

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/334733787>

# ON THE VARIATION IN SEVERAL ROCK PROPERTIES DUE TO MAGNESIUM SULFATE WEATHERING TESTS – A CASE STUDY FOR LIMESTONES

Conference Paper · June 2019

DOI: 10.5593/sgem2019/1.2/S02.052

---

CITATION

1

READS

166

1 author:



Ekin Köken

Abdullah Gul University

52 PUBLICATIONS 155 CITATIONS

SEE PROFILE

**19<sup>th</sup> INTERNATIONAL MULTIDISCIPLINARY  
SCIENTIFIC GEOCONFERENCE  
S G E M 2 0 1 9**

**CONFERENCE PROCEEDINGS**

**VOLUME 19**



**SCIENCE AND TECHNOLOGIES IN GEOLOGY,  
EXPLORATION AND MINING  
ISSUE 1.2**

-----  
**HYDROGEOLOGY, ENGINEERING GEOLOGY AND  
GEOTECHNICS**

**OIL AND GAS EXPLORATION**  
-----

**30 June - 6 July, 2019**  
**Albena, Bulgaria**

---

## **DISCLAIMER**

This book contains abstracts and complete papers approved by the Conference Review Committee. Authors are responsible for the content and accuracy.

Opinions expressed may not necessarily reflect the position of the International Scientific Council of SGEM.

Information in the SGEM 2019 Conference Proceedings is subject to change without notice. No part of this book may be reproduced or transmitted in any form or by any means, electronic or mechanical, for any purpose, without the express written permission of the International Scientific Council of SGEM.

Copyright © SGEM2019

All Rights Reserved by the International Multidisciplinary Scientific GeoConferences SGEM

Published by STEF92 Technology Ltd., 51 “Alexander Malinov” Blvd., 1712 Sofia, Bulgaria

Total print: 5000

**ISBN 978-619-7408-77-5**

**ISSN 1314-2704**

**DOI: 10.5593/sgem2019/1.2**

**INTERNATIONAL MULTIDISCIPLINARY SCIENTIFIC GEOCONFERENCE SGEM  
Secretariat Bureau**

E-mail: [sgem@sgem.org](mailto:sgem@sgem.org) | URL: [www.sgem.org](http://www.sgem.org)

**INTERNATIONAL SCIENTIFIC COMMITTEE**

---

**Acad. Prof. DSc. Valeriy Bondur**

Vice President of the Russian Academy of Sciences, Moscow, Russia

**Prof. DSc. Raimonds Ernsteins**

UNESCO, University of Latvia, Latvia

**Prof. DSc. Viktor Savinuh**

Cosmonaut (incl. Salyut 7), President of the Association of Russian Universities, Moscow, Russia

**Prof. Dr. Steffen Lehmann**

University of Nevada, Las Vegas, USA

**Prof. DSc. Stefan Dimov**

University of Birmingham, UK

**Prof. DSc. Victor Tsvetkov**

Academy of Space Named after E. K. Tsiolkovsky and Academy of Natural Sciences, Moscow, Russia

**Distinguished Professor DSc. Tien-Hui Chiang**

UNESCO, Zhengzhou University, China

**Prof. DSc. Nikolay Leonyuk**

Moscow State University, Russia

**Prof. DSc. Baiba Rivza**

University of Life Sciences and Technologies, Latvian Academy of Science, Latvia

**Prof. DSc. Kirill Chistyakov**

Saint-Petersburg State University, Vice-President of Russian Geographical Society, Russia

**Prof. DSc. Mirela Mazilu**

University of Craiova, Romania

**Prof. DSc. Olga Trapeznikova**

Russian Academy of Science, Russia

**Prof. DSc Yevgeniy A.Kontar**

University of Illinois, Federal GEOS Funding (USA), USA

**Prof. DSc Sergey Gandzha**

South Ural State University, Russia

**Prof. Dr. Dr.h.c. Harald Schuh**

GFZ German Research Centre for Geosciences, Potsdam, Germany

**Prof. Dr. Dr.h.c. Michael Sideris**

University of Calgary, Canada

**Prof. Dr. Dr.h.c. Krystyna Januszkiewicz**

Poznan University of Technology, Poland

**Prof. Dr. Dr.h.c. Slaveyko Gospodinov**

University of Architecture, Civil Engineering and Geodesy, Sofia, Bulgaria

**Prof. Dr. Dr. Habil Dusan Huska**

Slovak University of Technology, Bratislava, Slovakia

**Prof. Dr. Rodney Stevens**

University of Gothenburg, Sweden

**Prof. Geol. Dr. Gerardo Brancucci**

Università di Genova, Italy

**Prof. Dr. Jan Kaźmierczak**

Silesian University of Technology, Polish Academy of Sciences, Poland

**Prof. Dr. Rui Moura**

University of Porto, Portugal

**Prof. Dr. Androula Nassiopoulou**

UNESCO, Institute of Nanoscience & Nanotechnology Athens, Greece

**Prof. Dr. Peter Frigaard**

Aalborg University, Denmark

**Prof. Dr. Ing.Karel Pavelka**

Czech Technical University in Prague, Czech Republic

**Prof. Dr. Greet Deruyter**

Ghent University, Belgium

**Prof. Dr. Elena Peneva**

University of Architecture, Civil Engineering and Geodesy, Sofia, Bulgaria

**Prof. Dr. Tiberiu Rus**

Technical University of Civil Engineering, Bucharest, Romania

**Assoc. Prof. Dr. Alexander Ivanov**

Nizhny Novgorod state University of Architecture and Civil Engineering, Russia

## CONFERENCE PROCEEDINGS CONTENTS

### CONTENTS

---

#### HYDROGEOLOGY, ENGINEERING GEOLOGY AND GEOTECHNICS

1. **A NEW APPROACH TO THE ASSESSMENT OF NATURAL RISKS FOR PIPELINES**, Prof.A. I. Zhiron, Assoc.Prof. Dr.S. F. Boltramovich, St. A. I. Ovchinnikova, Russia.....3
2. **ABOUT THE MECHANISM OF A LIMIT STATE PREPARING IN A LANDSLIDE-PRONE MASS AND THE DISPLACEMENT OF A LANDSLIDE BLOCK AS AN ELEMENT OF A DISSIPATIVE STRUCTURE**, Dr. German Postoev, PhD Andrey Kazeev, Ksenia Fedotova, Russia..... 11
3. **AN EXAMPLE OF GEOTECHNICAL AND GEOPHYSICAL INVESTIGATION WORKS IN SOFT SOILS**, Full Prof. Stjepan Strelec, PhD Student Filip Dodigovic, Assoc.Prof. Dr. Kreso Ivandic, PhD Student Kristijan Grabar, Croatia ..... 19
4. **ANALYSIS OF CHANGE IN RAINFALL RUNOFF CONDITIONS AND ASSESSMENT OF THE IMPACT OF THE OUTFLOW ON FLOOD WATERS IN THE BUILT-UP AREA OF SOKOLOV**, Ing. Martin Dedic, Ing. Ales Kankovsky, Czech Republic .....27
5. **ANALYSIS OF GROUP HOLE EFFECTT TUNNEL EXCAVATION BY PBA METHOD**, Dr. Dongyang Geng Assoc.Prof. Dr Karel Vojtasik, Czech Republic.....35
6. **ANALYSIS OF STABILITY OF RESISTANCE STRUCTURE IN THE CONSTRUCTION OF THE A1 HIGHWAY, LUGOJ-DEVA SECTION, LOT 2 KM: 27 + 620 ч 47 + 090**, PhD. Student Ileana PASCU, PhD. Student Crina-Adriana Draganescu, PhD. Lect. Liliana GURAN, Romania .....43
7. **ANALYSIS OF SUBMERGED PILES AND LAYERED SUBSOIL**, Ing. Lenka Uhlirova - Ing. Lubomir Prekop, PhD., Slovakia .....51
8. **ANALYTICAL STUDY ON THE SWELLING BEHAVIOR IN TUNNELING OF CLAY/SULFATE FORMATIONS- ISFAHAN SUBWAY TUNNEL**, Assoc. Prof. Dr. Ehsan Moosavi, Assoc. Prof. Dr. Reza Shirinabadi, Iran.....57
9. **ANTHROPOGENIC FACTORS AND THEIR INFLUENCE ON FORMATION AND DISTRIBUTION OF GROUNDWATER WITHIN THE PLATFORM DENUDATION PLAINS OF THE ARID ZONE OF KAZAKHSTAN (CENTRAL KAZAKHSTAN)**, L.M. Kazanbayeva, N.K. Iskakov, A.A. Nurgazyieva, I.K. Rakhmetov, Kazakhstan.....63

- 10. APPLICATION OF GEOCHEMICAL AND ISOTOPIC STUDY (( $\delta^{15}\text{NNO}_3$ ,  $\delta^{18}\text{ONO}_3$ ,  $\delta^{34}\text{SSO}_4$ ,  $\delta^{18}\text{OSO}_4$ )) TO ASSESS THE EXTENT OF HUMAN IMPACT ON GROUNDWATER QUALITY IN THE AREA OF KUŃNICA WARZYŃSKA RESERVOIR (SOUTHERN POLAND), Dr. Sabina Jakobczyk-Karpierz, M.Sc. Kinga Slosarczyk, Poland .....71**
- 11. AUTOMATIC CRACK WIDTH DETERMINATION IN CONCRETE STRUCTURES, Ing. Jakub Rubint, Ing. Stanislav Rubint,, Slovakia.....79**
- 12. BASIC INDEX PROPERTIES OF CLAYS IN RELATION TO THE CONTENT OF DIATOMS, Assoc. Prof. CSc. Věra Glisníková, Assoc. Prof. Ph.D. Alexandra Erbenová, Czech Republic.....87**
- 13. CHARACTERISTICS OF VARIATION IN SELECTED HYDROGEOLOGICAL PARAMETERS OF DUSZNIKI ZDROJ MEDICINAL WATERS (SUDETY MTS, POLAND), Dr. Elzbieta Liber-Makowska, Dr. Barbara Kielczawa, Poland .....95**
- 14. CHEMICAL COMPOSITION AND WATER QUALITY OF THE CIESZYN TUFA SPRINGS (SOUTHERN POLAND). GEOCHEMICAL CONDITIONS AND ANTHROPOGENIC HAZARDS, Assoc. Prof. Dr. Jacek Rozkowski, Dr. Hanna Rubin, Dr.Krystyn Rubin, Dr. Piotr Siwek, M.Sc. Kinga Slosarczyk, Poland..105**
- 15. COMPARATIVE ANALYSIS LAKE AREA DISTRIBUTION WITHIN THERMOKARST PLAINS AND THERMOKARST PLAINS WITH FLUVIAL EROSION FOR THE NATURAL RISK ASSESSMENT, Prof. Dr. Victorov A.S., Dr. Orlov T.V., Prof. Dr. Trapeznikova O.N., Dr. Archipova M.V., Russia ..... 113**
- 16. COMPARISON OF SHALLOW LANDSLIDE STABILITY MODELS THROUGH LABORATORY SIMULATIONS, Vladislav Ivanov, Davide Brambilla, Riccardo Andreoli, prof. Laura Longoni, prof. Monica Papini, Italy..... 121**
- 17. CONTROL OF STRESS-STRAIN STATE CHANGES IN CONCRETE OF HIGH-PRESSURE DAM BOTTOM SIDE, V.D. Baryshnikov, D.V. Baryshnikov, L.N. Gakhova, A.P. Khmelinin, Russia..... 129**
- 18. DESCRIPTION OF THE INFORMATIONAL SYSTEM OF GROUNDWATER RESOURCES AND RESERVES OF KAZAKHSTAN, PhD Yermek Murtazin, PhD Oxana Miroshnichenko, PhD Lyudmila Trushel, Kazakhstan..... 137**
- 19. DESIGN OF A ROAD EMBANKMENT REINFORCED USING A GEOGRID, Dr. Monika Sulovska, Dr. Jakub Stacho, Slovakia ..... 145**
- 20. DETERMINATION OF IMPACT OF GROUND WATER PUMPING ON WATER RESOURCES IN ADJACENT AREA, Prof. Ing. Andrej Šoltész, PhD., Assoc. Prof. Ing. Dana Baroková, PhD., Ing. Michaela Červeňanská, Ing. Lea Čubanová, PhD., Slovakia..... 153**

