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RHEOLOGICAL PROPERTIES OF THE SALT IN RELATION TO HALOKINESIS

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Abstract: The article relates to the rheological properties of the salt with respect to halokinesis mainly in terms of microstructures. Phenomena are considered in terms of a non-Newtonian fluid, taking into account anomalies for small scales. Experiment on reviewing the movements that have a direct correlation with the deformation (strain) and stress. In the study, the maximum observed values were measured: the incremental displacement vector and finite displacement vector. These indicators together with the deformations can give us full information about the stress of the rock mass. Results of studies in relation to the larger scale could provide consistent information on the salt layer rheology and resistance or susceptibility to deformation of the underlying layers of the above. This would be important information during the construction of mines (for example: oil rig, pithead, mineshaft), drift mining and strip mining.

Keywords: rheology, salt tectonics, halokinesis, non-Newtonian fluid, incremental displacement vector, incremental displacement vector

1. INTRODUCTION

Halokinesis is defined as movement of salt and salt bodies or another term is “salt tectonics”. The study of halokinesis includes subsurface flow of salt as well as the emplacement, structure, and tectonic influence of salt bodies used to refer to the study of salt bodies and their structures is "salt tectonics" (Allaby and Allaby, 1999).

Rheology is the study of the flow of matter, primarily in a liquid state, but also as "soft solids" or solids under conditions in which they respond with plastic flow rather than deforming elastically in response to an applied force (Schowalter, 1978).

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"Rheology" was coined by Eugene C. Bingham, in 1920, from a suggestion made by his copartner, Markus Reiner (Steffe, 1996). The term was inspired by the aphorism, *panta rhei*, "everything flows"(Barnes, 1982; Beris and Giacomin, 2014).

Rheological equations (or Constitutive equations) - mathematical statement of the relationship.

Elasticity: stress and strain are uniquely related. Knowing the stress, you know the strain and vice versa. This is the Hooke's law:

$$\sigma_n = Ee_l \tag{1}$$

where E is called Young's modulus of the material.

Poisson's ratio (v) is the ratio of radial contraction (expansion) strain to longitudinal extension (shortening) strain:

$$\sigma_n = Ee_l \tag{2}$$

Therefore, in a uniaxial extension or compression experiment, there will be lateral (radial) stress.

In an isotropic material, the elastic behavior is completely described if the Young's modulus and Poisson's ratio of the material are known by experiment.

$$\sigma_r = Ee_r = -\nu Ee_l \tag{3}$$

2. CONTINUUM MECHANICS

Newtonian fluids can be characterized by a single coefficient of viscosity for a specific temperature but rheology generally accounts for the behavior of non-Newtonian fluids, by characterizing the minimum number of functions. So we can relate stresses with rate of change of strain or deformation. In a non-Newtonian fluid, the relation between the shear stress and the shear rate is different and it can even be time-dependent. Well a constant coefficient of viscosity cannot be defined. The best indicators of rheological properties are those, which relate stress and strain rate tensors under many different flow conditions.

A Newtonian Fluid is one where there is a linear relationship between stress and strain-rate. The ratio of stress to strain-rate is the viscosity of the fluid. A Hookean solid is one where there is a linear relationship between stress and strain: the ratio of stress to strain is the modulus of the solid. Many materials have intermediate properties between those of a Newtonian fluid and a Hookean solid. If the properties are predominantly solid-like, the materials are called non-Hookean and the materials are described as viscoelastic. If they are predominantly fluid-like, they are called non-Newtonian and the materials are described as elasticoviscous.

To start over the study of the phenomenon of plasticity rheological layers halokinesis we need to consider the scale of the petrographic analysis with petrotectonics (microstructure), then go to the structural analysis (mezostructure), and finally to examine the scale of regional tectonics (macrostructure and megastructure).

2.1. MACROSTRUCTURES

Elements of both brittle tectonics and plastic deformation are the result of events that occurred earlier. Example of the behavior of layers of salt and salt domes are deformations of rock structures under the influence of subsurface movements of the salt masses. For example: salt with viscosity index of 1018 Pa·s leads to isolated box folds. Multiple salt layers (1018 Pa·s) result in long-wavelength folding (Ruh et al, 2012). These movements are caused by high pressure rocks lying above. Salt weight plasticized under pressure is driven by higher layers to the surface and burst through the rocks.

