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# A FORTRAN algorithm for correcting normal resistivity logs for borehole diameter and mud resistivity

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## Abstract

The FORTRAN[1/] algorithm described in this report was developed for applying corrections to normal resistivity logs of any electrode spacing for the effects of drilling mud of known resistivity in boreholes of variable diameter. The corrections are based on Schlumberger departure curves that are applicable to normal logs made with a standard Schlumberger electric logging probe with an electrode diameter of 8.5 cm (3.35 in). The FORTRAN algorithm has been generalized to accommodate logs made with other probes with different electrode diameters. Two simplifying assumptions used by Schlumberger in developing the departure curves also apply to the algorithm: (1) bed thickness is assumed to be infinite (at least 10 times larger than the electrode spacing), and (2) invasion of drilling mud into the formation is assumed to be negligible.

1/ The use of a trade name does not necessarily constitute endorsement by the U.S. Geological Survey.

## Introduction

The FORTRAN algorithm described in this report is based on Schlumberger departure curves for a normal probe under conditions of no invasion of drilling mud and infinite bed thickness with electrodes N and B at an infinite distance from each other and from probe electrodes A and M. These curves are published in Schlumberger Document Number 3 (1949). In developing the algorithm, the Schlumberger departure curves were digitized to obtain values of Ra/Rm for Rt/Rm ranging from 0.1 to 1000 and AM/d ranging from 0.2 to 700 as shown in table 1. Ra is apparent resistivity, Rm is mud resistivity, Rt is true resistivity, AM is electrode spacing, and d is hole diameter. A stepwise multiple regression procedure was applied to the digitized data divided into two sets: one for $Rt/Rm \leq 1$, the other for $Rt/Rm \geq 1$. Log(Rt/Rm) was taken as the dependent variable, and log(Ra/Rm) and log(AM/d), together with their powers and cross-products up to 4th degree, were taken as the independent variables. The two resulting equations of fitted surfaces have multiple correlation coefficients of 0.9936 for $Rt/Rm \leq 1$ and 0.9996 for $Rt/Rm \geq 1$ when carried to 11 terms given in equations (1) and (2) below:

For $Rt/Rm \leq 1$

$$S = 0.98989832\, x_1^2 - 0.14939863\, x_1 - 0.025675792\, x_2^4 + 0.067224059\, x_2^3 + 0.076110412\, x_2^2 - 0.19797682\, x_2 - 0.023026418\, x_1^2 x_3 - 0.18076212\, x_2^2 x_3 + 0.85238666\, x_2 x_3 - 1.0115236\, x_3 - 0.0012422286 \qquad (1)$$

Table 1.--Values of Ra/Rm tabulated for Rt/Rm ranging from 0.1 to 1000 and AM/d ranging from 0.2 to 700 obtained from Schlumberger departure curves for normal device, no invasion, and beds of infinite thickness (Schlumberger document no. 3, 1949).