- 21. ECOLOGICAL STATUS OF OLD OIL BOREHOLES IN CENTRAL NORTHERN BULGARIA**, M. Sc. Sava Kolev, M. Sc. Mila Trayanova, M. Sc. Hristomir Stanev, Assoc. Prof. Nikolay Hristov, Bulgaria ..... 161
- 22. ENGINEERING GEOLOGICAL INVESTIGATION FOR THE HYDROTECHNICAL TUNNEL PORTAL PROTECTION (KAKANJ, BOSNIA AND HERZEGOVINA)**, Assoc. Prof. Dr. Indira Sijercic, Prof. Dr. Rejhana Dervisevic, Assoc. Prof. Dr. Kemal Gutic, Assoc. Prof. Dr. Hamo Isakovic, Bosnia and Herzegovina..... 169
- 23. ENGINEERING GEOLOGICAL ZONING OF KARELIA (RUSSIA)**, Alexander Nikiforov, Russia ..... 177
- 24. ENGINEERING-GEOLOGICAL CONDITIONS ANALYSIS OF THE LICENSED HYDROCARBON DEPOSIT AREA ON THE SHELF IN THE SOUTHERN PART OF THE KARA SEA**, PhD in Geology and Mineralogy, Associated Professor, T.N. Nikolaeva, Geotechnic I.A. Vikdorovich, Russia ..... 185
- 25. ENGINEERING-GEOLOGICAL STRUCTURE OF THE BASIS OF THE ROADS IN "SOLOVETSKY" SETTLEMENT**, Assoc. Prof., Ph.D., Dr. Sergey Aksenov, Assistant, Victor Veshnyakov, Student, Darina Grigorieva, Russia ..... 191
- 26. ENVIRONMENTAL EFFECTS OF MINING WASTE USAGE DURING A GRAVEL PIT RECLAMATION IN THE VISTULA VALLEY IN OSWIECIM (SOUTHERN POLAND)**, Marek Sołtysiak, PhD, Eng., Dominika Dąbrowska, PhD, Tomasz Krzykawski, PhD, Marzena Barczyk, MSc, Pelagia Domagalska, MSc, Poland ..... 199
- 27. ENVIRONMENTAL PROBLEMS OF SOUTH KAZAKHSTAN AND POLLUTION OF DRINKING GROUNDWATER**, M.A. Mukhamedzhanov, L.M. Kazanbayeva, A.A. Nurgaziyeva, I.K. Rakhmetov, Kazakhstan..... 207
- 28. ESTIMATION OF HYDRAULIC CONDUCTIVITY OF ARTIFICIAL FINE-GRAINED SOIL BASED ON PORCHET METHOD - AN EXAMPLE OF TAILINGS POND GILOW, SW POLAND**, Dr. Magdalena Worsa-Kozak, Dr. Krzysztof Chudy, Poland..... 215
- 29. EVALUATION OF GROUT CURTAIN PARAMETERS OF PALCMANSKÉ MAĽA DAM FOUNDATION**, Prof. Ing. Emília Bednárová, PhD., Ing. Miroslav Hmirak , Ing. Martin Bakeš, Slovakia ..... 223
- 30. EVALUATION OF INTERFACE SHEAR STRENGTH PROPERTIES OF GRAVELS REINFORCED USING A WOVEN GEOGRID**, Dr. Jakub Stacho, Dr. Monika Sulovska, Assoc. Prof. Ivan Slavik, Slovakia ..... 231

- 31. FEATURES OF NATURAL WATERS COMPOSITION IN ONE OF THE LARGEST INDUSTRIAL ZONES IN EUROPE**, Assoc. Prof. Dr. R. Kh. Musin, Assoc. Prof. Dr. E. A. Korolev, Engineer A. R. Galieva, Student K. E. Zotina, Russia .....239
- 32. FIRE SAFETY OF POLYMER SLEEPERS IN TERMS OF FIRE PROPAGATION**, Assistant Professor Vit Lojda, Aran van Belkom, M.Sc., Czech Republic.....247
- 33. GEOMECHANICAL SUBSTANTIATION OF DEEP MINING IN COMPLICATED MINING-GEOLOGICAL AND GEODYNAMIC CONDITIONS**, PhD Inna E. Semenova, PhD Ivan M. Avetisian, Prof. DSc. Anatoly A. Kozyrev, Russia.....257
- 34. GEOMECHANICAL SUPPORT THE STABILITY OF DIP OPEN-PITS**, PhD Sedina S.A., Berdinova N.O., Dr. Shamganova L. S. Kalyuzhnyy E., Kazakhstan.....265
- 35. GEOTECHNICAL RESEARCH FOR THE SAFE PLACEMENT OF CIVIL CONSTRUCTIONS**, Ph.D Student Dorin Dragan, Prof. Dr. Victor Arad, Ph.D Student Daniel Diaconescu, Ph.D. Student Dumitru Sfarloaga, Ph. D. Student Sergiu Lungu, Romania.....273
- 36. GEOTECHNICAL RISK ANALYSIS FROM THE A1 HIGHWAY, LUGOJ-DEVA SECTION, LOT 2 (KM: 27 + 620M и 47 + 090M) AND REDUCING SOLUTIONS THEREOF**, Ph.D. Student Ileana PASCU, Ph.D. Student Crina-Adriana DRAGANESCU, Ph.D. Lect. Liliana GURAN, Romania.....281
- 37. GEOTECHNICAL STUDIES ON THE UNDERGROUND INFRASTRUCTURE IN SLANIC SALT MINE**, Prof. Dr. Victor Arad, Prof. Dr. Susana Arad, Prof. Dr. Ilie Onica, Assoc. Prof. Dr. Liliana Samoila, Assoc. Prof. Dr. Ioel Veres, Romania .....289
- 38. HUMAN IMPACT ON GROUNDWATER IN THE AKTOBE REGION**, A.M.Yermenbai,S.V. Osipov, Yu.N. Livinsky, Kazakhstan.....297
- 39. HYDROCHEMICAL CHARACTERIZATION OF GROUNDWATER IN MESOZOIC AQUIFERS IN CENTRAL NORTHERN BULGARIA**, M. Sc. Mila Trayanova, M. Sc. Sava Kolev, Assoc. Prof. Nikolay Hristov, Prof. Aleksey Benderev, Assistant Nikola Sechkaryov, Bulgaria .....305
- 40. HYDRODYNAMIC CONSEQUENCES OF THE OPEN PIT CLOSURE AND RECLAMATION IN THE ASPECT OF LABORATORY AND MODEL TESTS**, Msc. Katarzyna Niedbalska, Assoc. Prof.DSc. Przemyslaw Bukowski, Poland .....313
- 41. HYDROGEOLOGICAL CONDITIONS IN THE AREA OF MUNICIPAL LANDFILL BASED ON MODELLING STUDIES, SOUTHERN POLAND**, Dr. Slawomir Sitek, M.Sc. Sylwia Nowacka, Dr. Dominika Dabrowska, Poland.....321

