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Aspects on Some Problems of Geotechnical Chemistry

by Rolf Söderblom

Preface

The report presented here is a preliminary description of some chemical research work performed in connection with the investigations of quick clay deposits, mainly in the Göta River Valley.

After the first presentation of the results, the work has proceeded and the following should be added. As mentioned in the report, only some types of organic material possess dispersing properties, but there are also other types which seem to be of importance, as can be seen from consistency determinations. Reactions of the organic matter in the ground, e.g. oxidation from percolating water, may change the clay properties.

The study of the reactions, however, meets with difficulties in the separating of organic gels from minerals. Destruction of humus by hydrogenperoxide will change the behaviour of the clay. Thus, an increase of the salt content in the pore water will then not cause a stiffening of the clay. Interpretation of the test is rather intricate, owing to the obscurity of the influence on the mineral part.

Details from further investigations will be published later.

Stockholm, December, 1960.
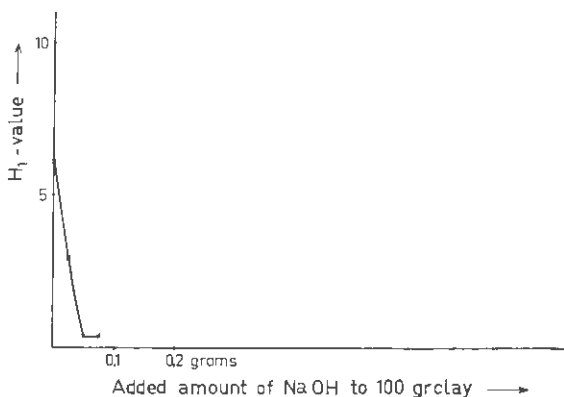
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Fig. 1. Influence of alkali on the H_1-value of a humic penetrated clay from Rosenkälla, Sweden (K 6766 sample 8124).

theoretical conceptions of the influence of dispersing agents, this clay should be quick when treated with alkali, which is shown in Table 1. The clay from this site is generally not quick owing to the fact that it is not sufficiently alkaline.

All conditions for quick clay formation of this kind are fulfilled at a site very close to the railway line between Broddby and Rosshyttan. A schematic view of the deposits is shown in Fig. 2. The peat deposit is about 2.9 m thick and, below this, there is a layer of postglacial clay about 0.2 m thick, followed by varved glacial clay. As shown in Fig. 4, the high sensitive clay begins at 3.5 m below ground surface and the sensitivity increases towards the bottom. The quick clay is found in the varved part of the clay deposit.

The laboratory examination performed on a core taken from this site gave the following results. The clay profile is in its full length permeated by humic acid from the peat deposit, which constitutes a dispersing agent for clay in alkaline solution. Thus, the H_1-value and the sensitivity of this clay profile depends on the pH-value. When a sample having a rather high H_1-value is treated with sodium hydroxide, the H_1-value will change as shown in Fig. 3. A slight change in pH may cause a sharp change in H_1 which shows that there can be very small differences in pH between sensitive and insensitive clays.

Table 1. The effect of alkaline solutions on humic-infiltrated clay

(Sample 4155, K 6766, Rosenkälla, Sweden)

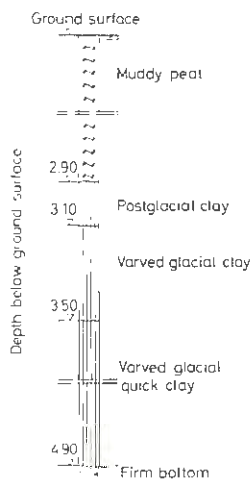| Treatment during 48 hours	Cone tests			Notes
	H_3	H_1	H_3/H_1	
None	67.4	11.3	6.0	
Water	25.0	1.37	18.3	
0.1 g NaOH in 0.5 1 H_2O	39.5	0.43	91.9	The clay will dissaggregate into dispersed powder. The surface destroyed
0.2 g NaOH in 0.5 1 H_2O	22.8	<0.34	>67.0	The surface disintegrated.
0.3 g NaOH in 0.5 1 H_2O	10.2	<0.34	>30.0	The surface disintegrated.
0.5 g NaOH in 0.5 1 H_2O	16.5	1.37	12.0	The sample quite destroyed.

