И.П.** – доктор экономических наук, кандидат физико-математических наук, профессор, заведующая кафедрой «Прикладная информатика и математика» Забайкальского государственного университета, (Чита, Россия).

**Голик В.И.** – доктор технических наук, профессор: профессор кафедры «Технология разработки месторождений» Северо-Кавказского горно-металлургического института (государственного технологического университета), (Владикавказ, Россия).

**Гроппен В.О.** – доктор технических наук, профессор, заведующий кафедрой «Автоматизированная обработка информации» Северо-Кавказского горно-металлургического института (государственного технологического университета), (Владикавказ, Россия).

**Дребенштедт К.** – профессор, декан Фрайбергской горной Академии, (Фрайберг, Германия).

**Заксенхофер Р.** – заведующий кафедрой нефтегазовой геологии, профессор Горного университета в Леобене, (Леобен, Австрия).

**Залиханов М.Ч.** – доктор географических наук, профессор, академик РАН, Главный научный сотрудник Высокогорного геофизического института Росгидромета, (Нальчик, Россия).

**Лурье П.М.** – доктор географических наук, профессор, ведущий метеоролог Северо-Кавказского управления по гидрометеорологии и мониторингу окружающей среды, (Ростов-на-Дону, Россия).

**Матвеева Л.Г.** – доктор экономических наук, профессор, заведующая кафедрой «Информационная экономика» экономического факультета Южного федерального университета, (Ростов-на-Дону, Россия).

**Минцаев М.Ш.** – доктор технических наук, профессор, ректор Грозненского государственного нефтяного технического университета им. акад. М.Д. Миллионщикова, (Грозный, Россия).

**Прхалова М.** – программный специалист отдела «Экология и науки о Земле» Секретариата ЮНЕСКО, (Париж, Франция).

**Ревякин В.С.** – доктор географических наук, профессор кафедры «Общая география» Национального исследовательского Томского государственного университета, руководитель региональной группы «Алтай-Саяны» в составе сети горных центров мира, (Алтай, Россия).

**Сысоев Н.И.** – доктор технических наук, профессор кафедры «Нефтегазовая техника и технологии» Южно-Российского государственного политехнического университета (НПИ) имени М.И. Платова, (Новочеркасск, Россия).

**Темираев Р.Б.** – доктор сельскохозяйственных наук, профессор, заведующий кафедрой «Технология продуктов общественного питания» Северо-Кавказского горно-металлургического института (государственного технологического университета), (Владикавказ, Россия).

**Хосаев Х.С.** – доктор технических наук, профессор кафедры «Теоретическая и прикладная механика» Северо-Кавказского горно-металлургического института (государственного технологического университета), (Владикавказ, Россия).

**Штадельбауэр Й.** – доктор философских наук, профессор Фрайбургского университета, (Фрайберг, Германия).

## FOUNDER

NORTH CAUCASIAN INSTITUTE OF MINING AND METALLURGY (STATE TECHNOLOGICAL UNIVERSITY)

## EDITORIAL TEAM

**Chief Editor – Yuri V. Dmitrak** – DSc in Technical Sciences, Professor, Rector of the North Caucasian Institute of Mining and Metallurgy (State Technological University) (Vladikavkaz, Russia)

## FIRST DEPUTY OF EDITOR-IN-CHIEF

**Elena A. Khadzaragova** – First Deputy Editor-in-Chief, DSc in Technical Sciences, Professor, Vice-Rector on Research and Innovation North-Caucasian Institute of Mining and Metallurgy (State Technological University) (Vladikavkaz, Russia)

## DEPUTY CHIEF EDITORS:

**Roman V. Klyuev** – DSc in Technical Sciences, Professor, Head of Department "Power Supply of Industrial Enterprises", North Caucasian Institute of Mining and Metallurgy (State Technological University) (Vladikavkaz, Russia)

**Alexey N. Gunya** – DSc in Geographical Sciences, Professor (Institute of Geography, Russian Academy of Sciences, Moscow, Russia)

**Valery N. Khetagurov** – DSc in Technical Sciences, Professor of Department of Technological Science and Equipment, North Caucasian Institute of Mining and Metallurgy (State Technological University) (Vladikavkaz, Russia)

## EDITORIAL EXECUTIVE SECRETARY:

**Earth Sciences – Ibragim A. Kerimov** – DSc in Physics and Mathematics, Professor, Vice President of the Academy of Sciences of the Chechen Republic (Grozny, Russia)

**Engineering Sciences – Yuri I. Kondratyev** – DSc in Technical Sciences, Professor, North Caucasian Institute of Mining and Metallurgy (State Technological University) (Vladikavkaz, Russia)

## EDITORS:

**Yury I. Karaev** – Director of the International Innovation Scientific-Technological Centre "Sustainable Development of Mountain Territories" (IISTC "Mountains") (Vladikavkaz, Russia)

**Indira A. Misikova** – Head of the Editorial Department of North Caucasian Institute of Mining and Metallurgy (State Technological University) (Vladikavkaz, Russia)

## EDITORIAL BOARD:

### Chairman:

**Vladimir M. Kotlyakov** – DSc in Geographical Sciences, Academician of the Russian Academy of Sciences, Honorary President of the Russian Geographical Society, Chairman of "Crystal Compass" National Award Expert Board, Member of the Intergovernmental Panel on Climate Change (Moscow, Russia)

### Co-Chairmans:

**Rolf Weingartner** – Professor of the University of Bern (Switzerland)

**Alexander S. Dzasokhov** – PhD in Historical Sciences, DSc in Political Sciences, Deputy Chairman of the Russian Commission for UNESCO (Moscow, Russia)

**Rudolf Kawalla** – PhD in Technical Sciences, Professor, Director of Institute of Metal Processing Pressure Freiberg University of Mining and Technology (Germany)

**Lev A. Puchkov** – DSc in Technical Sciences, Professor, Corresponding Member, Russian Academy of Sciences, Member of the Academy of Natural Sciences, Member of the International Academy of Higher Education (Moscow, Russia)

## EDITORIAL BOARD MEMBERS:

**Asylbek A. Aidaraliev** – DSc in Medical Sciences, Academician, National Academy of Sciences of the Kyrgyz Republic, Head of the UNESCO Department "Sustainable Mountain Development" of EDUCATIONAL RESEARCH AND PRODUCTION COMPLEX "INTERNATIONAL UNIVERSITY OF KYRGYSTAN" (Bishkek, Kyrgyz Republic)

**Hektor E. Babayan** – PhD in Physico-Mathematical Sciences, Head of Department, Institute of Geological Sciences, National Academy of Sciences of Republic of Armenia (Yerevan, Republic of Armenia)

**Yuri P. Badenkov** – PhD in Geographical Sciences, Deputy Director of Science, Institute of Geography, Russian Academy of Sciences (Moscow, Russia)

**Vladimir N. Bol'shakov** – DSc in Biological Sciences, Professor, Academician, Russian Academy of Sciences (Moscow, Russia)

**Vladimir S. Vagin** – DSc in Economic Sciences, Professor, Minister of Housing and Communal Services of the Rostov Region (Rostov-on-Don, Russia)

