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EMERGENCE OF CONTACT FILMS DURING FRICTION. GEOTRIBOLOGICAL FILMS

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Abstract: *Focusing on frictional surfaces contact interaction study, tribology comprises, beside the well-known friction/wear problems, the research on the genesis, characteristics and functioning of the films formed by the interacting materials in the contact zone. Self-building films occur as natural formations in frictional pairs, such as the secondary protective films, the frictional films formed at the selective transfer during friction, and the geotribofilms between adjacent geological rock plates in the Earth's crust. The paper focusses on the creation of geotribofilms, especially of the mica schist films acting as lubricating films in the shear zones of friction between rock plates. Specifics of geotribological processes and products are the wide extent of scales, which they cover, and the possibility for history time tracking of the entire development of the object.*

Keywords: *friction films, variety of tribology scale levels, geotribological friction films*

1. INTRODUCTION

Concentrating on the contact interaction of frictional surfaces, tribology comprises the study of the contact or the third or body. Surface interaction controls and manages the functioning of practically every mechanism and device through the friction in contact pairs. Friction - a resistance to movement - is a global natural phenomenon of energy transformation and dissipation during the joint action of two surfaces in contact. It represents the processes of deformation and damaging in tribo-couple surface layers. Through managing friction, tribology affects our quality of life.

Friction results of two opposite and simultaneous trends: accumulation of potential energy by the deformable contact and release (dissipation) of that energy. The first one defines the effect of deformation and leads to plastic deformation and damage. The second trend defines the heat effect of friction. Both trends reveal the mechanisms of transformation and dissipation of energy during friction. [1] The high pressures together with shift deformation (i.e. the main components of the friction process), deliver immense energy to the material, and high reaction velocities. [2]. This offers great potential for the utilization of tribology.

The most popular tribological studies are on friction, wear, and on the inserted in the contact coatings and lubricating layers. The emerged during friction films covering the contact surfaces belong to the self-building films. The study of the emergence, the mechanisms of creation and the characteristics of films of material between contacting bodies, and the consequences of film destruction of a film, which are usually manifested by severe friction and wear. Film formation between any pair of sliding objects is a natural phenomenon, a part of the self-regulation and self-organization, aiming protection of the systems' life, which can occur without human intervention. Film formation might be the fundamental mechanism preventing the extremely high shear rates at the interface between two sliding objects. [3]

In the fight for longevity and reliability of the tribosystems, against the disadvantages of friction [4], tribology considers the emergence of films between solid frictional surfaces in the contact evolution in diverse exemplary applications. Self-building films emerge based on the self-organization and synergy in the contact zone [1], and occur in mechanical and non-mechanical tribosystems. Numerous examples are known, like the secondary surface protective films [5,6], the frictional films formed at the selective transfer of material during friction [2,7-12], and the geotribofilms between adjacent geological rock plates in the Earth's crust which control the friction process [13,14]. Geotribology embraces contact processes on the most wide-ranging in scales: from micro/nano- level in the crystal lattice of rocks to mega- or geological level in the contact zones of Earth's crust geological plates, hence the study of geotribofilms is extremely interesting also in the quest of basic resemblance and similarity between friction on various scale level. [15,16]

The paper focusses on the creation of geotribofilms, especially of the mica schists films in the shear zones of friction between rock plates acting as lubricating films.

2. FRICTIONAL FILMS IN NON-MECHANICAL AND INORGANIC TRIBOSYSTEMS. GEOTRIBOFILMS.

The mechanical tribosystems with interacting metal surfaces (machines and mechanisms on the scale-level of everyday life), are subject to the most common tribology research. Non-mechanical sliding systems are not so popular in tribology; however, they provide many interesting examples of film formation during friction [2,3,13,14]. For instance, studies of the movement between adjacent geological plates on the surface of the earth reveal that a thin layer of fragmented rock and water forms between contacting rock plates. [13,14] Chemical reactions between rock and water under high temperatures (about 600°C) and pressures (about 100 MPa) improve the lubricating function of the material in this layer [2,3,13,15,16]. Laboratory tests confirm that sliding friction inducts emergence of a self-building film of fragmented rock at the interface with solid rock. A pair of self-sealing layers attached to both rock surfaces prevent the leakage of water necessary for the lubricating action of the layer of fragmented rock and water [3,13,14]. The thickness of the layer of fragmented rock is between 1 - 100 m, however it is insignificant when compared to the extent of geological plates and these layers can be classified as 'films' [3]. Sliding on a geological scale is controlled by the properties of these lubricating films, and this hints on a fundamental similarity between friction on different scale levels.