Fig. 2. Schematic view of a clay deposit close to the railway line Broddbo — Rosshyttan, Sweden.
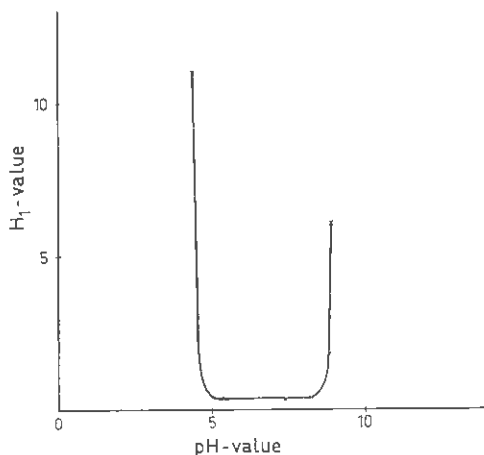
Fig. 3. Influence of alkali on the H_1-value of a clay from Rosshyttan (depth 3.0—3.1 m).

The pH as a function of depth is shown in Fig. 4 and, in agreement with the above discussion, the clay should be most sensitive at the bottom. The sensitivity curve (Fig. 4) shows that this is the case. The agreement between the pH and the sensitivity agrees with the above theory.

A photograph of a clay core is shown in Fig. 5.

A geological examination of the core has been made by T. N. A. Jerbo, Geotechnical Department of the Swedish Railways. The glacial part of the core was proved to be sedimented in fresh water, thus not in saline or brackish water. This clay contains a relatively large amount of organic material. By using a special type of pollen analysis, Mr. Jerbo has succeeded to confirm that
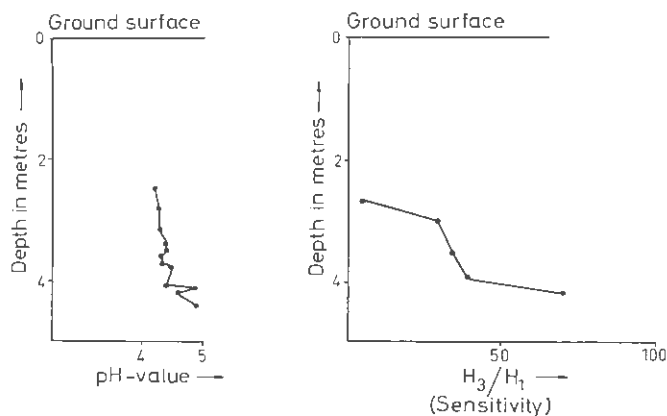

Fig. 4. Comparison between pH-value and sensitivity (H_3/H_1) for a humic penetrated clay from Rosshyttan.
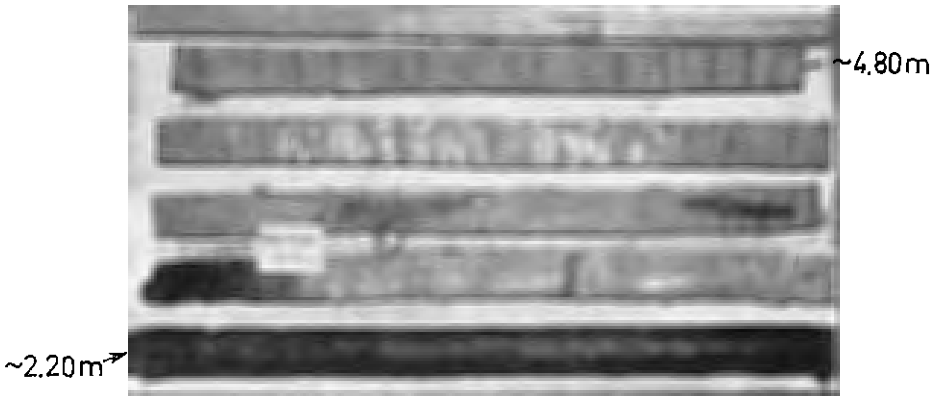
Fig. 5. Photograph of a clay core from Rosshyttan, Sweden.

the organic material in the clay is not derived from organisms sedimented together with the clay material. The clay has undoubtedly received its humus content by infiltration from the peat deposit.

Jerbo has also investigated the occurrence of peat and quick clay at various sites in Sweden and has already found some fifty places where quick clay peptisized by humic substances appears to exist.

Some of the most important places occur on the coast of the Baltic Sea where deposits of fresh water-sedimented quick clay are often situated in the vicinity of layers of organic material. Suspicions have arisen that the organic layer and the resultant clay destruction in its vicinity contributed to the extensive landslide in Kramfors and an examination will therefore be carried out as soon as possible.

Reports on the geological examination of the core taken from Rosshyttan and of the work in Kramfors will be published later by the Swedish Railways.

Quick clays of this kind seem to exist even in other countries. Newland and Alley (1955) describe a dark grey clay from Whangamarino, New Zealand, geologically proved to have originally been sedimented in fresh water. This clay underlies a 15-foot layer of peat and was found to be a quick clay.