**Sergey D. Viktorov** – DSc in Technical Sciences, Professor, Deputy Director for Research Institute of Comprehensive Exploitation of Subsoil, RAS (Moscow, Russia)

**Serjio Vinciguerra** – Associate Professor of the Department "Earth Sciences" University of Turin (Turin, Italy)

**Irina P. Glazyrina** – DSc in Economic Sciences, PhD in Physical and Mathematical Sciences, Professor, Head of the Department of Applied Mathematics, Informatics" of Trans-Baikal State University (Chita, Russia)

**Vladimir I. Golik** – DSc in Technical Sciences, Professor, Professor of the Department "Development of mineral deposits", North-Caucasian Institute of Mining and Metallurgy (State Technological University) (Vladikavkaz, Russia)

**Vitaly O. Groppen** – DSc in Technical Sciences, Professor, Head of Automated Processing of Information, North Caucasian Institute of Mining and Metallurgy (State Technological University) (Vladikavkaz, Russia)

**Carsten Drebenstedt** – Dean of the Freiberg Mining Academy, Professor (Freiberg, Germany)

**Rainhad Sachsenhofer** – Head of the Department "Petroleum Geology", Professor of Leoben Mining University (Leoben, Austria)

**Mihail Ch. Zalikhhanov** – DSc in Geographical Sciences, Academician, Russian Academy of Sciences (Nalchik, Russia)

**Petr M. Lur'e** – DSc in Geographical Sciences, Professor, Member of the Dissertation Council at the Southern Federal University (Rostov-on-Don, Russia)

**Ljudmila G. Matveeva** – DSc in Economics, Professor, Head of Department of the Information Economy of Economic Faculty of South Federal University (Rostov-on-Don, Russia)

**Magomed Sh. Mintsaeu** – DSc in Technical Sciences, Professor, Rector of Acad. M.D. Millionshtchikov Grozny State Oil Technological University (Grozny, Russia)

**Marie Prchalova** – Programme Specialist, Division of Ecological and Earth Sciences, UNESCO Secretariat (Paris, France)

**Viktor S. Revyakin** – DSc in Geographical Sciences, Professor, Member, Russian Academy of Natural Sciences and the Russian Ecological Academy (Barnaul, Russia)

**Nikolaj I. Sysoev** – DSc in Technical Sciences, Professor of Petroleum Engineering and Technology of M.I. Platov South-Russian State Technical University (Novocherkassk, Russia)

**Rustem B. Temiraeu** – DSc in Agricultural Sciences, Professor, Head of the Department "Food technology" North-Caucasian Institute of Mining and Metallurgy (State Technological University) (Vladikavkaz, Russia)

**Khazbi S. Khosaev** – DSc in Technical Sciences, Professor, Deputy Director of Centre for International Cooperation, External Relations and Sustainable Development, North Caucasian Institute of Mining and Metallurgy (State Technological University) (Vladikavkaz, Russia)

**Jorg Stadelbauer** – DSc in Philosophy, Professor (Germany)

INTERNATIONAL



## SCIENTIFIC JOURNAL "SUSTAINABLE DEVELOPMENT OF MOUNTAIN TERRITORIES"

The journal is included in the List of publications recommended by Supreme Attestation Commission (VAK)

The journal is included in the International Reference Database and Scopus citation System

### Address of the editorial office, founder, publisher:

44 Nikolaev Street, Vladikavkaz,  
RNO-Alania, 362021,  
NORTH CAUCASIAN INSTITUTE  
OF MINING AND METALLURGY  
(STATE TECHNOLOGICAL UNIVERSITY)  
Editorial Office of the journal "Sustainable  
Development of Mountain Territories".  
Tel.: +7(918) 707-39-25,  
+7 (8672) 40-73-60,  
+7 (8672) 40-72-28.

### Internet address:

<http://www.naukagor.ru>  
E-mail: [editor@naukagor.ru](mailto:editor@naukagor.ru)

Authors are responsible for the content of the articles.

Editorial staff is not in the position

to return the submitted materials.

Editorial staff is not responsible for the information in promotional materials.

Reprinting is allowed only with the permission of the editorial office and reference to the journal «Sustainable Development of Mountain Territories» is required.

The journal is registered in the Federal Service for Media Law Compliance and Cultural Heritage Protection.

Registration Certificate  
PI No FS 77-27831 From April, 19 2007

Published since 2009 Is free

**Editor MISIKOVA I.A.**

**Technical translation**

**PEYKAROVA N.I.**

**Computer design and make-up**

**PROVOTOROVA N.M.**

Covering – 50 copies

Order No 206

Signed to print: 20.12.2019

Date of actual release:

30.12.2019

Printed by IE T.V. Harchenko,

112 A Mechnikov st.

344013, Rostov-on-Don

© «Sustainable development of mountain territories», 2019

## СОДЕРЖАНИЕ

<b>НАУКИ О ЗЕМЛЕ</b> .....	<b>ТЕХНИЧЕСКИЕ НАУКИ</b> .....
<p>Бероев С.Б., Хацаева Ф.М.  <b>ПРИОРИТЕТНЫЕ НАПРАВЛЕНИЯ            ЭКОЛОГИЧЕСКОГО ПРИРОДОПОЛЬЗОВАНИЯ            ГОРНЫХ ТЕРРИТОРИЙ            РЕСПУБЛИКИ СЕВЕРНАЯ            ОСЕТИЯ-АЛАНИЯ</b> ..... 429</p> <p>Кнауб Р.В., Игнатъева А.В.  <b>ВЛИЯНИЕ ПРИРОДНЫХ НЕБЛАГОПРИЯТНЫХ            ЯВЛЕНИЙ НА УСТОЙЧИВОЕ РАЗВИТИЕ            ГОРНЫХ ТЕРРИТОРИЙ            (На примере регионов Сибирского            федерального округа)</b> ..... 436</p> <p>Корчагина Е.А.  <b>ИССЛЕДОВАНИЕ ТЕМПЕРАТУРНОГО РЕЖИМА            В ГОРНЫХ РАЙОНАХ КАБАРДИНО-БАЛКАРИИ            И КАРАЧАЕВО-ЧЕРКЕСИИ            В 1951–2015 гг.</b>..... 449</p> <p>Marta Magadan-Diaz, Jesus Rivas-Garcia  <b>SUSTAINABLE TOURISM IN MOUNTAIN            PROTECTED AREAS OF ASTURIAS:            AN ANALYSIS FROM TOURISTS' PERCEPTIONS            AND PROFILES</b> ..... 459</p> <p>Мищук С.Н., Фетисов Д.М., Комарова Т.М.  <b>ПЕРСПЕКТИВЫ ИНДУСТРИАЛЬНОГО            РАЗВИТИЯ ЕВРЕЙСКОЙ АВТОНОМНОЙ            ОБЛАСТИ В СОВРЕМЕННЫХ            ЭКОНОМИЧЕСКИХ УСЛОВИЯХ</b>..... 475</p> <p>Помазкова Н.В., Фалейчик Л.М., Усманов М.Т.  <b>ОЦЕНКА БИОКЛИМАТИЧЕСКИХ УСЛОВИЙ            ДЛЯ РАЗВИТИЯ ТУРИЗМА В НАЦИОНАЛЬНОМ            ПАРКЕ «КОДАР» (Северное Забайкалье)</b>..... 484</p> <p>Кортиев Л.И., Кортиев А.Л., Тедеев А.Г.  <b>ЛАНДШАФТНОЕ ПРОЕКТИРОВАНИЕ ГОРНЫХ            АВТОМОБИЛЬНЫХ ДОРОГ И ИХ НАУЧНО-            ТЕХНИЧЕСКОЕ СОПРОВОЖДЕНИЕ</b>..... 498</p> <p>Чотчаев Х.О., Колесникова А.М., Гогмачадзе С.А.,            Читишвили М.И.  <b>СЕЙСМИЧЕСКАЯ ОБСТАНОВКА            НА ТЕРРИТОРИИ г. АЛАГИР            (Республика Северная Осетия-Алания)</b> ..... 505</p>	<p>Третьяк А. Я., Нырков Е. А., Сидорова Е. В.,            Борисов К. А.  <b>РЕЗУЛЬТАТЫ ПРИМЕНЕНИЯ НОВЫХ            КОНСТРУКЦИЙ БУРОВЫХ ДОЛОТ,            АРМИРОВАННЫХ РЕЗЦАМИ            ГРЕБНЕОБРАЗНОЙ ФОРМЫ PDC</b>..... 519</p> <p>Фомин А.Н., Кузнецов С.Н.  <b>МАТЕМАТИЧЕСКОЕ МОДЕЛИРОВАНИЕ            ДВИЖЕНИЯ КАПЕЛЬ ВОДЫ В ВЕРТИКАЛЬНОМ            ВЕНТИЛЯЦИОННОМ СТВОЛЕ ШАХТЫ</b> ..... 528</p> <p>Копылов А.С.  <b>ПОВЫШЕНИЕ УСТОЙЧИВОСТИ ВЫПУСКНЫХ            ВОРОНОК ПРИ ИЗМЕНЕНИИ ФРАКЦИОННОГО            СОСТАВА ВЫПУСКАЕМОЙ РУДЫ</b>..... 535</p> <p>Гавришин А.И.  <b>ВЛИЯНИЕ ШАХТНЫХ ВОД НА СОСТОЯНИЕ            ОКРУЖАЮЩЕЙ СРЕДЫ В ВОСТОЧНОМ            ДОНБАССЕ</b> ..... 547</p> <p>Петров Ю.С., Соколов А.А., Раус Е.В.  <b>МАТЕМАТИЧЕСКАЯ МОДЕЛЬ ОЦЕНКИ            ТЕХНОГЕННОГО УЩЕРБА ОТ            ФУНКЦИОНИРОВАНИЯ ГОРНЫХ            ПРЕДПРИЯТИЙ</b> ..... 554</p> <p>Quang Phuc Le, Tien Dung Le, Duc Thang Pham,            Anh Tuan Nguyen  <b>STRATA MOVEMENT WHEN EXTRACTING THICK            AND GENTLY INCLINED COAL SEAM FROM A            PHYSICAL MODELLING ANALYSIS:            A CASE STUDY OF KHE CHAM BASIN,            VIETNAM</b>..... 561</p> <p><b>ИНФОРМАЦИЯ ДЛЯ АВТОРОВ</b>..... 568</p> <p><b>ПОДПИСКА</b>..... 570</p>

## CONTENTS

<b>EARTH AND PLANETARY SCIENCES ENVIRONMENTAL SCIENCES .....429</b>	<b>ENGINEERING..... 519</b>
S.B. Beroev, F.M. Khatsaeva PRIORITY AREAS OF ENVIRONMENTAL MANAGEMENT OF MOUNTAINOUS AREAS OF THE REPUBLIC OF NORTH OSSETIA-ALANIA.. 429	A. Ya. Tretyak, E.A. Nirkov, E.V. Sidorova, K.A. Borisov NEW CONSTRUCTIONS OF ARMORED PDC DRILL BITS ..... 519
P.V. Knaub, A.V. Ignateva INFLUENCE OF THE NATURAL ADVERSE PHENOMENA ON SUSTAINABLE DEVELOPMENT OF MOUNTAIN TERRITORIES (On the example of Regions of Siberian Federal District) ..... 436	A.N. Fomin, S.N. Kuznetsov MATHEMATICAL SIMULATION OF WATER DROP MOTION IN VERTICAL SHAFT VENTILATION..... 528
E.A. Korchagina THE INVESTIGATION ON TEMPERATURE REGIME IN THE HIGHLANDS OF THE KABARDINO-BALKARIEN AND KARACHAY-CHERKES REPUBLIC FROM 1951 to 2015..... 449	A.S. Kopylov IMPROVING THE STABILITY OF THE FINAL CRATER WHEN CHANGING THE FRACTIONAL COMPOSITION S. OF PRODUCED ORE..... 535
Marta Magadan-Díaz, Jesus Rivas-García SUSTAINABLE TOURISM IN MOUNTAIN PROTECTED AREAS OF ASTURIAS: AN ANALYSIS FROM TOURISTS' PERCEPTIONS AND PROFILES..... 459	A.I. Gavrishin INFLUENCE OF MINE WATERS TO THE STATE OF THE ENVIRONMENT IN THE EASTERN DONBASS ..... 547
S.N. Mishchuk, D.M. Fetisov, T.M. Komarova INDUSTRIAL DEVELOPMENT PROSPECTS OF JEWISH AUTONOMOUS OBLAST IN CURRENT ECONOMIC CONDITIONS ..... 475	Yu.S. Petrov, A.A. Sokolov, E.V. Raus A MATHEMATICAL MODEL FOR ESTIMATING TECHNOGENIC LOSSES FROM THE OPERATION OF MINING ENTERPRISES..... 554
N.V. Pomazkova, L.M. Faleychik, M.T. Usmanov EVALUATION BIOCLIMATIC CONDITIONS FOR DEVELOPMENT OF TOURISM IN THE KODAR NATIONAL PARK (Northern Transbaikalia) ..... 484	Quang Phuc Le, Tien Dung Le, Duc Thang Pham, Anh Tuan Nguyen STRATA MOVEMENT WHEN EXTRACTING THICK AND GENTLY INCLINED COAL SEAM FROM A PHYSICAL MODELLING ANALYSIS: A CASE STUDY OF KHE CHAM BASIN, VIETNAM ..... 561
L.I. Kortiev, A.L. Kortiev, A.G. Tedeev LANDSCAPE DESIGN OF MOUNTAIN ROADS AND THEIR SCIENTIFIC AND TECHNICAL SUPPORT .... 498	INFORMATION FOR AUTHORS ..... 568
Kh.O. Chotchayev, A.M. Kolesnikova S.A. Gogmachadze, M.I. Fidarova SEISMIC SITUATION IN THE TERRITORY OF ALAGIR (Republic of North Ossetia-Alania) ..... 505	MAGAZINE SUBSCRIPTION..... 570