| | AM/d | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| t/R- | 0.2 | 0.3 | 0.5 | 0.7 | 1.0 | 1.5 | 2.0 | 3.0 | 5.0 | 7.0 | 10 | 15 | 20 | 30 | 50 | 70 | 100 | 150 | 200 | 300 | 500 | 700 |
| 0.1 | 0.700 | 0.570 | 0.360 | 0.240 | 0.155 | 0.110 | 0.089 | 0.081 | 0.086 | 0.094 | 0.098 | 0.100 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| 0.2 | 0.740 | 0.630 | 0.440 | 0.340 | 0.250 | 0.195 | 0.180 | 0.180 | 0.197 | 0.200 | 0.200 | 0.200 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| 0.3 | 0.780 | 0.680 | 0.520 | 0.435 | 0.350 | 0.285 | 0.265 | 0.270 | 0.290 | 0.295 | 0.300 | 0.300 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| 0.5 | 0.840 | 0.780 | 0.670 | 0.600 | 0.530 | 0.470 | 0.460 | 0.465 | 0.490 | 0.495 | 0.500 | 0.500 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| 0.7 | 0.900 | 0.860 | 0.800 | 0.760 | 0.710 | 0.680 | 0.660 | 0.670 | 0.690 | 0.695 | 0.700 | 0.700 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| 1.0 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| 1.5 | 1.15 | 1.20 | 1.30 | 1.40 | 1.50 | 1.55 | 1.60 | 1.60 | 1.52 | 1.50 | 1.50 | 1.50 | 1.50 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| 2.0 | 1.30 | 1.40 | 1.65 | 1.80 | 1.95 | 2.10 | 2.15 | 2.15 | 2.05 | 2.01 | 2.00 | 2.00 | 2.00 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| 3.0 | 1.50 | 1.75 | 2.20 | 2.50 | 2.80 | 3.15 | 3.30 | 3.30 | 3.17 | 3.10 | 3.05 | 3.00 | 3.00 | 3.00 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| 5.0 | 1.95 | 2.50 | 3.30 | 3.80 | 4.50 | 5.15 | 5.60 | 5.85 | 5.70 | 5.45 | 5.30 | 5.10 | 5.00 | 5.00 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| 7.0 | 2.45 | 3.00 | 4.10 | 5.00 | 6.10 | 7.20 | 8.00 | 8.60 | 8.40 | 7.90 | 7.30 | 7.10 | 7.00 | 7.00 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| 10 | 2.90 | 3.85 | 5.40 | 6.60 | 8.30 | 10.5 | 11.7 | 12.5 | 12.5 | 12.1 | 11.3 | 10.8 | 10.5 | 10.1 | 10.0 | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| 15 | 3.65 | 5.00 | 7.20 | 9.25 | 12.0 | 15.0 | 17.5 | 20.0 | 21.5 | 20.0 | 18.7 | 17.0 | 16.5 | 15.5 | 15.0 | 15.0 | ---- | ---- | ---- | ---- | ---- | ---- |
| 20 | 4.30 | 6.00 | 9.00 | 12.0 | 15.0 | 19.0 | 23.0 | 26.0 | 28.0 | 27.5 | 25.5 | 23.5 | 22.0 | 21.0 | 20.0 | 20.0 | ---- | ---- | ---- | ---- | ---- | ---- |
| 30 | 5.50 | 7.80 | 12.4 | 16.0 | 20.5 | 27.0 | 32.0 | 40.0 | 46.0 | 46.5 | 44.0 | 38.5 | 35.0 | 32.0 | 30.5 | 30.0 | 30.0 | ---- | ---- | ---- | ---- | ---- |
| 50 | 7.00 | 10.5 | 16.5 | 22.0 | 29.0 | 39.0 | 48.0 | 60.0 | 73.0 | 76.5 | 74.5 | 67.0 | 60.0 | 55.0 | 52.0 | 50.5 | 50.0 | 50.0 | ---- | ---- | ---- | ---- |
| 70 | 9.00 | 13.0 | 20.5 | 27.5 | 37.0 | 51.0 | 63.0 | 82.0 | 105. | 120. | 120. | 110. | 96.0 | 84.0 | 75.0 | 73.0 | 71.0 | 70.0 | 70.0 | ---- | ---- | ---- |
| 100 | 11.0 | 16.0 | 26.0 | 35.0 | 48.0 | 65.0 | 83.0 | 115. | 145. | 165. | 170. | 165. | 150. | 130. | 115. | 110. | 105. | 100. | 100. | ---- | ---- | ---- |
| 150 | 14.0 | 20.5 | 34.0 | 45.5 | 63.0 | 89.0 | 115. | 150. | 200. | 230. | 250. | 240. | 230. | 200. | 175. | 165. | 160. | 155. | 150. | 150. | ---- | ---- |
| 200 | 17.0 | 25.0 | 40.0 | 55.0 | 76.0 | 110. | 135. | 180. | 255. | 295. | 330. | 340. | 320. | 280. | 240. | 225. | 210. | 205. | 200. | 200. | ---- | ---- |
| 300 | 21.0 | 31.0 | 50.0 | 69.0 | 95.0 | 140. | 180. | 250. | 360. | 435. | 500. | 550. | 555. | 505. | 425. | 370. | 340. | 320. | 310. | 300. | 300. | ---- |
| 500 | 28.0 | 41.0 | 69.0 | 95.0 | 130. | 195. | 255. | 355. | 530. | 660. | 810. | 935. | 990. | 970. | 830. | 735. | 635. | 565. | 535. | 515. | 500. | ---- |
| 700 | 34.0 | 49.0 | 80.0 | 120. | 160. | 240. | 300. | 440. | 670. | 860. | 1100. | 1300. | 1400. | 1500. | 1300. | 1200. | 1000. | 870. | 810. | 750. | 710. | 700. |
| 000 | 40.0 | 60.0 | 100. | 140. | 195. | 285. | 380. | 540. | 830. | 1120. | 1420. | 1780. | 2000. | 2300. | 2200. | 1870. | 1630. | 1350. | 1250. | 1170. | 1100. | 1000. |

