

ZETA POTENTIALS OF LONG ISLAND AQUIFER MATERIAL

Alysa N. Suero
Martin A.A. Schoonen
Department of Geosciences
SUNY Stony Brook
Stony Brook, NY 11794-2100

Abstract

Zeta potential was determined for aquifer material from three locations in Long Island. The zeta potential is used to ascertain the material's surface charge; the sign of the zeta potential is the same sign as the surface charge. The varying zeta potentials where the mineral compositions and/or grain sizes are similar must be caused by a change in the aquifer material's surface coatings. Differences in zeta potential, and hence, in the surface charges, are seen among all three Long Island sites. Furthermore, the zeta potentials of the samples from each location also vary with depth.

Introduction to Zeta Potential

At the interface of a charged solid and a liquid there is always a separation of electrical charge. The surface of the solid has an excess of one charge and the balancing charge is found in the adjacent surface region of the liquid. The arrangement of the charges at the solid and liquid interface is referred to as the double layer.

The double layer is an electrical cloud near the solid surface composed of both a rigid zone, known as the Stern layer, and a diffuse layer. Ions having the opposite charge as the solid are immediately attracted to the surface of the solid and attach, forming the Stern layer. Additional ions of the same charge as the Stern layer are also attracted by the oppositely charged solid's surface but are simultaneously repelled by the like charges in the Stern layer. This dynamic equilibrium results in the formation of a diffuse layer. The diffuse layer is also composed of ions with the same sign of charge as the solid with the concentration of these ions decreasing with distance from the solid. Together the Stern layer and the diffuse layer form the double layer. The thickness of the double layer is a function of the pH and ionic strength of the solution.

The boundary between the Stern layer and the diffuse layer is called the shear plane. The electric potential at the shear plane is called the zeta potential. A change in zeta potential reflects a change in surface charge.

Zeta potentials have been calculated for aquifer material from three Suffolk County Water Authority drill sites. The zeta potential, and particularly the associated sign (positive or negative) determines the relationship between grain coatings and surface charge.

Experimental Procedure

Due to the grain size, the most effective method for measuring the zeta potential of the aquifer material is through streaming potential. A special Teflon cylinder was designed and manufactured especially for this purpose. In the capillary of the cylinder a solution that is pumped at a constant rate across the surface of the aquifer material. The movement of the fluid through the capillary under the influence of a pressure gradient displaces the diffuse region and causes a potential difference to develop between the ends of the capillary. That is, the moving

liquid causes excess charges near the solid/liquid interface to be carried downstream. The downstream charge transport, or electrical current, causes a buildup of an electrical field. The buildup of the electrical field drives the current back against the direction of flow. This measured potential difference across the ends of the capillary is called the streaming potential. In these experiments the liquid is assumed to behave as a Newtonian fluid, where the liquid is moving sufficiently slowly to negate turbulence and other non-linear effects.