<b>42. IMPACT THE TUNNEL EXCAVATION WITH LOW OVERBURDEN TO ROCK MASS</b> , Dr. Jana Chabronova, Dipl.Ing. Jan Snopko, Slovakia .....	329
<b>43. INFLUENCE OF ANTHROPOGENIC ENVIRONMENTAL CHANGES ON THE GROUNDWATER FORMATION IN KAZAKHSTAN</b> , S.V. Osipov, Yu.N. Livinsky, A.M. Yermenbai, Kazakhstan .....	337
<b>44. INFLUENCE OF WATER LEVEL OF THE KARST SPRING BULAĀ ON BALNEOLOGICAL PROPERTIES OF THE THERMAL SPRING SVETI STJEPAN IN ISTARSKJE TOPLICE SPA (CROATIA)</b> , Mladen Kuhta, Dr. Zeljka Brkic, Croatia .....	343
<b>45. INVESTIGATION OF PROCESS OF STEEL PILES VIBRODRIVING</b> , Dr. Sc. Ing. Polukoshko S.N., Latvia.....	351
<b>46. ISOTOPIC APPROACH TO IDENTIFICATION OF SULPHATE ORIGIN IN THE TRIASSIC AQUIFER IN RECHARGE AREA OF THE ŁAZY BŁĘDOWSKIE WELL FIELD (SOUTHERN POLAND)</b> , M.Sc. Kinga Slosarczyk, Dr. Sabina Jakobczyk-Karpierz, Dr. Hanna Rubin, Prof. Dr. Andrzej Kowalczyk, Assoc. Prof. Dr. Andrzej Witkowski, Poland.....	361
<b>47. MAIN FEATURES OF ENGINEERING-GEOLOGICAL AND GEOTECHNICAL RESEARCH OF MICROBIOTA INFLUENCE ON HARD ROCKS IN THE URBAN UNDERGROUND SPACE</b> , Prof. Dr. Regina E. Dashko, Assist. Prof. Dr. Ivan V. Alekseev, Russia.....	369
<b>48. MECHANICAL AND PHYSICAL CHARACTERIZATION OF ROCK MATERIAL FROM COIMBRA SLOPES (CENTRAL PORTUGAL)</b> , Assoc. Prof. Dr. Pedro Santarem Andrade, MSc. Diana Costa, Portugal .....	377
<b>49. NON-DESTRUCTIVE RESEARCH OF CEMENT COMPOSITE DEGRADATION USING X-RAY CT</b> , Ing. Vendula Zajicova, Ing. Kamil Soucek, Ph.D. , RNDr. Lubomir Stas, CSc. , Ing. Michaela Smolakova2, Czech Republic .....	385
<b>50. NUMERICAL MODELING ON PERFORMANCE EVALUATION OF ANCIENT TUNNEL – DEZH-MANDEH TUNNEL</b> , Assis. Prof. Dr. Ehsan Moosavi, Assis. Prof. Dr. Reza Shirinabadi, Iran .....	393
<b>51. ON THE E50 MODULUS OF TAILINGS DAM MATERIALS</b> , Assist. Prof. Dr. Nikolay Kerenchev, Bulgaria .....	399
<b>52. ON THE VARIATION IN SEVERAL ROCK PROPERTIES DUE TO MAGNESIUM SULFATE WEATHERING TESTS - A CASE STUDY FOR LIMESTONES</b> , Dr. Ekin KOKEN, Turkey .....	405
<b>53. PIPELINE ACCIDENTS IN THE NORTH OF THE USA: ANALYSIS OF GEOMORPHOLOGICAL FACTORS</b> , Prof. Andrey Zhirov, Assoc. Prof., Dr. Sergei Boltramovich, St. Natalya Alaguzova, St. Anastasia Ovchinnikova, Russia.....	413

- 54. PROSPECTS FOR THE USE OF THE MEDICAL MUD OF SORA ARASAN-KUNDUZDY (SOUTH - EAST KAZAKHSTAN) IN BALNEOLOGY,** Candidate of geological and mineralogical sciences Sergey Kan, Engineer of the highest category Oleg Kalugin, Candidate of Biological Sciences Sholpan Kurmangaliyeva Doctoral student Zhanna Tleuova, Kazakhstan.....421
- 55. QUALITATIVE AND QUANTITATIVE ANALYSIS OF A SPRING DISCHARGE HYDROGRAPH IN A PRE-ALPINE WATERSHED,** Vladislav Ivanov, Davide Brambilla, prof. Laura Longoni, prof. Monica Papini, Italy.....427
- 56. QUANTITATIVE AND QUALITATIVE PROTECTION OF NATURAL MINERAL WATER RESOURCES USING A PROCESS-BASED METHOD. CASE STUDY: LOWER CIUC BASIN, ROMANIA,** Assoc. Prof. Dr. Iulian Popa, Prof. Dr. Alexandru Danchiv, Dr. Adrian Iurkiewicz, Romania.....435
- 57. RECENT PROGRESS IN TESTING OF GROUND ANCHORS,** Ing. et Ing. Jan Stefanak, Ph.D. and Assoc. Prof. Ing. Lumir Mica, Ph.D., Czech Republic.....447
- 58. REUSE OF WASTE MATERIALS AS SUSTAINABLE SOLUTION TO STABILIZE THE EXPANSIVE CLAY SOILS,** Dr. Eng. Cornelia Florentina Dobrescu, Dr. Geol. Elena-Andreea Calarasu, Romania .....455
- 59. ROLE OF COAL LAYERS FOR THE FORMATION OF CHEMICAL COMPOSITION OF THE UPPER PONTIAN AQUIFER, NORTHWEST BULGARIA,** Eng. Aglaida Toteva, Assoc. Prof. Dr. Diana Rabadzhieva, Assist. Boyka Mihaylova Prof. Dr. Aleksey Benderev, Bulgaria.....461
- 60. SEASONAL VARIATION IN CONTAMINATION AND SOURCES OF POLYCYCLIC AROMATIC HYDROCARBONS IN THE CIESZYN TUFA SPRING WATER (SOUTHERN POLAND),** M.Sc. Kinga Slosarczyk, Dr. Sabina Jakobczyk-Karpierz, Dr. Hanna Rubin, Assoc. Prof. Dr. Jacek Rozkowski, Prof.Dr. Tadeusz Magiera, Poland .....469
- 61. SOIL STABILITY ASSESSMENT UPON PROJECTING A NEW METRO LINE IN MOSCOW,** Dr. Irina Kozliakova, Dr. Olga Eremina, Irina Kozhevnikova, Nadezhda Anisimova, Russia.....477
- 62. SPECTRAL ANALYSIS OF THE RECTANGULAR TANK,** Ing. Lenka Uhlirova - prof. Ing. Norbert Jendzelovsky, PhD., Slovakia.....485
- 63. STATISTICAL PROCESSING OF GEOLOGICAL DATA FOR THE ROIL16 GROUNDWATER BODY,** PhD. Teodora Vasile, Romania.....493
- 64. STUDY OF ROCK CLIFF EROSION AND STABILITY IN CUIO AND KALOHANDA (WESTERN ANGOLA),** Assoc. Prof. Dr. Pedro Santarém Andrade, MSc. Manuel Segundo, Assoc. Prof. Dr. Pedro Miguel Callapez, Portugal .....501

<b>65. STUDY OF THE HYDROGEOLOGICAL RESPONSES FROM THE FAR EARTHQUAKES</b> , Dr. Ella Gorbunova, Dr. Alina Besedina, Russia.....	507
<b>66. TESTING THE UNBOUND LAYERS OF PAVEMENTS FROM RECYCLED ASPHALT MIXTURES</b> , Ing. Juraj Šrámek, PhD., Assoc. Prof. Dr. Ing. Katarína Zgútová, Prof. Ing. Dr. Martin Decký, Slovakia .....	515
<b>67. THE ANALYSIS OF CHANGING HYDRODYNAMIC CONDITIONS AIMING TO VALIDATE GEO-MIGRATION MODEL WITH INSUFFICIENT BENCHMARK DATA</b> , Assist. Prof. Ekaterina Leonteva, Assist. Prof. Anastasia Grebneva, Student Valentina Erzova, Russia.....	523
<b>68. THE MORPHOLOGICAL PATTERN DEVELOPMENT OF THERMOKARST PLAINS WITH FLUVIAL EROSION: STOCHASTIC MODELING FOR RISK ASSESSMENT</b> , Prof. Dr. Alexey Victorov, Dr. Timofey Orlov, Dr. Veronika Kapralova, Prof. Dr. Olga Trapeznikova., Russia.....	531
<b>69. THE TRANSFORMATION OF THE COMPOSITION OF THE GROUNDWATER IN THE AREA OF HIGH TECHNOGENIC LOAD MINING PRODUCTIONS</b> , Assistant Professor Pogoreltseva E. I., Associate Professor Zaitsev D. A., Professor Khaustov V. V., Russia .....	541
<b>70. THE USE OF FINITE ELEMENT METHOD IN DESIGN OF THE ROCKFILL DAM BODY OF THE PUMP-STATION HYDROPOWER PLANT.</b> , Assoc. Prof. Hrustinec Lubos, Ph.D., Prof. Dr. Eng. Sumeč Jozef, DSc., Assoc. Prof. Kuzma Jozef, Ph.D., Slovakia .....	549
<b>71. THE USE OF THE FINITE ELEMENT METHOD IN THE OPTIMIZATION OF THE FOUNDATION OF A BRIDGE STRUCTURE OVER THE DANUBE RIVER.</b> , Assoc. Prof. Hrustinec Lubos, Ph.D., Assoc. Prof. Kuzma Jozef, Ph.D., Prof. Dr. Eng. Sumeč Jozef, DSc. Slovakia .....	557
<b>72. UTILIZING A PRESSURE PAPER FOR THE DETERMINATION OF CONTACT PARAMETERS BETWEEN AGGREGATE AND A RAILWAY SLEEPER</b> , Assistant Professor Vit Lojda, Jaroslav Jerabek, Assistant Professor Leos Hornicek, Czech Republic.....	565
<b>73. VIBRATION OF ADJACENT BUILDING DUE TO IMPACT PILE DRIVING BY DIESEL HAMMER</b> , Assistant Victor Veshnyakov, Russia .....	573
<b>74. VOLUME CHANGES OF SOILS AS A SECONDARY CAUSE OF FAILURE OF THE RETENTION RESERVOIRS</b> , Assoc. Prof. Ing. PhD. Ivan Slavik, Slovakia .....	579
<b>75. WORKFOW FOR THE GEOTECHNICAL LANDSLIDE MODEL - CASE STUDY FROM NORTH CROATIA</b> , Kristijan Grabar, PhD student, Prof. Stjepan Strelec, PhD, Jasmin Jug, PhD student, Davor Stanko, PhD, Croatia.....	587

