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A General Correction For Spontaneous Potential Well Logs In Fresh Water

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A GENERAL CORRECTION FOR SPONTANEOUS POTENTIAL WELL LOGS IN FRESH WATER

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ABSTRACT

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A generalized empirical relationship was found which corrects spontaneous potential (*SP*) readings from well logs run in fresh water wells. The function was found by correlating measured and calculated spontaneous potentials. The calculated values are based on actual measured ionic content of groundwaters and are fully corrected for environmental effects and ion species. Without the empirical relationship the electrically equivalent to an NaCl solution resistivity, R_{we}, is generally too low for fresh waters when computed with existing commercially available functions. The low R_{we} makes the water appear saltier than it really is.

One hundred sixty-two (162) individual formations from one hundred four (104) different shallow well logs from widely separated regions of the United States and different types of aquifers were examined. Each formation used in the study had to have a spontaneous potential, mud resistivity data, a chemical analysis of water from the zone, and not be in communication with other zones. Every *SP* had the existing commercially available geometric corrections applied.

A computer program was developed which computes a simulated *SP* from the chemical analysis and mud data. This simulated *SP* was plotted against the measured *SP*. The resulting relationship is given by:

MEASURED *SP* = 0.3782 × SIMULATED *SP* + 6.9172

for 0 mv < SIMULATED *SP* < + 50 mv.

This type of relationship is consistent with earlier work by the author in a localized area. The function can only be applied in fresh waters with simulated *SP*s in the indicated domain since simulated and measured *SP*s converge in brine formations.

INTRODUCTION

Spontaneous potential (*SP*) well logs have been used in both the groundwater and petroleum industries for many years. The main uses have been for bed boundary definition and for correlation of formations. In the petroleum industry they are used to calculate the formation water resistivity in brine formations and to locate the base of the fresh water for setting surface casing. In fresh water wells they are generally used only in a qualitative manner to identify brackish or salt water formations.

The difficulty in the quantitative use of spontaneous potential logs in fresh water is due to the apparent resistivity deviating from the true resistivity in thin beds (geometric errors) and the predominance of divalent ions (chemical errors). Chemical errors arise as a consequence of the derivation of the theory which requires that a single cationic and anionic species be present. Since the theory and experimentation was originally petroleum oriented, sodium and chlorine were chosen, whereas in groundwater calcium and magnesium dominate. Corrections are readily available for both the geometric and chemical errors but ground water hydrologists have found that even after applying them the error in calculating water resistivity from the *SP* has been excessive.

McConnell (1983) showed that in a local area in southern Oklahoma an empirical correction had to be applied in addition to the standard chemical and geometric corrections to achieve reliable results. This study was undertaken to determine if a single empirical correction could be found to yield accurate water resistivities in fresh water aquifers from widely different regions of the United States and types of aquifers.

THEORY

The *SP* arises due to the difference in salinities of the drilling mud filtrate and the formation water. Three potentials develop; a liquid junction potential, a membrane potential, and an electrokinetic potential. Assuming the electrokinetic potential is negligible (McConnell, 1983; p. 364) the total electromotive force is the sum of the former two.

The liquid junction potential develops when two fluids of different salinity are brought together without an intervening shale membrane. For all species the potential is given by:

$$E_{\mathrm{L}} = -\frac{RT}{F} \sum_i \frac{1}{Z_i} \int_1^2 t_i \, \mathrm{d} \ln a_i \tag{1}$$

where z_i is the valence of the ith species, t_i is the transport number, a_i is the activity, F is the Faraday, R is the gas constant, T is the absolute temperature, and $\sum_i$ is the summation over all species (Lynch, 1962). The transport number is the fraction of the current carried by each species.