For $Rt/Rm \geq 1$

$$S = 0.015270453\, x_1^3 - 0.065033900\, x_1^2 + 1.2427109\, x_1 - 0.0031720250\, x_2^4 - 0.022673233\, x_2^3 + 0.12836914\, x_2^2 - 0.056806217\, x_2 - 0.0033741998\, x_1^2 x_3 + 0.0020463816\, x_2^2 x_3 + 0.059729697\, x_2 x_3 - 0.24143625\, x_3 - 0.13580321 \qquad (2)$$

where

$S = \log(Rt/Rm)$,

$x_1 = \log(Ra/Rm)$,

$x_2 = \log(AM/d)$,

$x_3 = x_1 x_2$ .

After S has been evaluated, true resistivity can be computed from the relationship:

$$Rt = Rm(\exp S) \ . \qquad (3)$$

The significance of hole diameter, d, in parameter AM/d is that it determines the thickness of mud in the annular space between the probe and the borehole wall when the probe is centered in the borehole. The thickness of mud in the annulus is (d-3.35)/2 inches for the standard Schlumberger probe with an electrode diameter of 8.5 cm (3.35 inches). The Schlumberger curves and equations (1) and (2) are valid for this particular electrode diameter. For any other probe with a different electrode diameter dp, used in a hole having a measured diameter d', the annulus is (d'-dp)/2, for which equations (1) and (2) are not valid if d' is used in place of d. In order to obtain valid results from equations (1) and (2) we must compute a different value for d which can be regarded as an effective hole diameter. To accomplish this, we equate (d-3.35)/2 to (d'-dp)/2 and solve for d to obtain the following equation:

$$d = d' + 3.55 - dp \ . \qquad (4)$$

For example, if the FORTRAN algorithm is applied to logs made with a Gearhart-Owen probe with an electrode diameter of 0.73 cm (1.85 inches), the effective hole diameter that is required for valid results from equations (1) and (2) are:

$$d = d' + 3.55 - 1.85 = d' + 1.50 \text{ inches} \qquad (5)$$

Equation (5) can be interpreted as follows: since the Gearhart-Owen probe is 1.50 inches smaller in diameter than the Schlumberger probe, the effective hole diameter for use with the departure curves must be increased by 1.50 inches over the measured hole diameter in order to make the annulus the same for the Schlumberger probe for which the departure curves were derived and the actual Gearhart-Owen probe. The value 1.50 is represented in the FORTRAN algorithm by "dcorr" which is computed as dcorr = 3.35 - dp near the beginning of the program segment.

## Description of FORTRAN algorithm

The computational program segment listed in this report must be preceded by an input routine for reading the resistivity log values of Ra (ohm-meters) into array xlog(i,1), and resistivity log depths (feet) into array zlog(i,1). If a caliper log is available, the hole diameter values (inches) are read into array xlog(i,2) with corresponding depths read into array zlog(i,2). Both logs should be digitized at the same depth interval (usually 0.5 or 1.0 ft). The resistivity of fluid in the borehole is stored as "Rm", the electrode diameter of the probe as "dp", and the nominal hole diameter as "diam". The nominal hole diameter is used in place of the caliper log in intervals where the caliper log is missing. The index of the last (deepest) data points in arrays xlog(i,j) and zlog(i,j) is stored in array nm(j) where j = 1 represents the resistivity log, and j = 2 represents the caliper log.