## OIL AND GAS EXPLORATION

---

- 76. A BAYESIAN CLASSIFICATION PROCEDURE FOR THE PROBLEM OF RESERVOIR FACIES DETERMINATION BASED ON MARKOV NETWORKS**, Assist. Prof. Artem Zaikin, Assist. Prof. Rustem Salimov, Russia .....597
- 77. A NOVEL MODULAR METHOD FOR INTENSIFICATION PLANNING**, Adam Pasztor PhD Student, Kamenar Mark MSc Student,, Hungary .....605
- 78. ADVANCED TECHNIQUES FOR DETERMINING PARAMETERS OF INTEREST IN THE SHALE GAS EXPLORATION**, Prof. Dr. Eng. Frunzescu Dumitru, Assoc. Prof. Dr. Eng. Branoiu Gheorghe, PhD Student Georgescu (Jugastreanu) Cristina-Maria, PhD Student Lungu Ionut-Andrei, Romania.....615
- 79. AN APPLICATION OF KALMAN FILTER MODEL TO RESERVOIR PRESSURE MAINTENANCE**, Assist. Prof. Artem Zaikin, Assist. Prof. Rustem Salimov, Russia .....627
- 80. ANALYSIS OF FLOW DISTRIBUTION IN FRACTURED-CAVERNOUS CARBONATE RESERVOIR BASING ON TRACER TESTS AND ISOTOPE SURVEY**, Maria Shipaeva, Vladislav Sudakov, Ruslan Khairtdinov, Aydar Sattarov, Russia .....635
- 81. APPLICATION OF BOREHOLE ELECTRICAL IMAGING TO THE STUDY OF SARMATIAN DEPOSITS FROM NORTH-WESTERN MOLDAVIAN PLATFORM (ROMANIA)**, Assoc. Prof. Dr. Bogdan-Mihai NICULESCU, Constantin-Laurian CIUPERCA, Lecturer Dr. Gina ANDREI, Romania.....643
- 82. APPLICATION OF SYNTHETIC LOGGING CURVES FOR GEOMECHANICAL MODELING**, Senior Lecturer Victor Kosarev, Assoc. Prof. Dr. Ilmir Nugmanov, Chief Geologist Ruslan Khayrtdinov, Assistant Eduard Ziganshin, Master student Zilia Rizvanova, Russia .....655
- 83. ASPECTS ON TESTING ELECTRICAL EQUIPMENT WITH TYPE OF PROTECTION FLAMEPROOF ENCLOSURE “D”**, PhD Eng. Lucian Moldovan, PhD Eng. Sorin Burian, PhD Eng. Mihai Magyari, PhD Eng. Dragos Fotau, PhD Eng. Marcel Rad, Romania .....663
- 84. ASPECTS REGARDING THE VOLTAGE IMPULSE IGNITION TEST FOR STATOR INSULATION SYSTEMS OF ELECTRIC MOTORS USED IN POTENTIALLY EXPLOSIVE ATMOSPHERE**, PhD. Eng. Dragoş Fotău, PhD. Eng. Mihai Magyari, PhD. Eng. Lucian Moldovan, PhD. Stud. Eng. Marcel Rad PhD. Eng. Diana Sălaşan, Romania .....671

- 85. CATALYTIC IN-SITU COMBUSTION PROCESS IN THE PRESENCE OF METAL OXIDE PARTICLES**, PhD. Student Seyedsaeed Mehrabi Kalajahi, Assoc. Prof. Dr. Mikhail A. Varfolomeev, Dr. Chengdong Yuan, Russia .....677
- 86. CATALYTIC OXIDATION OF HEAVY CRUDE OIL USING COPPER BASED CATALYST FOR IN-SITU COMBUSTION ENHANCED OIL RECOVERY**, MSc. Student Sarvarjon Talipov, Assoc. Prof. Dr. Mikhail A. Varfolomeev, Dr. Chengdong Yuan, Kamil Sadikov, PhD. Student Seyedsaeed Mehrabi Kalajahi, Russia .....683
- 87. CHARACTERIZATION OF HYDRAULIC OIL WASTE TO THERMAL DEGRADATION USING THE THERMOGRAVIMETRIC ANALYSIS METHOD COUPLED WITH INFRARED SPECTROMETRY**, Ph.D Chem. Eng. Nălboc Irina, Ph.D Stud. Eng. Drăgoescu Răzvan, Ph.D Chem. Prodan Maria, Ph.D Chem. Szollosi Moța Andrei, Ph.D Stud. Fiz. Șuvar Sonia, Romania.....689
- 88. CHARGING RISK WITH ELECTROSTATIC CHARGES OF WORKERS FROM EX AREAS**, Ph.Student.D.Eng. Mihai POPA, Ph.D.Eng. Adrian JURCA, Ph.D.Eng.Florin Adrian PAUN, Ph.D.Eng Niculina VATAVU, Ph.D.Eng.Mihaela PARAIAN, Romania .....697
- 89. CLASSIFICATIONS AND METHODOLOGIES OF RESERVES CALCULATION IN UNCONVENTIONAL TIGHT/SHALE GAS RESERVOIRS**, Prof. Dr. Stanislaw Nagy, Poland.....705
- 90. COMPLEX CARBONATE RESERVOIRS DEVELOPMENT OPTIMIZATION AND INCREASING THE EFFICIENCY OF HORIZONTAL WELL OPERATION**, Albina Sitdikova, Lenar Minikhaïrov,Albert Miyassarov Rinat Khuzin, Dinar Salikhov, Russia .....713
- 91. COMPLEX CHARACTERIZATION OF ORGANIC-RICH CARBONATE SHALES SATURATION**, Aliya Mukhametdinova, Tagir Karamov, Natalia Bogdanovich, Alexey Cheremisin, Vladimir Plotnikov, Russia .....719
- 92. CONSIDERATIONS ON THE TESTING OF BREATHING AND DRAINING DEVICES USED IN ELECTRICAL EQUIPMENT WITH FLAMEPROOF ENCLOSURE TYPE OF PROTECTION**, Sc. Res. III PhD Eng. Marcel Rad, Sc. Res. I PhD Eng. Lucian Moldovan, Sc. Res. I PhD Eng. Mihai Magyari, Sc. Res. III PhD Eng. Dragoș Fotău, Sc. Res. Assist. PhD Eng. Diana Salasan, Romania.....727
- 93. STRUCTURE OF VEREYSKY OIL RESERVOIR FROM AKANSKOYE OILFIELD OF THE TATARSTAN REPUBLIC**, Assoc. Prof. Dr. Barieva E.R., Assoc. Prof. Dr. Kolchugin A.N., Assoc. Prof. Dr. Eskin A.A., Assoc. Prof. Dr. Korolev E.A., Prof. Dr. Morozov V.P., Russia.....735

<b>94. CRITICAL POINTS OF PRESURIZED ENCLOSURE FOUND WITH CFD - AN EXAMPLE</b> , Sc. Res. I PhD Eng. Tiberiu Csaszar, Sc. Res. I PhD Eng. Sorin Burian, Sc. Res. I PhD Eng. Marius Darie, Sc. Res. III PhD Eng. Cosmin Colda, Sc. Res. Eng. Danut Grecea, Romania .....	743
<b>95. CRUDE DISTILLATION UNIT AND THE TECHNOLOGY ADOPTED IN RUSSIA</b> , Serge-Bertrand Adiko, Aydar A. Akhmediyarov, Mikhail A. Varfolomeev, Russia .....	751
<b>96. CURRENT DRIVERS AND PRICE DEVELOPMENT ON NATURAL GAS MARKET – FOCUS ON EUROPE</b> , Prof. Dr. Saleh Mothana Obadi Dr. Matej Korcek, Slovakia .....	759
<b>97. DETERMINATION THE AKAN OIL FIELD RESERVOIRS VELOCITIES ANISOTROPY FROM CROSS-DIPOLE ACOUSTICS LOGGING</b> , Senior Lecturer Victor Kosarev, Assoc. Prof. Dr. Ilmir Nugmanov, Chief Geologist Ruslan Khayrtdinov, Russia .....	771
<b>98. DIMENSIONING OF HAZARDOUS ZONES RESULTING FROM THE RELEASE OF LNG AS A FUNCTION OF THE TYPE OF PLACE OF OCCURRED UNSEALING AND UNSEALING SCENARIO</b> , PhD. Eng. Kalbarczyk-Jedynak A., Prof. PhD. Eng., Master Mariner Ślączka W., Poland.....	779
<b>99. DISTRIBUTION OF LIGHT HYDROCARBONS IN THE SELECTED AREA OF THE CARPATHIAN FOREDEEP – CASE STUDY FROM SE POLAND</b> , Adrianna Gora, Henryk Sechman, Piotr Guzy, Anna Twarog, Poland.....	787
<b>100. DISTRIBUTIONS OF LIGHT HYDROCARBONS IN THE NEAR SURFACE ZONE CONNECTED WITH MEASUREMENTS OF MAGNETIC SUSCEPTIBILITY IN THE MARGINAL PART OF THE CARPATHIAN FOREDEEP AND OUTER CARPATHIANS – CASE STUDY FROM SE POLAND</b> , Adrianna Gora, Anna Wojas, Henryk Sechman, Piotr Guzy, Anna Twarog, Poland.....	795
<b>101. EFFECT OF COMPOSITION OF OXYGEN–NITROGEN GAS MIXTURES ON HEAVY CRUDE OIL OXIDATION PROCESS USING TG-FTIR</b> , Aydar A. Akhmediyarov, Dmitrii A. Emelianov, Mikhail A. Varfolomeev, Russia.....	803
<b>102. EFFECT OF THE REACTION TIMES ON THE THERMAL VISBREAKING PROCESS OF HEAVY HYDROCARBON FEEDSTOCK</b> , Ameen A. Al-Muntaser, Mikhail A. Varfolomeev, Muneer A. Suwaid, Richard Djimasbe, Diana I. Garayeva, Russia.....	809
<b>103. EFFECT OF TRIPOLI OF THE PERVOMAYSKOE FIELD ON THE HEAVY CRUDE OIL COMBUSTION BY HP-DSC</b> , PhD Student Mustafa Abaas PhD Student Ameen A. Al-Muntaser , MSc student Kristina A. Ariskina, Assoc. Prof. Dr. Mikhail A. Varfolomeev , Dr. Chengdong Yuan1, 2, Russia .....	815