# STRATA MOVEMENT WHEN EXTRACTING THICK AND GENTLY INCLINED COAL SEAM FROM A PHYSICAL MODELLING ANALYSIS: A CASE STUDY OF KHE CHAM BASIN, VIETNAM

<sup>1,2</sup>Quang Phuc Le,  
<sup>2</sup>Tien Dung Le,  
<sup>3</sup>Duc Thang Pham,  
<sup>4</sup>Anh Tuan Nguyen

## 1. Introduction

Mining operation by underground method creates voids below surface and changes pre-mining stress state. The rocks surrounding an underground excavation tend to move to reach a new equilibrium state of stress. Different points in surrounding rocks and on surface at a certain time move in different magnitudes, resulting in vertical deformation (tilt, curve, twist) and horizontal deformation (compressive, tensile, slip). Movement and deformation of rock strata caused by underground mining can form zones of subsidence, caving, deformation, fracture and toppling on surface. This consequently interrupts normal operation of equipment such as hoist, lift and plants; increases slope failure, gas emission and water inrush into mining area; and changing surface and underground water conditions [1 – 4].

Mining practice from Quang Ninh coalfield in Vietnam over the years reports a number of broken/damaged facilities caused by underground mining such as: sinking and inclination of fan station at level +142 Mao Khe coal mine; water burst from open pit into Adit +60 Thong Nhat coal mine; water burst from watercourse and used roadways into mining areas at Vang Danh and Mong Duong coal mines with flow rate up to 200 m<sup>3</sup>/h. These incidents, however, were only preliminarily investigated by using field observation. Corresponding solutions and measures seem to be inactive and perfunctory. An improved understanding of strata movement and deformation caused by Quang Ninh underground mining is therefore of particular importance and necessity to the efficiency and productivity of Vietnam coal industry.

This paper presents an analysis of height of strata caving, evolution of deformation and movement zone, caving angle in strike direction, maximum surface subsidence and strata movement when mining thick-gently inclined and/or closely distributed coal seams by using a physical model based on a case study of Khe Cham basin. The paper's findings are useful for engineers to better plan and design technical solutions to improving safety in thick coal seam extraction.

## 2. Development of physical model

### 2.1 Study site

The site of study includes thick and gently inclined coal seams at Khe Cham basin, which are representative for Quang Ninh geo-mining conditions. According to [5], coal reserves distributed in these seams is approximately 150,446 tonnes, accounting for 47.4% of total coal reserves at Khe Cham basin. The geological setting along the cross-section XVI of the basin is used for the study with following information. The strata include interbedded conglomerate, sandstone, siltstone, claystone and two main coal seams. Seam 10 is 55 m underneath surface and is 8 m thick; immediate roof is siltstone with an average thickness of 5 m while main roof is sandstone with a thickness of 30 m. Seam 9 is 65 m below Seam 10 and is 5 m thick; immediate roof and floor are mainly siltstone with thickness of 11 and 9 m, respectively while main roof is 20 m thick of sandstone. The inter-burden between two seams is clay-coal with an average thickness of 2.5 m. The rock properties of Khe Cham coal basin are shown in Table 1 [5].

### 2.2 Model frame

In accordance with strata movement analysis when mining thick-gently inclined

УДК: 622.273.3:622.014  
 DOI: 10.21177/1998-4502-2019-11-4-560-566

*Quang Ninh coalfield over the years has witnessed geotechnical issues such as surface subsidence and strata caving, deformation and fracture due to the underground coal mining. These issues have been preliminarily investigated mostly by using field observation. The corresponding solutions and measures, however, seem to be inactive and perfunctory. This paper presents an analysis of height of strata caving, evolution of deformation and movement zone, caving angle in strike direction, surface subsidence and strata movement when mining thick-gently inclined and/or closely distributed coal seams by using a physical model based on a case study of Khe Cham basin, Quang Ninh coalfield, Vietnam. The model shows that roof strata cave cyclically with a height being 5-6 times mining height; caving angle ranges from 64 to 67 degrees; maximum subsidence magnitude stabilises around 1.5 m; and strata behaviour caused by the mining of lower seam is less severe as that of the upper seam. The paper's findings are useful for engineers to better plan and design technical solutions to improving safety in thick coal seam extraction.*

### КЛЮЧЕВЫЕ СЛОВА:

*Physical Modelling, Subsidence, Movement, Deformation, Caving, Khe Cham.*

*Статья поступила в редакцию 19.09.2019.*

<sup>1</sup>Saint-Petersburg Mining University (Mining University), Saint-Petersburg, Russia

<sup>2</sup>Hanoi University of Mining and Geology, Vietnam

<sup>3</sup>Quang Ninh University of Industry, Vietnam

<sup>4</sup>Vietnam Institute of Mining Science and Technology, Vietnam

Rock properties at Khe Cham coal basin

Rock unit	Compressive strength, kg/cm <sup>2</sup>	Yield strength, kg/cm <sup>2</sup>	Volume weight, g/cm <sup>3</sup>	Specific weight, g/cm <sup>3</sup>	Internal friction angle, degree	Cohesion strength, kg/cm <sup>2</sup>
Conglomerate and sandstone	1785-178	258-208	2.79-2.4	2.87-2.56	32°	381.66
	966.88	233	2.56	2.67		
Sandstone	1778-111.8	223-1.16	2.85-2.51	2.93-2.69	31°	324.88
	966.88	97.31	2.64	2.72		
Siltstone	1086-114	171-36	2.84-2.5	2.92-2.1	30.34°	213.55
	48	87.5	2.65	2.73		
Claystone	204-124		2.65-2.43	2.59-2.52		
	168.41		233	2.56		

coal seam, a physical model is designed in a flat frame with rotational axis being perpendicular to the frame plane, which is based on the prototype of VNIMI [6]. The dimension of model frame is 3590 mm in length, 2244 mm in height and 1648 mm in thickness. Rotational angle of the model is from 0 to  $\pm 90$  degrees, as illustrated in Fig. 1.

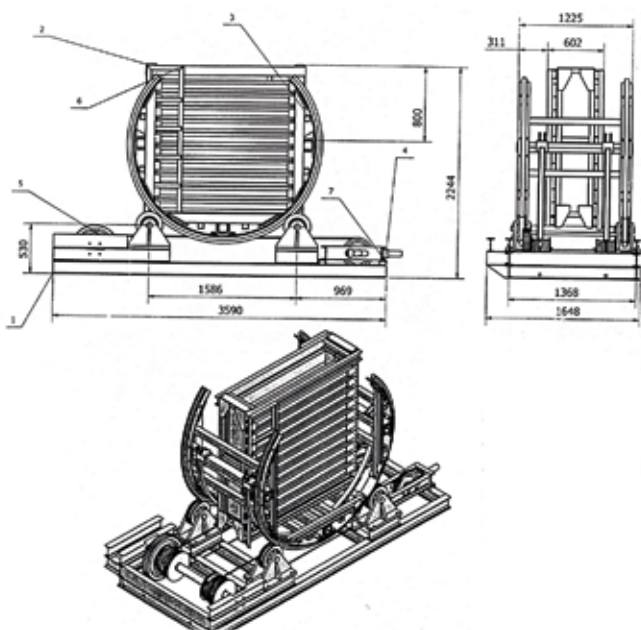


Fig. 1. Model frame with 1- base frame, 2- rotational frame, 3 - drum frame, 4 - pull leg, 5 - drive part, 6 - ladder part, 7 - cable part

### 2.3 Uniformity ratio and equivalent material in model

The model is 200 mm in length, 1500 mm in height and 1500 mm in thickness with a uniformity ratio regarding length of 1:100. Uniformity ratio regarding volume weight is 0.6:1 (0.6 gram in model is equivalent to 1 tonne in reality) while the ratio regarding time is 1:10. The material properties in model are calculated according to uniformity ratios and shown in Table 2.