In Switzerland, fresh water-sedimented quick clays have also been said to exist. Dispersing processes of the kind described above are mentioned by Hager (1948). He maintains that hydroxyl ions coming from the destruction of soil and clay minerals together with organic material will cause a dispersion of the soil material.

Grim (1948) points out that certain chemicals will change the orientation of the water adsorbed on the clay. He has also dealt briefly with the question of the adsorption of organic material on clay.

Emerson (1959) has shown that the organic material in sodium clays causes a dispersion of the clay.

On the other hand, the organic dispersing agents described in the present work do not necessarily consist chemically of sodium humate.

Bloomfield (1956) has made a detailed study of the dispersion of kaolinite by different leaf extracts. He found that the activity of extracts of *Dacrydium franklinii* leaves appeared to be caused by their polysaccharide content and that of *Agathis sautralis* bark by polyphenols. The active components of aspen leaves include a polysaccharide and an acid dispersing agent.

In our case, where the dispersing agents are formed by chemical processes in peat, it seems possible that polysaccharides, oxalates and similar components can also be formed, but a complete chemical study of these processes has not yet been carried out.

In this connection, the dispersing properties of lignin preparations (cf. Lawson 1951) should, in addition, be mentioned.

It is also of interest that tannin preparations (quebracho) are used as dispersing agents for clay in the drilling mud industry (cf. Rogers, 1948, and Alexander, 1946). Tannin can be formed by chemical processes in humus (German Patent, No. 708 466, 1941) and can play some part in the quick clay formation.

Influence of dispersing agents on the strength of a clay

In Sweden it is often necessary to reckon with dispersing reactions in natural clays. It is of interest to study the influence of these substances on the mechanical properties. A literature study shows that this problem has not yet been probed sufficiently. It has often been supposed that processes forming quick clays reduce the shear strength of undisturbed clays only slightly whereas the remoulded clays are strongly attacked — a rather conflicting supposition.

In order to study this question, some experiments were carried out. The first experiments with carbonate dispersing agents (cf. Söderblom, 1959, p. 731) confirmed chiefly the difficulty of influencing the shear strength of undisturbed clay. More systematic experiments with different kinds of dispersing agents showed that some peptizisers do in fact reduce the shear strength of undisturbed clays.

In Tables 2 and 3, a series of experiments illustrating this is shown. Slices

Table 2. The effect of peptiziser-solutions on a clay sample (2996)

Treatment during 24 hours	Cone tests			Notes
	H_3	H_1	H_3/H_1	
None	36.4	3.50	10.4	
1 g Na_2CO_3 0.5 1 H_2O	36.9	0.63	58.6	Crack in the sample. No disaggregation
2 g Na_2CO_3 0.5 1 H_2O	20.7	0.76	27.2	Some disaggregation
3 g Na_2CO_3 0.5 1 H_2O	14.7	0.47	31.3	Some disaggregation
1 g $Na_4P_2O_7$ 0.5 1 H_2O	29.0	< 0.34	> 85.3	The clay will disaggregate to dispersed powder. The surface destroyed
2 g $Na_4P_2O_7$ 0.5 1 H_2O	22.1	< 0.34	> 65.0	More disaggregated
3 g $Na_4P_2O_7$ 0.5 1 H_2O	30.4	< 0.34	> 89.4	The surface disaggregated

Table 3. The effect of acid-alkaline solutions on a humic-infiltrated clay

(Sample 4155, K 6766, Rosenkälla, Sweden

Treatment during 24 hours	Cone tests			Notes
	H_3	H_1	H_3/H_1	
None	101.0	14.3	7.1	—
Distilled water	37.8	8.55	4.4	Cracks in the sample, otherwise unchanged
0.1 g HCl in 0.5 l H_2O....	28.2	6.95	4.1	Unchanged
0.2 g HCl in 0.5 l H_2O....	43.2	10.0	4.3	Cracks in the sample, otherwise unchanged
0.1 g NaOH in 0.5 l H_2O..	57.1	3.23	17.7	Affected on the surface. Dispersed material precipitated
0.2 g NaOH in 0.5 l H_2O..	48.0	1.14	42.1	Strongly attacked, the sample almost disaggregated

of unremoulded clay were placed in solutions of $Na_4P_2O_7$ and Na_2CO_3 at different concentrations and the ions were permitted to diffuse into the sample for 24 hours. As seen in the tables, the influence on the shear strength may increase with increasing concentration of the agent.

The circumstances were found to be the same when peat-impregnated slices of clay were placed in different concentrations of NaOH.

