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A PRIMARY STUDY ON INTERFACE CONDITIONS OF ICE SATURATED CLAY

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By using an electronic scanning microscope the interface conditions surrounding ice saturated soil particles, including montmorillonite, kaolinite and multi-mineral Neimong clay, are observed under different temperatures and solution consentrations. Results show that under certain temperatures below zero the shape and the thickness of unfrozen water film sorrounding the soil particles changes with soil type, temperature and concentration. The shape of the unfrozen water film surrounding the ice saturated clay particles can be divided into *three types: smooth, winding and overflow.*

INTRODUCTION

The interface conditions among soil particles, unfrozen water film, ice and vapor are important contents of the physics of frozen soils. The interface conditions formed under certain conditions result from comprehensive actions of various forces. The study in this area is of great significance for understanding water phase changing, cryogenic structure forming and water migrating in frozen soils, and also for physico-mechanics of frozen soils. For many years, few international studies have been done in this area. For instance, Anenian (1970) pointed out that the bond energy of water surrounding frozen soil particles decreases with an increase in the distance between water molecules and soil particles in the power form. Doctovalov (1973) showed that the structure of water layers changes with the distance to the soil particles and can be divided into three types: an active energy zone of bounded water, a non active energy zone of bounded water and an active energy zone of frozen water. Anderson and Morgenstern (1973) described the existant multi-layers of water surrounding mineral particles, i.e., the disordered zone located both at surfaces of silicate substract and ice, respectively, and the zone of enhanced order located between two disordered zones. But further research is difficult due to the limitation of study measures.

Recently, Chinese and Russian scientists made a joint effort to research the interface conditions of water surrounding ice saturated soil particles with different temperatures and concentration by using an electronic scanning microscope. The purpose of this paper is to present some observed results.

SAMPLE PREPARATION

There are three kinds of soils used in the test, i.e., kaolin and montmorillonite (taken from Russia) and multi-mineral Neimong clay (taken from China). The physical properties are shown in Table 1.

The kaolin, montmorillonite and Neimong clay are mixed with distilled water and a solution of natrium chrorite, respectively. The samples are quickly frozen under temperatures of 10 to 15 degree centigrade below zero. Afterwards, the samples are put into a chamber with a constant temperature for 48 hours. Then each sample is split into two pieces by a knife and spreaded on a fresh surface with the plexiglass solution with the same temperature as the sample, and then put away in a chamber with a constant tem-

Table 1 Physical properties of the clay

Soil type	Particle composition %			Liquid limit	Plastic limit	Gravity	Surf. area
	>0.05mm	0.05-0.002	<0.002	%	%	g/cm³	
Kaolin	0.5	44.7	54.8	51.0	31.0	2.64	30
Montmori.	0.2	46.7	53.5	114.0	44.0	2.45	560
Neimonclay	0.2	50.8	47.1	32.8	20.4	2.73	28

Table 2 Shape of unfrozen water film under different temperatures and concentration conditions

Soil type	Sample No.	Temperature,°C	Concentration,Mole	Film shape
Kaolin	G-01	-1.5	0	NOT SEEN
	G-02	-1.5	0.1	SMOOTH
Montmori-llonite	M-01	-1.5	0	SMOOTH
	M-02	-1.5	0.1	WINDING
		-1.5	0.1	OVERFLOWING
Neimong clay	N-01	-11	0	NOT SEEN
	N-02	-11	0.1	NOT SEEN
	N-03	-11	0.5	NOT SEEN
	N-04	-11	1.0	SMOOTH
	N-05	-5	0	NOT SEEN
	N-06	-5	0.1	SMOOTH
	N-07	-5	0.5	SMOOTH
	N-08	-3	0	NOT SEEN
	N-09	0.1	0.1	SMOOTH

perature for one or two days to allow the plexiglass solution to dry. Finally, the dried film is taken off the sample and the sample is used for observation on the electric scanning microscope.

RESULTS AND ANALYSIS

Table 2 shows the observation results. It can be seen that the unfrozen water film of ice saturated clay is not always observed under various conditions by electronic scanning microscope. For example, the unfrozen water film can not be seen in kaolin without solutes, and with a temperature of -1.5°C; for Neimong Clay without solutes and with a temperature of -3°C. And the thickness of unfrozen water film observed has reached the order of μm. The fact mentioned above indicates that the use of the electronic scanning microscope to investigate the interface conditions on ice saturated clay has its limitations, the thickness of unfrozen water film must reach the order of μm. But it also implies that the thickness of unfrozen water film of ice saturated clay is not uniform.

