UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Mapping of Brine Contamination in Osage County, Oklahoma, Using Transient Electromagnetic Soundings

by

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Introduction

Time-domain electromagnetic surveys were performed in Osage County, Oklahoma as part of a U.S. Geological Survey research project to detect and map the lateral extent of brine which has escaped from injection wells. The injection wells are used in secondary recovery of petroleum. Leaking surface casings, bottom-hole packers, and long strings have caused extensive pollution of near-surface aquifers in Osage County. Identification of the leaking wells is difficult due to the more than 34,000 wells of which about 10,000 are still producing in a 5,951 km^2 area (Thorman and Hibshman, 1979). Since the brine is a very good electrical conductor, electromagnetic methods seemed well suited for detecting and mapping the pollution. The transient electromagnetic sounding technique was chosen because of its high sensitivity to conductive zones and superior resolution compared to other electromagnetic techniques.

To date two separate investigations have been performed in Osage County. The first survey is described in a companion report (Raab and Frischknecht, 1984). Following completion of these field surveys, test wells were drilled and a suite of borehole logs run at both sites. Comparison of the well logs and surface geophysical investigations will be the subject of a subsequent report.

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Field Procedure and Equipment

Transient soundings were made using a SIROTEM II system (Buselli and O'Neill, 1971). The SIROTEM system injects a bipolar, square-wave current into a large loop. When the current is turned off, the loop is switched to the receiver, and the voltage induced in the loop is recorded as a function of time. The SIROTEM system records and stacks the transients from several thousand turnoffs, and reports the averaged voltage-current ratios.

Square loops 76.2 m or 152.4 m on a side were used. Four to six runs of 2,048 transients per run were made at each site. The polarity of the receiver leads was reversed on alternative runs to reduce instrument noise.

Due to the numerous pipes found at the site a map of their location was made. This was useful in determining where loops could be placed in an attempt to minimize cultural noise.

Data Preparation

The recorded voltage-current ratios were converted to late stage apparent resistivity (Kaufman and Keller, 1983, p. 457) using the formula

$$\rho_a = \frac{\mu_o}{4\pi t}\left(\frac{2\mu_o L^4}{5tV/I}\right)^{2/3}$$

where μ_o is the free space permeability, L is the length of a side of the transmitter loop, t is the time since current turnoff, and V/I is the voltage-current ratio (all in SI units). The voltage-current values from several runs were averaged before conversion to apparent resistivity. Data from the first

two SIROTEM channels (0.4 ms and 0.8 ms) were not used because they showed the influence of noise and transmitter turnoff effects. The later-time data were rejected when the data appeared to be noisy and the apparent resistivity curves no longer behaved smoothly.

Inversion of Soundings

Initial models for the data were obtained by curve matching using a catalog of layered-earth models (Kaufman and Keller, 1983). These models served as starting points for a non-linear least-squares inversion by computer (Anderson, 1982). Best-fit two, three, and four-layer models were found for each sounding. Fits with the simplest model which gave results commensurate with the uncertainty of the data were used.

Field Area

The study area is located in the South Burbank Oil Field, Osage County, Oklahoma near the town of Little Chief (about 19 miles west of Pawhuska, Oklahoma). Two sites have been investigated in this general area. The investigation of Site #1 is described in Raab and Frischknecht (1984). This report describes the work done at Site #2. A total of 19 transient soundings were made at this location. Of these, four soundings were not useable due to noise and instrument problems. Figure 1 shows the site map with the locations of the loops.

Severe surface contamination was reported in the SE quarter of Section 9, Range 6 East, Township 25 North. The pollution emanated from a cliff face in the vicinity of well #1W (330N,220E). This well has a total depth of 2,853 ft. Extensive damage to vegetation was evident down slope from the well in the north-west direction. After repair to well #1W the surface seepage stopped.

The sounding sites were chosen to form two cross sections, one going northwest-southeast and the other running east-west. The actual locations had to be modified to avoid pipeline, fences, and high-tension wires.

Soundings SBU-2 through SBU-5 were not used due to equipment problems. Their locations are not shown as other soundings provided similar coverage. Soundings SBU-1 and SBU-6 occupy nearly the same locations, but were made on different days.

Results

Results of the inversions are presented in Figures 2 through 16. Figures 2a through 16a contain the output from the inversion program. This consists of the sounding title, the convergence criteria, and the effective loop radius ($A=\pi^{-1/2}L$). See Dennis *et al.* (1981) for a discussion of the convergence criteria.