These results indicate a reduction in the shear strength of a natural clay by means of dispersing agents, but the general problems associated with the dispersing process have not yet been definitely solved.

Suitable materials for studies of dispersing processes

Since a natural clay is of heterogeneous composition and is easy to separate into fractions of different particle sizes which react differently to dispersion and since the fractions vary relatively in quantity and activity from one clay to another, a different test material would be more suitable for our principle investigations.

The ideal material would be a synthetic clay having reproducible properties and being available in large amounts, but such a material has hitherto been impossible to find.

Because the clay fraction of the Swedish clays consists principally of illite, it would seem suitable to choose illite as a model material.

A fractionated and completely classified illite clay would be the best material in our case but, because of the difficulties involved in producing such a clay, we have initially chosen another material which is more easily obtainable.

In the present methodological studies, kaolinite was chosen as a rather pure material although unfortunately its properties differ to a certain extent from those of the Swedish natural clays. For example, kaolinite generally has a smaller water-adsorbing power than a Swedish clay. The dispersing effects seem

to be the same for kaolinite and natural clay and this fact determined our choise of kaolin for study purposes. However, the various samples of the same material appear to differ from each other, thus making it necessary to test the material carefully before use.

Model studies on kaolin

The dispersing effect depends on the water content of the system. This can be studied by measuring the dispersibility at different water contents. In such an investigation, the best method is to plot the results obtained in so-called consistence-curves for the system kaolin-water.

Table 4. Consolidation and dispersing of kaolin-silt and natural clay

Treatment	Cone test			Notes
	H_3	H_1	H_3/H_1	
Kaolin consol. 2 kg/cm² 4 hrs.	33.2	29.4	1.1	
Silty fine-sand (coarse material) cons. 2 kg/cm².	{295.0 95.0	2.05 2.05	143.9 46.3	Inhomogeneous
50 % kaolin + 50 % coarse material cons. 2 kg/cm² 4 hrs.	33.2	16.9	2.0	
Kaolin cons. 2 kg/cm² 4 hrs, treated with 1 g $Na_4P_2O_7$ in 500 ml H_2O.	—	—	—	Liquid
50 % kaolin + 50 % coarse material cons. 2 kg/cm² 4 hrs treated with 1 g $Na_4P_2O_7$ in 500 ml H_2O.	—	—	—	Liquid
Kaolin cons. 2 kg/cm² 4 hrs, treated with 0.2 g $Na_4P_2O_7$ in 500 ml H_2O.	—	—	—	Liquid
50 % kaolin + 50 % coarse materials cons. 2 kg/cm² 4 hrs, treated with 0,2 g $Na_4P_2O_7$ in 500 ml H_2O.	434	0,36	1205	
50 % kaolin + 50 % coarse material cons. 2 kg/cm² 4 hrs, treated with 1 g Na_2CO_3 in 500 ml H_2O.	526	<0,34	>1547	
50 % kaolin + 50 % coarse material cons. 2 kg/cm² 4 hrs, treated with 0.2 g Na_2CO_3 in 500 ml H_2O.	386	22.1	17.5	
Glac. clay recons. 2 kg/cm² 72 hrs. Treated with 1 g $Na_4P_2O_7$ in 500 ml H_2O 24 hrs.............	163	4.71	34.6	

EXPERIMENTAL PROCEDURE

200 grams of kaolin and 100 grams of water were carefully mixed and homogenized. The remoulded shear strength (H_1) was determined by a fall cone test. One ml of water was added from a burette, the mixture carefully homogenized and the resulting H_1-value determined. The experiment was continued in this manner until the H_1-value had decreased to a non-measurable quantity (< 0.34). H_1 was then plotted against the amount of added water.

In Fig. 6, the curve for the system 200 grams kaolin/100 grams water is shown with and without the addition of 1 gram Na_2CO_3 to 500 grams of clay as a dispersing agent. The dispersing agent causes the shear strength curve (H_1-value) to drop much more quickly but the curves seem to approach each other asymptotically at high and low water contents.
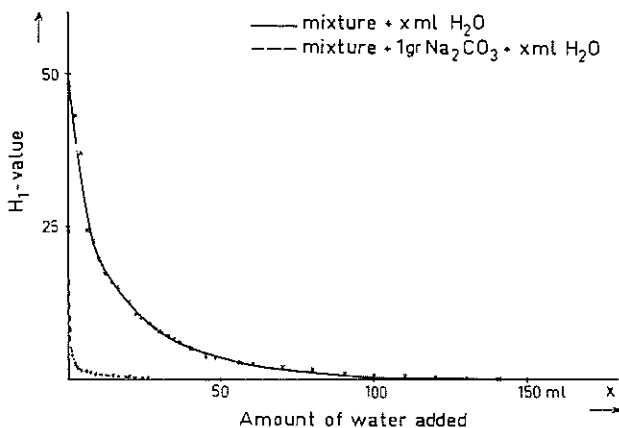
Fig. 6. Influence of water on the H_1-value of a mixture of 200 g
dry kaolin and 100 g water.