For an NaCl solution:

$$E_{\mathrm{L}} = -\left(\frac{RT}{F}\right) \left[\frac{0.4}{1} \int_1^2 \mathrm{d} \ln a_{\mathrm{Na}^+} + \frac{0.6}{-1} \int_1^2 \mathrm{d} \ln a_{\mathrm{Cl}^-} \right] \tag{2}$$

1 and 2 refer to the natural logarithm of activities at the two end points. Upon integrating:

$$E_{\mathrm{L}} = -\left(\frac{RT}{F}\right) \left[0.4 \ln \left(\frac{a_{\mathrm{Na}_2^+}}{a_{\mathrm{Na}_1^+}} \right) - 0.6 \ln \left(\frac{a_{\mathrm{Cl}_2^-}}{a_{\mathrm{Cl}_1^-}} \right) \right] \tag{3}$$

Since $a_{Na^+} = a_{Cl^-} = a_{NaCl} = a_m$:

$$E_L = -\left(\frac{RT}{F}\right)\left[-0.2\ln\left(\frac{a_{m_2}}{a_{m_1}}\right)\right] = 11.5\log\left(\frac{a_2}{a_1}\right) \tag{4}$$

at 25°C. E has units of millivolts (mv).

The membrane potential develops when two fluids of different salinity are brought together with an intervening shale membrane. It develops through the over and underlying shale. Since the Cl^- cannot migrate through the negatively charged shale but the Na^+ can, the transfer numbers for sodium and chlorine in shale are $t_{Na^+} = 1$ and $t_{Cl^-} = 0$. The potential is given by:

$$E_m = -\left(\frac{RT}{F}\right)\sum_i \frac{1}{Z_i}\int_1^2 t_i\,d\ln a_i \tag{5}$$

For an NaCl solution:

$$E_m = -\left(\frac{RT}{F}\right)\left[\frac{1}{1}\int_1^2 d\ln a_{Na^+} + \left(\frac{0}{-1}\right)\int_1^2 d\ln a_{Cl^-}\right] \tag{6}$$

which upon integrating gives:

$$E_m = -\left(\frac{RT}{F}\right)\ln\left(\frac{a_{m_2}}{a_{m_1}}\right) \tag{7}$$

At 25°C:

$$E_m = -59\log\left(\frac{a_2}{a_1}\right) \tag{8}$$

Since the total electromotive potential, E_c, equals the sum of all of the current times resistance drops along the current path:

$$E_c = E_m + E_L \tag{9}$$

E_c is known as the static spontaneous potential (SSP). The current path is through the mud, shale, uninvaded formation, invaded zone, and back into the mud. Therefore:

$$E_c = E_m + E_L = -70.5\log\left(\frac{a_2}{a_1}\right) = -K\log\left(\frac{a_{water}}{a_{mud\ filtrate}}\right) \tag{10}$$

For sodium, calcium, and magnesium groundwater systems several authors (Gondouin et al., 1957) have shown that eqn. (8) is given by:

$$E_m = -K\log\left\{\frac{(a_{Na^+} + \sqrt{a_{Ca^{2+}} + a_{Mg^{2+}}})_{water}}{(a_{Na^+} + \sqrt{a_{Ca^{2+}} + a_{Mg^{2+}}})_{mud\ filtrate}}\right\} \tag{11}$$

where E_m is the membrane potential (mv), K is a constant, a_{Na^+} is the activity of the sodium, $a_{Ca^{2+}}$ is the activity of the calcium, and $a_{Mg^{2+}}$ is the activity of the

magnesium. Since resistivities are inversely proportional to activities eqn. (11) can be expressed for an electrically equivalent NaCl solution as:

$$E_m = -K \log \left\{ \frac{R_{mfe}}{R_{we}} \right\} \tag{12}$$

where R_{mfe} is the resistivity of an equivalent NaCl solution mud filtrate, and R_{we} is the resistivity of an equivalent NaCl solution formation water.

Assuming an analogous form for the smaller liquid junction potential:

$$E_L = -K \log \left\{ \frac{R_{mfe}}{R_{we}} \right\} \tag{13}$$

Therefore:

$$E_c = E_m + E_L = -K \log \left\{ \frac{R_{mfe}}{R_{we}} \right\} \tag{14}$$

These potentials are developed at the mud filtrate invasion front/formation water interface, the shale/borehole interface, and the formation water/shale interface. Since current is free to flow through the formation, the shale, and the drilling mud, the static spontaneous potential, E_c must be dropped in the sandstone, shale, and the mud. Each drop is directly proportional to the resistivity of the zone.