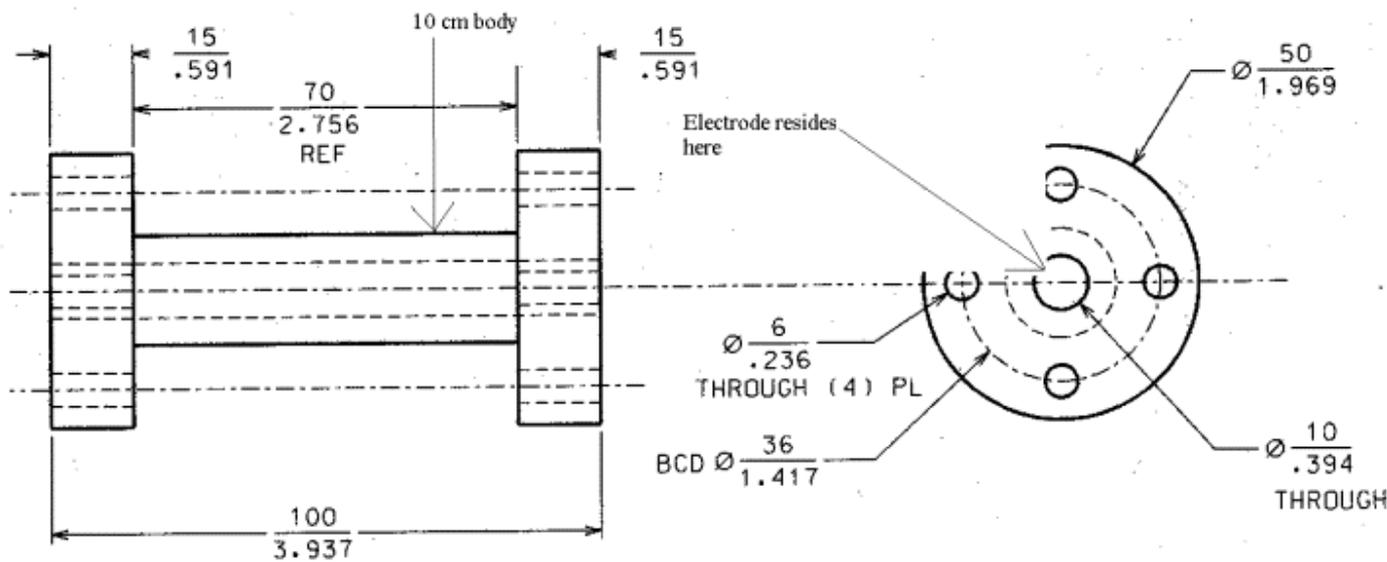


Figure 1. Schematic of experimental cylinder. The body is 10 cm long and the electrodes are 1 cm in diameter.

The sample capillary within the Teflon cylinder is ten cm in length, with a diameter of one cm (figure 1). There are two silver chloride electrodes, also one cm in diameter, at each end of the capillary, used to measure electric potential. Also connected to the cylinder are a differential pressure meter and a conductivity meter.

There is only one mathematical equation used to calculate zeta potential:

$$\zeta = (-V_s / \Delta P) (\mu \lambda / \epsilon_0 \epsilon_T)$$

ζ = zeta potential (mV)

V_s = streaming potential (mV)

ΔP = differential pressure (Pa)

μ = viscosity (Pa s)

λ = conductivity ($\Omega^{-1} \text{ m}^{-1}$)

ϵ_0 = permittivity of a vacuum (Fm^{-1})

ϵ_T = relative permittivity

To test the apparatus, the zeta potential of quartz was determined. Quartz has a known zero point of charge, or zpc, at approximately pH two to three. The zpc is the point at which the surface charge equals zero; hence, at the zpc the zeta potential also equals zero. As shown in figure 2, near pH three the zeta potential is very close to zero. It would be a fair estimation of a zpc for this quartz sample to cross the x-axis close to pH two. This result indicated that the experimental setup is functioning properly and further experiments can be performed.

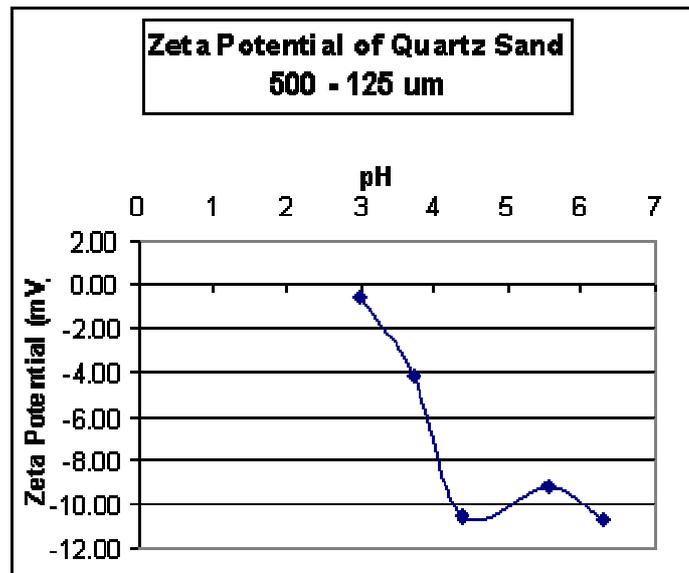


Figure 2. The zpc of this quartz sample can be extrapolated to be near pH 3. This is an acceptable value for quartz grains.

Long Island Aquifer Material

Experimental aquifer material was obtained from three drillings conducted by the Suffolk County Water Authority: Farmingdale, Northport, and Shirley, Long Island.