Materials for building model are mainly composed of

quartz sand, mica, talc powder, paraffin, chalk and clay. To ensure the equivalent material has properties conforming to the above uniformity ratios, it is necessary to carry out processing and combining these components together. The coordination rate follows the composition diagrams in Fig. 2 [7]. This work is carried out and tested many times (at least 03 experiments per sample) in the laboratory with specialized equipment. The test results are presented in Table 3.

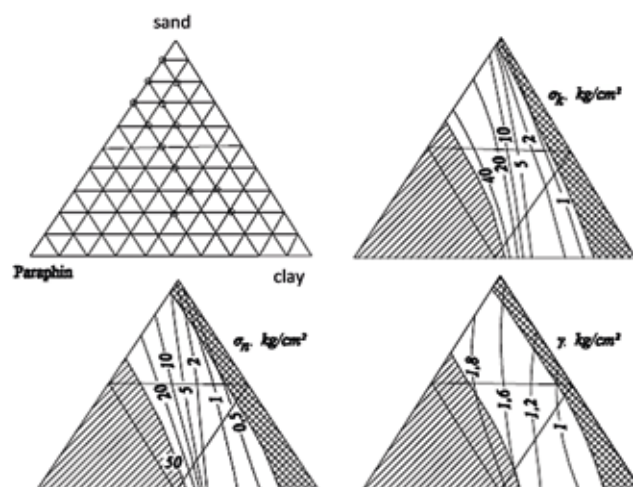


Fig. 2. Composition diagram of paraffin-sand-chalk mixture

### 2.4 Model construction

The model is constructed in upward sequence. Layers are equally horizontally laminated with a thickness of 1 cm per layer. To avoid the inter-cohesion between layers, an interval of 15 minutes is used for each layer building while a density of 0.046 g/cm<sup>2</sup> of mica is placed between two layers. The process for setting and building model is as follows [5]:

**Step 1:** selection of material component, calculation of material uniformity ratio to real rock strata;

**Step 2:** calculation of volume of all model materials;

**Step 3:** blending materials in 5 to 10 minutes then drying at 1250°C in 30 minutes. After each 10 minutes

Table 2

Uniformity ratio of rock material parameter in physical model

Parameter	Symbol, equation	Value
Length	$\alpha_l$	1:100
Volume weight	$\alpha_\gamma$	0,6:1
Time	$\alpha_t$	1:10
Weight	$\alpha_m = \alpha_\gamma \times \alpha_l^3$	0,6:10 <sup>6</sup>
Tensile, compressive strength	$\alpha_{n\acute{e}n} = \alpha_{k\acute{e}o} = \alpha_l \cdot \alpha_\gamma$	0,6:100
Cohesion strength	$\alpha_c = \alpha_l \cdot \alpha_\gamma$	0,6:100
Internal friction angle	$\alpha_\phi = tg\phi_{TT}/tg\phi_M$	1:1
Young modulus E	$\alpha_E = \alpha_l \cdot \alpha_\gamma$	0,6:100
Poisson $\nu$	$\nu_{TT} = \nu_M$	1:1

Table 3

Result of testing sample for model

Component	Properties		Mixture				Properties	Temperature
	Density, g/cm <sup>3</sup>	Weight, g	% according to weight	% according to volume	Grain size	Porosity		
- Quart sand	2,5	225	32,5	30	0,15	36,0	$\sigma_n = 2,1 \text{ kg/cm}^2$ $\sigma_k = 0,5 \text{ kg/cm}^2$ $= 1,62 \text{ g/cm}^3$ $\sigma_n/\sigma_k = 4,0$	130
- Clay	2,74	4,11	59,5	50	0,40	48,0		
- Paraffin	0,9	54	8,0	20				

the mixture is blended to ensure the paraffin is equally melted into quart sand and clay;

**Step 4:** when the mixture's colour turns into dark yellow, put it into tank then stirring at 1300°C in 45 minutes;

**Step 5:** clean and install model frame;

**Step 6:** place materials into model frame.

The result of model construction is shown in Fig. 3

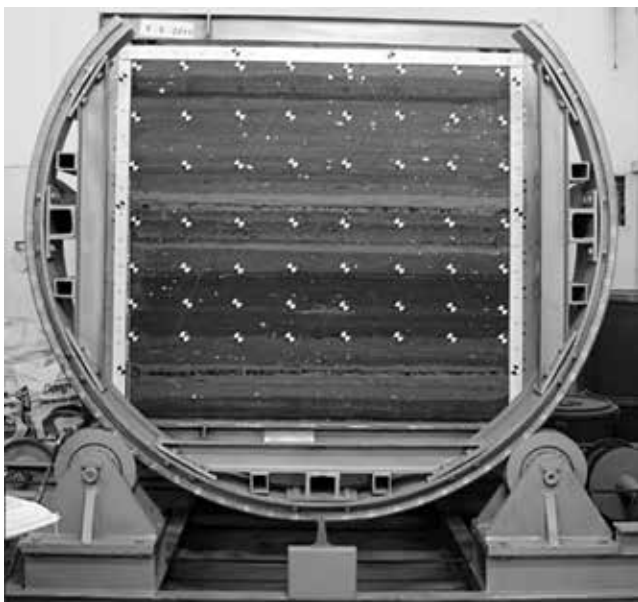


Fig. 3. Physical model after construction

### 2.5 Modelling of extraction

The model simulates a retreat longwall mining with top coal caving. To model the progressive mining, wooden prop is removed sequentially in accordance with real face advance. That is, one wooden prop is removed after every 2.4 hours, which is equivalent to a face advance rate of 1 m per day. Top coal recovery is manually implemented by using rake with a recovery rate of 70 %, equivalent to 4.5 cm thickness in Seam 10 and 2 cm thickness in Seam 9.

Seam 10 is extracted first then mining Seam 9. Before mining the lower seam, an interval is allowed for complete movement of rock strata caused by the upper seam extraction. To minimise the impact of truncated boundary condition, 20 cm length of material at left and right boundaries are unmined.

### 2.6 Model monitoring

To monitor the strata movement, a monitoring network is installed by placing markers (points) in the model. Markers that aligned on one horizontal line form one observation line. There are 12 lines from I to XII downward. Each line consists of eight points from 1 to 8 from left to right.