The portion of the voltage dropped in the drilling mud and the quantity which is measured by the logging tool is the spontaneous potential. Since the static spontaneous potential is determined by the relative salinity of the formation water and mud filtrate, the total formation water salinity can be determined only if the mud filtrate salinity is known and if the spontaneous potential equals the static spontaneous potential. The spontaneous potential equals the static potential only when the voltage drop in the formation and the shale equals zero.

Since the current, I, must be the same along the sandstone, shale, and mud path, and:

$$I = \frac{V}{r} \tag{15}$$

where V is voltage and r is resistance, then:

$$I = \frac{V_m}{r_m} = \frac{V_{sh}}{r_{sh}} = \frac{V_{sd}}{r_{sd}} \tag{16}$$

m, sh, and sd are mud, shale, and sand, respectively. In addition:

$$E_c = SSP = V_m + V_{sh} + V_{sd} \tag{17}$$

and:

$$r = \frac{RL}{A} \tag{18}$$

where R is the resistivity, L is the length of the current path, and A is the cross sectional area through which the current flows. Noting that the spontaneous potential is equal to the voltage drop in the mud, and combining eqns. (16), (17) and (18) (Dresser Atlas, 1975):

$$SP = SSP \left\{ \frac{\dfrac{R_m L_m}{A_m}}{\dfrac{R_m L_m}{A_m} + \dfrac{R_{sh} L_{sh}}{A_{sh}} + \dfrac{R_{sd} L_{sd}}{A_{sd}}} \right\} \qquad (19)$$

For an NaCl solution K is a function of temperature only and eqn. (14) can be expressed as:

$$SSP = - \left[60.0 + 0.133 \, T(°F) \right] \log \left\{ \frac{R_{mfe}}{R_{we}} \right\} \qquad (20)$$

Rearranging:

$$R_{we} = \frac{R_{mfe}}{10^{(-SSP/K)}} \qquad (21)$$

where K is given by $[60.0 + 0.133 \, T(°F)]$. R_{we} is computed from log measurements and is related empirically to the true water resistivity (R_w) which in turn is related to the total dissolved solids (TDS).

SP CORRECTIONS

Log data must be taken from the headings, the SP curve and the 16 inch normal or equivalent shallow resistivity device. The SP is measured at the maximum (absolute value) deflection from the shale base line. The shale base line shifts as the log enters saline formations. In thick fresh water zones the base line can curve sharply until it becomes straight in brackish waters. Measurements must be made from a curve smoothed through the shale points.

Equation (21) was derived for an NaCl solution, however groundwater contains more calcium and magnesium than sodium, and more bicarbonate than chloride. Equation (11) shows that divalent ions carry more of the current than monovalent ions. This makes the water appear saltier (more negative SP) than it really is (Wyllie, 1963). It is also apparent from eqns. (11) and (20) that:

$$R_{we} = \frac{A}{(a_{Na^+} + \sqrt{a_{Ca^{2+}}} + a_{Mg^{2+}})_{water}} \qquad (22)$$

where A is a constant.

R_{we} is computed with eqn. (22) and R_w is computed from conductivity measurements using all available chemical analyses from wells in the area of interest. R_{we} is then plotted against R_w, and R_w is plotted against TDS for the same wells. The analyses must be from the single zone of interest and the effects of NaCl mud invasion must have dissipated prior to sampling (McConnell,

1985). Once these field calibrations curves are developed the TDS can be determined for formations in wells without analyses but which have *SP* logs. The measured *SP* is used, along with the measured R_{mfe}, to calculate R_{we} from eqn. (21). TDS is found from the correlations.