- 104. EFFECTIVENESS OF SURFACTANTS COMPOSITION INJECTION IN LOW-PERMEABLE LAYERS UNDER HIGH-TEMPERATURE CONDITIONS,** Alexandra Scerbacova, Pavel Afanasev, PhD Alexander Cheremisin, Ekaterina Dvoretzkaya, Igor Koltsov, Russia .....821
- 105. EFFECTS OF CLAY OF ALEKSEEVSKY FIELD ON CRUDE OIL COMBUSTION BY TG-FTIR,** MSc student Kristina A. Ariskina, PhD Student Ameen A. Al-Muntaser , PhD Student Mustafa Abaas, Assoc. Prof. Dr. Mikhail A. Varfolomeev, Dr. Chengdong Yuan, Russia .....829
- 106. EVALUATION OF NONLINEAR CIRCUITS WITH INTRINSIC SAFETY USING SPARK TEST APPARATUS SIMULATOR,** Danut Grecea, Sorin Burian, Marius Darie, Tiberiu Csaszar, Cosmin Colda, Romania .....837
- 107. EVALUATION OF THE SAFETY LEVEL TO THE HIGH-QUALITY VAULT WITH A V RESISTANCE LEVEL, BASED ON THE GAZ EXPLOSION TEST RESULTS,** PhD. Eng Radeanu Cristian, PhD. Eng Vasilescu Gabriel Dragos, PhD. Eng Attila Kovacs, PhD. Eng Robert Laszlo, Miron Claudia, Romania .....845
- 108. EXPERIMENTAL AND NUMERICAL SIMULATION OF HOT WATER INJECTION TO DEEP CARBONATE RESERVOIR,** Ph.D student Aysylu Askarova, Evgeny Popov , Ph.D. Aleksey Chermisin , Kirill Maksakov , Ph.D. Artem Nekrasov , Russia .....851
- 109. EXPRESS METHOD FOR MEASURING THE DRILLING MUDS RHEOLOGICAL PARAMETERS,** Biletskiy M.T., Ratov B.T., Syzdykov A.Kh., Delikesheva D.N., Kazakhstan .....861
- 110. FEATURES OF FLUID FILTRATION IN VARIOUS BALL PACKINGS IN A WIDE RANGE OF REYNOLDS NUMBERS (PART 2),** Assoc. Prof. Dr. Aleksei Evseev, Russia .....869
- 111. GAS SEEPS AS THE BLACK SEA HYDROCARBON RESOURCE,** Assoc. Prof.Dr. Sergii Goshovskyi, Ukraine .....877
- 112. GEODYNAMIC ASPECTS OF THE FORMATION AND PLACEMENT OF SUPERVISCOUS OIL RELEASES AND NATURAL BITUMENS OF THE CENTRAL AREAS OF THE URAL-VOLGA REGION,** Prof. Dr. Uspensky B.V., Assoc. Prof. Dr. Korolev E.A., Researcher Valeeva S.E., Russia.....883
- 113. HISTORY ABOUT OIL AND GAS IN ROMANIA, NEW CONCEPT ABOUT MANAGEMENT, PERSONAL POINT OF VIEW,** Assoc. Lecturer. PhD. Alina-Daniela Mihalcea, Romania .....889
- 114. IDENTIFICATION OF FLUID CONTACTS BY USING FORMATION PRESSURE DATA AND GEOPHYSICAL WELL LOGS,** Assoc. Prof. Dr. Bogdan-Mihai NICULESCU, PhD Candidate Constantin-Laurian CIUPERCA, Romania.....897

- 115. IMPACT ASSESSMENT OF COMBUSTION PRODUCTS OF SOLID HETEROGENEUS PROPELLANTS ON COAL SAMPLES IN A LABORATORY ROCKET MOTOR**, MSc Kamil Hebda, PhD Lukasz Habera, MSc Antoni Frodyma, Eng. Edward Godzik, MSc Piotr Koslik, Poland.....909
- 116. IMPROVING WELL OPERATION BY SELECTING THE OPTIMAL LENGTH OF HORIZONTAL SIDETRACKS FOR FIELDS AT THE LATE STAGE OF DEVELOPMENT**, Sitdikova Albina, Minikhaïrov Lenar, Garifullina Vasilya, Nazipova Aliya, Fayzetdinova Razilya, Russia .....915
- 117. INFLUENCE OF THE COMPOSITION OF OXYGEN–CARBON DIOXIDE GAS MIXTURE ON THE OXIDATION PROCESS OF HEAVY CRUDE OILS**, Aydar A. Akhmadiyarov, Assoc. Prof. Dr. Mikhail A. Varfolomeev, Russia .....923
- 118. INTEGRATED LOGGING-WHILE-DRILLING (LWD) METHODS IDENTIFY BOREHOLE BREAKOUTS IN HOSTILE ENVIRONMENTS**, Eng. Constantin-Laurian CIUPERCA, Assoc. Prof. Dr. Bogdan-Mihai NICULESCU, Eng. Petr KRAVETS, Romania.....929
- 119. INTEGRATED SYSTEM FOR PRESSURIZED ENCLOSURES TESTS**, Sc. Res. I PhD Eng. Marius DARIE, Sc. Res. I PhD Eng. Tiberiu CSASZAR, Lect. PhD. Chem. Clementina Sabina Moldovan, Sc. Res. III PhD Eng. Cosmin COLDA, Sc. Res. Eng. Danut GRECEA, Romania.....937
- 120. INVESTIGATION OF FILTRATION FLOW INSIDE THE PORES USING REFRACTIVE INDEX MATCHING AND LDA (PART 1)**, Assoc. Prof. Dr. Aleksei Evseev, Russia.....945
- 121. LABORATORY SCREENING OF EFFECTIVE CROSS-LINKED POLYMERS TO IMPROVE THE EFFICIENCY OF OIL RECOVERY AT CARBONATE DEPOSITS WITH HIGH MINERALIZATION OF RESERVOIR WATER**, Dr. Li Kexing, Aidar Z. Mustafin, Aydar A. Akhmadiyarov, Ruslan K. Khayrtdinov, Assoc. Prof. Dr. Mikhail A. Varfolomeev, Russia.....953
- 122. LOW-FREQUENCY, LOW-NOISE MOLECULAR-ELECTRONIC HYDROPHONE FOR OFFSHORE AND TRANSIT ZONE SEISMIC EXPLORATION**, D.L. Zaitsev, E.V. Egorov, M.A. Ryzhkov, G.O. Velichko, V.I. Gulenko, Russia.....961
- 123. MACROSCOPIC ELECTRICAL CONDUCTIVITY FOR MICROSTRUCTURES OF SANDSTONES**, Prof. Dr. Mikhail Epov, Prof. Dr. Olga Soboleva, Dr. Ekaterina Kurochkina, Russia .....969
- 124. METHOD OF ICEBERG HAZARD ESTIMATION IN THE KARA SEA, BASED ON REALIZATIONS OF THE NUMERICAL MODEL**, Anastasiia Tiugaleva, Dr. Roman Guzenko, Dr. Sergey Klyachkin, Dr. Ruslan May, Russia.....977

- 125. METHOD TO CALCULATE APPARENT PERMEABILITY OF HYDRAULIC FRACTURES**, Adam Pasztor PhD Student , Tamas Lengyel PhD, Hungary .....985
- 126. METHODOLOGY FOR ASSESSING A POTENTIAL SURFACE HYDROCARBONS LEAKAGE FROM FAULTS**, Assoc. Prof. Dr. Eng. Efrosima Zaneva-Dobranova, Chief Assist. Prof. Dr. Eng. Nikolay Hristov, Assoc. Prof. Dr. Svetlana Bratkova, Bulgaria .....993
- 127. METHODS FOR OIL AND GAS SUPPLY CHAIN OPTIMIZATION IN THE ENVIROMENTAL ISSUES GLOBALLY**, Assoc. Lecturer. PhD. Alina-Daniela Mihalcea, Romania .....1001
- 128. MODELING THE RADIAL VARIATION OF THE HYDROCARBON COLLECTORS RESISTIVITY, USING THE KRIGING TECHNIQUE**, Prof. Dr. Daniela Doina Neagu, Prof. Dr. Ion Malureanu, Drd. Eng. Mariana Laura Nistor., Romania.....1009
- 129. MODIFIED DRILLING FLUIDS FOR WORKOVER JOBS IN OIL WELLS**, D. Sc. Eng. Jan Ziaja, Dr eng. Aleksandra Jamrozik, Prof. Rafał Wiśniowski, MSc. Robert Czarnota, Poland .....1017
- 130. NANO-ADDITIVES EFFECT ON A RESERVOIR-FRIENDLY DRILLING FLUID FROM THE DRILLER'S VIEW**, Gyula Varga, Dr. Adam Konecz,Dr. Tamas Fancsik, Dr. Anita Jobbik, Hungary .....1025
- 131. OPTIMIZATION TESTING OF SHAPED CHARGES USED IN OIL INDUSTRY WITH NUMERICAL METHODS**, PhD Łukasz Habera, MSc Antoni Frodyma, MSc Kamil Hebda, MSc Piotr Koślik, PhD Zenon Wilk, Poland.....1031
- 132. OXIDATION OF HEAVY CRUDE OIL USING OIL-SOLUBLE TITANIUM OXIDE IN IN-SITU COMBUSTION PROCESS**, PhD. Student Meisam Babapour Golafshani, Assoc. Prof. Dr. Mikhail A. Varfolomeev, Dr. Chengdong Yuan, PhD. Student Seyedsaeed Mehrabi Kalajahi, Russia.....1039
- 133. PORE STRUCTURE INVESTIGATION OF UPPER DEVONIAN ORGANIC-RICH SHALES WITHIN THE VERKHNEKAMSK DEPRESSION**, Tagir Karamov, Aliya Mukhametdinova, Natalia Bogdanovich, Vlalimir Plotnikov, Zhanna Khakimova, Russia .....1045
- 134. POWER FLUCTUATION INDEX (PFI) - A METHOD OF EVALUATING THE EFFICIENCY AND QUALITY OF PERFORMED HORIZONTAL DIRECTIONAL WELLS (HDD)**, D.Sc. Eng. Jan Ziaja , Prof. Rafal Wisniowski, Poland.....1053

- 135. RESEARCH ON THE USE DRONES FOR MONITORING AND RESOURCES VALORIFICATION IN THE EXTRACTIVE INDUSTRY**, Marin Silviu NAN, Catalin PLOTOGEA, Danut GRECEA, Alin SULTAN, Daniel Cosmin VITAN, Romania ..... 1061
- 136. SCALE DEPENDENCY INVESTIGATION FOR POROUS MEDIA - EXPERIMENTAL AND NUMERICAL APPROACHES FOR CARBONATE ROCKS**, Assoc. Prof. Dr. Ilmir Nugmanov, Senior Lecturer Victor Kosarev, Master student Firdaves Khusnutdinov, Bachelor student Ildus Zakirov, Russia..... 1069
- 137. SOME FEATURES OF THE OIL-SATURATED DOLOMITE RESERVOIRS FROM THE LOWER MISSISSIPPIAN OF THE VOLGA-URAL BASIN, RUSSIA**, Assoc. Prof. Dr. Kolchugin A.N., Prof. Dr. Morozov V.P., Assoc. Prof. Dr. Korolev E.A., Assoc. Prof. Dr. Eskin A.A. Russia ..... 1075
- 138. SPECIFICITY OF RESERVOIR SIMULATION OF HEAVY OIL FIELD ACCOUNTING ROCK WETTABILITY**, Albina Sitdikova, Lenar Minikhairov, Rinat Khuzin, Albert Miyassarov, Dinar Salikhov, Russia..... 1081
- 139. STUDY OF MORPHOMETRY AND INTERNAL STRUCTURE OF ICE RIDGES AND STAMUKHAS BY MEANS OF THE IMPROVED TECHNOLOGY OF WATER THERMAL DRILLING**, Dr. Roman B. Guzenko  
Dr. Yevgeny U. Mironov, Dr. Victor V. Kharitonov, Stepan V. Khotchenkov, Dr. Ruslan I. May, Russia..... 1089
- 140. THE BEST AVAILABLE TECHNIQUES FOR THE CONTROL OF SOLID AND TREATMENT OF OIL-CONTAMINATED DRILLING WASTE**, Dr. Eng. Aleksandra Jamrozik, Prof. Dr. Rafal Wisniowski, Prof. Dr. Andrzej Gonet, , Poland ..... 1099
- 141. THE EFFECT OF MOLECULAR WEIGHT OF WATERBORNE POLYURETHANES ON KINETIC HYDRATE INHIBITION**, PhD. Student Abdolreza Farhadian, Assoc. Prof. Dr. Mikhail A. Varfolomeev, Russia ..... 1109
- 142. THE INFLUENCE OF LITHOLOGICAL CHARACTERISTICS OF SANDY COMPLEXES ON THE PRODUCTIVITY OF HIGH VISCOSITY OILS DEPOSITS**, Khassanov D.I., Yachmeneva E.A., Grunis E.G., Russia ..... 1117
- 143. THE OCEAN-BOTTOM SEISMIC CABLE SYSTEM BASED ON LOW-NOISE HIGH-SENSITIVE MOLECULAR-ELECTRONIC TRANSFER SENSORS**, A.S. Shabalina, PhD. E.V. Egorov, A.V. Rudakov, A.V. Vishnyakov, Russia ..... 1125
- 144. THE OIL SECTOR AND OIL COMPANIES IN THE ECONOMIC STRATEGY OF SOME OIL-EXPORTING COUNTRIES**, Senior Lecturer Galina Kulikovskaya, Assoc. Prof., Senior scientific researcher Dr. Gurgen Gukasyan, Russia ..... 1133