The program begins by testing Rm to assure that it is greater than zero; the program stops if it is not. Then dcorr, the electrode diameter correction is computed as described previously. Next the caliper log, if it is available, is alined with resistivity log by calling subroutine aline to obtain a hole diameter value at depth zlog(i,1). Then the normalized apparent resistivity Ram is computed by dividing the observed resistivity xlog(i,1) by the mud resistivity Rm. If Ram is less than or equal to zero, xlog(i,1) is set equal to zero and the correction procedure is skipped. If Ram is nearly equal to 1 (0.95 < Ram < 1.05) the correction procedure is also skipped. Otherwise the procedure is continued with the computation of a value of AM/d corrected for electrode diameter and stored as AMd = AM/(xdiam + dcorr). Then, if Ram is very small (Ram < 0.1), Ram is set equal to 0.1 to prevent extrapolation of wild values. Then a test is made for large values of AMd for which no correction is required, using the criterion $125/AMd^3 \leq Ram$ which can be represented as a straight line on the logarithmic departure curves passing through points AMd = 5 at Ram = 1 and AMd = 10.8 at Ram = 0.1. If AMd falls to the right of this line the correction procedure is skipped, but if it falls to the left the correction formula for Ram < 1 is applied. For values of Ram > 1 a similar test is made for large values of AMd using the criterion $\sqrt{AMd^3/125} \geq$ Ram which can be represented as a straight line on the logarithmic departure curves passing through points AMd = 5 at Ram = 1 and AMd = 500 at Ram = 1000. If AMd falls to the right of this line the correction procedure is skipped, but if it falls to the left the correction formula for Ram > 1 is applied. If the resulting corrected value Rtm exceeds 1000, which is beyond the upper boundary of the departure curves, an extrapolation procedure is used to obtain an approximate correction under the assumption that curves for large Rtm replicate those in the range 500 < Rtm < 1000, but with peaks and other corresponding points falling along parallel lines with slopes of 1.5 on the logarithmic departure curve scale. Finally the normalization for mud resistivity is removed by multiplying the normalized value Rtm by Rm and the result is stored back in array xlog(i,1) as the corrected resistivity, and may be printed or plotted by output routines of the user's choice.

Subroutine aline is a general-purpose subroutine for alining one or two auxiliary logs stored in arrays xlog(i,2), zlog(i,2), and xlog(i,3), zlog(i,3) with a primary log stored in array xlog(i,1), zlog(i,1). Only one auxiliary log (the caliper log) is required to make the correction to the primary log (the resistivity log) in the algorithm described in this report. Subroutine aline searches the caliper log depth array zlog(i,2) for a depth that matches the specified depth of interest of the primary log, zlog(i,1), and returns the appropriate value of hole diameter to the main program as xaline(2). If an exact depth match is not available, linear interpolation is used to compute xaline(2). If the specified depth of interest of the primary log is beyond the range of depths representing the caliper log, a value of xaline(2) = 0 is returned to the main program, and nominal hole diameter (diam) is used instead.

The FORTRAN listing in this report is part of a generalized log interpretation program developed and used by the U.S. Geological Survey on the Honeywell Multics computing system. The FORTRAN compiler for this system requires a nonstandard format for FORTRAN statements; in particular, lower-case ASCII characters are used, and no continuation-card numbers are needed in column 6. However, Multics programs can be converted to standard FORTRAN format for use with other computers.