Relating R_{mfe} to R_{mf} is more difficult. Many water well loggers do not measure or record the mud or drilling fluid electrical properties. Even in wells which have R_{mf} measured the relationship between R_{mfe} and R_{mf} may vary depending on the mud type and the composition of the make-up water. The oil field relationship of:

TABLE 1

Wells used in the data set

Location	Type of well	Depth (m)
Hawkins, West Tex.	water	94.5
Sugarland, Fort Bend Co., Tex.	water	283.5
Sect. 14-5N-8W, Grady Co., Okla.	oil	119.5
Sect. 8-3N-5W, Grady Co., Okla.	oil	76.2
Sect. 36-18N-6E, Creek Co., Okla.	oil	164.0
Sect. 8-17N-7E, Creek Co., Okla.	oil	148.4
Sect. 7-15N-7E, Creek Co., Okla.	oil	182.9
Sect. 9-14N-7E, Creek Co., Okla.	oil	46.6
Sect. 15-7N-6E, Seminole Co., Okla.	oil	213.4
Sect. 20-9N-6E, Seminole Co., Okla.	oil	214.9
Sect. 2-5N-10W, Caddo Co., Okla.	oil	53.3
Sect. 1-5N-10W, Caddo Co., Okla.	oil	51.8
Sect. 3-5N-9W, Caddo Co., Okla.	water	61.8
Sect. 17-14N-2W, Oklahoma Co., Okla.	oil	193.6
Sect. 15-12N-3W, Oklahoma Co., Okla.	oil	243.8
Sect. 24-11N-3W, Oklahoma Co., Okla.	oil	239.3
Sect. 3-5N-9W, Caddo Co., Okla.	oil	106.7
Sect. 31-11N-2W, Oklahoma Co., Okla.	oil	233.2
Norfolk, Va.	water	258.5
Sect. 11-55N-77W, Sheridan, Wyo.	miner. explor.	235.9
Sect. 32-19N-1W, Glenn Co., Calif.	water	181.4
Sect. 32-21N-1W, New Madrid Co., Mo.	research	396.3
24S-5W, Soledad Canyon, N.M.	water	176.8
24S-5W, Soledad Canyon, N.M.	water	367.3
24S-5W, Soledad Canyon, N.M.	water	365.8
23S-5W, Soledad Canyon, N.M.	water	272.5
Soledad Canyon, N.M.	water	259.1
Soledad Canyon, N.M.	water	152.4
Soledad Canyon, N.M.	water	243.9
75 wells from		
Sect. 32-1N-3W, Carter Co., Okla.	oil	various
Sect. 1-5S-2W, Carter Co., Okla.	oil	various
Sect. 14-2S-3W, Carter Co., Okla.	oil	various
Sect. 21-1S-3W, Carter Co., Okla.	oil	various

$$R_{\mathrm{mfe}} = 0.85\,R_{\mathrm{mf}} \tag{23}$$

(Schlumberger, 1972) holds only under certain conditions. McConnell (1986) investigated this problem and sets out guidelines for the $R_{\mathrm{mfe}}-R_{\mathrm{mf}}$ function for different types of groundwater and oil wells.

Looking at eqn. (19) it is seen that as R_{sd} and R_{sh} approach zero or as A_{sd} and A_{sh} approach infinity the SP approaches SSP. The shale resistivity is normally low due to ion exchange ($\simeq 5\,\Omega\mathrm{m}$), however the sandstone resistivity is high ($\simeq 50\,\Omega\mathrm{m}$). Since A_{sd} and A_{sh} are squared terms SP approaches SSP as the area increases, even if the resistivity is high. A_{sd} is the formation face in the borehole so that A_{sd} increases as the sandstone thickens. A_{sh} is assumed to approach infinity in the published correction charts (Dresser Atlas, 1975). These correction charts must be applied to all the input data.

METHOD OF INVESTIGATION

Hundreds of well logs from widely separated regions of the United States were examined from which a subset of 104 were chosen. The remaining were rejected because of missing data. Each log had to contain complete mud data on the heading and the well had to have chemical analyses run in distinct zones.