**145. THE RELATIONSHIP BETWEEN ELASTIC AND RESERVOIR PROPERTIES ON THE EXAMPLE OF SANDY DEPOSIT FROM ONE OF THE FIELDS IN WESTERN SIBERIA.,** Yachmeneva E.A., Gilmutdinov S.R., Russia .....1141

**146. UPGRADING OF TATARSTAN HEAVY CRUDE OIL USING COFE2O4-NANOPARTICLES CATALYST AT 300°C,** PhD Student Muneer. A. Suwaid  
PhD Student Ameen A. Almuntaser, Assoc. Prof. Dr. Mikhail A. Varfolomeev, B.E S. Khramov, MSc student L. Khaziakhmetov1, Russia.....1149

**147. UPGRADING OF “DOMANIK” SHALE OIL BY SUPERCRITICAL WATER,** R Djimasbe, Ameen A. Al-muntaser, Mikhail A. Varfolomeev, Muneer A. Suwaid, Russia .....1155

**148. VISUALIZATION AND RECORD METHODS FOR THE INITIATION OF AIR-METHANE EXPLOSIVE ATMOSPHERES,** PhD. Stud. Eng. Adrian Bogdan Simon-Marinica, PhD. Emilian Ghicioi, PhD. Nicolae-Ioan Vlasin, PhD. Marius Cornel Suvar, Eng. Gheorghe Daniel Florea, Romania .....1165



## ON THE VARIATION IN SEVERAL ROCK PROPERTIES DUE TO MAGNESIUM SULFATE WEATHERING TESTS – A CASE STUDY FOR LIMESTONES

**Dr. Ekin KÖKEN**

Abdullah Gül University, Engineering Faculty, Department of Materials Science and Nanotechnology, Kayseri, **Turkey**

### ABSTRACT

Contributions to the behavior of rock materials under various conditions provide a practical knowledge about issues relating the performance and long-term serviceability of rocks. In this study, various limestones with varying textural features were investigated in terms of their resistance against magnesium sulfate weathering tests. For this purpose, initial physico-mechanical properties of limestones were determined. Then, rock materials were subjected to magnesium sulfate weathering tests (up to 20 cycles) and the variation in physico-mechanical properties were determined for each rock type.

As a result of laboratory tests, compared to initial rock properties, effective porosity ( $n_e$ , %) increased in the range of 3% – 14% and 12% – 35% after 10<sup>th</sup> and 20<sup>th</sup> magnesium sulfate weathering cycles, respectively. Uniaxial compressive strength of rocks (UCS, MPa) decreased by 9% – 24% after 10<sup>th</sup> cycles and by 32% – 58% after 20<sup>th</sup> cycles. Brazilian tensile strength of rocks (BTS, MPa) decreased in the range of 7% – 19% and 20% – 49% after 10<sup>th</sup> and 20<sup>th</sup> cycles, respectively. Similar to the variations in UCS and BTS, Tangential Young Modulus ( $E_{ti}$ , GPa) also decreased at a rate of 13% – 28% and 23% – 64% after 10<sup>th</sup> and 20<sup>th</sup> cycles, respectively. However, the values of Tangential Poisson's Ratio ( $\nu_{ti}$ ) fluctuated with progressive accelerated weathering cycles, which could be linked to varying axial and lateral strain rates at 50% of UCS values for the limestones investigated. Furthermore, the variation in crack initiation stress  $\sigma_{CI}$  (MPa) due to progressive magnesium sulfate tests were also evaluated considering two strain-based methods and the findings showed that  $\sigma_{CI}$  of limestones slowly decreased with increasing weathering test cycles.

It could be claimed that cyclic magnesium sulfate tests performed on rock materials would be beneficial for assessing the long-term serviceability of rocks. In this context, mud-supported limestones seem to have a greater resistance against magnesium sulfate weathering tests compared to the grain-supported ones. However, the number of samples should be increased in order to achieve a comprehensive understanding about the degradation processes of limestones.

**Keywords:** Limestone, Magnesium sulfate weathering test, Strength, Deformability, Stress-Strain

## INTRODUCTION

Geotechnical characterization of rock materials is one of the principle parts in assessing their durability especially for building stones. Owing to the physical, chemical and biological processes, the weathering degree in rocks increases which is dependent upon several external factors such as the usage area, meteorological features of the environment and the elapsed time throughout its usage. The resistance of rocks against various environmental conditions is mainly measured by both field measurements and accelerated weathering tests in laboratory [1, 2]. Excluding the mechanical impacts, most destructive environmental factors for rocks could be declared the drying – wetting, freezing – thawing, heating – cooling and salt crystallization processes. Of these environmental factors, effects of freezing – thawing and salt crystallization become much important in terms of the durability of building stones and monuments. Effects of freezing – thawing cycles in nature are directly attempted to represent by experiments where freezing – thawing cabinets are used [3] whereas it is indirectly simulated by magnesium sulfate soundness tests in laboratory [4].

Heidari et al. [5] conducted an extensive laboratory investigation about the disintegration process of limestones and concluded that strength properties such as uniaxial compressive strength (UCS, MPa), Brazilian tensile strength (BTS, MPa) decrease whereas effective porosity ( $n_e$ , %) increase with progressive freezing – thawing and salt crystallization processes. As mentioned in the above-mentioned study, UCS of limestones decreased approximately by 29% after 16 cycles of magnesium sulfate tests. Momeni et al. [6] concluded that, after 90 cycles of magnesium sulfate tests, UCS of granitic rocks decreased at a rate of 22% – 26%. Furthermore, the researchers claimed that higher values of  $n_e$  resulted in a higher disintegration for granitic rocks under the influence of sodium and magnesium sulfate solutions. Köken et al. [7] stated that UCS of basaltic rocks decreased in the range of 23% – 28% after 40 cycles of magnesium sulfate tests.

Above-mentioned studies showed that rock strength properties decrease with increasing magnesium sulfate test cycles. However, the strength reduction rates due to magnesium sulfate tests are changeable for different rock lithologies. In this study, the variation in several rock properties of limestones due to magnesium sulfate tests was investigated. For this purpose, initial physico-mechanical properties of each rock type were determined. Then, cylindrical core samples were subjected to magnesium sulfate weathering tests (up to 20 cycles) and the variation in physico-mechanical properties were determined. The rate of increase (ROI) and decrease (ROD) observed in considered rock properties were stated and discussed.

## MATERIALS AND METHODS

Representative rock blocks of six different limestones were obtained from rock quarries located in various parts of Turkey. Cylindrical core samples with a diameter of  $54.0 \pm 0.02$  mm were obtained from these rock blocks. Following that, they were cut considering the geometrical instructions of related testing methods. Physical and mechanical properties of rocks were determined in accordance with the suggested methods by International Society of Rock Mechanics (ISRM) [8]. The physical properties considered in this study are dry unit weight ( $\gamma_d$ , kN/m<sup>3</sup>) and effective porosity ( $n_e$ , %).

Mechanical properties include uniaxial compressive strength (UCS, MPa), Brazilian tensile strength (BTS, MPa), Tangential Young Modulus ( $E_{ti}$ , GPa) and Tangential Poisson's Ratio ( $\nu_{ti}$ ). Mineralogical and textural properties of limestones were also determined by thin sections observations and investigated limestones were identified in accordance with the classification of Dunham [9].

Saturated magnesium sulfate solutions were prepared at  $21 \pm 1$  °C by using magnesium sulfate heptahydrate salt ( $MgSO_4 \cdot 7H_2O$ ) for the investigation of variations in selected rock properties, Smooth-cut core samples were placed into the saturated magnesium sulfate solution for 16 – 18 hours. Then, they were taken out of the solution and left to drain for 4 – 6 hours. Following that, core samples were placed in a drying-oven at  $105 \pm 2$  °C for 24 hours. The entire process described above was acknowledged as one cycle of magnesium sulfate weathering test ( $N_{ft-m} = 1$ ), which approximately took 2 days. Core samples were subjected to 20 cycles (i.e.  $N_{ft-m} = 20$ ) of magnesium sulfate tests in total. During the determination of above-mentioned rock properties, each test to determine selected rock properties was repeated at least five times and average values of related rock properties were presented.

## LABORATORY STUDIES

Six types of limestones with different textural properties were used in this study. Laboratory studies were divided into three parts. In the first part, physico-mechanical properties of each limestone were determined using core samples prepared (Fig 1a). Physical properties of limestones determined in this study were dry unit weight ( $\gamma_d$ ,  $kN/m^3$ ) and effective porosity ( $n_e$ , %) whereas mechanical properties were uniaxial compressive strength (UCS, MPa), Brazilian tensile strength (BTS, MPa), Tangential Young Modulus ( $E_{ti}$ , GPa) and Tangential Poisson's ratio ( $\nu_{ti}$ ). Physico-mechanical properties were determined in accordance with the suggested methods by ISRM [8].