The same effect was found when using Swedish natural clay. Fig. 7 shows
the corresponding curve for Frescati-clay and carbonate. The curve is very
similar to the kaolin curve. Possibly, this phenomenon may explain why quick
clay upon consolidation loses its sensitivity.

If kaolin is dispersed with $Na_4P_2O_7$ and the mixture partly dried, an elastic
material is obtained which can be formed into a ball. When rapidly stressed,
this material gives a brittle rupture and the 100 grams cone test gives a pene-
tration of only a few millimetres. The substance obtained is thus rather firm.
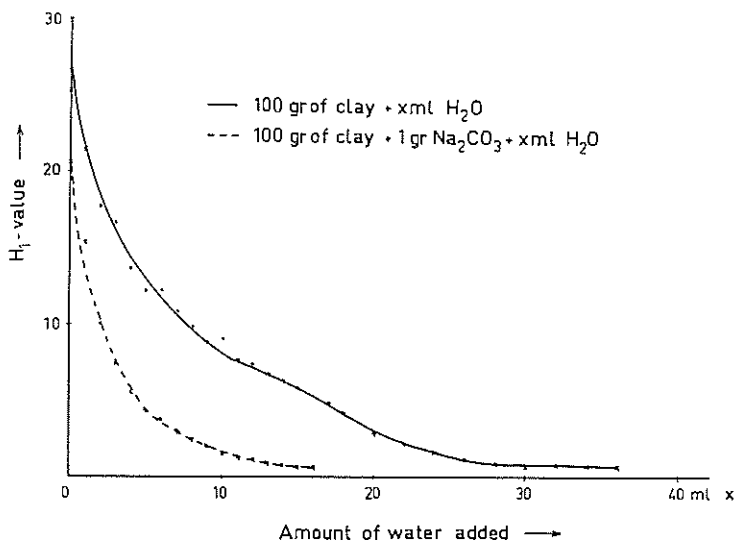

Fig. 7. Influence of water on the H_1-value of a remoulded clay from Frescati,
Sweden.

If left under gravitational load for a few seconds, it will disaggregate, giving rise to a shear strength which is too low to be determined by the cone test.

This seems to indicate that the clay has lost its cohesive properties showing dilatancy.

SENSITIVITY EXPERIMENTS

If an unremoulded dispersible clay sample is treated with a solution of a dispersing agent, no essential difference in the mechanical properties is in most cases noticed until the sample is remoulded and broken down. The fact that the unremoulded shear strength may be differently affected is of special interest for reactions of this kind.

The results obtained in these experiments have lead to the following preliminary point of view.

The quick clays examined are built up of a skeleton of uninfluenced coarse material which is non-cohesive, and this is mixed with cohesive material in which the cohesive properties are reduced by the influence of dispersing agents. The clay is thus sensitive to mechanical changes in the non-cohesive skeleton.

Balls made of kaolin and water were placed in various solutions of a number of dispersing agents of different concentrations. In all cases, the balls were disaggregated to a powder.

The experiments were extended to comprise tests on kaolins which had been consolidated before the chemical treatment. A solution of pyrophosphate was allowed to trickle through the sample after concluded consolidation. Also in this case it was impossible to measure a sensitivity because the sample became a liquid.

This seems to point to the difficulties of building up a high sensitivity by dispersing pure clay material.

In the literature it is concluded that a salt-coagulated material is necessary in order to form a metastable sensitive product. However, the pronounced tendency of the glacial clays to become quick upon treating with dispersing agents and, in particular, the natural fresh water sedimented quick clays contradict such a conclusion.

According to the above, sensitivity should be formed if, instead of pure kaolin, we use kaolin mixed with coarser material. For this reason, consolidation experiments were performed on mixtures of kaolin-silt, and dispersing agents were allowed to trickle through the sample exactly as in the use of pure kaolin. By careful dispersion, very high sensitivities were obtained. If the influence is made stronger, the colloidal material will begin to flow and the system will disaggregate similarly to the case of a natural clay, cf. p. 373.

In natural quick clay, it seems possible that organic gels will give rise to an increased viscosity.[1]

The organic material in a clay appears as several different chemical substances — some of which possess dispersing properties. This points to the impossibility of getting a relation between the content of organic dispersing agents in a clay and the carbon content.

