

Electrokinetic solid-liquid separation of an ultrafine kimberlite suspension*

by W. WILMANS† and J.S.J. VAN DEVENTER‡

SYNOPSIS

Electrokinetic dewatering of kimberlite slime under constant direct currents of 0,5 to 2 A and dewatering under constant applied potentials of 16,5 to 46,5 V are considered. The combined effects of electrophoresis and the addition of $8,3 \times 10^{-3}$ M Mg^{2+} ions on the one hand, and 1 to 10 p.p.m. of the anionic polyacrylamide flocculant Praestol 2935 on the other, were investigated in a 3-litre Perspex electrophoretic cell. The electro-osmotic dewatering experiments were conducted in a 3-litre Perspex electro-osmotic cell at various electrode spacings, as well as with a moving anode (top electrode).

During electrophoretic dewatering, the zeta potential of the kimberlite particles did not change significantly, whereas the pH and temperature showed marked increases with time. The addition of Praestol 2935 enhanced the settling of the sludge bed owing to the additional effect of flocculation. The addition of electrolyte $Mg(ClO_4)_2$ retarded the separation process, partly as a result of gel formation in the slurry. During the electro-osmotic experiments, the rate of dewatering was found to be approximately proportional to the applied constant direct current, and to be independent of the electrode spacing. In general, electro-osmotic dewatering seemed to be more energy-efficient than electrophoretic dewatering.

SAMEVATTING

Elektrokinetiese ontwatering van kimberlietslyk by konstante gelykstrome tussen 0,5 en 2 A asook ontwatering by konstante spannings tussen 16,5 en 46,5 V word bespreek. 'n Perspex elektroforetiese sel met 'n volume van 3 liters is gebruik om die gekombineerde effek van elektroforese tesame met die byvoeging van $8,3 \times 10^{-3}$ M Mg^{2+} -ione enersyds, en die byvoeging van tussen 1 en 10 d.p.m. anioniese poliakrielamied flokkulant Praestol 2935 andersyds, te ondersoek. Elektro-osmotiese eksperimente met verskillende elektrodespasiërings asook met 'n bewegende anode (boonste elektrode) is uitgevoer in 'n Perspex elektro-osmotiese sel met 'n volume van 3 liters.

Gedurende elektroforetiese ontwatering het die zeta-potensiaal geen noemenswaardige verandering getoon nie, alhoewel die pH en temperatuur duidelik toegeneem het met tyd. Die byvoeging van Praestol 2935 bevoordeel die uitsakking van die flodderbed a.g.v. die addisionele effek van flokkulasie. Die byvoeging van 'n elektrolyt $Mg(ClO_4)_2$ benadeel gedeeltelik die skeidingsproses a.g.v. "gel"-vorming in die flodder. Gedurende elektro-osmotiese eksperimente is gevind dat die tempo van ontwatering benaderd eweredig is aan die konstante gelykstroom en onafhanklik is van elektrodespasiëring. In die algemeen is gevind dat elektro-osmotiese ontwatering 'n beter energiebenutting lewer as elektroforetiese ontwatering.

Introduction

It is well known that South Africa is experiencing a chronic shortage of water. Although the country is fortunate in having rapidly expanding mining and metallurgical industries, those industries are major consumers of water and depend heavily on its availability. This is the factor that makes the recycling of water in these industries of such vital importance. Other countries, including Australia, Botswana, and the U.S.A., depend largely on recycled water to meet their requirements.

Several methods are used internationally to recycle and re-use water in the mining and metallurgical industries. The use of thickeners to decrease the concentration of solids in water is a well-known and established practice, and flocculants are frequently used to enhance the consolidation of solids in suspension. Filtration is being used at a number of mines, and is a technique of solid-liquid

separation that has been researched thoroughly.

However, filtration and thickening fail to produce clarified water from slimes containing a substantial amount of small (sub-micrometre) clayey particles. Kimberlite slimes produced in the diamond-mining industry in Southern Africa contain such fine particles^{1,2}, which hardly settle to a compact sediment. The recovery of water for recycling to the treatment plant is therefore impeded, while land suitable for the construction of further slimes dams is no longer readily available.

These clayey kimberlite particles possess a built-in negative surface charge², which can be exploited in an external electrical field³ to accomplish solid-liquid separation³.

This paper describes the use of electrokinetic methods to dewater kimberlite slimes on a laboratory scale.

Industrial Applications

Although very little laboratory testwork has been done on the use of electrokinetic methods for solid-liquid separation, there are some industrial applications of this principle⁴.

Sprute and Kelsh³ described such an application at the Henderson Mine in Colorado. Underground slimes are dewatered and consolidated in two large collection pits

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† Post-graduate student.

‡ Senior Lecturer.

Both the above of the Department of Metallurgy, University of Stellenbosch, 7600 Cape Province.

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by the application of a direct current of about 400 A. In this application, electro-osmosis is used as a mechanism for separation. The slimes are treated electrically, and water is drained at the bottom of the pits to a collection sump. The authors claim that the process is economical and practical.

Similar work was done in tests on mines in Idaho and Mexico⁵. The three-electrode system used in the tests divided the material into two layers, the upper layer containing slimes that resisted dewatering, and the bottom layer containing coarse, easily drained material. A direct current of 55 A was applied alternately to the two layers, yielding a sufficiently dry and firmly consolidated slime after about 2,5 hours.

Lockhart and Strickland⁶ investigated the use of electro-osmosis to dewater tailings ponds at a coal washery. Low voltages were used over long periods of time to produce a 'spadeable' solid (of 60 to 70 per cent solids content). The energy consumption during these field tests varied between 14 and 30 kWh per ton of dry solids. Thus, the large-scale electro-osmotic dewatering of tailings ponds seems to be a feasible proposition in the case of coal tailings.

Theory of Electrokinetic Dewatering

Slurries containing fine clayey particles can be dewatered and consolidated by the application of a direct electric current if the partially immobile clay particles carry an electrostatic charge relative to the liquid in the slurry³. Siliceous clay particles, such as kimberlite, are normally charged negatively with respect to the surrounding water owing to the greater solubility of positive ions associated with these particles, and ion deficiencies in the interior of the clay particle⁷.

The surface of the particle, once charged, attracts ions of the opposite sign towards it, but they are retained in the medium by virtue of their thermal or kinetic energy. An electrostatic double-layer is thereby created in the vicinity of each particle. At some distance within the electrostatic double-layer, a shear plane develops between the particle and the atmosphere of counter ions. The electrical potential at this shear plane is known as the zeta potential⁸.

Electrokinetic dewatering depends on two fundamental mechanisms: electro-osmosis and electrophoresis. Under an applied direct electric current, the clayey particles could migrate through the surrounding stationary liquid phase to the positive electrode (anode). This would then represent a dominant electrophoretic mechanism⁹. On the other hand, the applied direct electric current could cause positive ions in the surrounding liquid and in the outer diffused part of the electric double-layer to migrate towards the negative electrode (cathode). These cations mechanically draw with them the residual mass of free water, which results in a movement of liquid in the pore meshwork of fine particles. This is the classical principle of electro-osmosis¹⁰.

Kimberlite slurries are very stable and do not show any tendency to settle by gravity alone. Mackenzie and Lovell¹ investigated the effect of different electrolytes on the stability of kimberlite slurries, and concluded that it is possible to coagulate particles in a slime through the addition of Mg^{2+} ions. However, these tests were con-

ducted on very dilute kimberlite slurries, which had a solids content of less than 1 per cent. The addition of polyvalent counter ions such as Mg^{2+} and Ca^{2+} tends to reduce the effective charge density in the diffuse double-layer and leads to a reduction in magnitude of the zeta potential and the stability of the colloidal system¹.