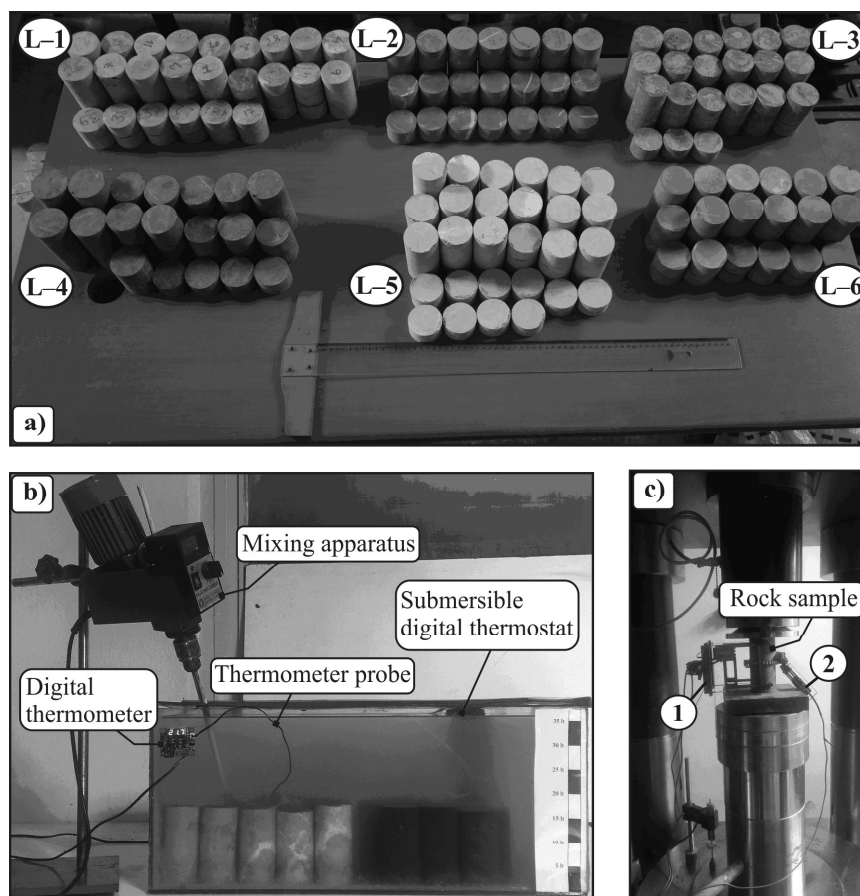
Second part of the laboratory studies covers the mineralogical and textural characterizations of limestones determined by thin section observations. Thin sections were prepared for each limestone and they were analyzed under a polarized microscope. In the last part of the laboratory studies, core samples were subjected to magnesium sulfate tests (Fig 1b) up to 20 cycles ( $N_{ft-m} = 20$ ) and the variations in several physical and mechanical properties were investigated. During UCS tests, axial and lateral deformations were measured using linear variable differential transformers (LVDTs) (Fig 1c).

Static–elastic constants (i.e.  $E_{ti}$  and  $\nu_{ti}$ ) of limestones were determined using stress-strain curves of each core sample. Axial ( $\varepsilon_z$ ), lateral ( $\varepsilon_l$ ) and volumetric deformations ( $\Delta = 2\varepsilon_l + \varepsilon_z$ ) were measured using LVDTs and  $E_{ti}$  (GPa) and  $\nu_{ti}$  were determined by the following equations:

$$E_{ti} = \frac{\sigma_z}{\varepsilon_z} \quad (1)$$

$$\nu_{ti} = -\frac{\varepsilon_l}{\varepsilon_z} \quad (2)$$

where:  $\varepsilon_l$  and  $\varepsilon_z$  are lateral and axial deformations, which correspond to the axial stress levels of 50% of UCS, respectively (i.e. values of  $\varepsilon_l$  and  $\varepsilon_z$  correspond to  $\sigma_z \approx 0.5UCS$ ).



LVDT sensors; sensor 1 used to measure axial deformations, sensor 2 used to measure lateral deformations.

Fig 1. Some of the laboratory equipments and materials used in the study a) Core samples b) Magnesium sulfate test c) Uniaxial compressive strength (UCS) test

As a result of thin section observations, limestones were characterized in terms of their textural properties (Table 1). Consequently, the texture of limestones varied from mud-supported to grain-supported types according to Dunham [9]. Moreover, weathering grade of limestones was found to be between unweathered ( $W_1$ ) and moderately weathered ( $W_3$ ) types.

The variation in stress-strain curves of limestones due to progressive magnesium sulfate cycles are given in Fig 2a. These curves, some of which were illustrated in Fig 2a, were used for the determination of crack initiation stress ( $\sigma_{CI}$ , MPa). For this purpose, two quantitative strain-based methods were adopted in this study.

The implementation of these methods to determine  $\sigma_{CI}$  is given in Fig 2b and Fig 2c. Fig 2b shows the implementation of the volumetric stress response (VSR) method, which was proposed by Pengfei et al. [10]. On the other hand, the implementation of lateral strain response (LSR) method by Nicksiar and Martin [11] is given in Fig 2c. Crack initiation stress for each limestone was determined by averaging values (i.e.  $\sigma_{CI(VSR)}$  and  $\sigma_{CI(LSR)}$  values) obtained from VSR and LSR approaches.

Table 1. Mineralogical and textural properties of the investigated limestones.

Rock type	Description	Texture	Mineralogical composition	Weathering Grade
L-1	Wackestone <sup>(I)</sup>	Mud-supported limestone with oolites.	Micro crystalline calcite (80%), skeletal and non skeletal fragments (18%) <sup>(II)</sup> , Siderite (2%)	W <sub>1</sub> – W <sub>2</sub> <sup>(III)</sup>
L-2	Grainstone	Grain-supported limestone with bearing dolomite. Densely veined with sparry calcite.	Micro crystalline calcite (24%), well-crystallized calcite (58%), skeletal and non skeletal fragments (6%), dolomite (10%), glauconite (2%).	W <sub>1</sub>
L-3	Mudstone	Mud-supported limestone with very fine-grained micro crystalline type. Randomly veined with sparry calcite in various thickness.	Micro crystalline calcite (90%), skeletal and non skeletal fragments (10%)	W <sub>1</sub>
L-4	Packstone	Grain-supported limestone with oolites. No calcite veins.	Micro crystalline calcite (60%), well-crystallized calcite (4%), skeletal and non skeletal fragments (25%), Siderite (7%), glauconite (2%), Opaque minerals (2%)	W <sub>1</sub> – W <sub>2</sub>
L-5	Mudstone	Mud-supported limestone. Densely veined with sparry calcite.	Micro crystalline calcite (90%), well-crystallized calcite (3%), skeletal and non skeletal fragments (7%)	W <sub>1</sub>
L-6	Packstone	Grain-supported limestone with fossiliferous micritic carbonate mud. No calcite veins.	Micro crystalline calcite (60%), well-crystallized calcite (5%), skeletal and non skeletal fragments (18%), Siderite (5%), glauconite (2%), Opaque minerals (10%)	W <sub>2</sub> – W <sub>3</sub>

**Note: (I)** Limestones were described according to Dunham [9]. **(II)** Skeletal and non skeletal fragments include fossils (e.g. foraminifers) oolites and pisolites etc. **(III)** Weathering grades of limestones were stated according to ISRM [8]. W<sub>1</sub>: Unweathered W<sub>2</sub>: Slightly weathered and W<sub>3</sub>: Moderately weathered.

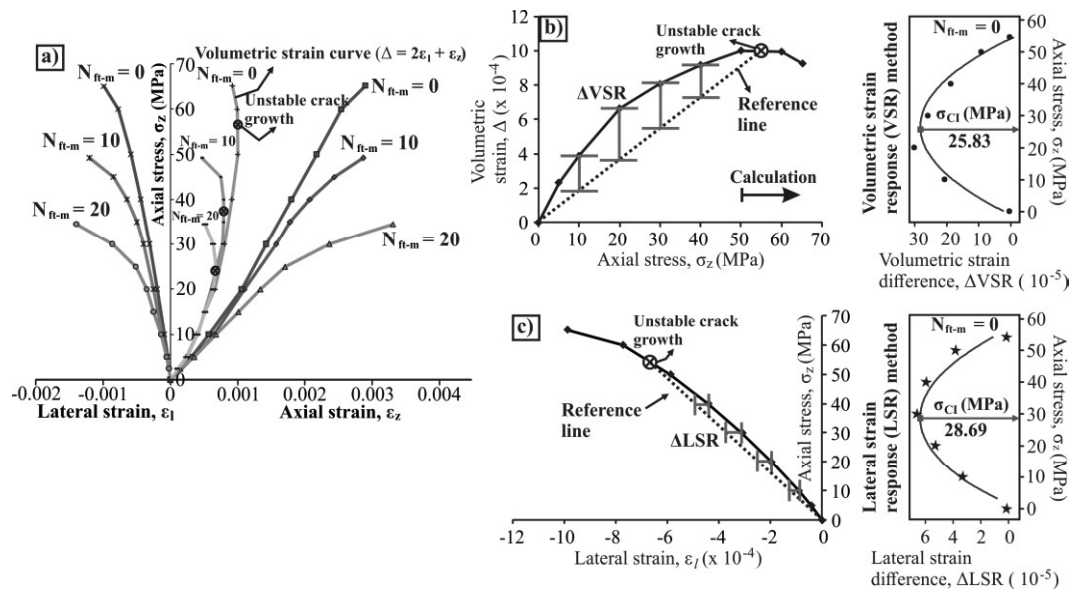


Fig 2. Determination of crack initiation stress a) Typical stress-strain curves of a limestone (L-1) b) Implementation of VSR method c) Implementation of LSR method.

Laboratory test results are given in Table 2. It was acquired that the values of  $\gamma_d$ , UCS, BTS and  $E_{ti}$  decreased whereas  $n_e$  of limestones increased with increasing  $N_{ft-m}$  in magnesium sulfate tests. Similar to the variations in the above-mentioned parameters,  $\sigma_{CI}$  also decreased with progressive magnesium sulfate tests.

Table 2. Laboratory test results.