The observation is implemented by using photometric method with camera Nikon D7000 in combination with image data processing software Microstation, IRAS/C. The model is photographed at an interval of 15 minutes [8]. The photographing continues until the complete displacement of rock strata. The error in observation is calculated by testing model in several times [8].



### 3. Movement and deformation laws of rock strata and surface

#### 3.1 Height of strata caving

The model extraction shows that the underground mining causes strata movement and deformation and consequently forms zones of subsidence, fracture and caving. The caving zone is dependent on the dimension and length of face advance. The near-field caving zone forms together with caving spans with a height of 10–12 cm in the model, which is equivalent to 10–12 m in reality (Fig. 4).

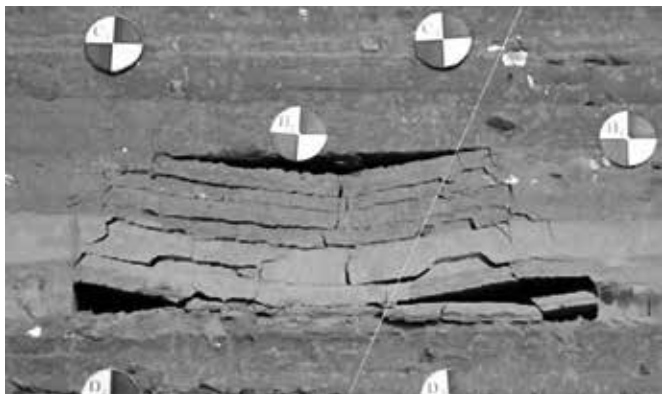


Fig. 4. Extraction and caving of roof strata in model

During the mining, immediate roof caves to form a complete caving zone while main roof sags afterward in larger span and forms fractured zone [9]. The model shows that the height of complete caving zone increases as the face advances. At 80 m of face advance, the caved rock fills the void caused by mining. The caving height remains stable around 10–12 m, which is 5–6 times the mining height, as plotted in Fig. 5.

#### 3.2 Evolvement of displacement and movement area

The roof strata above caving zone are severely deformed and form fractured zone in shear and tensile fracturing. The fracture system is clearly observed at and

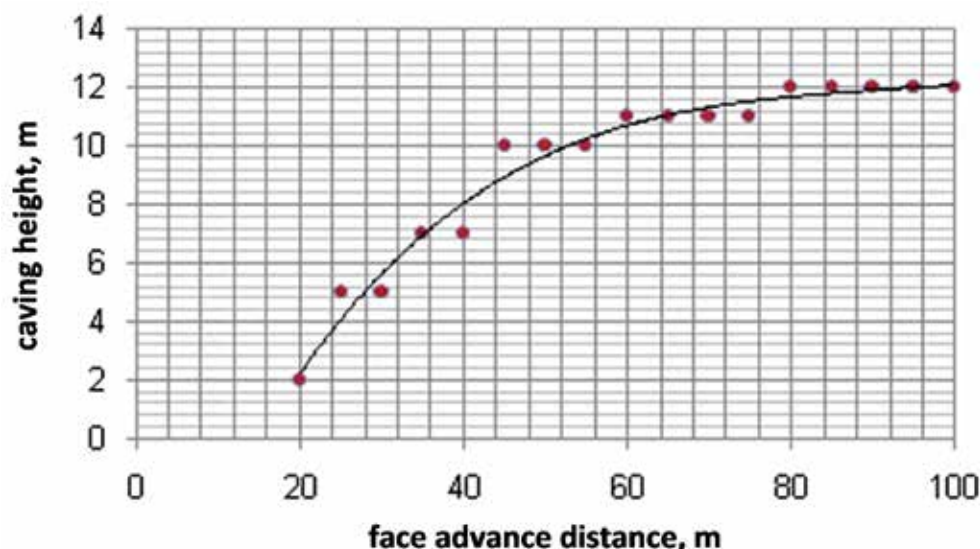


Fig. 5. Relationship between caving height and face advance distance

around mining area while it is less observed at further area [10]. It is seen from the model that the roof strata move in block shape whose dimension is in linkage with caving span. When coal face advances far enough, a new caving span occurs, and the roof strata behave as cantilever beams. This rock movement repeats as the face advances, creating new fractures around coal face while closing far-face fractures. As a result, it is concluded that the movement and deformation of roof strata is in discrete and wave-cycle form.

#### 3.3 Caving angle in strike direction

Caving angle in strike direction is defined as the angle between tangential line of caving zone and horizontal line. Observation from model indicates that the caving angle fluctuates between 64 and 67 degrees (Fig. 6). This angle is consistent with the angle theoretically calculated according to VNIMI's method, which is 65 degrees [6].

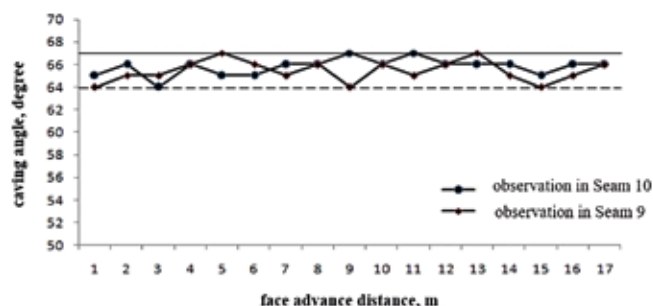


Fig. 6. Caving angle in strike direction when face advances

#### 3.4 Surface subsidence

The model shows that the distance of face advance affects surface subsidence. When the face advances to a certain distance, the subsidence magnitude is stable around its maximum value and is independent of face distance [11; 12]. It is seen that by photometric method, no surface subsidence is observed within 20 m of face advance. When face advances at 30 m, the surface subsides and reaches 0.4 m at 40 m of face advance.

The subsidence rapidly increases from 0.4 to 1.4 m when face advances from 40 to 65 m, then stabilising at 1.5 m. The bottom of subsidence curve shifts from concave shape to flat shape. This demonstrates that when the face advances far enough, one cycle of roof strata movement is complete (Fig. 7). The maximum subsidence in the model is close to the value theoretically calculated according to VNIMI's method, which is 1.6 m [6].

The model observation shows that at a certain depth of cover, a small distance in face advance does not significantly affect the surface.

When the distance increases, the zone of deformation and movement increases toward surface, forming subsidence basin. The subsidence at centre of the basin reaches a maximum value of approximately 70-80% of mining height before stopping increasing. This is because caved rock fills up mining void and prevents roof strata to move downward (Fig. 8).

### 3.5 Strata movement when mining closely distributed seams

In initial operation, the mining at Seam 9 does not significantly affect the mining at Seam 10 and surface. However, when the face advances far enough, the deformation and movement zone above Seam 9 increases to Seam 10. Roof strata above these seams are significantly deformed. The monitoring reveals that although this process is essentially not different from first extraction (at Seam 10), there is no tension, delamination and large tensile fracture as in mining Seam 10. This is due to the fact that the roof strata above Seam 10 have been broken and reduced their stability.