A distinct property of the kimberlite slurry is its ability to 'set' to a weak gel at high concentrations of solids². When 'gelling' conditions prevail, the platy particles are immobilized. In a stirred suspension, the particles are then no longer free to orientate themselves in the shear gradient, and the silky 'streakiness' disappears, as observed by O'Gorman and Kitchener².

Experimental

Samples of kimberlite slimes were obtained from the slimes dam of Premier Diamond Mine near Pretoria. The mineralogy and characteristics of the kimberlite slimes are listed in Tables I and II. Analytically pure magnesium perchlorate ($Mg(ClO_4)_2$), which is used as an electrolyte in electrokinetic experiments, was obtained from Merck. Two anionic polyacrylamide flocculants (Praestol 2830 and Praestol 2935), were supplied by the Diamond Research Laboratory of De Beers Mines Division in Johannesburg.

TABLE I
CONSTITUENTS OF KIMBERLITE SLIMES¹

Fe_2SO_3	9,03%
SiO_2	48,12%
Al_2O_3	6,61%
MgO	25,30%
Other	10,94%

TABLE II
CHARACTERISTICS OF KIMBERLITE SLIMES

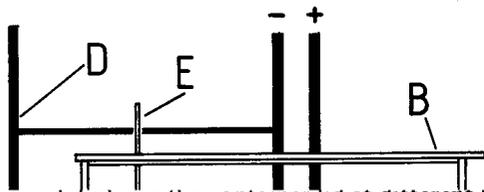
Solids content	8,1% (by mass)
Cation-exchange capacity	27 meq per 100 g
Density of kimberlite	2800 kg/m ³
Density of slurry	≈ 1050 kg/m ³
Particle size ¹	80% < 1 μm
Zeta potential	-45 mV
pH	9,0
Surface area ¹	60,8 m ² /g

Electrophoretic Experiments

For the purpose of this paper, electrokinetic dewatering taking place with the positive electrode (anode) at the bottom of the experimental vessel is referred to as electrophoretic dewatering.

Fig. 1 is a schematic diagram of the electrophoretic cell, which is made of Perspex. The cubic container, A, with dimensions (13,5 by 13,5 by 13,5 cm³) is fitted with a tight-fitting lid, B. The two stainless-steel electrodes, C, are connected to two insulated copper rods that protrude through the container lid, B. The upper electrode (cathode) is held in position by an insulated stand, D.

The two electrodes were connected to a 20A/360V power supply via insulated copper wires. The electrodes were of identical construction and the dimensions are given in Fig. 2.



drawn through holes in the container lid at different levels in the slurry. Care was taken not to disturb the slurry; therefore, samples were drawn starting at the upper level and moving downward. These four samples were then combined into one sample to represent the slurry in the container.

After the pH had been measured, the sample was prepared for zeta-potential measurements. About 50 ml of sample was centrifuged at 4000 r/min for 2 hours. One

drop (about 0,06 ml) of the remaining sample was placed in 25 ml of clear supernatant liquid, and the zeta potential was measured by the use of a Riddick zeta-meter.

The slurry in the container was then discarded, and the container was filled with 2 litres of 'fresh' kimberlite slime for the next experiment. Several parameters, such as pH,

- C - ANODE CLAMP
- D - ANODE
- E - FILTER CLOTH
- F - CONTAINER
- G - LID

Fig. 3—Side elevation of electro-osmotic cell

The power supply used for the electro-osmotic experiments was the same as that used for the electrophoretic experiments. The electro-osmotic cell was filled with 2 litres of kimberlite slime for each experiment. A slight positive pressure was maintained in the conycylindrical base B below the filter cloth to prevent any premature dewatering of slurry before the power was switched on. A direct current was then applied to the slurry to draw water to the cathode by electro-osmosis. Immediately after the water started to flow in part B, the total volume of water recovered by electro-osmosis was collected in a measuring cylinder.

The required voltage necessary to maintain the constant direct current was measured throughout the experiment. When the flow of water had decreased to such an extent that no significant dewatering occurred, the current was switched off. Electro-osmotic experiments were conducted at different fixed electrode spacings, as well as with the anode always in contact with the upper surface of the sludge bed. The effect of different current densities on electro-osmotic dewatering was also investigated.

Results and Discussions

Electrophoresis with No Additives

Fig. 4 shows settling results for a slurry with a solids content of 8,1 per cent treated by direct currents of 0,5, 1,0, 1,5, and 2,0 A. These graphs show clearly that an increase in the magnitude of direct current enhances electrophoretic dewatering.

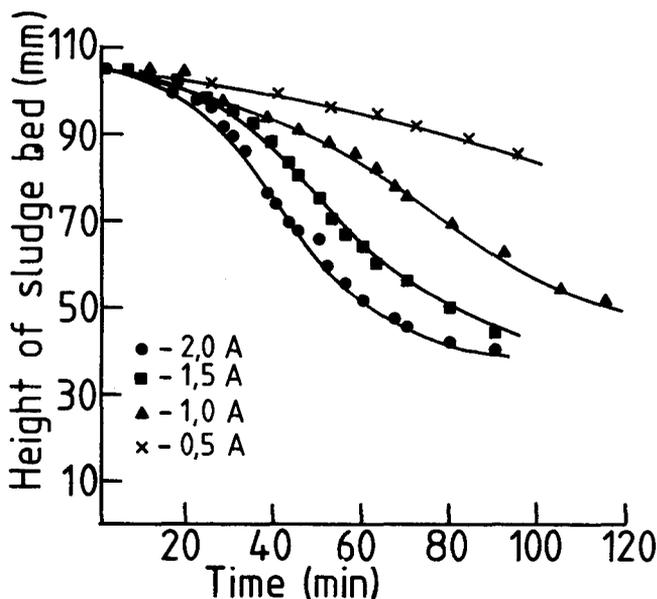


Fig. 4—Change in height of the sludge bed during electrophoresis at different constant currents for a slurry with a solids content of 8,1 per cent

A definite increase in temperature accompanied the settling of the sludge bed during these experiments, and is illustrated in Fig. 5. This rise in temperature was mainly the result of hydrolysis that took place at the electrodes. The increased temperature of the slurry caused its resistivity to decrease, and the required electrical potential necessary to maintain a constant direct current of specific magnitude was reduced. (Fig. 6).

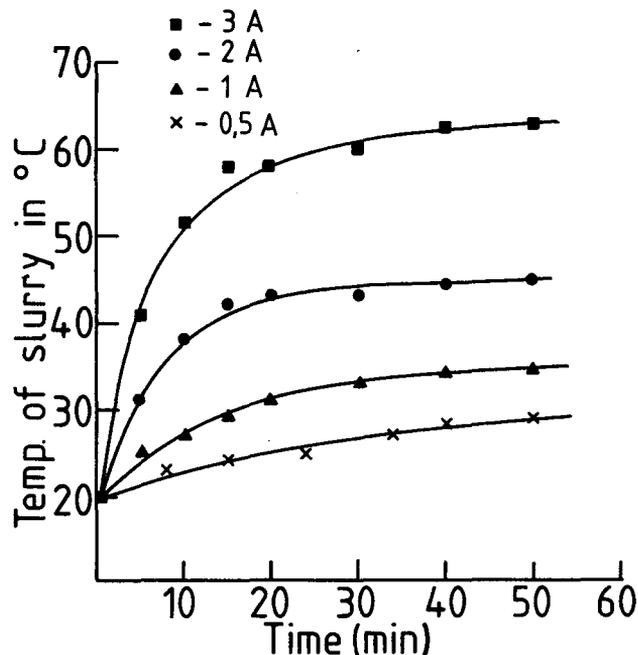


Fig. 5—Increase in temperature during electrophoresis at different constant currents for a slurry with a solids content of 8,1 per cent