The logs were obtained from the files of the Oklahoma City Geological

input log and chemical data

compute chemical activities of the formation water from the Debye and Huckel theory (Sawyer and McCarty, 1978)

compute R_{mfe} from R_{mf} (McConnell, 1985) and correct all resistivities to 24°C (Schlumberger, 1972)

determine equivalent NaCl concentration and resistivity of the formation water (Dresser Atlas, 1979) or use measured conductivity

compute R_{we} from the total Ca^{2+}, Mg^{2+}, and Na^{+} activity, eqn. (22)

compute SP, eqn. (21), and correct both the computed and measured SP for bed thickness and resistivity (Dresser Atlas, 1979)

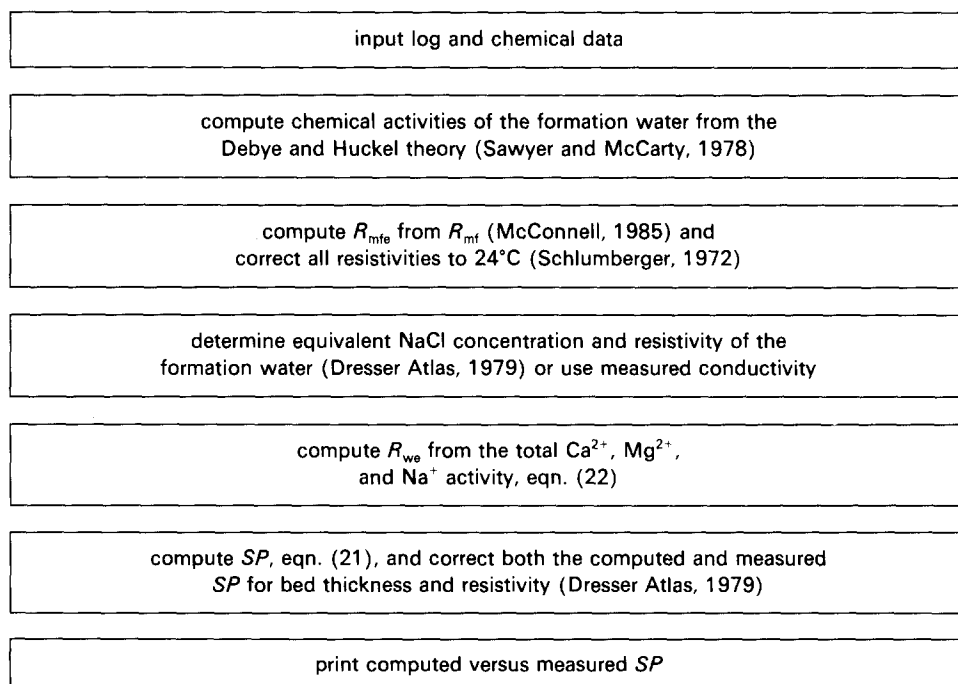| print computed versus measured SP |
| --- |

Fig. 1. Spontaneous potential calculation algorithm.

Society, the United States Geological Survey (USGS) publications, the USGS open file reports, the Society of Professional Well Log Analysts publication "The Log Analyst", and the National Water Well Association publication "Groundwater". One hundred sixty-two individual formations were evaluated from the 104 well logs. The well locations are listed in Table 1.

To determine the magnitude of the correction, the measured SP was compared to the computed SP for each zone. A simulator computer program was written which computes the SP from the chemical analysis, formation geometry data, and the R_{mf}–R_{mfe} relationships for the appropriate type of well and mud situation (program available upon request). Input data consisted of the formation depth, SP, R_{mf}, reference temperature, shallow resistivity, deep (true) resistivity, formation thickness and the chemical analysis. The algorithm is shown in Fig. 1.

The program has both an SP simulation routine and a routine to correct the measured SP for the thin bed effect. The SP simulation routines proceed along the following steps.

(1) A complete chemical analysis is input, including the measured conductivity and TDS if available. If not available the TDS is found by summing the constituents, and the conductivity is computed by converting the actual chemical analysis to an equivalent NaCl solution. This is done by first searching a table of digitized experimental curves (Schlumberger, 1972) of conversion coefficients. The conversion coefficient for a particular ionic concentration is found, then multiplied by the concentration, giving an electrically equivalent NaCl concentration for that species. The NaCl concentrations are then summed. For example, at a TDS of $1000\,\text{mg}\,l^{-1}$ and a Mg^{2+} concentration of $500\,\text{mg}\,l^{-1}$ the conversion coefficient is 1.62 so that the equivalent NaCl concentration is $(1.62)\,(500) = 810\,\text{mg}\,l^{-1}$ NaCl.

