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Short communication

Significance of the uncertainty level for the modeling of ground deformation ranges

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1. Introduction

In any domain of science, including the Earth Sciences, modeling relies on mathematical formulae used for generalizing properties of the modeled medium. Models aiming to predict the state of deformations on the surface, describe the propagation of the displacement state through the rock mass to the surface terrain.[1–6] Deformations of the rock mass or surface are a result of operation of stress caused by mining, drilling of tunnels or other similar activities. Regardless the degree of generalization, the model should describe the most important properties of the modeled phenomenon. On the other hand, it should be simple enough to enable efficient 3D modeling, without involving costly and advanced computer systems. The most important parameters of the rock mass should stay stable and unchanged over the modeling time. The quality of the modeling depends on the uncertainty of the model, e. g. uncertainty of particular variables and parameters and also components related to the generalization of actual conditions by the model. The uncertainty of the model, stemming from its simplification and its lack of likeness to the actual rock mass conditions, is sometimes treated as a systematic error.[7,8] However this approach is disputable. A linear model describes a nonlinear phase of movements in the rock mass with low reliability. The description of a phase in which the movement fully develops is relatively more accurate. The uncertainty of the result of modeling should be always indicated as it is important from the point of view of safety of an object that undergoes surface deformation. The values of displacements and strains should be established at the prediction stage. As far as the terrain surface is concerned, it is important to determine the range which frequently defines various degrees of hazard.[9,10] From the engineering point of view the uncertainty of the course of borderlines is an extremely important issue. This particularly matters for the range of negative impact, where the values of strains and deformations are low. Uncertainty of the model thanks to which the strain border line is represented by uncertainty of its parameters. The measure of this uncertainty can be determined with the reverse analysis method, i.e. by defining standard deviation of the model parameters. The main objective of the research lies in defining the methodology of predicting a boundary of safe horizontal strains for a given confidence level, with the assumed uncertainty of model parameters.

2. Background

In technology, the conception of range of influence is usually referred to any phenomenon that has a negative environmental impact.[11,12,8,13,14] This can be noise, source of radiation or underground tremor.[15–17] Having assumed that the results of a negative impact are strongest in the zone of action (within its source), and vanish with the distance from the center, one may try to determine the admissible range of impact. The border line will separate the zone of hazard from the safe area beyond this zone. Speaking about admissible range of impacts one has to tackle the problem of hazard and its precise definition. In the Earth Sciences hazard is frequently referred to the potential exceeding of resistance parameters of objects localized in the rock mass or on the surface (e.g. elements of tunnel housing, pillars in underground workings, houses or technical infrastructure).[6] Hazard is a qualitative category, which is frequently viewed as a probability of occurrence of a catastrophe (probability that the resistance of an object is exceeded and thus the object can be damaged.) This approach can be encountered in many publications, e.g.[18–21] The

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definition of resistance or strength of an object is a key element of such an analysis. Resistance is frequently defined as a tolerance to ground strains which have not lead to a considerable loss of usability of an object yet, e.g., [22] The artificial intelligence methods, e.g. artificial neural networks or fuzzy classifiers turn out to be very useful for investigating hazards in areas subjected to strains of ground (natural or anthropogenic) in the analysis of qualitative factors, e.g. usability.[23–25] These methods allow for rough evaluation of both mining impact and also resistance parameters of objects subjected to strains. In this way the uncertainty factors that are important for both aspects of the analysis can be incorporated, e.g. [25] When the rock mass stress are modeled, the uncertainty or erroneousness of variables of the model can be accounted for by numerous probabilistic methods, e.g. by frequently applied data mining methods (classification tree), Monte Carlo method or propagation of errors, thanks to which the uncertainty of deterministic parameters defining, e.g. the properties of the rock mass, can be included. Numerous authors worked on this method while determining the hazard in the rock mass with the use of numerical geomechanical models, e.g. [3,4,23,26] The uncertainty of data describing rock mass properties is frequently described with geostatic methods, as observed by, e.g.[27]

Experience reveals that the range of negative impacts on the rock mass can be determined on the basis of the uncertainty factor if the following conditions are met: (a) the model describing the displacement in the rock mass should be verified on many cases, and its usability in the model confirmed. (b) The variables and parameters of the model should be easily definable, independent and scarce. According to the recent Dutch investigations, models based on numerous variables and parameters (even if potentially very accurate) can be distorted and consequently the results of the prediction erroneous, e.g.[28] Therefore the number of parameters should be reduced while modeling strains and deformations of the rock mass. (c) The uncertainty of parameters of the model should be definable on the basis of scientific research methods. It would be best if the boundary values of particular variables in the model could be determined during extraction (geometry of deposit, geometry of designed mining panels, boundary conditions for convergence or compaction caused by extraction.) Importantly, the model should be locally parametrized. Parameters characterizing the properties of the rock mass (e.g. mechanical modules of rocks) should be determined from local samples and scaled to actual mining conditions. This also refers to the possible disturbances in the build of the rock mass.