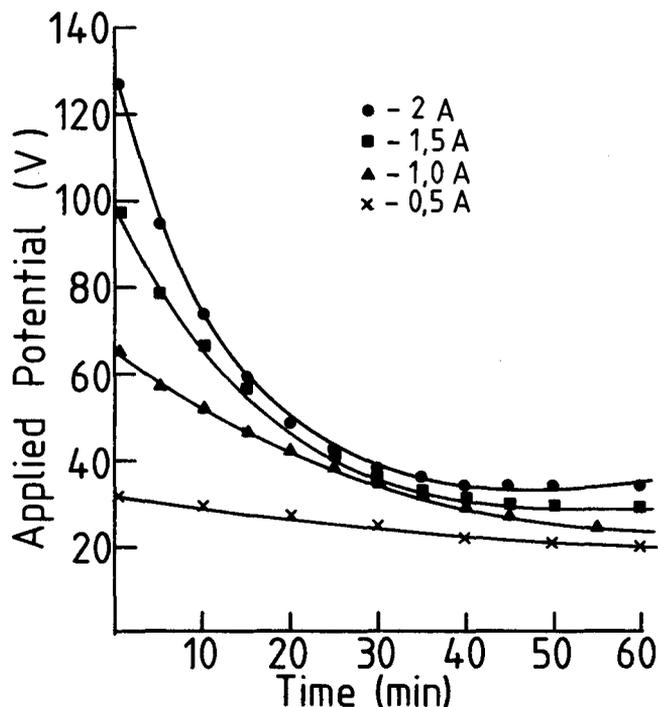
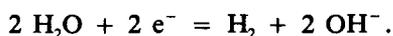


Fig. 6—Decrease in applied potential during electrophoresis at different constant currents for a slurry with a solids content of 8,1 per cent

The increase in pH that took place during electrophoretic dewatering at constant direct currents is illustrated in Fig. 7. The change in pH from 9 to 12 can also be attributed to the hydrolysis that took place at the cathode and the anode. Evolution of hydrogen was visible at the cathode and corresponds to the following equation:



However, very little evolution of gas was observed at the anode, which indicates that the principal reaction occurring was probably the oxidation of the anode. This insufficient evolution of oxygen, together with the free evolution of hydrogen, caused the pH value to rise. Such changes in temperature, potential, and pH were also observed by Sprute and Kelsh⁷.

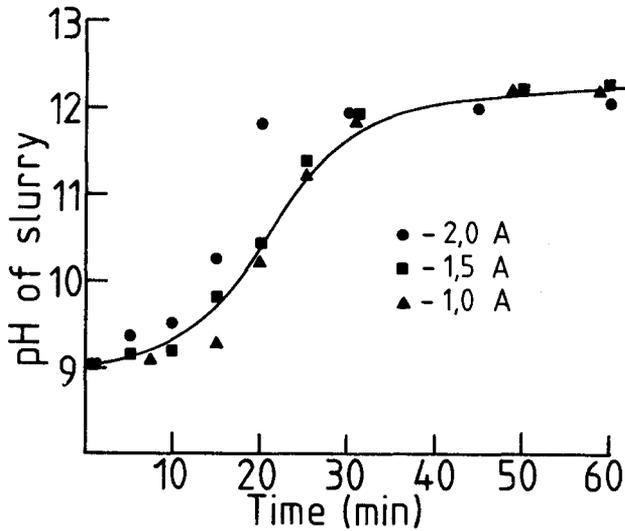


Fig. 7—Increase in pH during electrophoresis at different constant currents for a slurry with a solids content of 8,1 per cent

When a slurry with a solids content of 8,1 per cent was treated by the use of constant electrical potentials of 46,5, 36,5, 26,5, and 16,5 V, the results illustrated in Fig. 8 were obtained. From Fig. 8, the relation between the electrophoretic settling velocity, U_E , and the applied constant potential gradient, E_{AV} , was obtained at 30, 40, 50, and 60 minutes. These results are illustrated in Fig. 9, and show that U_E varied linearly with E_{AV} above 2,5 V/cm. Yukawa *et al.*¹¹ observed this linear relationship at all values of E_{AV} during the dewatering of a slurry of calcium carbonate.

Fig. 10 illustrates the results when slurries with solids contents of 8,1, 6,7, 4,65, and 3,09 per cent by mass were subjected to electrophoretic settling at a direct current of 2A. Dilution of the original slurry with a solids content of 8,1 per cent was achieved by the addition of clear supernatant liquor from kimberlite slurry prepared by centrifugal methods. The required electrical potential necessary to maintain a constant direct current of 2A was almost identical for all these experiments (Fig. 11). Figs. 10 and 11 show clearly that the concentration of kimberlite particles in the slurry does not significantly affect electrophoretic dewatering.

The zeta-potential response of the particles with time when a slurry with a solids content of 8,1 per cent was treated by direct currents of 1 and 2A is shown in Fig. 12. Since the zeta potential showed no significant change as time progressed, the settling of particles during electrophoretic dewatering is not the result of any change in zeta potential.

Figs. 8, 9, and 10 seem to indicate that the applied direct current and potential act as the main driving force for electrophoretic dewatering.

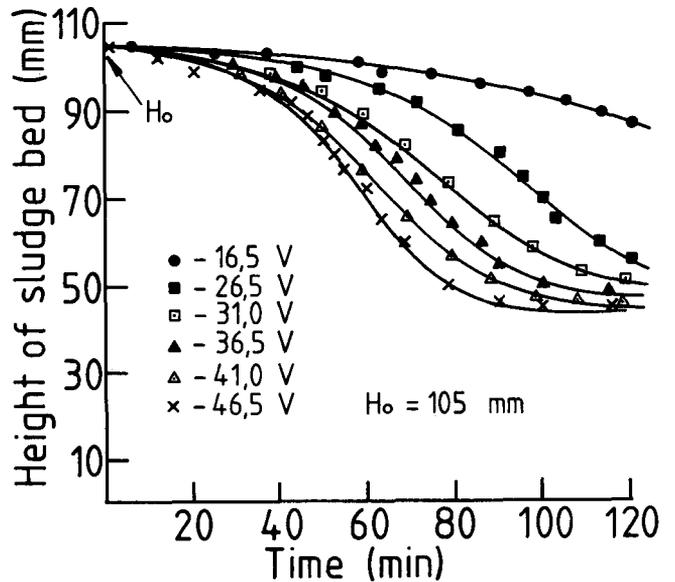


Fig. 8—Change in height of the sludge bed during electrophoresis at different constant potentials for a slurry with a solids content of 8,1 per cent