Example

An example of a result obtained by use of the program is given below along with input resistivity and caliper log data that can be used as a test case. In the example, mud resistivity (Rm) is 3 ohm-meters, nominal hole diameter (diam) is 5.0 inches, and the probe electrode diameter (dp) is 1.85 inches.

| | Input data | | | | Output data | |
|---|---|---|---|---|---|---|
| | Observed 16" normal log | | Caliper log | | Corrected 16" normal log | |
| | Depth(ft) | Ra(ohm-m) | Depth(ft) | Diam(in) | Depth(ft) | Rt(ohm-m) |
| Array: | zlog(i,1) | xlog(i,1) | zlog(i,2) | xlog(i,2) | zlog(i,1) | xlog(i,1) |
| | 20.0 | 10 | 16.0 | 4.88 | 20.0 | 9.18 |
| | 20.5 | 20 | 16.5 | 5.02 | 20.5 | 17.78 |
| | 21.0 | 30 | 17.0 | 5.01 | 21.0 | 26.17 |
| | 21.5 | 50 | 17.5 | 4.89 | 21.5 | 43.00 |
| | 22.0 | 70 | 18.0 | 4.79 | 22.0 | 60.21 |
| | 22.5 | 100 | 18.5 | 4.73 | 22.5 | 87.13 |
| | 23.0 | 200 | 19.0 | 4.70 | 23.0 | 187.60 |
| | 23.5 | 200 | 19.5 | 4.65 | 23.5 | 306.56 |
| | 24.0 | 500 | 20.0 | 4.62 | 24.0 | 596.99 |
| | 24.5 | 700 | 20.5 | 4.60 | 24.5 | 968.26 |
| | 25.0 | 1000 | 21.0 | 4.59 | 25.0 | 1665.87 |
| | 25.5 | 800 | 21.5 | 4.60 | 25.5 | 1201.26 |
| | 26.0 | 600 | 22.0 | 4.60 | 26.0 | 799.75 |
| | 26.5 | 400 | 22.5 | 4.61 | 26.5 | 461.93 |
| | 27.0 | 300 | 23.0 | 4.63 | 27.0 | 319.12 |
| | 27.5 | 200 | 23.5 | 4.68 | 27.5 | 195.03 |
| | 28.0 | 100 | 24.0 | 4.72 | 28.0 | 89.70 |
| | 28.5 | 80 | 24.5 | 4.80 | 28.5 | 70.86 |
| | 29.0 | 60 | 25.0 | 4.85 | 29.0 | 52.70 |
| | 29.5 | 40 | 25.5 | 4.91 | 29.5 | 35.15 |
| | 30.0 | 25 | 26.0 | 4.97 | 30.0 | 22.25 |