Bearing in mind above conditions, further analyses were based on a stochastic model of the rock mass, the fundamentals of which were formulated by Litwiniszyn and Smolarski many years ago.[29,6] The stochastic models are frequently used for modeling strains and displacements of surfaces as they are based on the so-called influence function. Such models based on [30,31] were appreciated by specialists in many European countries. These models were very practicable currently in China and India ,[32,33] in the Australian hard coal basin (Newcastle area), and locally in the U.S.A.[34] Advantageously, these models have few parameters (usually 2 to 3), which significantly reduces the uncertainty of the results of modeling.

The basic aim of the research lies in identifying the range of negative impact of underground mining on the surface objects and uncertainty connected with the course of the border line. The analyses were undertaken as a direct response to the growing interest of energy and power industry who were willing to localize power stations in areas directly neighboring with the mining sites. It is also other branches of industry, which want to place their production in areas formerly subjected to the influence of underground mines. There are legal regulations all over the World, according to which the entrepreneurs bear the responsibility before the owners of the real estate staying under the influence of the mining activity. In this context it is absolutely crucial to localize the range of admissible, safe strains on a certain level of significance.

3. The research area

3.1. Characteristic of mining-geologic conditions

Investigations carried out within this project covered two major copper ore mining areas. The mine has a concession for

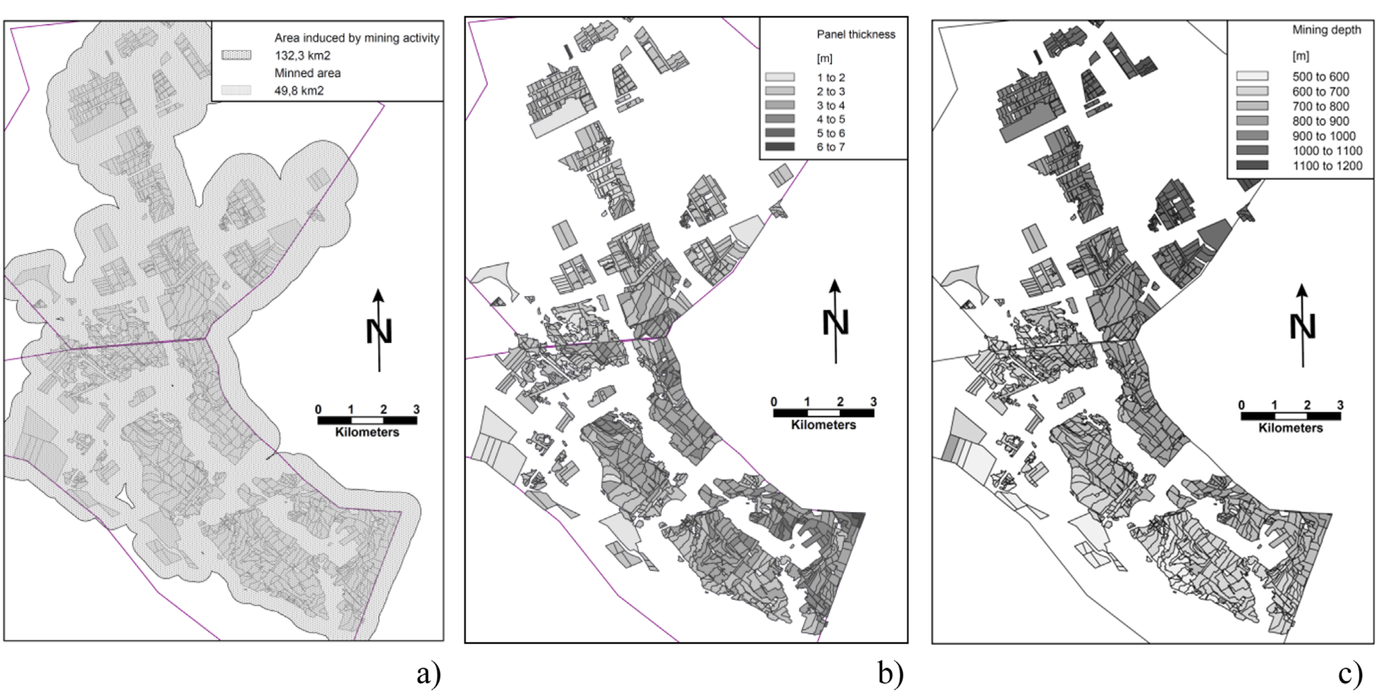

Fig. 1. Area of study (area influenced by mining(a), mining panels thickness (b), depth of extraction (c)).