The example with geotribological films chosen in the paper refers also to another peculiarity and importance: geotribological products offer the opportunity to observe rests and relics of the whole period of the formation the object. The geotribological objects allow time tracking of the processes of the entire development: from the initial moment, passing through the changes and modifications, up to the ending of the process with new crystallizations.

3. TRIBOMETAMORPHIC MICA SCHISTS AS A LUBRICANT IN THE TECTONIC ZONES OF FRICTION

The chosen example comes from the inorganic nature, namely from the study of friction in the multiple shear zones of friction created in the Earth's crust during tectonic movements.

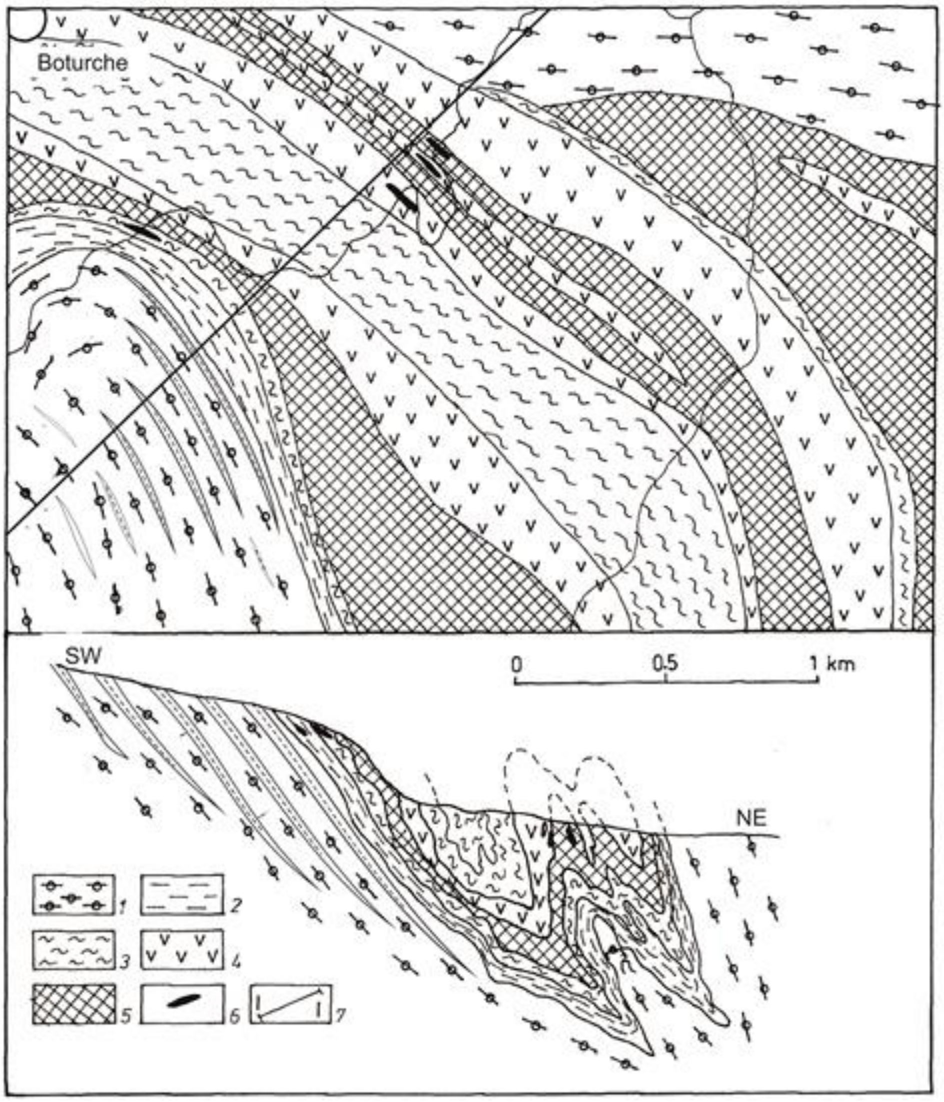

Figure 1. a. Geological map of a region in the Eastern Rhodopes, Bulgaria;

b. Section line I-I (magnified)

1. Porphiroblastic gneisses with thin films of mica schists; 2. Deformed gneisses; 3. Mica schists; 4. Amphibolites; 5. Serpentinites; 6. Amphibolitized eclogites; 7. Section line I-I

The mica schists are metamorphic rocks that form either by crystallization of fine-grained pelitic (clay or mud) sediments during regional metamorphism, or by the tribological processes in the shear zones of friction.