The surface subsidence caused by mining both Seam 9 and 10 increases and is proportional to the face advance distance. The maximum value reaches the total thickness of both seams, which is 2.9 cm in the model (Fig. 8).

Results from the physical modelling enable to establish deformation and movement laws of roof strata and surface, as illustrated in Fig. 9.

## 4. Conclusions

Based on a case study of Khe Cham basin in Quang Ninh coalfield of Vietnam, the authors have investigated roof strata movement and surface subsidence caused by longwall mining by developing a physical model. The conclusions are as follows:

- The underground mining creates a zone of com-

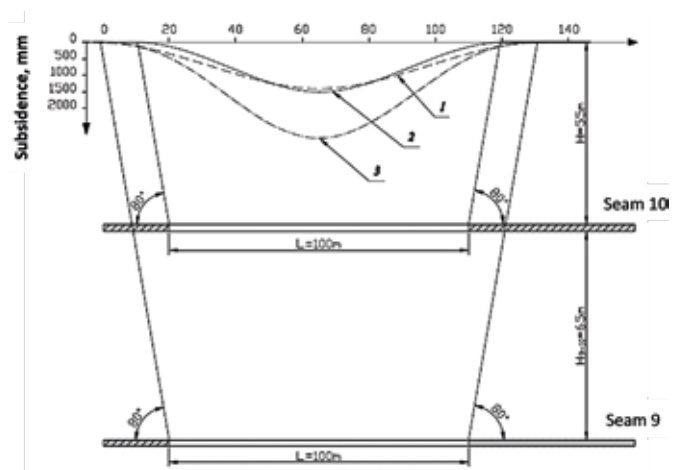


Fig. 8. Caving angle and subsidence caused by extractions of single seam and all seams

plete caving. The zone's dimension is dependent on the distance of face advance, reaching a maximum value when the face advances about 80 m. Roof strata cave cyclically with a caving height being 5-6 times the mining height;

- Caving angle of roof strata in strike direction fluctuates between 64 and 67 degrees;
- Surface subsidence increases significantly at the face distance of 40 to 65 m, corresponding to a magnitude of 0.4 to 1.4 m, respectively. The maximum subsidence value is 1.5 m. The bottom of subsidence basin shifts from concave shape to flat shape;
- Rock strata behaviours such as tension, delamination and large tensile fracture when mining the lower seam (Seam 9) are not as severe as those when mining the upper seam (Seam 10) due to the previous rock failure and movement.

The paper's findings are helpful to engineers for designing driving/extraction schedule and pillars for efficiently and safely mining thick-gently inclined coal seams.

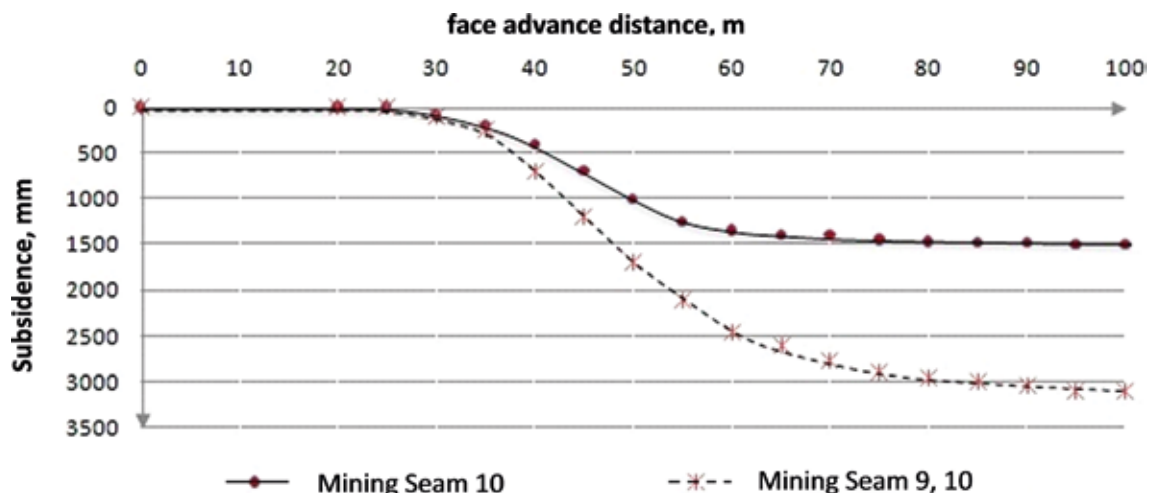


Fig. 7. Relationship between face advance and surface subsidence

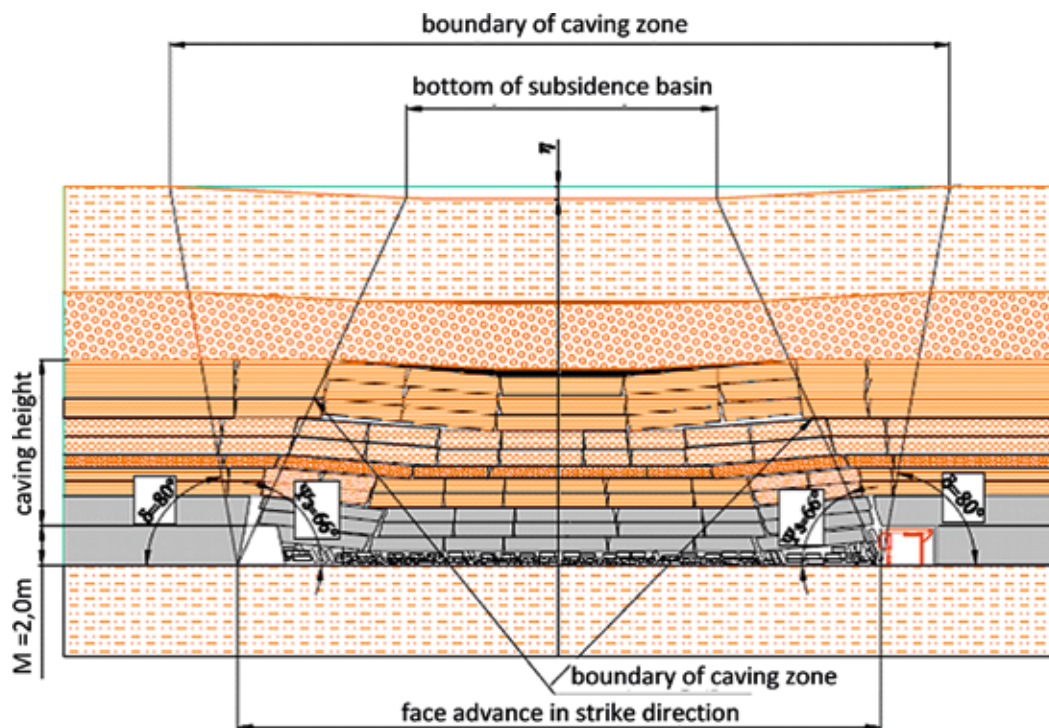


Fig. 9. Deformation and movement of roof strata and surface in physical model ( $\Psi_3$  – caving angle in strike direction;  $\delta$  – angle of movement;  $\eta$  – maximum subsidence)