The R_{we} is found in two different ways: (a) the summed equivalent NaCl concentration is used to find R_{we} directly; and (b) the total activity of the formation water $(a_{Na^+}\,\sqrt{a_{Ca^{2+}} + a_{Mg^{2+}}})$ is reciprocated to give R_{we}. The ionic concentrations are converted to activities by computing the activity coefficients by the Guntelberg approximation to the Debye–Huckel theory (Sawyer and McCarty, 1978). This form is used to find the SP. The former value is used as a quality check.

(2) The mud properties are determined next. The user chooses either an unconditioned bentonite water well mud or heavily conditioned oil well mud R_{mf}–R_{mfe} function. The R_{mf} is either input or found from the mud resistivity (R_m).

(3) The R_{we} and R_{mfe} are corrected to the same formation temperature.

(4) The thin bed correction is determined from a set of approximating equations. The equations represent the logging company charts (Dresser Atlas, 1979). The SP is then corrected to SSP. The simulated SSP can be corrected down to a thin bed value if desired. An example calculation is given in the Appendix.
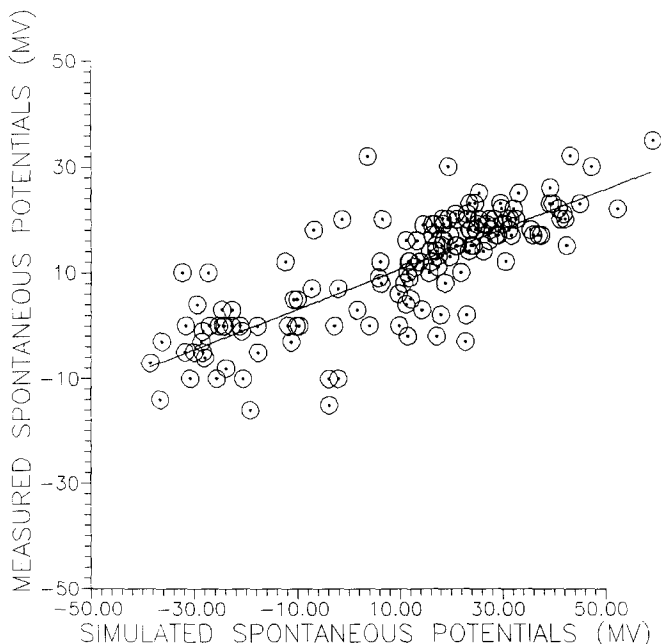
Fig. 2. Measured versus calculated spontaneous potentials.

RESULTS

The computer simulated spontaneous potential versus measured spontaneous potential plot is given as Fig. 2. The data scatter but the regression analysis best fit line appears logically acceptable. The best fit was linear with:

$$\text{MEASURED } SP \;=\; 0.3782 \times \text{SIMULATED } SP + 6.9172 \tag{24}$$

for $0\,mv < \text{SIMULATED } SP < \;+50\,mv$. Even though the data extend down to $-30\,mv$ the domain value of $0\,mv$ was chosen since less data occur in this region and since the simulated and measured SP must converge at low (more negative) SPs these data appear less reliable. Since this is an empirical relationship it is important that it only be applied within the stated domain.