As mentioned above, it is only the colloidal fraction of a natural clay which is influenced by a dispersing agent. Preliminary experiments have shown that even the colloidal fraction of a clay contains undispersible constituents.

Dispersibility of different types of clays

Not all types of Swedish natural clays are influenced by dispersing agents and the influence seems to differ for various dispersing agents. Pyrophosphates and oxalates seem to reduce the remoulded shear strength of most Swedish clays but it is very common to find clays that are only slightly affected by carbonates and humates.

Hitherto only qualitative experiments concerning these effects have been made, i.e. we have investigated whether a specially treated clay is dispersible or not. The preliminary tests will be supplemented by quantitative tests.

It is possible by chemical means to transform an undispersible clay into a dispersible form and it seems that the positive ions of the system play a decisive rôle.

The content of exchangeable ions in all the systems investigated was below the critical value specific for the system in question with regard to its mechanical stability. The tests showed essentially that Na^+ Ca^{2+} and Fe^{3+} clays are dispersible. If an undispersible clay is boiled with NaCl, $CaCl_2$ or $FeCl_3$ and the clay is then filtered off and leached, it becomes dispersible. The effect appeared to be greatest in the case of Fe^{3+}.

EXPERIMENTS

The material used was black sulphide clay from Älvängen having the geotechnical constants shown in Table 5. The first step in the examination was to expose the sample to salt leaching. According to Table 5, this treatment did not seem to give a quick clay. In both the natural state and in the leached state, the clay was undispersible by humates and carbonates. When the clay, was boiled with dilute HNO_3, the Fe^{2+} sulphides were dissolved and the iron

Table 5. Influence of salt leaching of the properties of clay
from Älvängen, Sweden

Treatment	Cone tests			Re-sistance, electr. Ω	Notes
	H_3	H_1	H_3/H_1		
None	128	24.3	5.3	34	Black postglacial sulphide clay. Not dispersible.
Dialysis for 3 weeks........	52	12.2	4.3	620	Slightly dispersible.
Original clay treated with 1 g Na_2CO_3 100 g clay ..	—	24.3	—	—	Experiments on remoulded clay
Dialyzed, treated with 1 g Na_2CO_3 100 g clay	—	3.06	—	—	

was oxidized to Fe^{3+}, this treatment thus corresponding to a boiling of undispersible clay with $FeCl_3$, and according to the foregoing the clay became dispersible after leaching. The same effect was obtained when the clay was exposed to water dialysis of a long duration, the iron becoming oxidized to Fe^{3+} and the colour of the clay changing from black to grey. Natural oxidation processes seem however to change this Göta River clay to an easily dispersible material.

Field examinations in the Göta River Valley

The results of the examination of clay from Älvängen showed that salt leaching alone is not sufficient for making the clay from the Göta River Valley highly sensitive. On the other hand, it is possible to do this by a suitable chemical treatment and subsequent exposure of the clay to a dispersing process. This indicates the possibility of the existence of natural dispersing processes in the valley and it seems to be of great importance to ascertain whether or not this is the case. This has revealed quite new aspects concerning the question of clay destroying processes.

The rather rich occurrence of brown mud and peat deposits in this valley and on the ridges points to the possibility of humic dispersing processes similar to those at Rosshyttan.

At certain levels, the clay also has permeable layers of silt and sand. In many cases, brown-coloured humic water flows through these layers. This water is relatively acid and possesses a certain hydrostatic pressure.

A clay having such a layer is shown in Fig. 8. Humates penetrate into the clay from this layer. The permeation takes place under acid conditions according to Forslind (for instance, 1948), and may give a stabilization of the water lattice and thus no humates penetrate the individual clay crystals and the clay is not dispersed. At a greater distance from the layer, the clay is alkaline and thus sensitive to the influence of the humates.

The insensitive clay in the vicinity of the layer would on the other hand be easily dispersed by alkali, a fact which is employed in the following.
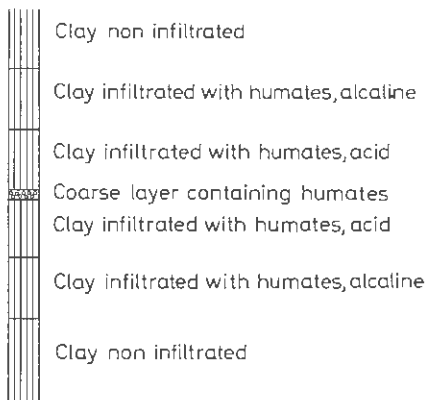
Clay non infiltrated