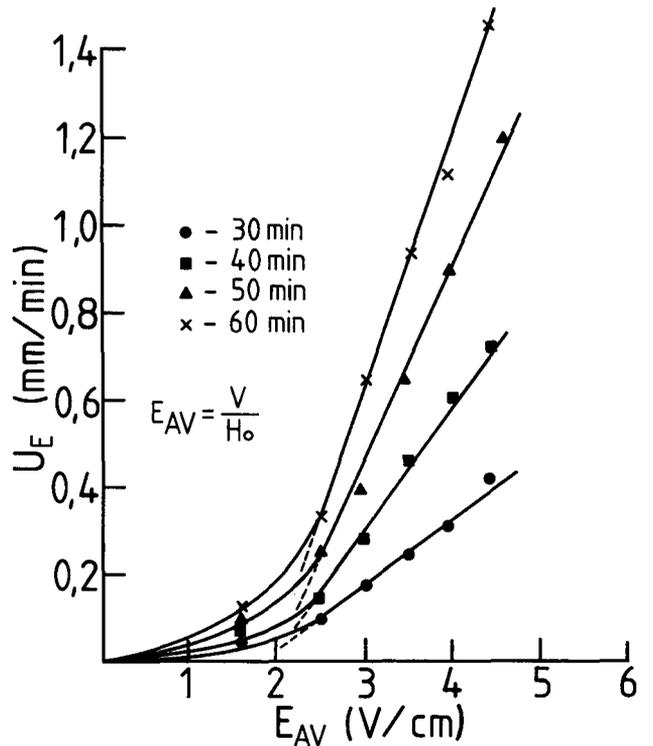


Fig. 9—Relation between electrophoretic settling velocity, U_E , and applied potential gradient, E_{AV} , after different periods of settling

Electrophoresis and Mg^{2+} Addition

In the discussion on zeta potential and its effect on the coagulation of particles in a slurry, it was mentioned that a decrease in the magnitude of the zeta potential is a necessary condition under normal circumstances for coagulation. With this in mind, an attempt was made to decrease the magnitude of the zeta potential in order to enhance coagulation, and simultaneously to treat the

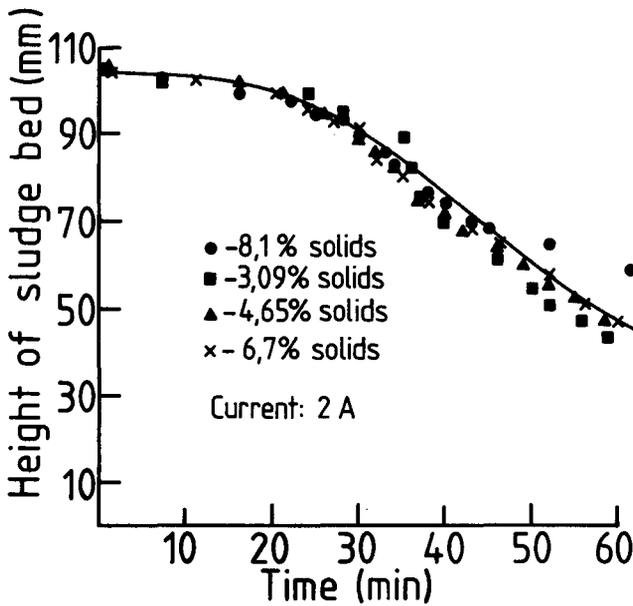


Fig. 10—Change in height of sludge bed during electrophoresis at different concentrations of slurries when treated by a direct current of 2 A

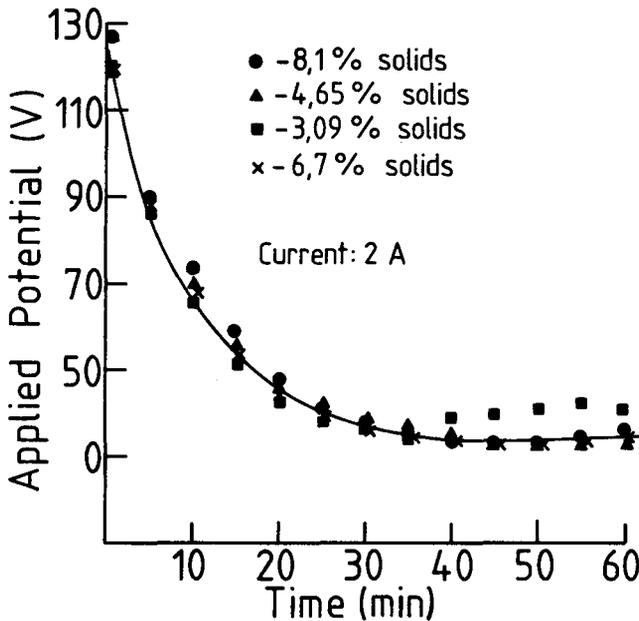


Fig. 11—Decrease in applied potential during electrophoresis at different concentrations of slurries when treated by a direct current of 2 A

slurry electrically to see whether any improvement in the rate of electrophoretic settling could be achieved.

For these experiments, $Mg(ClO_4)_2$ was used as the electrolyte. Mackenzie and Lovell¹² found the ClO_4^- ion to be indifferent to the kimberlite lattice, and its effect on the zeta potential to be negligible. The addition of $Mg(ClO_4)_2$ to the slurry would therefore mean that only the Mg^{2+} would play a role in affecting the zeta potential. The effect of the concentration of $Mg(ClO_4)_2$ on the zeta potential of the particles is illustrated in Fig. 13. It is evident from this graph that the zeta potential becomes less negative with increasing concentration of $Mg(ClO_4)_2$.

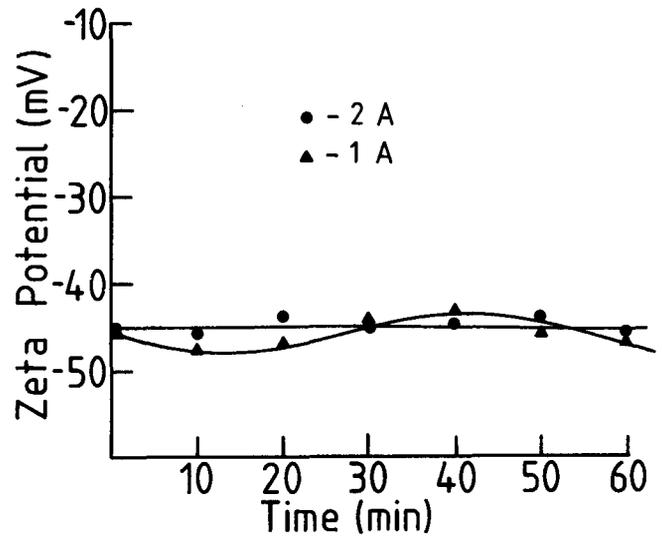


Fig. 12—Change in zeta potential during electrophoresis at different constant currents for a slurry with a solids content of 8.1 per cent

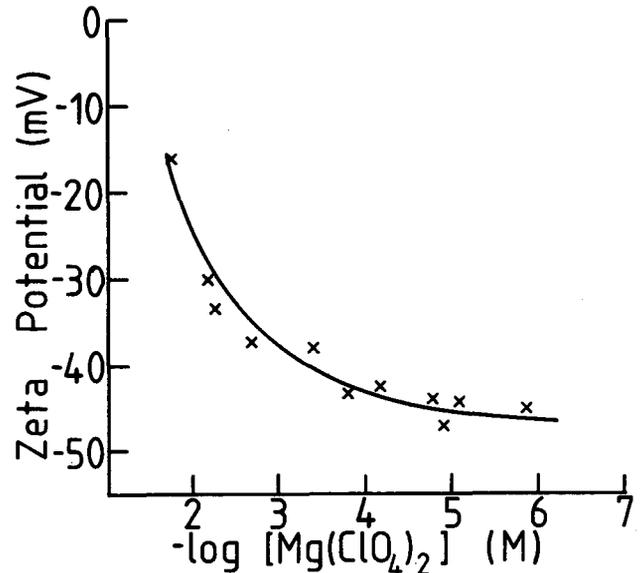


Fig. 13—Zeta potential as a function of the concentration of $Mg(ClO_4)_2$

Fig. 14 shows the results for an electrophoretic experiment in which a slurry containing 8.1 per cent solids and 8.3×10^{-3} M $Mg(ClO_4)_2$ was treated by direct currents of 1 and 2A. Only a slight degree of electrophoretic settling occurred, and the results were not as favourable as when electrophoresis occurred without the addition of electrolyte. (Compare with Fig. 4.) This unusual behaviour may be a direct result of kimberlite moving to a 'gel' state. Normally, when gel formation is not involved, a decrease in the negative zeta potential would enhance the coagulation of particles¹.