## ЛИТЕРАТУРА:

1. Nguyen Anh Tuan, Le Duc Nguyen, Le Quang Phuc, Study on effect of strata movement in underground-surface combined extraction by using numerical model, *Mining Technology Bulletin*, 2011, vol 3: 34–39.
2. Qiao Qiuqiu, Dou Linming, Cen Chuanhong, et al. Analysis on strata pressure behavior at fully-mechanized caving face of deep mine [J]. *Coal Mine Safety*, 2012, 43(5): 166–169
3. Wang Qingxiong, Ju Jinfeng. Study on mine strata pressure behavior law of 450m ultra long fully-mechanized coal mining face [J]. *Coal Science and Technology*, 2014, 42(3): 125–128.
4. Chen Chong, Yao Enguang, Zhang Zhe. Actual measurement and analysis on behavior rule of pressure of fully-mechanized working face in thin coal seam [J]. *Zhongzhou Coal*, 2013, (1): 4–7.
5. Study on parameters of strata movement when extracting thick coal seams by using physical model, *Institute of Mining Science and Technology*, 2010.
6. Rules for the protection of structures and natural objects from the harmful effects of underground mining in coal deposits. *St. Petersburg*, 1998
7. Kuznetsov G.N. Installation of mountain pressure on models. *Moscow, Ugletekhizdat*, 1959, 218p
8. Latyshev O. G. Destruction of rocks. *Moscow, Teplotekhnika*, 2007, 672 p.
9. Grebenkin S.S., Pavlysh G.N., Samoylov V.L., Petrenko YU.A., Management of rock mass condition. *Donetsk, DonNTU*, 2010.
10. Hongwei Wang, Yaodong Jiang, Sheng Xue, Lingtao Mao, Zhinan Lin, Daixin Deng, Dengqiang Zhang, Influence of fault slip on mining-induced pressure and optimization of roadway support design in fault-influenced zone. *Journal of Rock Mechanics and Geotechnical Engineering*, 2016, Vol 8, pp.660–671.
11. Kanlybayeva Zh. M. Patterns of rock displacement in the massif. *Moscow, Nauka*, 1968, 108 p.
12. Lobkov N. I. Features of formation of mining pressure during cleaning works. *Scientific works of the UkrNDMI of National Academy of Sciences of Ukraine*, Vol 14, 2014. (In Ukrainian)

## СВЕДЕНИЯ ОБ АВТОРАХ / Information about authors:



**Le Quang Phuc** – Lecturer of Hanoi University of Mining and Geology, Hanoi, Vietnam; Postgraduate of Saint-Petersburg Mining University (Mining University), Saint-Petersburg, 199106, Russian Federation.  
E-mail: lequangphuc@humg.edu.vn

**Ле Куанг Фук** – преподаватель Ханойского горного дела и геологии университета, Ханой, Вьетнам; аспирант Санкт-Петербургского горного университета, 199106, г. Санкт-Петербург, Россия  
E-mail: lequangphuc@humg.edu.vn



**Nguyen Anh Tuan** – Ph.D., Director of Vietnam Institute of Mining Science and Technology, Hanoi, Vietnam.  
E-mail: [nguyenanhtuan@gmail.com](mailto:nguyenanhtuan@gmail.com)

*Нгуен Ань Туан – директор Института горной науки и техники, Ханой, Вьетнам.*

*E-mail: [nguyenanhtuan@gmail.com](mailto:nguyenanhtuan@gmail.com)*



**Le Tien Dung** – Ph.D., Lecturer of Hanoi University of Mining and Geology, Hanoi, Vietnam.  
E-mail: [letiendung@humg.edu.vn](mailto:letiendung@humg.edu.vn)

*Ле Тиен Зунгь – преподаватель Ханойского университета горного дела и геологии, Ханой, Вьетнам.*

*E-mail: [letiendung@humg.edu.vn](mailto:letiendung@humg.edu.vn)*



**Pham Duc Thang** – Ph.D., Lecturer of Quang Ninh University of Industry. Yen Tho – Dong Trieu, Quang Ninh – Viet Nam.  
E-mail: [phamducthangmct@gmail.com](mailto:phamducthangmct@gmail.com)

*Фам Дик Тханг – преподаватель Куангниньского индустриального университета. Иентхо – Донгчеу, Куангнинь Вьетнам,  
E-mail: [phamducthangmct@gmail.com](mailto:phamducthangmct@gmail.com)*

## ДВИЖЕНИЕ ПЛАСТОВ ПРИ ИЗВЛЕЧЕНИИ ПЛОТНОГО И ПОЛОГОГО УГОЛЬНОГО ПЛАСТА ИЗ АНАЛИЗА ФИЗИЧЕСКОГО МОДЕЛИРОВАНИЯ: НА ПРИМЕРЕ БАСЕЙНА КХЕ-ЧАМ, ВЬЕТНАМ

<sup>1,2</sup> Ле Куанг Фук,\*

<sup>2</sup> Тиен Зунгь Ле,

<sup>3</sup> Фам Дик Тханг,

<sup>4</sup> Нгуен Ань Туан

<sup>1</sup> Санкт-Петербургский горный университет, 199106, Санкт-Петербург, Россия

<sup>2</sup> Ханойский университет горного дела и геологии, Вьетнам, [lequangphuc@humg.edu.vn](mailto:lequangphuc@humg.edu.vn)

<sup>3</sup> Куангниньский индустриальный университет, Иентхо–Донгчеу, Куангнинь, Вьетнам, [phamducthangmct@gmail.com](mailto:phamducthangmct@gmail.com)

<sup>4</sup> Вьетнамский институт горной науки и техники, Ханой, Вьетнам

DOI: 10.21177/1998-4502-2019-11-4-560-566

Куангнинское угольное месторождение на протяжении многих лет было свидетелем геотехнических проблем, таких, как оседание поверхности и обрушение пластов, деформация и разрушение из-за подземной добычи угля. Эти вопросы были предварительно исследованы в основном с помощью полевых наблюдений. Однако соответствующие решения и меры представляются неактивными и поверхностными. В настоящей работе представлен анализ высоты обрушения пластов, развития зоны деформации и движения, угла обрушения в направлении удара, оседания поверхности и движения пластов при разработке мощных пологих и/или близко расположенных угольных пластов с использованием физической модели, основанной на при-

мере бассейна Кхе-Чам, угольного месторождения Куангнин, Вьетнам. Модель показывает, что кровельные пласты прогибаются циклически с высотой в 5-6 раз больше высоты горной выработки; угол обрушения колеблется от 64 до 67 градусов; максимальная величина просадки стабилизируется около 1,5 м; и поведение пластов, вызванное разработкой нижнего пласта, менее серьезно, чем поведение верхнего пласта. Выводы статьи полезны инженерам для лучшего планирования и разработки технических решений по повышению безопасности при добыче мощных угольных пластов.

**Ключевые слова:** физическое моделирование; просадка; движение; деформация; обрушение; Кхе Чам.