Mica schists are platy rocks and consist of micas (biotite, muskovite), feldspar, and quartz. They may define a planar texture (foliation – arrangement in planes) or a linear texture (lineation – for the minerals built long flakes in one direction). Schists form layers alternated with gneisses, marbles, and quartzites in the metamorphic complexes.

Mica schists form also in the shear zones of friction, which arise during tectonic movements and locate alongside lithological contacts - the boundaries between rocks of different mineral composition, with different physico-mechanical and rheological properties, and hence reacting in a particular of way to deformations. They represent the weak places in the rock complex, where there is most often a rupture and genesis of tribozones. Secondary shear zones may also occur parallel to the main zone (Figure 1) in a homogeneous rock due to the irregularity of stress in the rock formations.

The rock plates are moving along the shear zones, so friction occurs resulting in a process of deformation and disintegration of the rocks manifested as bending, cataclasis and mylonitization. At the same time, in the crystal lattice of the minerals also occur elastic and plastic deformations and appear defects: vacancies, dislocations and cracks, which lead to the complete decomposition of the mineral to molecular and atomic level. Mylonitization in the tribological zones of friction goes through elastic and plastic deformation of minerals, appearance of defects in the crystal lattice up to complete decomposition of the minerals to molecular and atomic level. The newly created tribomaterial is similar to the fine-grained pelitic sediments.

The mechano-chemical and tribochemical processes in the tribozone cause a rapid increase in temperature, pressure and chemical activation of the components in the restricted space of the zone, resulting in recrystallization of the crushed material and occurring of new metamorphic product. Some rocks such as granites and gneiss are composed mainly of quartz and feldspars (plagioclase and orthoclase), the latter rich in aluminum Al and silicon Si. These brittle minerals disintegrate quickly in the shear zones of friction. Due to the high temperatures and in the presence of water penetrating the zones, nuclear crystallization of muscovite is initiated in the disintegrated material. When rocks are basic (rich in Fe and Mg), biotite, chlorite, talc and antigorite, which also have a flaky appearance, are formed instead of muscovite.

Flaky minerals form thin monomineral films, which adhere to the surfaces of the tribozones, and if the disintegrated material is of larger quantity, they can form layers of rocks – schists, parallel to the main tribological zone (Figure 1), which contain new feldspars and quartz. The surfaces of the tribological zones covered with mica or schists favor the sliding of the rock plates or blocks, and thus play the role of lubricants in the subsequent tectonic movements.

A typical example of creation of mica schists as a result of tectonic friction was observed in the Eastern Rhodopes - the Bela River [17]. A zone of mica shale is formed on the steep contact between gneisses and a varied rock formation. They contain relics of feldspar clusters, evidence of their tribogenesis. These rocks now mark the main tribological zone of friction between heterogeneous rock formations. Parallel to the main zone in the gneiss substrate, parallel schists zones occur that gradually fall away, disappearing away from the contact.

4. CONCLUSION

1. Film formation between any pair of sliding objects is a natural phenomenon related to the tribosystem's striving to preserve its integrity and life through self-organization and synergy in the tribosystem ;
2. Self-building films occur during friction in mechanical and non-mechanical tribosystems;
3. Specifics of the geological non-mechanical systems, i.e. of the geotriboproducts, are the following:

   = Contact processes in geotribology develop on the most wide-scales: from micro/nano- level to mega- or geological level;

   = Geotribological objects allow time tracking of the processes of the entire development of the object;
4. The rocks deform, destruct, desintegrate and transform into fine grained materials in the shear zones of friction. A nuclear crystallization take place due to increased temperature in the tribozones of friction;
5. The destructed gneisses transform into muscovite mica schists with similar chemical composition;
6. As they are films on the contact surfaces, mica schists favour the tectonic movements playing the role of a lubricant.

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