Clay infiltrated with humates, alcaline

Clay infiltrated with humates, acid

Coarse layer containing humates
Clay infiltrated with humates, acid

Clay infiltrated with humates, alcaline

Clay non infiltrated

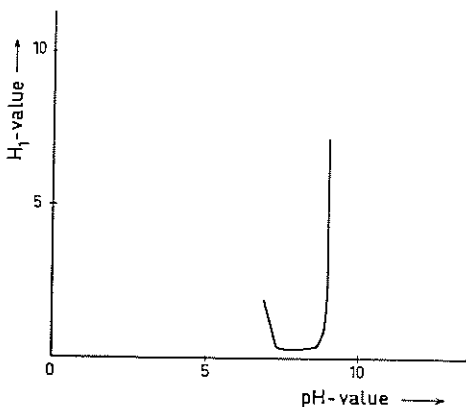Fig. 8. Penetration of humates in a clay containing a permeable layer.

Fig. 9. Influence of alkali on the H_1-value
of a clay from Göta, Sweden (depth
2.80 m).

Fig. 9 contains a curve illustrating the influence of alkali on a clay from Göta taken at a level where we have to expect humic infiltration at a sensitivity minimum. The H_1-value is lowered by alkali and the curve for the H_1 at different pH is similar to that obtained for the Rosshyttan clay. This indicates clearly the occurrence of processes of the same kind in both cases. Other similar experiments have shown that dispersing processes of this kind are probably relatively common in the Göta River Valley.

Examination of the dispersibility of natural clays have hitherto not been carried out systematically, due to the short time which has elapsed since the detection of these processes in Nature. We have therefore first of all attempted to find a suitable field method.

The method adopted is as follows:

The sensitivity and shear strength is measured by vane borings. Salt sounding curves are taken parallelly. If the clay is salt, this seems to be sufficient for the clay to be assumed insensitive. Hitherto we have not found salt quick clays in Sweden. According to Newland and Alley (1955), such clays exist at least in New Zealand.

If the clay is not saline and not quick, it is tested for dispersibility. For simplicity, remoulded samples are taken with a side-intake sampler from every 1/2 metre. The H_1-value is determined by a cone test and, thereafter, the sample is made alkaline with sodium hydroxide until the H_1-value has reached a minimum. The quotient of the H_1-value in the natural state and the value in the alkaline state is a measure of the dispersibility and the humic permeation of the clay. It is also a rough measure of the sensitivity which, in this special case, can arise as a consequence of increased alkalinity.

If the clay is not dispersible by sodium hydroxide and is not quick but there is nevertheless a peat deposit, an examination is carried out to discover whether humate isolated from the deposit will disperse the clay or not. If the clay is dispersed by humate, it is possible that the dispersing agent has not reached the clay. If not, it is considered to be an undispersible type and the possible chemical reactions which may give rise to dispersibility are then studied.

Table 6. Influence of alkali of clay samples from a profile from Intagan, Sweden

Depth below ground surface in metres	H_1-value before treatment	H_1-value after treatment	Dispersibi-lity	pH-value	Notes
3	28.4	25.0	1.1	6.8	
3.5	16.9	12.2	1.4	7.2	
4.5	7.1	6.9	1.0	7.5	
5	5.5	3.8	1.4	7.8	
6	1.5	1.3	1.2	7.9	Disp. with peat extr. 4.5
9	5.8	4.4	1.3	7.9	
13	8.1	5.8	1.4	7.9	

By examinations of this kind, we have found satisfactory support for our theories in a profile taken from a site near Intagan, Göta River Valley. The strength reduction for sodium hydroxide is very low near the river. Here isolated humates are dispersible (Table 6). The clay is rather alkaline in the whole profile and, at some levels, it is highly sensitive. This shows that the insensitive parts of the profile in this case probably lack sufficient amounts of dispersing agents.

At a greater distance from the river (about 500 m), the clay is more dispersible by alkali (Fig. 10). This indicates a greater permeation than that near the river. The clay is most sensitive at the bottom where it is also most alkaline.