The electrical double-layer repulsion decreases with the addition of electrolyte, and the weaker London-Van der Waals forces of attraction begin to have an effect as the particles come into contact. An open 'house-of-cards' structure is established, and the slurry sets into a weak gel². Gel-forming slurries such as that of kimberlite show very little syneresis, and therefore retard the settling

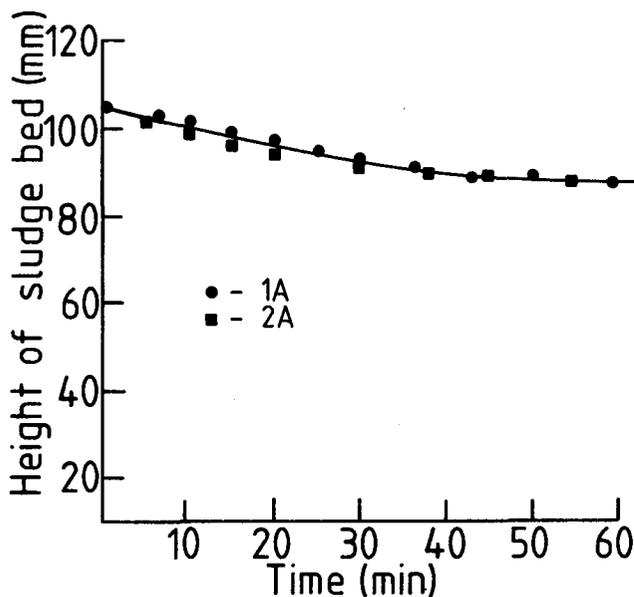


Fig. 14—Change in height of the sludge bed during electrophoresis at different constant direct currents for a slurry containing 8,1 per cent solids and $8,3 \times 10^{-3} \text{ M Mg(ClO}_4)_2$

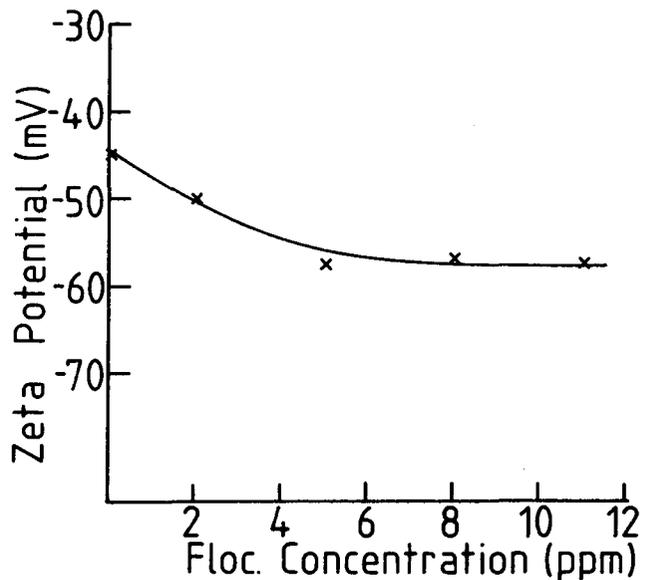


Fig. 15—Zeta potential as a function of the concentration of Praestol 2935

of the sludge bed during electrophoresis.

Electrophoresis and Flocculant Addition

It is commonly assumed that neutralization of the zeta potential is a logical basis for the selection of a flocculant. Accordingly, since kimberlite particles have a negative zeta potential, a cationic flocculant would be the most appropriate to use. Work done by O'Gorman and Kitchener² exposed the fallacy of this assumption. The use of cationic flocculants is bound to be wasteful because the polyelectrolyte chains are strongly attracted to the surfaces of the particles and are therefore no longer available for bridging².

Both anionic polyacrylamide flocculants, viz Praestol 2830 and Praestol 2935, were compared regarding their ability to settle kimberlite particles without the use of electrophoretic treatment. Their respective influences on the rate of electrophoretic dewatering of slurry were also compared.

During batch settling tests with no flow of current, Praestol 2830 did not produce a clear mudline between the murky supernatant liquid and the consolidated solids. Praestol 2935 showed a clearer mudline, which settled slightly more slowly than the murky interface of Praestol 2830. However, the concentration of solids in the resulting supernatant liquids showed Praestol 2935 to be more favourable. From a slurry with an initial solids content of 8,1 per cent, 10 p.p.m. of Praestol 2935 produced a supernatant liquid with a solids content of 4,45 per cent, as against the solids content of 5,7 per cent in the supernatant liquid produced by 10 p.p.m. of Praestol 2830 after 60 minutes of consolidation.

At similar dosages, these two flocculants revealed no significant difference in the rate of dewatering after electrophoretic treatment of 60 minutes. Based on this fact, and the observation that Praestol 2935 produced a clearer supernatant liquid during batch settling tests, it was decided that Praestol 2935 should be used as the flocculant in further experiments.

The negative charge on a kimberlite particle may not be too high to prevent adsorption of Praestol 2935 onto the particle. The slight increase in negative zeta potential shown in Fig. 15 suggests some such adsorption.

Fig. 16 shows electrophoretic results at a direct current of 1,5 A for a slurry with a solids content of 8,1 per cent containing 0, 1, 3, and 10 p.p.m. of Praestol 2935. As shown, the increased addition of Praestol 2935 enhanced the settling of the sludge bed. Fig. 17 reveals that no significant change in the pattern of potential decrease occurred with increased addition of flocculant while a direct current of 1,5 A was maintained. Therefore, the improved electrophoretic dewatering cannot be ascribed to any electrical effect but should be attributed to the additional effect of flocculation.

Electro-osmotic Experiments

Suspensions of fine clayey particles such as kimberlite settle slowly to form a highly viscous sediment that is difficult to dewater because of the fineness of the pores between particles. Since electro-osmotic flow is relatively insensitive to pore size, it is an attractive method for the dewatering of suspensions of fine particles⁶.

During electro-osmotic dewatering, the positive upper electrode can either be kept at a constant distance from the negative electrode at the bottom of the vessel or can follow the descent of the mudline as dewatering progresses. Fig. 18 shows results for the electro-osmotic flow of water when a slurry with a solids content of 8,1 per cent was treated by direct currents of 0,5 to 2,5 A at a constant electrode spacing of 30 mm. From this graph, it is evident that electro-osmotic dewatering is approximately proportional to the applied direct current.

Patterns of changes in pH, temperature, and applied potential similar to those observed during electrophoretic dewatering (Figs. 5, 6, and 7) were also obtained during electro-osmotic dewatering. The same arguments as were used to explain these changes also apply in the case of electro-osmosis.