The first table of each inversion output listing contains the observed (OBS.Y(I)) and calculated (CAL) apparent resistivities, and the residual (RES), i.e. the difference between the observed and calculated apparent resistivity. The residual is also expressed as a percentage of the calculated resistivity. The last column (X(I,1)) gives the measurement time in

seconds. The line following the table gives the RMS error of the fit.

The second table is the parameter correlation matrix. This matrix provides a measure of the interdependence of the model parameter estimates. A high correlation between parameters indicates that only the ratio of the parameters can be determined, while a high inverse correlation between parameters means that only their product can be resolved. Only the lower half of the symmetric correlation matrix is shown. The column of integers to the left gives the parameter number. It corresponds to the first column of integers in the following two tables. As an example, the second entry in the first column of any correlation matrix is the correlation between the second and first unconstrained model parameters.

The third table gives the model parameter estimates (PARM_SOL.), the standard deviation in the parameter estimate (STD_ERROR), the relative error (REL_ERROR) which is the standard deviation divided by the model parameter, and the percentage relative error (%ERROR). The column of integers to the left gives the parameter number.

The last table gives the final model parameter estimates: parameter number and name, layer conductivities and resistivities, layer thicknesses, and depths to the bottom of each layer. All units are SI. The parameter SHIFT can be used to multiply the apparent resistivity data by a constant. It was always held fixed at a value of 1.0.

Figures 2b through 16b present the observed apparent resistivity (circles) and the computed model apparent resistivity (solid line) as a function of scaled time (Tau = $(2\pi t)^{1/2}$. The interpreted model resistivities as a function of depth are given in Figures 2c through 16c. Model parameters that are held fixed are shown as dashed lines.

The interpretation for each sounding is discussed below.

Sounding SBU-1 (Figure 2)

The data are fit with a two-layer model. The first layer resistivity is 15 ohm-m and the second layer resistivity is 0.7 ohm-m. The first layer is 54 m thick. The first layer resistivity is not as well determined as that of the second layer. Attempts to model the data with the second layer resistivity constrained at 1.4 ohm-m were not successful. A slightly better fit was obtained with a three-layer model, but the noise in the data do not justify the use of a more complicated model.

Sounding SBU-6 (Figure 3)

This sounding was located very near to SBU-1. The same model could not be used for both soundings. A two-layer model was used, and the first layer resistivity was held fixed at 30 ohm-m. The thickness of this layer was estimated to be 40 m. The basement resistivity was found to be 1.2 ohm-m.

Sounding SBU-7 (Figure 4)

The sounding curve appears to be due to an H-type section (middle layer conductive). A reasonable fit can be obtained for this type of model. In fact, the curve shows the influence of a nearby pipe. The results have no

geological significance and have been included only as an example of the influence of cultural noise. These effects are typically confined to later times of the sounding and are characterized by a very rapid increase in resistivity which can not be modelled by a layered earth. The increase is often so sudden that it is diagnostic.

Sounding SBU-8 (Figure 8)

The data appear to be interpretable with a two-layer earth, however after numerous attempts it was found that a three-layer model gave a lower rms error and better parameter estimates. The critical diagnostic feature is that the apparent resistivity for two-layer models can not decrease as rapidly to the broad, relatively flat region between Tau = 0.1 and Tau = 0.3 as can three-layer models. The final results have a 7.0 ohm-m, 44 m thick first layer resting upon a 2.0 ohm-m, 86 m thick second layer. The basement resistivity is 4.3 ohm-m. The first and third layer resistivities are not as well determined as the second layer resistivity.

Sounding SBU-9 (Figure 6)

A four-layer model was used at the site. The layer resistivities are 52 ohm-m, 2.5 ohm-m, 310 ohm-m, and 2.5 ohm-m respectively. The layer thicknesses are estimated to be 29 m, 70 m, and 102 m. All parameters were well resolved with the exception of the third layer resistivity. Another inversion was attempted by fixing the first and third layer resistivities at 52 ohm. This gave an equally good fit with the third and fourth layer resistivities of 2.8 ohm-m and 3.0 ohm-m respectively. The layer thicknesses were estimated to be 35 m, 70 m, and 90 m respectively. The second result does not have the exceedingly high second layer resistivity.

Sounding SBU-10 (Figure 7)

A two-layer model with the first layer resistivity constrained at 30 ohm-m was used for this sounding. The first layer thickness was determined to be 49 m, and the basement resistivity is estimated to be 1.0 ohm-m. This sounding is fairly typical of the soundings made with the smaller loop (L=76.2 m) in that only two layers could be used, the first layer resistivity had to be constrained, and the basement was found to be quite conductive. The first layer had to be constrained too since there were not enough data at earlier times to determine the resistivity of this layer. Unconstrained models did not give very good fits and the first layer resistivity was not well resolved.