The field application of this correction would require using the inverse of eqn. (24) to determine the true (or simulated) SP from an SP log reading. For example, a measured SP of $15\,mv$ would first have the normal geometric and chemical corrections applied. The SP would then be further corrected by applying eqn. (24), giving $21.4\,mv$. The corrected value would be used to compute R_{we}. The magnitude of the correction can be quite large and for fresh water formations with measured SPs greater than $11\,mv$ always corrects in the direction of fresher water. Using the measured potential of $15\,mv$ and assuming an $R_{mfe} = 2\,\Omega m$ and a temperature of $24°C$ the R_{we} is:

$$R_{we} = \frac{2\,\Omega m}{_{10}(-15/70)} = 1.64\,\Omega m \tag{25}$$

whereas the corrected value of 21.4 mv gives $R_{we} = 2.02\,\Omega m$ or a difference of 19% relative to $2.02\,\Omega m$. Since the R_{we}–R_w function is nonlinear this can represent a large change in R_w.

The reasons for the correction are not entirely obvious to the author. The correlation of Fig. 2 has all the chemical and geometric corrections applied to the data. In addition analytic solutions (Dakhnov, 1962) and finite element models (McConnell, unpubl.) indicate that the standard logging company correction charts should give accurate results.

In brine formations the SP is known to yield accurate results, generally at SPs more negative than -80 mv to -100 mv. Thus the correction is needed and is applicable only in fresh waters. When the R_{mf}–R_{mfe} function is known the source of the error must reside in eqn. (11). In the original development by Gondouin et al. (1957, p. 68) this relationship was tested in the laboratory using cut shale disks for a number of Na^+–Ca^{2+}–Mg^{2+} mixtures with an error determined for each test. The magnitude of the error was in the range of -1 mv to $+2$ mv. In the previous example of 15 mv corrected to 21.4 mv an error of 2 mv accounts for only 31% of the correction.

CONCLUSIONS

Good results can be obtained when calculating the total dissolved solids of fresh groundwater from spontaneous potential well logs if special precautions are taken. A geometric correction must be applied to obtain the static spontaneous potential (SSP) from the spontaneous potential (SP). In addition the equivalent mud filtrate (R_{mfe}) — true mud filtrate resistivity (R_{mf}), equivalent formation water resistivity (R_{we}), true formation water resistivity (R_w), and true formation water resistivity (R_w) — total dissolved solids (TDS) correlations must be known.

Even with all these corrections the computed salinity tends to be too high in fresh groundwaters. An empirical relationship between the simulated SP and the measured SP from widely different groundwaters from the United States shows that the error is uniform and predictable and is given by:

MEASURED SP = 0.3782 × SIMULATED SP + 6.9172

for 0 mv < SIMULATED SP < 50 mv. The origin of this error appears to be due to the difference in efficiency of the laboratory-derived governing equation and the real systems.

APPENDIX

A log from section 1 - 5N - 10W was chosen as an example (Fig. 3). A thick fresh water sandstone is found at 160 ft (48.77 m). The calculation proceeds as follows.
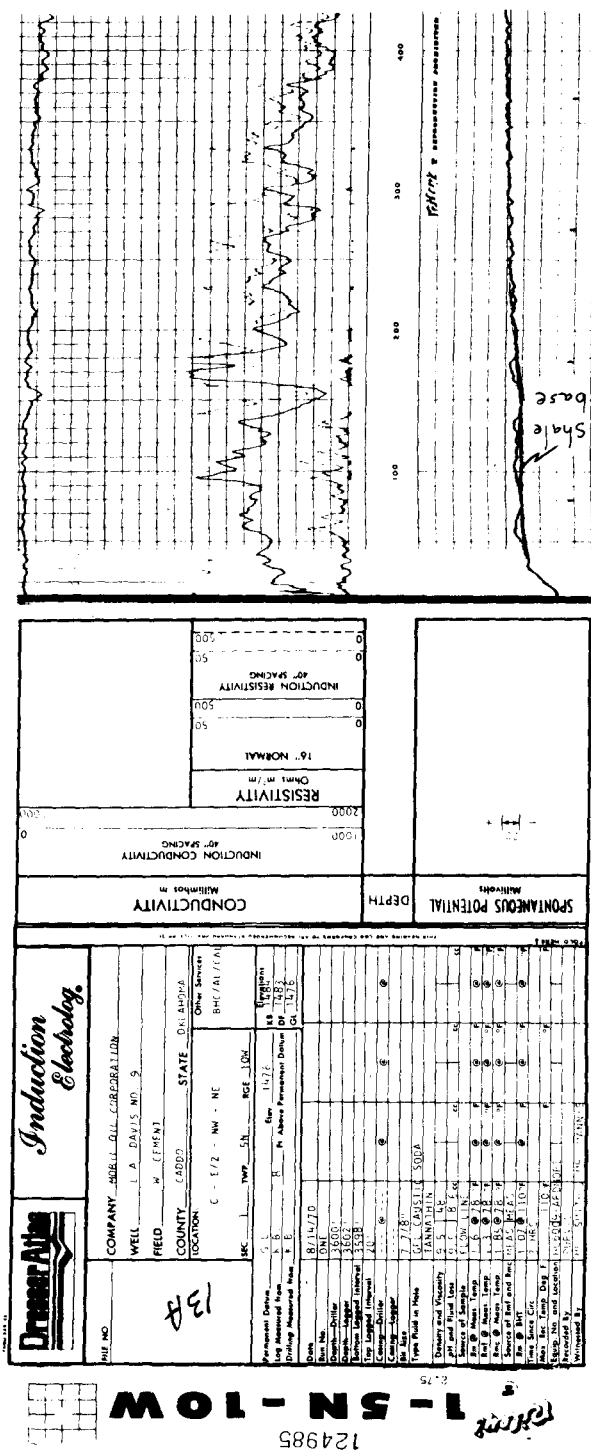
Fig. 3. Well log used in example calculations.