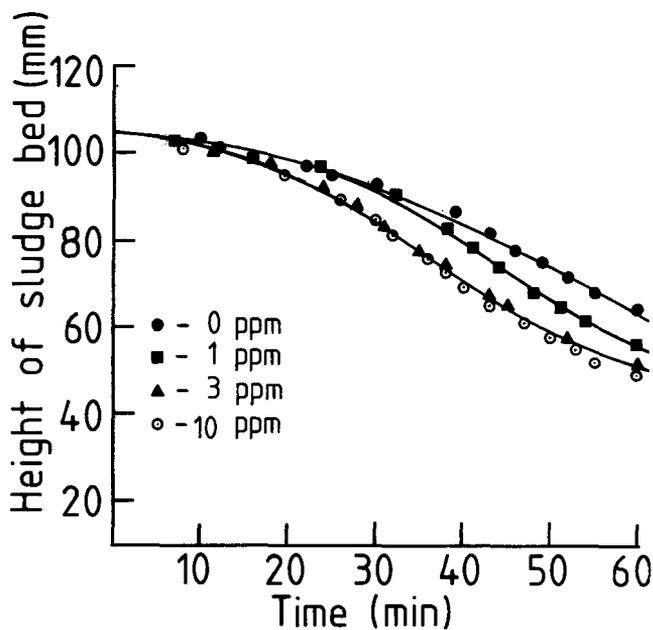


Fig. 16—Change in height of the sludge bed during electrophoresis at different additions of Praestol 2935

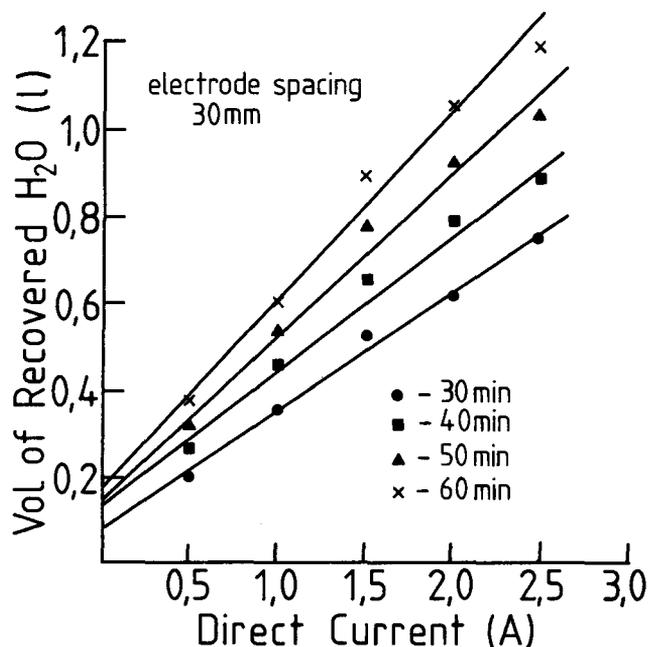


Fig. 18—Relation between the volume of water recovered and the applied direct current at different time intervals and a constant electrode spacing of 30 mm

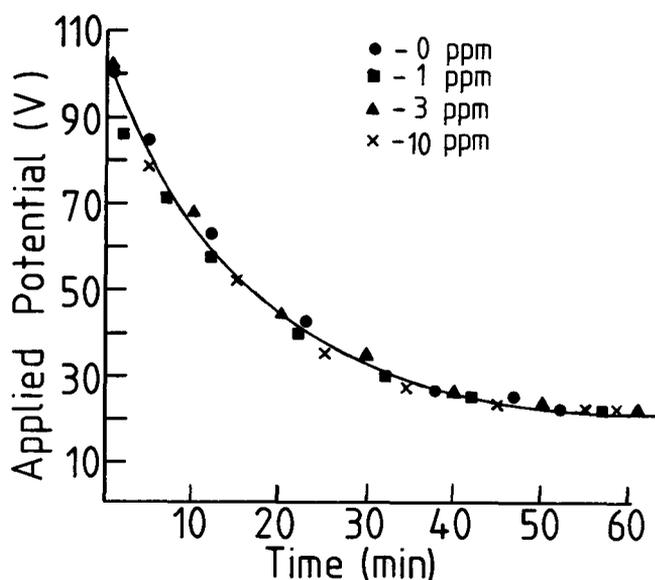


Fig. 17—Decrease in applied potential during electrophoresis at different additions of Praestol 2935

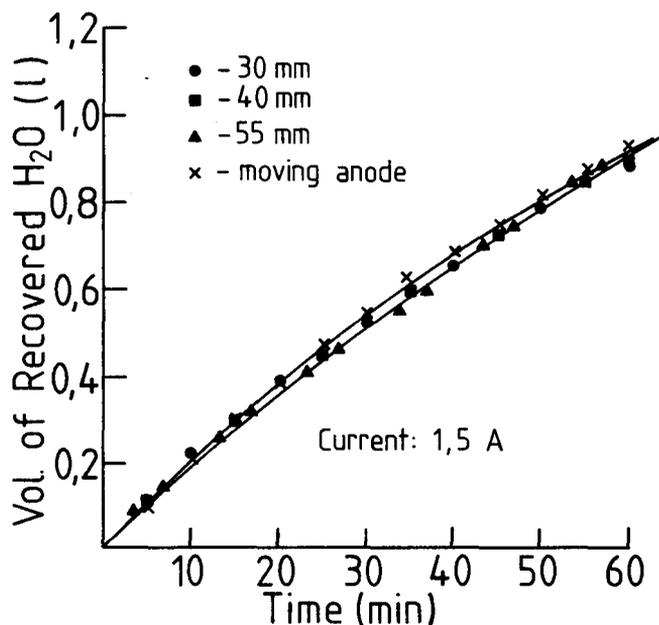


Fig. 19—Volume of recovered water during electro-osmosis at different electrode spacings

Electro-osmotic experiments were also conducted at different constant electrode spacings. Fig. 19 illustrates electro-osmotic dewatering at constant electrode spacings of 30, 40, and 55 mm and a constant direct current of 1,5 A. Fig. 19 also shows the result when the anode (top electrode) follows the descent of the mudline during electro-osmotic dewatering. No significant change in dewatering occurred at different electrode spacings.

Fig. 20 shows that the applied potential necessary to maintain a constant direct current of 1,5 A decreased with decreasing electrode spacing. These results were recalculated to yield Fig. 21. No significant change of gradient

in the applied potential was evident during the first 30 minutes of electro-osmotic dewatering with fixed electrodes. The more obvious change in applied potential gradient after 30 minutes cannot be ascribed to different patterns of increase in temperature, since almost identical patterns were measured for different spacings of the fixed electrodes. However, the steadily increasing concentration of solids between the two electrodes with decreasing electrode spacing increases the resistance of the slurry, and this may be responsible for the increased gradient in applied potential.

When fixed electrodes were used, slurry had to be

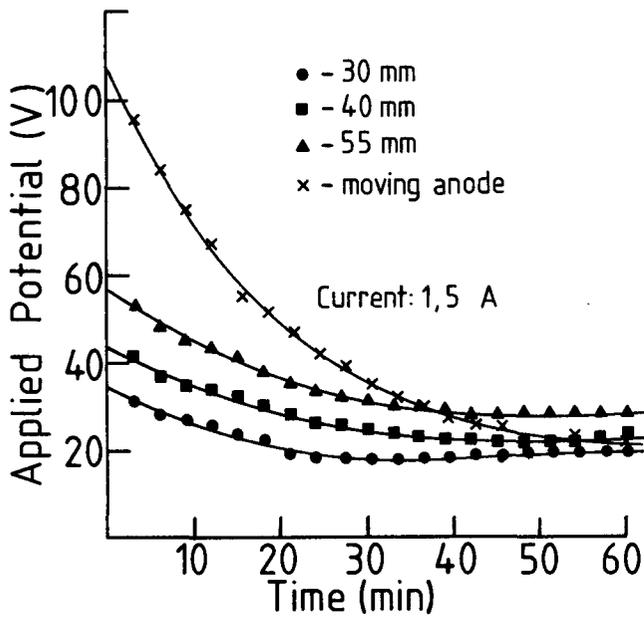


Fig. 20—Decrease in applied voltage during electro-osmosis at different electrode spacings