Sounding SBU-11 (Figure 8)

A Q-type section monotonically decreasing resistivity was fit to this sounding. The layer resistivities decrease from 9.3 ohm-m for the first layer to 3.8 ohm-m for the second layer to 1.7 ohm-m for the third layer. The first layer is 35 m thick, and the second layer is nearly three times as thick (94 m).

Sounding SBU-12 (Figure 9)

The resistivity at this site decreases with depth and is fit with a three-layer model. The layer resistivities were determined to be 8.6 ohm-m, 3.2 ohm-m, and 1.0 ohm-m going from the surface to depth. The layer thicknesses are 53 m and 124 m respectively. The resistivity of the deeper

layer is slightly better determined than the surface layer resistivity.

Sounding SBU-13 (Figure 10)

This sounding is very similar to the two previous soundings. The geoelectric section becomes more conductive with depth. The layer resistivities are 11 ohm-m, 5.3 ohm-m, and 2.0 ohm-m. Although the first layer is about as thick (31 m) as for soundings SBU-11 and SBU-12, the second layer is noticeably thicker (179 m).

Sounding SBU-14 (Figure 11)

This sounding distinguishes itself from the previous Q-sections only in that the first layer is substantially more resistive (39 ohm-m) than for the other models. The second and third layer resistivities are 4.4 ohm-m and 1.9 ohm-m respectively. The first and second layer thicknesses are 23 m and 138 m.

Sounding SBU-15 (Figure 12)

This Q-section has a 34 ohm-m first layer, a 4.5 ohm-m second layer, and a 1.2 ohm-m basement. The first two layers are 29 m and 194 m thick respectively. The error is largest in the determination of the first layer resistivity.

Sounding SBU-16 (Figure 13)

The sounding continues the trend set by most of the previous soundings in that the apparent resistivity decreases with depth. A four-layer model was necessary to fit the data. The layer resistivities going from the surface downward are respectively 61 ohm-m, 4.9 ohm-m, 1.8 ohm-m, and 0.7 ohm-m. The basement resistivity is quite low. The first layer is estimated to be only 7 m thick, while the second and third layers are 173 m and 150 m thick respectively.

Sounding SBU-17 (Figure 14)

This sounding was interpreted with a four-layer model. The layer resistivities increase from 4.5 ohm-m to 6.5 ohm-m and then decreases to 2.9 ohm-m and 1.2 ohm-m. The layer thicknesses are 15 m, 166 m, and 131 m respectively. The sharp decrease in the apparent resistivity in the last four data points could not be fit with a layered earth model. This could be due to lateral inhomogeneities at depth.

Sounding SBU-18 (Figure 15)

This sounding was originally fit with a 3 layer model. To maintain uniformity of interpretation among stations, a fourth layer was added. The error in the fit remained about the same, and the error in the parameter estimates is not too large. Therefore there is not strong statistical evidence against adding this layer. The layer resistivities decrease with depth (32 ohm-m, 4.7 ohm-, 2.6 ohm-m, and 158 m respectively.

Sounding SBU-19 (Figure 16)

Use of a smaller loop size for this sounding than was used for most of the other soundings resulted in the transient being recorded over a shorter time range. The data are interpreted as a three-layer section with layer resistivities of 23 ohm-m, 4 ohm-m, and 2 ohm-m respectively.

Cross Section A-A′ (Figure 17)

Overall the cross section shows a layered earth geometry with fairly horizontal layers becoming more conductive with depth. Two anomalous zones are seen in the second layer at sites SBU-6 and SBU-10, where the interpreted second layer is more conductive than surrounding layers. This situation was also noted at SBU-1 which is offset a few tens of meters from SBU-6. While soundings SBU-6, SBU-15, SBU-10, and SBU-11 appeared to be interpretable using one-dimensional models, the cross section produced by setting these interpretations side by side is obviously not one-dimensional. The conductivity model in this region is quite complex, being influenced by the spatial distribution of the brine contamination. Determination of a three-dimensional model which fits the data is not practical. In the cross section, the estimate extent of the brine contamination has been shaded.

Cross Section B-B′ (Figure 18)

This cross section is similar to cross section A-A′. In general the layers are nearly horizontal with small variations in resistivity from sounding to sounding. At soundings SBU-9, SBU-6, SBU-15, and SBU-10 there are noticeable departures from one-dimensional behavior in the second layer. This is attributed to three-dimensional distribution of the brine contamination.