## FORTRAN ALGORITHM

```
c NORMAL RESISTIVITY LOG - mud and hole diam correction
c
c   xlog(i,1) = resistivity log readings, ohm-meters
c   zlog(i,1) = resistivity log depths, feet
c   nm(1)     = index of last reading in resistivity log array
c   xlog(i,2) = caliper log readings, inches
c   zlog(i,2) = caliper log depths, feet
c   nm(2)     = index of last reading in caliper log array
c   nlog      = number of logs in set: 2 if caliper log is available, 1 if not
c   dp        = diameter of logging probe electrodes, inches
c   dcorr     = diff between Schlum electrode diam and dp (3.35-dp), inches
c   AM        = spacing between electrodes A and M, inches
c   AMd       = AM/(xdiam+dcorr)
c   Rm        = mud resistivity, ohm-meters
c   Ram       = apparent resistivity/Rm
c   Rtm       = corrected resistivity/Rm
c   diam      = nominal hole diameter, inches
c   xaline(2) = hole diameter from caliper log at depth z(i,1), inches
c   xdiam     = xaline(2) if caliper log reading is available at depth z(i,1)
c            (or)
c             = diam (nominal diameter) if caliper log is not available
c
           common xlog,zlog,nm,nlog
           dimension xlog(5000,3),zlog(5000,3),nm(3),xaline(3)
c
3000       if(Rm.gt.0.) go to 3005
           print," STOP - Rm.le.0"
           stop
3005       nres=nm(1)
           dcorr=3.35-dp
           do 3018 i=1,nres
           xdiam=diam
           if(nlog.eq.1) go to 3007
           call aline(i,xaline)
           if(xaline(2).ne.0.) xdiam=xaline(2)
3007       Ram=xlog(i,1)/Rm
           if(Ram.gt.0.) go to 3008
           xlog(i,1)=0.
           go to 3018
c test for no correction when Ram=1 and when Ram<1 and AM/d is large
3008       if(abs(Ram-1.).lt.0.05) go to 3018
           AMd=AM/(xdiam+dcorr)
           if(Ram.gt.1.) go to 3010
           if(Ram.ge.0.1) go to 3009
           go to 3018
3009       test=125./AMd**3
           if(test.le.Ram) go to 3018
```

```
c apply correction formula for Ram<1
          x1=alog(Ram)
          x2=alog(AMd)
          x3=x1*x2
          xlog(i,1)=Rm*exp((-1.4939863e-1*x1+9.8989832e-1)*x1+(((-2.5675792e-2*
          x2+6.7224059e-2)*x2+7.6110412e-2)*x2-1.9797682e-1*x2+x3*(-1.0115236-
          2.3026418e-2*x1*x1+(x2*-1.8076212e-1+8.5238666e-1)*x2)-1.2422286e-3)
          go to 3018
c test for no correction when Ram>1 and AM/d is large
3010      test=sqrt(AMd**3/125.)
          if(test.ge.Ram) go to 3018
c apply correction formula for Ram>1
          ix=0
          Ro=Ram
3012      x1=alog(Ram)
          x2=alog(AMd)
          x3=x1*x2
          Rtm=exp(((1.5270453e-2*x1-6.5033900e-2)*x1+1.2427109)*x1
          +(((-3.1720250e-3*x2-2.2673233e-2)*x2+1.2836914e-1)*x2-5.6806217e-2)*
          x2+x3*(-2.4143625e-1-3.3741998e-3*x1*x1+(2.0463816e-3*x2+5.9729697e-2)
          *x2)-1.3580321e-1)
          if(Rtm.le.1000.) go to 3014
          Ram=Ram*.5
          AMd=AMd*.75
          ix=1
          go to 3012
3014      if(ix.eq.1) Rtm=Ro*(Rtm/Ram)
          xlog(i,1)=Rt*Rm
3018      continue
c
3020      print 3025
3025      format(/" Rm and AM/d correction applied")
          end
```

```
      subroutine align(i,x)
c
c This subroutine aligns depths of 1 or 2 logs with a reference log stored
c in arrays xlog(i,1),zlog(i,1).  The logs to be aligned are stored in
c arrays xlog(i,2),zlog(i,2) if one log is to be aligned, and in arrays
c xlog(i,2),zlog(i,2) and xlog(i,3),zlog(i,3) if two logs are to be aligned.
c
c   nlog = number of logs to be aligned
c      i = depth index of reference log at alignment depth zlog(i,1)
c      x = array of x-values aligned with xlog(i,1):  x(1)=xlog(i,1)
c
      common xlog,zlog,nm,nlog
c
      dimension xlog(5000,3),zlog(5000,3),x(3),int(3),nm(3)
c
      x(1)=xlog(i,1)
      zref=zlog(i,1)
      if(i.gt.1) go to 20
      do 10 k=2,nlog
10    int(k)=ifix((zlog(1,1)-zlog(1,k))/(zlog(2,1)-zlog(1,1)))
c
20    do 70 k=2,nlog
      x(k)=0.
      j=i+int(k)
      if(j.le.0.or.j.gt.nm(k)) go to 70
      if(zlog(j,k).eq.zref) go to 60
      if(zlog(j,k).lt.zref) go to 40
30    j=j-1
      if(j.le.0) go to 70
      if(zlog(j,k).gt.zref) go to 30
      if(zlog(j,k).eq.zref) go to 60
      j1=j
      j2=j+1
      go to 50
c
40    j=j+1
      if(j.gt.nm(k)) go to 70
      if(zlog(j,k).lt.zref) go to 40
      if(zlog(j,k).eq.zref) go to 60
      j1=j-1
      j2=j
50    x(k)=((zref-zlog(j1,k))*(xlog(j2,k)-xlog(j1,k)))/
      (zlog(j2,k)-zlog(j1,k))+xlog(j1,k)
      go to 70
c
60    x(k)=xlog(j,k)
c
70    continue
      return
      end
```

## Reference

Schlumberger Well Surveying Corp., 1949, Resistivity departure curves: Schlumberger Well Surveying Corp., 121 p.