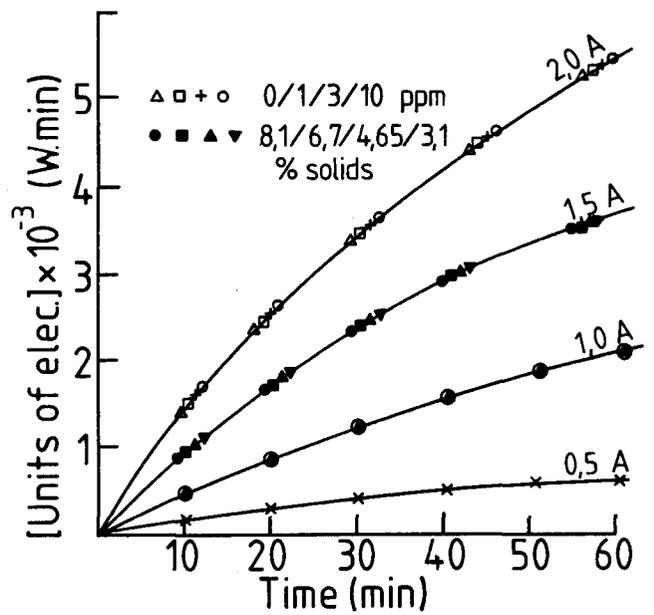


Fig. 22—Consumption of electricity during electrophoresis for different constant direct currents, different concentrations of slurries, and different additions of Praestol 2935

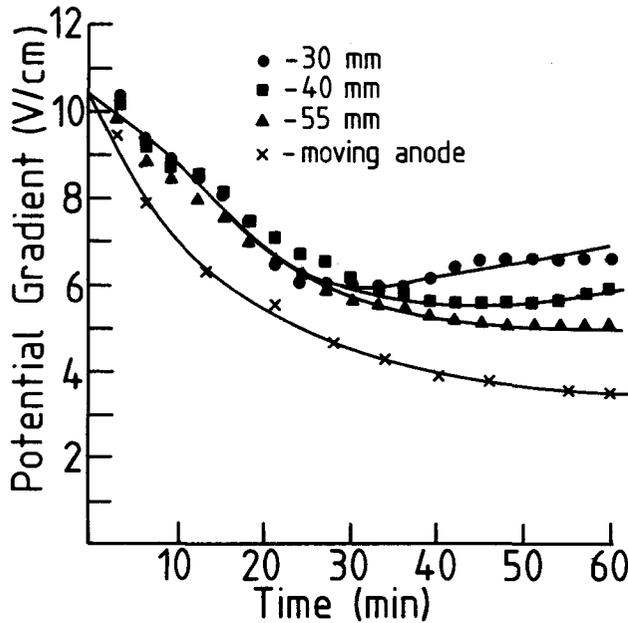


Fig. 21—Change in applied potential gradient during electro-osmosis at different electrode spacings

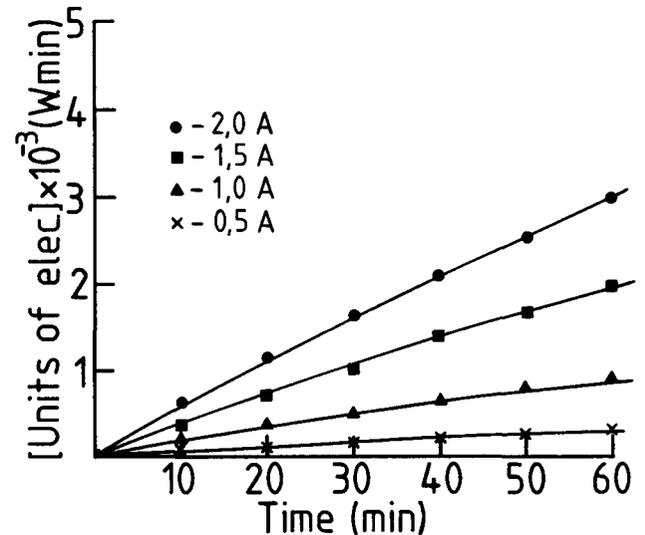


Fig. 23—Consumption of electricity during electro-osmosis at different constant direct currents

drawn through the porous cake that formed at the bottom of the anode. This increased the effective resistance of the material between the two electrodes. In the case of a moving anode, all the slurry to be dewatered was below this porous cake, which resulted in less resistance to the flow of current. Therefore, lower potential gradients were required when a moving anode was used, as shown in Fig. 21.

Efficiencies of Electrophoresis and Electro-osmosis

The volume of water recovered after a certain time interval and the accompanying energy consumption are two

useful criteria in a comparison of electrophoretic and electro-osmotic dewatering. The consumption of electrical energy for the various electrokinetic experiments is illustrated in Figs. 22 to 24.

Tables III to VII reflect the experimental conditions, as well as the volume of water recovered and the power consumption after 60 minutes of electrokinetic treatment. In general, electro-osmotic dewatering seems to be more energy-efficient than electrophoretic dewatering (compare Tables III and VI). The addition of flocculants produced an increase in the volume of recovered water and led to a more efficient process (Table V). However, the best

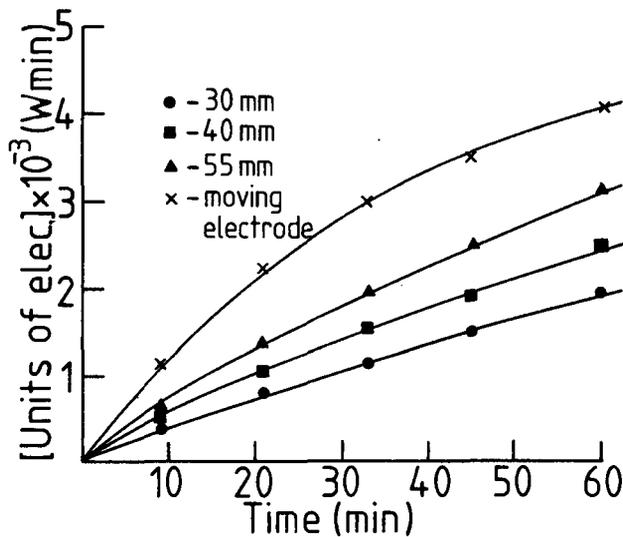


Fig. 24—Consumption of electricity during electro-osmosis at different electrode spacings

TABLE III

ELECTROPHORESIS AT DIFFERENT CONSTANT DIRECT CURRENTS*

Current, A	0,5	1,0	1,5	2,0
Units of electricity, W min	625	2100	3700	5525
Vol. of H ₂ O recovered, ml	190,5	419,0	771,5	1019,0
Power consumption, kWh/kl	54,7	83,5	79,9	90,4

* From Figs. 4 and 22

TABLE IV

ELECTROPHORESIS AT DIFFERENT PARTICLE CONCENTRATIONS*

Current, A	2	2	2	2
Solids, %	8,1	6,70	4,65	3,09
Relative density	1,052	1,043	1,035	1,018
Units of electricity, W min	5525	5525	5525	5525
Vol. of H ₂ O recovered, ml	857,1	1104,8	1123,8	1180,9
Power consumption, kWh/kl	107,4	83,4	81,9	78,0

* From Figs. 10 and 22

TABLE V

ELECTROPHORESIS AT DIFFERENT ADDITIONS OF FLOCCULANT*

Dosage of Praestol 2935, p.p.m.	0	1	3	10
Current, A	1,5	1,5	1,5	1,5
Units of electricity, W min	3700	3700	3700	3700
Vol. of H ₂ O recovered, ml	790,4	933,3	1028,6	1066,7
Power consumption, kWh/kl	78,0	66,1	60,0	57,8