Conclusions

Transient soundings were able to map three distinct layers in most of the study area. The uppermost layer had resistivities ranging from 6-52 ohm-m and was between 7 m and 54 m thick. The second layer had resistivities of 2.5 ohm-m to 6.5 ohm-m. Where brine contamination was present, the second layer resistivity dropped to about 1 ohm-m. This layer was between 90 m and 190 m thick. The third layer resistivity ranged from 1.0 ohm-m to 2.9 ohm-m.

Brine contamination produced resistivities in the range of 0.7 ohm-m to 1.7 ohm-m. The near surface extent of the contamination is not well defined due to the three dimensional geometry of the contamination. The extent of the contamination at depth is not well defined since the background resistivities decrease with depth. This results in the boundary between the contaminated and uncontaminated zones being less well defined. In a more resistive environment, the extent of the brine contamination would be easier to determine due to the large resistivity contrast.

References

Anderson, W. L., 1982, Nonlinear least-squares inversion of transient soundings for a coincident loop system (Program NLSTCO): U.S. Geological Survey Open-File Report No. 82-1064, 81 p.

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Dennis, J. E., Jr., Gay, D. M., and Welsh, R. E., 1981, An adaptive nonlinear least-squares algorithm: ACM Trans. Mathematical Software, 7, p. 348-368.
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Raab, P. V., and Frischknecht, F. C., 1984, Investigation of brine contamination using time-domain electromagnetic soundings: U.S. Geological Survey Open-File Report, in preparation.
Thorman, C. H., and Hibpshman, M. H., 1979, Status of mineral resources information for Osage Indian Reservation, Oklahoma: U.S. Bureau of Indian Affairs, Administrative Report BIA-47, 72 p.