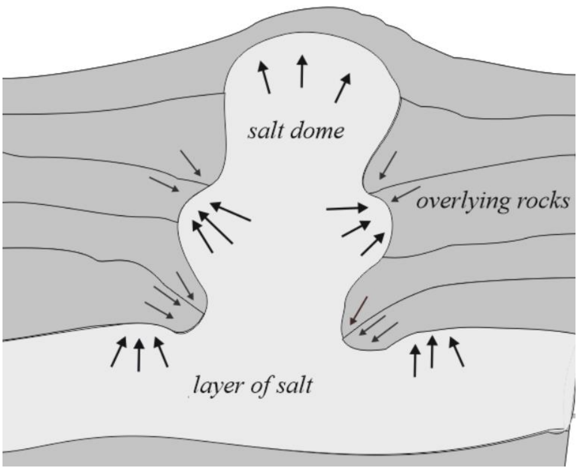

Fig. 1. Salt dome

The arrows in the above figure (Fig. 1) arrows illustrate the places where the most common is given the possibility of plastic deformation and brittle deformation and strains occurs most commonly. If changes have occurred in the structure of dome salt on the side of the arrow is on the dome side, if the arrow of injuries are on the side of the rock (Fig. 1). Directions of changes in the construction of the grains are usually arranged radially blows (Passchier and Trouw, 2005) and internally tangent to the surface defined by the boundary salt – rock (Vernon, 2004).

2.2. MICROSTRUCTURES

The rheology of rock salt during slow deformation in nature is controversial. Studies on microstructural propose that salt can be both -Newtonian and non-Newtonian viscous, and deformation is dominated by pressure solution and dislocation creep processes.

The deformation in rocks occurs as a result of many processes that take place on the scale of a single grain. Which of them will work in a particular case depends on factors such as lithology (Vernon and Clarke, 2008):

1. deformable mineral composition of rocks,
2. the intergranular solutions,
3. size of each particle,
4. privileged or particle orientation,
5. porosity and external factors such as:
    a. temperature,
    b. litostatic pressure,
    c. tension differential,
    d. pressure of the solutions in the intergranular spaces,
    e. size and type of deformation.

In the case of different classes of structures and tectonics departments taken into account the scale of the salt results are not the same- not in any scale you can see that the rate of deformation increases in an exponential manner, as it should be in the case of a non-Newtonian fluid. In small scales (microstructure) strain and deformation analysis gives a linear dependence, which would correspond to Newtonian fluids.

Rheology is a quantitative description of the rocks response to the stress. As a result of the stresses within the rock, it can react by halokinesis as follows:

1. elastic,
2. brittle,
3. brittle-ductile,
4. ductile.

Elastic deformation consist in that after the stress is removed the rock returns to its original shape. If the yield strength is exceeded (yield point) the rock starts to react brittle, ductile or brittle-ductile and the process of flow and strain accumulation begins (Blenkinsop, 2000).

In addition to the described yield strength rocks are permanent strain and the differential stress drops to zero the rock does not return to the pre-deformed shape. If the rock cracks (is crushed), it means the deformed brittle. In contrast deformation that involves a change in shape without crushing or cracking is referred to as ductile.

3. TEST

The experiment was to examine the microstructure and mesostructure representative samples. They were isolated seven units from two block of rock, which after a careful analysis using, inter alia, stereoscopic (dissecting microscope) and petrographic microscope (a type of optical microscope used in petrology or optical mineralogy to identify minerals in rocks and thin sections) has been structural microanalysis.

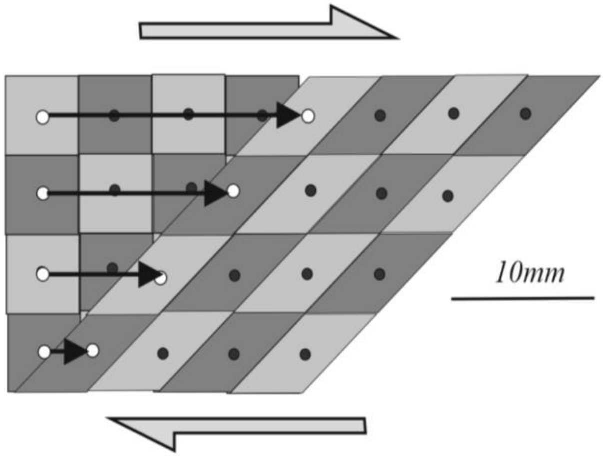

Fig. 2. Flow pattern

Consideration of the motion of particles in any medium, regardless of the forces that cause this movement is very convenient from the practical point of view. This approach is very useful in geology and geotechnics, because usually we have very little information on the forces which cause deformation process in rocks. Process of deformation growing with time is called progressive deformation. The difference between the initial and final deforming unit is defined as finite deformation.