Farmingdale, Long Island

Fourteen samples spanning 155 feet were analyzed for their zeta potentials (figure 3). The solution pumped through the cylinder was created to mimic the aquifer water in Long Island; a solution of 25 mg NaCl per liter of H₂O, which had a constant pH of 3.92 and conductivity of 56 uS/cm. All of the samples were medium to fine grained and all had a composition of greater than 90% quartz, with two exceptions. Ergo, since the samples have the same composition and size, the one factor to cause the marked difference in zeta potential per sample must be different surface charges caused by differing grain coatings.

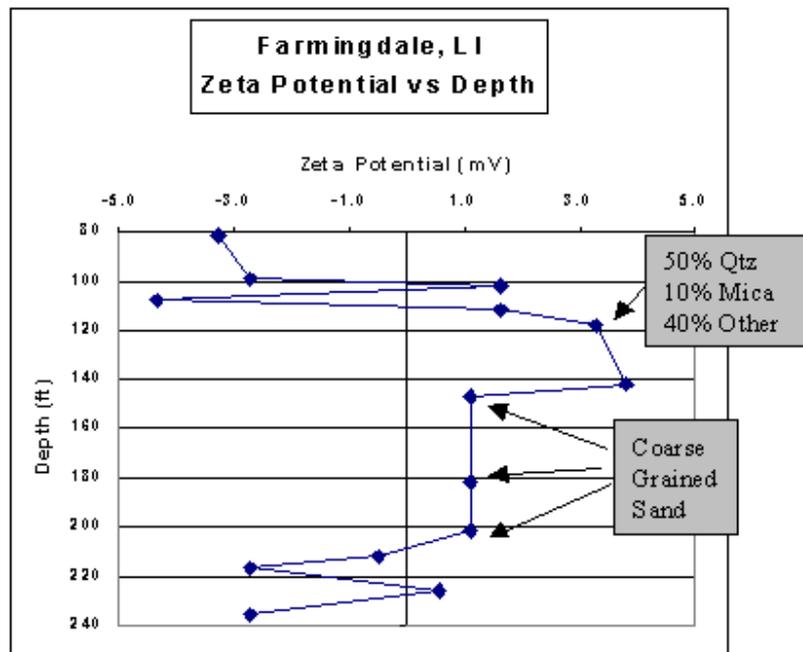


Figure 3. Zeta potentials of samples from Farmingdale, Long Island. Samples extracted in 1963. Input solution is 25 mg NaCl per Liter H₂O. Input conductivity is 56 uS/cm. All samples are medium to fine grained and greater than 90% quartz, with exceptions noted on graph.

Northport, Long Island

Eight samples spanning 180 feet were analyzed for their zeta potentials (figure 4). The solution pumped through the cylinder was created to mimic the aquifer water in Long Island; a solution of 25 mg NaCl per liter of H₂O, which had a constant pH of 4.72 and conductivity of 56 uS/cm. The grain size of these samples varied greatly with depth. The zeta potentials tended to reflect a negative charge more often than a positive charge, though most of the zeta potentials were near zero. This could indicate that the aquifer material as a whole has a similar surface coating on all the grains at all depths.

Shirley, Long Island

Nine samples spanning 100 feet were analyzed for their zeta potentials (figure 5). The solution pumped through the cylinder was created to mimic the aquifer water in Long Island; a solution of 25 mg NaCl per liter of H₂O, which had a constant pH of 5.75 and conductivity of 74 uS/cm. Within each stratigraphic layer the zeta potentials remain fairly consistent, with the exception of the clay layer found between 470 ft and 500 ft. The large difference between the zeta potentials within this layer could either be caused by differing mineral compositions or to differing surface coatings on the grains. This is further supported by the measurements of the change in the pH and conductivity of the solution after it has come into contact with the aquifer materials. After being exposed to the samples, the conductivity increased from approximately 3 to 25 uS/cm, while the pH decreased for each sample from 0.5 to 2 pH units. The changes in these parameters must be caused by differing grain surface coatings.

Conclusion

Aquifer material from three locations on Long Island were analyzed for their zeta potential, or surface charge. A solution to resemble the native Long Island aquifer water was

created and exposed to the aquifer material. The zeta potentials, which relate to the material's surface charge, vary with depth. The varying zeta potentials where the mineral compositions and/or grain sizes were similar must be caused by a change in surface coating.

References

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