$N_{ft-m} = 0$									
Rock type	$\gamma_d$ (kN/m <sup>3</sup> )	$n_e$ (%)	BTS (MPa)	UCS (MPa)	$E_{ti}$ (GPa)	$\nu_{ti}$	$\sigma_{CI(LSR)}$ (MPa)	$\sigma_{CI(VSR)}$ (MPa)	$\sigma_{CI-Mean}$ (MPa)
L-1	25.87	0.61	6.89	65.19	21.67	0.23	28.69	25.83	27.26
L-2	25.80	0.25	10.25	95.01	69.72	0.17	39.43	42.04	40.74
L-3	25.41	0.39	7.62	87.04	37.16	0.21	33.82	35.86	34.84
L-4	25.18	0.55	7.03	61.55	30.65	0.22	26.53	24.77	25.65
L-5	25.80	0.26	6.34	67.08	39.40	0.19	29.37	28.17	28.77
L-6	25.26	0.78	5.71	47.39	20.11	0.26	18.54	19.25	18.89
$N_{ft-m} = 10$									
Rock type	$\gamma_d$ (kN/m <sup>3</sup> )	$n_e$ (%)	BTS (MPa)	UCS (MPa)	$E_{ti}$ (GPa)	$\nu_{ti}$	$\sigma_{CI(LSR)}$ (MPa)	$\sigma_{CI(VSR)}$ (MPa)	$\sigma_{CI-Mean}$ (MPa)
L-1	25.35	0.65	6.15	49.20	18.64	0.22	18.75	20.56	19.66
L-2	25.56	0.26	8.19	86.46	60.20	0.16	32.57	36.09	34.33
L-3	25.16	0.43	7.08	72.18	29.52	0.19	26.87	29.12	28.00
L-4	24.91	0.60	6.34	50.28	24.07	0.23	20.05	18.77	19.41
L-5	25.44	0.28	5.78	55.39	35.14	0.19	19.48	18.95	19.22
L-6	24.41	0.89	4.57	35.69	14.43	0.28	14.19	12.56	13.38
$N_{ft-m} = 20$									
Rock type	$\gamma_d$ (kN/m <sup>3</sup> )	$n_e$ (%)	BTS (MPa)	UCS (MPa)	$E_{ti}$ (GPa)	$\nu_{ti}$	$\sigma_{CI(LSR)}$ (MPa)	$\sigma_{CI(VSR)}$ (MPa)	$\sigma_{CI-Mean}$ (MPa)
L-1	24.18	0.71	4.65	34.58	14.90	0.23	12.09	13.03	12.56
L-2	24.66	0.28	6.05	63.93	49.53	0.17	21.83	24.35	23.09
L-3	24.60	0.46	5.14	58.23	25.66	0.22	22.64	24.66	23.65
L-4	24.51	0.69	3.96	34.55	14.06	0.23	12.05	12.40	12.23
L-5	24.97	0.31	5.05	44.26	30.04	0.21	17.50	16.90	17.20
L-6	23.15	1.06	2.87	19.55	7.07	0.31	6.81	6.43	6.62

**Note:** Results obtained from core samples treated by magnesium sulfate tests in different number of cycles (e.g.  $N_{ft-m} = 10$ ).

## RESULTS AND DISCUSSION

Laboratory test results showed that the durabilities of limestones subjected to magnesium sulfate tests considerably decrease. Compared to the initial rock properties, the variations in selected rock properties due to progressive magnesium sulfate tests are listed in Table 3. Accordingly,  $\gamma_d$  of rocks were found to be the variable with presenting relatively minimal changes, whereas UCS seemed to be the most effected rock property under the influence of magnesium sulfate weathering tests.

It was observed that the mean value of  $n_e$  compared to the ones after 10 and 20 cycles of magnesium sulfate tests increased at an average rate of 8% (ROI = 3 – 14%) and 20% (ROI = 12 – 35%), respectively.

Table 3. Variations (in percentage) in several rock properties of limestones due to progressive magnesium sulfate tests.

Rock type	$\gamma_d$ (kN/m <sup>3</sup> )		$n_e$ (%)		BTS (MPa)		UCS (MPa)		$E_{ti}$ (GPa)		$v_{ti}$	
L-1	-2.01(*)	-6.53(**)	6.55	16.39	-10.74	-32.51	-24.53	-46.96	-13.98	-31.24	-3.88	-0.86
L-2	-0.93	-4.41	4.00	12.00	-20.09	-40.97	-9.00	-32.71	-13.65	-28.96	-4.09	1.75
L-3	-0.98	-3.19	10.25	17.95	-7.08	-32.55	-17.07	-33.10	-20.56	-30.95	-8.01	4.71
L-4	-1.07	-2.66	9.09	25.45	-9.81	-43.67	-18.31	-43.87	-21.47	-54.12	5.38	4.93
L-5	-1.39	-3.21	3.84	15.38	-8.83	-20.35	-17.43	-34.02	-10.81	-23.76	-2.54	9.14
L-6	-3.36	-8.35	14.10	35.89	-19.96	-49.74	-24.69	-58.75	-28.24	-64.84	7.22	20.15

**Note:** Negative and positive values indicate the rate of decrease (ROD) and the rate of increase (ROI) observed in rock properties, respectively. Values given in left (\*) and right (\*\*) columns indicate the variations in related rock properties determined after 10 and 20 cycles, respectively.

Mechanical rock properties such as BTS and UCS decreased at average rates of 36% (ROD = 20 – 49%) and 42% (ROD = 32 – 58%) after 20 cycles, respectively. The ROD in  $E_{ti}$  was found to be in the range of 13 – 28% and 23 – 64% for 10 and 20 cycles, respectively. However, the variation in  $v_{ti}$  values were changeable for investigated limestones. For instance, compared to the initial mean value of  $v_{ti}$  for grain-supported limestones (i.e. L-2), it decreased (ROD  $\approx$  4%) after 10 cycles but slightly increased (ROI  $\approx$  2%) after 20 cycles. For mud-supported limestones (i.e. L-1 and L-4),  $v_{ti}$  of L-1 decreased (ROD  $\approx$  4%) whereas  $v_{ti}$  of L-4 increased (ROI after  $\approx$  5%) after 10 cycles of magnesium sulfate tests. Generally, it could be claimed that  $v_{ti}$  of limestones slightly increase with progressive magnesium sulfate tests. However, the trend of axial and lateral strain rates was non-linear and therefore the variation in  $v_{ti}$  values of limestones fluctuated when axial stresses were around to be  $\sigma_z \approx 0.5\text{UCS}$ .

Focusing on the variations in stress-strain curves (e.g. Fig 2a) due to progressive magnesium sulfate tests, it was shown that, axial and lateral deformations non-linearly increase with increasing  $N_{ft-m}$  in magnesium sulfate tests. The stress levels when the unstable crack growth (where  $N_{ft-m} = 0$ ) began, were found to be in the range of  $\sigma_z \geq 0.76 - 0.90$  of the UCS for this study.

With progressive magnesium sulfate tests, crack propagation stresses occurred earlier than the above-mentioned stress levels. In parallel with this statement,  $\sigma_{CI}$  of limestones also decreased slowly. In general, crack initiation stress ( $\sigma_{CI}$ , MPa) levels of non-treated limestones varied between 0.40 – 0.42 of the UCS. With progressive magnesium sulfate tests,  $\sigma_{CI}$  values were found to be between 0.38 – 0.39 and 0.37 – 0.38 of the UCS after 10 and 20 cycles, respectively.

The findings obtained from this study reveal that the durability of limestones decreases with increasing  $N_{ft-m}$  in magnesium sulfate tests. Particularly, mud-supported limestones (i.e. L-3 and L-5) seem to have a greater resistance against magnesium sulfate weathering tests compared to the grain-supported ones (i.e. L-4 and L-6) for this study. However, this finding is only valid for the present study and therefore, number of samples should be increased to achieve a comprehensive understanding about the degradation processes of limestones.

## CONCLUSIONS

The present study covers a comprehensive laboratory investigation on the resistance of limestones against magnesium sulfate weathering tests. Core samples were subjected to saturated magnesium sulfate solution for 20 cycles in total and the variations in several rock properties were determined. The results showed that the durability of limestones decrease with progressive magnesium sulfate tests. The most effected rock property due to magnesium sulfate tests seems to be the UCS of rocks. Compared to the grain-supported ones, mud-supported limestones seem to have a greater resistance against magnesium sulfate tests. Last but not the least, long-term behavior of rocks could be assessed by accelerated weathering tests. As an inductive approach based on comparisons between natural and artificial environmental impacts on rocks, such investigations could also be beneficial for further studies.

## REFERENCES

- [1] Binal A., A new laboratory rock test based on free-thaw using a steel chamber, *Q. J. Eng. Geol. Hydrogeol.* 42(2), 2009, pp 179 – 198.
- [2] Ruedrich J., Siegesmund S., Salt and ice crystallization in porous sandstones, *Environ. Geol.* 52(2), 2007, pp 225 – 249.
- [3] TS EN 1367-1, Tests for thermal and weathering properties of aggregates – Part 1: Determination of resistance to freezing and thawing, 2009, pp 11.
- [4] TS EN 1367-2, Tests for thermal and weathering properties of aggregates – Part 2: Magnesium sulfate tests, 2010, pp 17.
- [5] Heidari M., Torabi-Kaveh M., Mohseni H., Assessment of the effects of freeze-thaw and salt crystallization ageing tests on Anahita Temple Stone, Kangavar, West of Iran, *Geotech. Geol. Eng.*, 35, 2017, pp 121 – 136.
- [6] Momeni A., Khanlari G., Heidari M., Hashemi S.S., The effect of cyclic weathering test on deterioration potential of granitoid rocks, *Geopersia*, 8(2), 2018, 143 – 156.
- [7] Köken E., Özarslan A., Bacak G., An experimental investigation on the durability of railway ballast material by magnesium sulfate soundness, *Granular Matter*, 20:29, 2018, pp 11.
- [8] ISRM, The complete ISRM suggested methods for rock characterization, testing and monitoring: 1974 – 2006 in: Ulusay R., Hudson J.A., (eds) Suggested methods prepared by the commission on testing methods, *Int. Soc. Rock Mech. (ISRM)*, Ankara, Turkey, 2007.
- [9] Dunham R.J., Classification of carbonate rocks according to depositional texture, *American Ass. Petroleum Geol.* 1, 1962, pp 108 – 121.
- [10] Pengfei L., Jianzhao H., Qingchi C., A volumetric strain-based method to determined crack initiation stress of low-porosity rocks, 5<sup>th</sup> Int. Conf. on Intelligent Systems Design and Engineering Applications, 2014, pp 106 – 108.
- [11] Nicksiar M., Martin C.D., Evaluation of Methods for determining crack initiation in compression tests on low-porosity rocks, *Rock Mech. Rock Eng.*, 45, 2012, pp 607 – 617.