* From Figs. 16 and 22

TABLE VI

ELECTRO-OSMOSIS AT DIFFERENT CONSTANT DIRECT CURRENTS*

Electrode spacing, cm	3,0	3,0	3,0	3,0
Current, A	0,5	1,0	1,5	2,0
Units of electricity, W min	275	925	1950	2950
Vol. of H ₂ O recovered, ml	380	620	890	1060
Power consumption, kWh/kl	12,1	24,9	36,5	46,4

* From Figs. 18 and 23

TABLE VII

ELECTRO-OSMOSIS AT DIFFERENT ELECTRODE SPACINGS*

Electrode spacing, cm	3,0	4,0	5,5	Moving
Current, A	1,5	1,5	1,5	1,5
Units of electricity, W min	1950	2475	3275	4080
Vol. of H ₂ O recovered, ml	900	900	900	910
Power consumption, kWh/kl	36,1	45,8	60,6	74,7

* From Figs. 19 and 24

result when flocculant was added was still not as good as the worst result during electro-osmotic dewatering at constant direct currents (compare Tables V and VI).

From Tables III to VII it seems as if electro-osmotic dewatering of kimberlite slimes takes place at a higher rate than electrophoretic dewatering. This was also observed visually during the experiments since electro-osmotic dewatering began immediately after the power was switched on, while electrophoretic dewatering took some time before the mudline started to descend.

Conclusions

- (1) The electrophoretic settling velocity, U_E , varies linearly with the average applied potential gradient, E_{AV} , above 2,5 V/cm and is not very dependent on the concentration of particles in the kimberlite slurry.
- (2) Electrophoretic treatment does not change the zeta potential of the kimberlite particles significantly. Therefore, electrophoretic settling cannot be ascribed to a change in zeta potential.
- (3) Although some adsorption of the flocculant Praestol 2935 occurred onto the kimberlite particles, this adsorption did not influence the electrical behaviour of the slurry. The improved electrophoretic dewatering with increasing additions of Praestol 2935 could therefore be attributed to the additional effect of flocculation.
- (4) Although the addition of Mg^{2+} ions lowered the magnitude of the zeta potential of the kimberlite particles, this did not lead to coagulation in the slurry. A weak 'gel' developed and contributed to the poor electrophoretic dewatering that occurred with the addition of $Mg(ClO_4)_2$.
- (5) Electro-osmotic dewatering was found to be approximately proportional to the applied constant direct current. No relationship was found between the rate of electro-osmotic dewatering and the distance between the two electrodes.

- (6) In general, electro-osmotic dewatering seemed to be more energy-efficient than electrophoretic dewatering.

Acknowledgements

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Development of PROTEC

PROTEC (Programme for Technological Careers) continues to develop despite the deteriorating condition of formal schooling in the Black communities. PROTEC now has nearly 2000 high-school students involved in its seven active branches—in Soweto, Alexandra, the East Rand, Johannesburg Western Areas, Sasolburg, Mma-batho, and Richards Bay.

Several hundred additional students from among the 1984 and 1985 school leavers are still involved with PROTEC, and are showing promising career progress. A large proportion of them are at university, technikon, or technical college, or receiving in-service training. Some are doing very well at university and at colleges.

The active involvement of students and parents in the programme, and the positive response of the communities, are healthy indicators for the future.

As a non-formal education programme, PROTEC is grappling with pressures to become more involved in formal schooling because of the general breakdown in this area in several of the branches. While alternative solutions are being devised in certain cases, PROTEC can never be a substitute for ongoing formal schooling. It is significant, however, that PROTEC retains credibility and communication with the communities, including the students, in finding short- and medium-term alternatives.

In these troubled times, PROTEC is serving an extremely important function in communicating and

bridging a widening gap between employers and the communities concerned. PROTEC's emphasis has shifted from serving the needs of employers in terms of narrow vocational development alone, to also meeting the human and long-term life needs of the communities and of donors, who are often subject to local and international pressure.

In response to this, it has become necessary for PROTEC to consider restructuring its Council to reflect more community and branch representation, and less control by the engineering societies. This should in no way be interpreted as a reduction in recognition of the valuable role being played by the engineering profession, which started PROTEC. Indeed, there is a growing need for this type of involvement but, with the expansion and decentralization of PROTEC, the emphasis will be increasing on contributions through the Branch Boards.

Should you wish to have more information about PROTEC, please contact

Celia Stephens
Public Relations Co-ordinator
P.O. Box 52657
Saxonwold
Johannesburg 2132.

Telephone: (011) 788-8652/7209.

Numerical methods in geomechanics

The 6th International Conference on Numerical Methods in Geomechanics (ICONMIG) will be held in Innsbruck (Austria) from 11th to 15th April, 1988. The organizers are the University of Innsbruck, the Austrian Society for Geomechanics, the Austrian Federal Chamber of Engineers, and the Austrian Society for Industrial Construction.

Numerical methods have become a powerful means of solving many nonlinear problems in geomechanics. Current developments are characterized by a steady expansion of nonlinear theories to describe the complex properties of soil and rock. Despite this continued development of theoretical principles, many problems remain to be solved before these methods can be used as the basis for all engineering design work. Thus, the stated goal of this Conference is to narrow the gap between theory and practice. Not only will the latest international developments be discussed, but their practical application will also be illustrated.

Above all, an attempt will be made to introduce new numerical models for describing geological materials, particularly discontinuum models. Another of the aspects to be treated by the Conference will be the use of probabilistic methods in geomechanics. As at preceding meetings, work on programming techniques, especially mesh generation, will be given detailed coverage. Examples of its application are expected to deal with tunnel and dam construction.

The topics include the following:

- *Theory:*
 - Constitutive laws of rock and soil
 - Modelling of joints and interfaces
- *Application and modelling:*
 - Tunnelling and underground openings
 - Dams
 - Soil/structure interaction
 - Mining
 - Interpretation of field measurements
- *Software:*
 - Computer programs in geomechanics
 - Mesh generation
 - Computer graphics
 - CAD in geomechanics
 - Use of microcomputers and personal computers.

A projected exhibition will present the international design standards for tunnels and dams, thus giving firms and design engineers a platform for practical illustration of how numerical models can be applied to actual construction work. The exhibition is further expected to promote discussion of theory and practice.

Enquiries should be directed to

Kongresshaus Innsbruck
ICONMIG 88
Rennweg 3
A-6020 Innsbruck
Austria.

Telephone (0 52 22) 36 5 21-274; Telex (057) 3138.

Hydraulic fill structures

A Conference on Hydraulic Fill Structures is to be held at Colorado State University, Fort Collins, U.S.A., from 14th to 17th August, 1988. (Please note the new dates for the Conference.)

The purpose of this speciality Conference, sponsored by the Geotechnical Division of the American Society of Civil Engineers, is to review experience and to promote the use of hydraulic fill methods for engineering purposes such as water-retention dams, tailings dams, offshore artificial islands, reclaimed lands, airports, and the use of dredged materials.

The topics will include

- seepage, settlement, and stability analyses
- *in situ* testing
- instrumentation
- slurry transport systems and material beneficiation
- and overview of past, present, and future trends in hydraulic fill structures.

A call for papers will be issued later. For further information, contact

W. David Carrier, III
Bromwell & Carrier, Inc.
P.O. Box 5467
Lakeland, FL 33807-5467
U.S.A.

Telephone: (813) 646-8591.