In the above figure (Fig. 2), we have identified the gray arrow velocity vector - the direction in which the point move in the rock during deformation process. It describes both the speed of the particles of the material in question and the recovery of the direction of its movement. While the black arrows indicate the incremental displacement vector - section parallel to the velocity vector connecting any two places point which was discussed in the rock during deformation or displacement vector finite – episode merged place where there was a material point before and after deformation.

Table 1. Summary of measurements

representative sample	**unit (number of unit)**	**incremental displacement vector, mm**	**finite displacement vector, mm**
1	1(1)	2.0	8.1
1	1 (2)	3.0	6.8
1	1 (3)	2.0	7.3
1	2 (4)	1.0	5.2
1	2 (5)	0.5	6.2
1	2 (6)	0.2	14.3
1	3 (7)	1.0	4.3
1	3 (8)	0.2	4.6
1	3 (9)	0.4	6.8
1	4 (10)	1,0	3.6
1	4 (11)	3.0	9.1
1	4 (12)	0.6	11.0
1	4 (13)	0.2	8.9
1	4 (14)	0.7	7.3
2	5 (15)	1.1	8.4
2	5 (16)	0.3	8.3
2	5 (17)	2.5	6.3
2	6 (18)	2.3	14.1
2	6 (19)	2.4	5.8
2	6 (20)	5.1	6.7
2	6 (21)	2.3	5.9
2	7 (22)	3.2	7.6
2	7 (23)	1.9	4.1
2	7 (24)	1.8	6.3
2	7 (25)	2.3	4.6
arithmetic mean		**1.6**	**7.3**

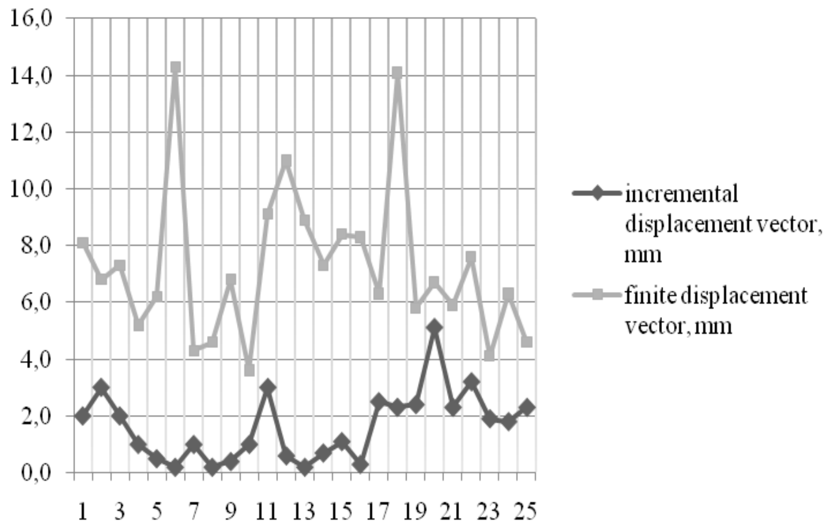

Fig. 3. Selection of the graphical data from Table 1. Abscissa: number of unit, ordinate, vectors.

In the experiment, the maximum observed values were measured: the incremental displacement vector and finite displacement vector. These indicators together with the deformations can give us full information about the stress of the rock mass. The average value for the incremental displacement vector is 1.6 mm, and the mean value of the finite displacement vector is 7.3 mm. Keep in mind that for a finite value of the displacement vector is the smallest value that can be read, but can be greater.

The observed samples were localized in the shear zone, which is an area with a very strong deformation. Their appearance is dependent on the conditions under which arose. The strongest deformation of rocks in the samples located in the central part of the shear zone and outside the extent of deformation decreases. Thus, the distribution of strain within the shear zone is heterogeneous. Outward deformation of the shear zones are continuous and no evidence of breaking the continuity of the rock. In both samples, we observe a little structure similar to the deformation wings.

4. SUMMARY

Examination of the rheological characteristics of the rocks is one of the methods for assessing their quality, so their knowledge seems to be very important and necessary in the design and future works.

The rheological properties of rock salt have a fundamental importance in predicting the long-term exploitation in underground mines. The investigation of deformed polycrystalline halite aggregates therefore helps understanding the role of deformation mechanisms that control deformation of rocks in general.

In this article, the obtained results indicate that the deformation runs in salt (halite) due to the deformation and deformation observed probably ran at shallow depths and/or in weak rocks.

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