According to the calculation for the ice saturated Neimong clay under the conditions mentioned above, the average thickness of the unfrozen water film is less than 100 angstrom, but the unfrozen water film with the thickness of several microns is observed under the electronic microscope. The existence of unfrozen water film with such a large thickness can not be explained by the double layer theory. Olphen, H.V.(1977) pointed out that the thickness of the electric double layer decreases with an increase in the concentration (see Table 3). One of the possible

Table 3 Approximate value of double layer thickness in relation to concentration under constant surface potential

counter ion concentration mole/dm³	thickness of double layer,angstrom	
	one-valence ion	two-valence ion
0.001	1000	500
1.0	100	50
100	10	5

explanations is the freezing point decreases with an increase in concentration.

According to the observations, the interface conditions of ice saturated clay can be divided into three types: smooth, winding and overflowing (see Photos). From the photos it is shown

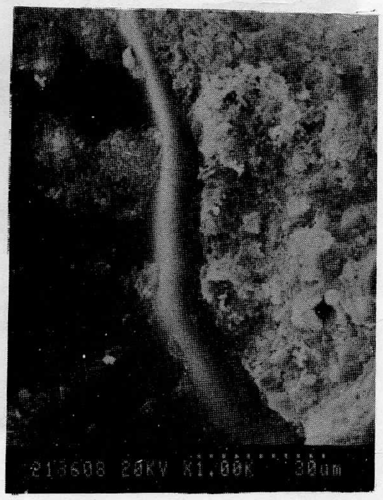

Photo 1 G-01

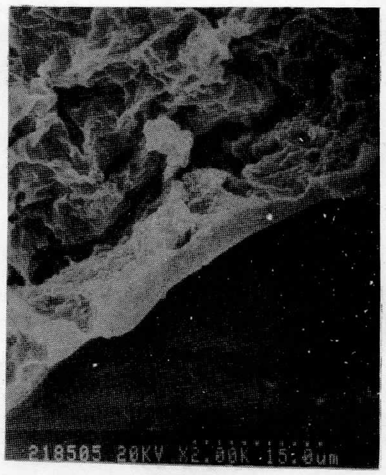

Photo 2 M-01

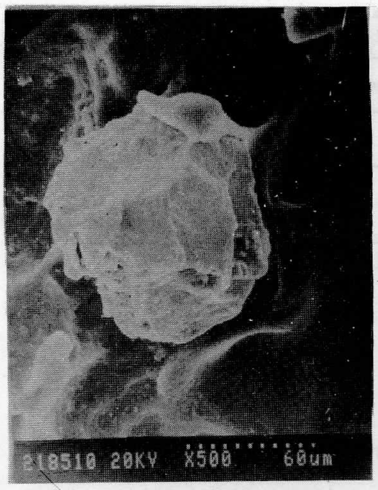

Photo 3 M-02

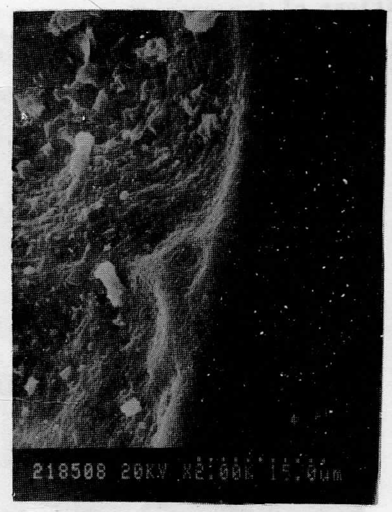

Photo 4 M-02

Photo 5 N-04

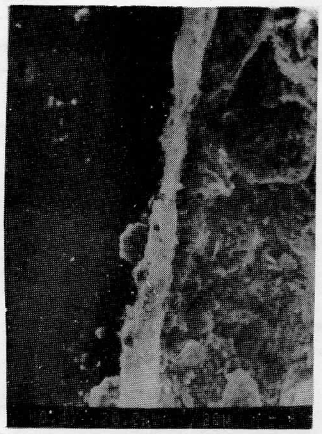

Photo 6 N-07

Photo 7 N-06

Photo 8 N-09

that for the smooth unfrozen water film, there is a white stripe band with uniform thickness surrounding the soil particle. For the winding unfrozen water film, its thickness changes from place to place and may be related to the distribution of charges on the surface of soil particles. For the overflowing unfrozen water film, the stripes of unfrozen water (white) and ice (black) are inlaid.

For montmorillonite all three types of interface conditions can be observed, but for kaolin and multi-mineral Neimong clay, only one type-the smooth one was observed, especially for Neimong clay, it only apears under higher concentration conditions. The fact mentioned above indicates that the interface conditions are related to the surface energy of soil particles. If the specific surface area is great, the complicated interface conditions may occur.

SUMMARY

The interface conditions of unfrozen water film is studied by using an electric scanning microscope. Observation shows that three types of interface conditions may occur in montmorillonite: smooth, winding and overflowing. For kaolin and multi-mineral clay with a lower surface energy, only the smooth one can be observed.

By using an electric scanning microscope, the shape of unfrozen water film can be observed only for those with a thickness greater than microns, which may be in the pores. Oifferent methods of studying the interface conditions between particles have to be found.

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