(1) Collect pertinent data:

(a) Chemical data. A chemical analysis of this water gives (all in $mg\,l^{-1}$):
Ca^{2+} = 100, Mg^{2+} = 12, Na^+ = 16, K^+ = 0, Si^{4+} = 24, HCO_3^- = 274,
CO_3^{2-} = 0, SO_4^{2+} = 7, Cl^- = 37, TDS = 399; and conductivity = 640
micromho cm^{-1}.

(b) Log data. R_m = 1.6 Ωm at 78°F (25.6°C), R_{mf} = 1.3 Ωm at 78°F (25.6°C),
formation temperature = 68°F (20°C), shallow resistivity = 35 Ωm, bed
thickness = 20 ft (6.1 m) and measured SP = 11 mv.

(2) Simulated SP calculations. Actually all these calculations are done on
the computer and are only shown here as an example:

(a) Compute the activities of the Ca^{2+}, Mg^{2+}, and Na^+ ions by the Debye–
Huckel theory. This yields $a_{Mg^{2+}}$ = 0.00032, $a_{Ca^{2+}}$ = 0.00155, and
a_{Na^+} = 0.00061. Evaluating A in eqn. (22) leads to:

$$R_{we} = 10^{[-\log(a_{Na^+} + \sqrt{a_{Ca2^+} + a_{Mg2^+}}) - 1.125]}$$

and R_{we} = 1.71.

(b) Compute the R_{mfe} by using the proper relationship for this type of well,
i.e.:

$$R_{mfe} = 0.85\,R_{mf} = 1.105\,\Omega m$$

(c) Compute SP by:

$$SP = -[64.26 + 0.2394(23.89°C)]\log\left(\frac{1.105}{1.71}\right)$$

$$SP = 13.3\,mv$$

(d) Correct the SP to SSP (thin bed correction). The bed thickness, 20 ft
(6.1 m), and the ratio shallow resistivity/R_m = 35 Ωm/1.6 Ωm = 21.2 are entered
into an empirical relationship of SP versus SSP correction factor (Dresser
Atlas, 1975). The resultant SP correction factor = 1.04 and SSP
= 13.3(1.04) = 13.8 mv.

(e) The simulated SSP = 13.8 mv.

(3) Measured SP. The measured SP is 11 mv. The SP correction factor is
found as shown above and the measured SSP = 11.4 mv.

(4) Using eqn. (24) the measured SP of 11.4 mv gives a corrected SP of:

$$\text{SIMULATED } SP = \frac{\text{MEASURED } SP - 6.9172}{0.3782} = 11.9\,mv$$

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