At a still greater distance from the river, the clay is very insensitive but shows a great dispersibility when treated with sodium hydroxide (Fig. 11). This indicates a high permeation. At depths of 3.5 and 5.5 m, there are distinct layers of sand which are brown-coloured due to the flowing water. At these levels (especially at 5.5 m), the pH value shows a minimum and the H_1-value reaches a maximum. According to the theory given here, the H_1-value should be low at levels where the pH is high and the figure also shows that this is in fact the case. In the vicinity of the coarser layers, the clay should show the highest dispersibility and this too appears to be correct. If this clay is alkalized, it will show the highest sensitivity at the levels where it is most dispersible and, if the permeation is the same at a place where the clay is
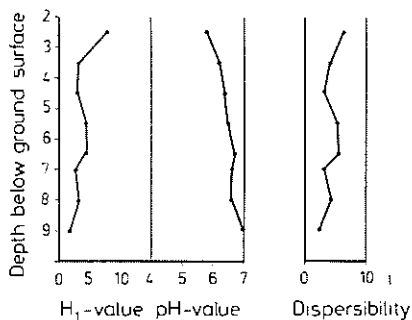

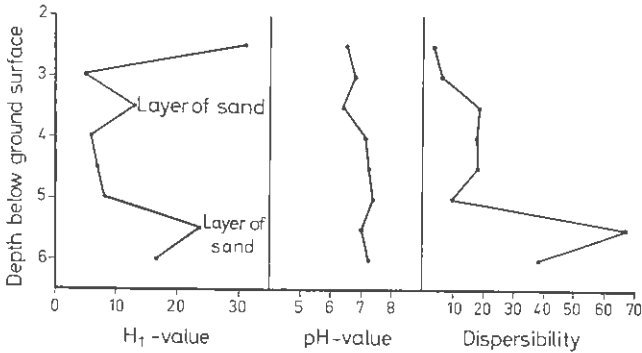Fig. 10. Influence of alkali on a clay profile from Intagan, Sweden. Depths in metres.

Fig. 11. Influence of alkali on a clay profile from Intagan, Sweden.
Depths in metres.

more alkalized, the sensitivity curve should correspond to the dispersibility
curve. Some sensitivity curves from this section indicate such a relation (Fig.
12).

The results obtained show that, in this section, we have to reckon with a
permeation of humic material coming from the vicinity of the ridge and fol-
lowing the coarser layer in the clay. An examination showed that, on the top
of the ridge, there are marshy grounds containing peat with dispersing prop-
erties. Maps indicate that peat deposits of this kind are common in the Göta
River Valley and consequently we must often reckon with processes of this
kind. The lateral destruction of the clay will also explain why quick clays
often occur in a certain region situated between the river and the ridge.

Natural carbonates and other agents may play an important part but, owing
to the obvious character of the humate processes, the possible carbonate proc-
esses have not yet been examined.

It is of interest to investigate whether a correlation exists between large
landslides and peat deposits. Preliminary examinations have been made in
Göta and Surte. In Göta, there is a large deposit containing a strong dispersing
agent and this deposit has two outflows where permeation may have occurred
and which are situated behind a recent large slide. In Surte, too, some peat
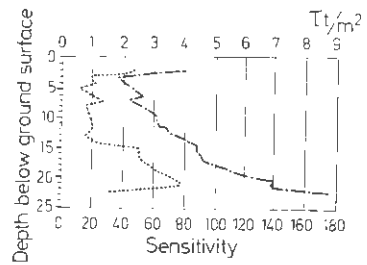deposits can be found behind the landslide there.

Fig. 12. Shear strength, to the right, and sensitivity
curves of a clay profile from Intagan, Sweden.
Depths in metres.

References

ALEXANDER, J., 1946: Colloid Chemistry. Vol 6 p. 518—522.

BLOOMFIELD, C., 1956: The deflocculation of kaolinite by leaf extracts. — Trans. Intern. Congr. Soil. Sci. 6. Congr. Paris. Vol B p. 27—32.

EMERSON, W. W., 1959: The Structure of Soil Crumbs. — J. Soil Sci. Vol 10 Nr 2 p. 242.

FORSLIND, E., 1948: The clay-water system. — Swed. Cement and Concrete Res. Inst. R. Inst. Technol., Stockholm, Nr 11.

GRIM, R. E., 1948: Some Fundamental Factors Influencing the Properties of Soil Materials. Proc. 2. Intern. Conf. Soil Mech. Found. Engng. Vol 3 p. 8—12.

HAGER, G., 1948: Die Kolloidbestandteile des Bodens und die Methoden ihrer Erkennung in Handbuch der Bodenlehre, Bd 7 p. 74.

LAWSON, L. L. and KEILEN, J. J., 1951: Pinewood Lignin as a ceramic deflocculant. — Amer. Cer. Soc. Bull. 30 p. 143—147.

NEWLAND, P. L. and ALLEY, P. H., 1955: Results of some Investigations on two Sensitive Clays. — New Zeal. Engng. Vol 10 p. 403—406.

ROGERS, W., 1948: Composition and Properties of Oil Well Drilling Fluids, p. 284 ff.

SÖDERBLOM, R., 1959: Aspects on some Problems of Geotechnical Chemistry. — GFF Bd 81 H 4 p. 727—32.