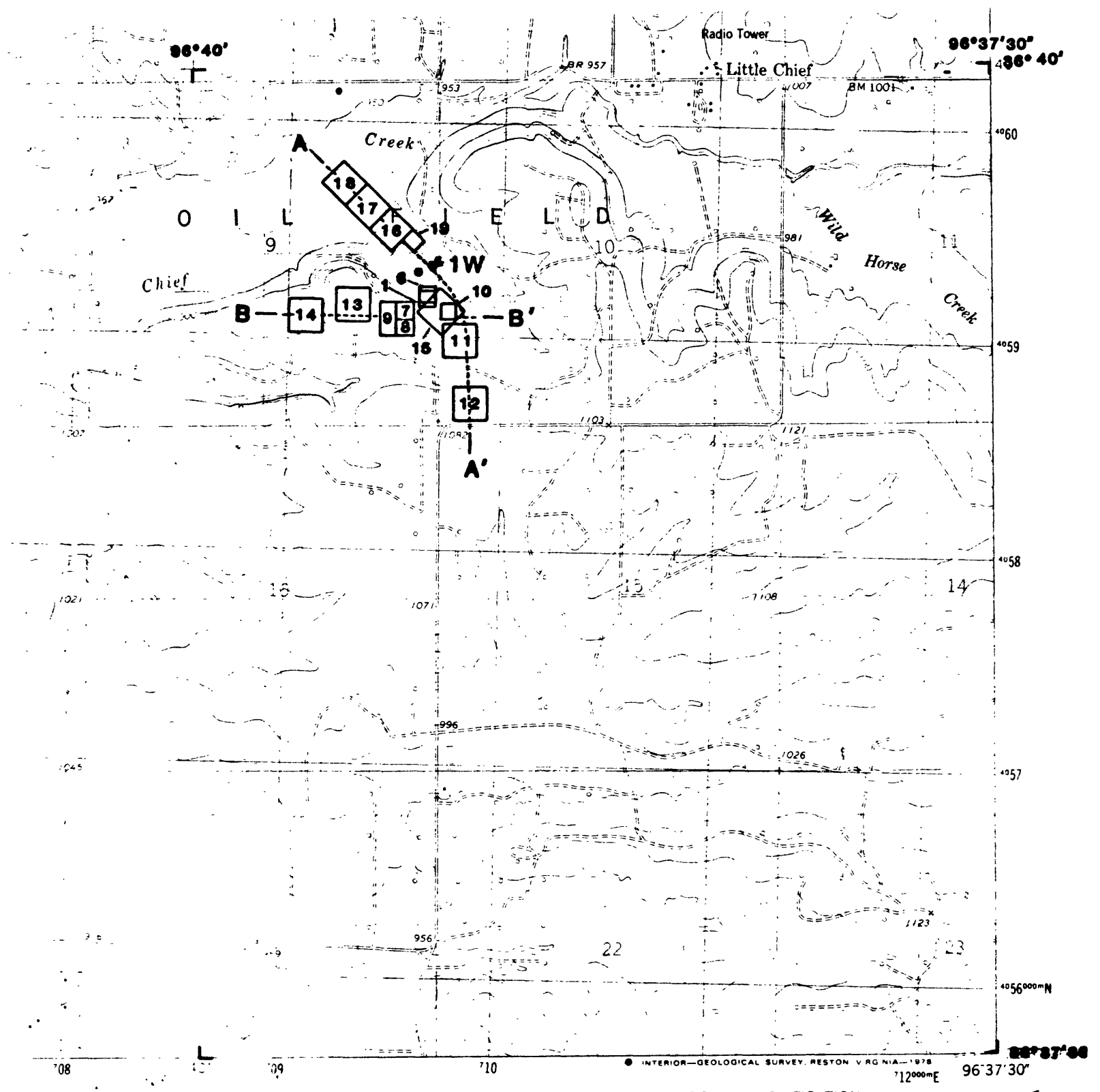

Figure 1

ROAD CLASSIFICATION

Primary highway, hard surface

Light-duty road, hard or improved surface

Secondary highway, hard surface

Unimproved road

Interstate Route U. S. Route State Route

1 MILE

7000 FEET

KILOMETER

OKLAHOMA

QUADRANGLE LOCATION

ILUCY CREEK
6657 II SE

VIRGINIA 22092
73069
REQUEST

BURBANK, OKLA.

NW/4 FAIRFAX 15' QUADRANGLE

N3637.5—W9637.5/7.5

1978

AMS 6657 II NW—SERIES V883

Figure 2a

```
<NLSTCO>:     SBU-1  South Burbank Unit, Pawhuska, OK

***** X-CONVERGENCE *****                    LOOP RADIUS=  43.0

  I     OBS.Y(I)       CAL            RES         %RES.ERR       X(I,1)
  1  0.684340E+01  0.711981E+01 -0.276E+00 -0.388232E+01  0.120000E-02
  2  0.567020E+01  0.561881E+01  0.514E-01  0.914575E+00  0.160000E-02
  3  0.489170E+01  0.474222E+01  0.149E+00  0.315221E+01  0.200000E-02
  4  0.405500E+01  0.391693E+01  0.138E+00  0.352486E+01  0.260000E-02
  5  0.337720E+01  0.326823E+01  0.109E+00  0.333427E+01  0.340000E-02
  6  0.293020E+01  0.286205E+01  0.682E-01  0.238118E+01  0.420000E-02
  7  0.262280E+01  0.258048E+01  0.423E-01  0.163998E+01  0.500000E-02
  8  0.237110E+01  0.237438E+01 -0.328E-02 -0.138258E+00  0.580000E-02
  9  0.211260E+01  0.215059E+01 -0.380E-01 -0.176630E+01  0.700000E-02
 10  0.187920E+01  0.194402E+01 -0.648E-01 -0.333435E+01  0.860000E-02
 11  0.172000E+01  0.179733E+01 -0.773E-01 -0.430233E+01  0.102000E-01
 12  0.161210E+01  0.166823E+01 -0.761E-01 -0.450934E+01  0.118000E-01
 13  0.153400E+01  0.160410E+01 -0.701E-01 -0.437013E+01  0.134000E-01
 14  0.145330E+01  0.150660E+01 -0.533E-01 -0.353757E+01  0.158000E-01
 15  0.140700E+01  0.140972E+01 -0.272E-02 -0.192853E+00  0.190000E-01
 16  0.141520E+01  0.133911E+01  0.761E-01  0.568246E+01  0.222000E-01
 17  0.137460E+01  0.128573E+01  0.889E-01  0.691170E+01  0.254000E-01
** RMSERR=  0.11264470E+00

CORRELATION MATRIX
 1  0.1000E+01
 2 -0.7382E+00  0.1000E+01
 3 -0.1842E+00  0.4481E+00  0.1000E+01

  **PARM_SOL.    STD_ERROR    REL_ERROR     % ERROR **

 1  0.6454E-01  0.2564E-02  0.3973E-01  0.3973E+01
 2  0.1501E+01  0.7660E-02  0.5104E-02  0.5104E+00
 3  0.5423E+02  0.1138E-02  0.2098E-04  0.2098E-02

********  E N D  ********     SBU-1  South Burbank Unit, Pawhuska, OK

PARAMETER NAME       FINAL SOLUTION        RESISTIVITY   LAYER DEPTH

   1   SIGMA( 1) =  0.64538427E-01    1  0.15494645E+02
   2   SIGMA( 2) =  0.15006410E+01    2  0.66638190E+00
   3   THICK( 1) =  0.54230255E+02                        1  0.54230255E+02
   4 * SHIFT     =  0.10000000E+01

     * FIXED
```

Figure 2b

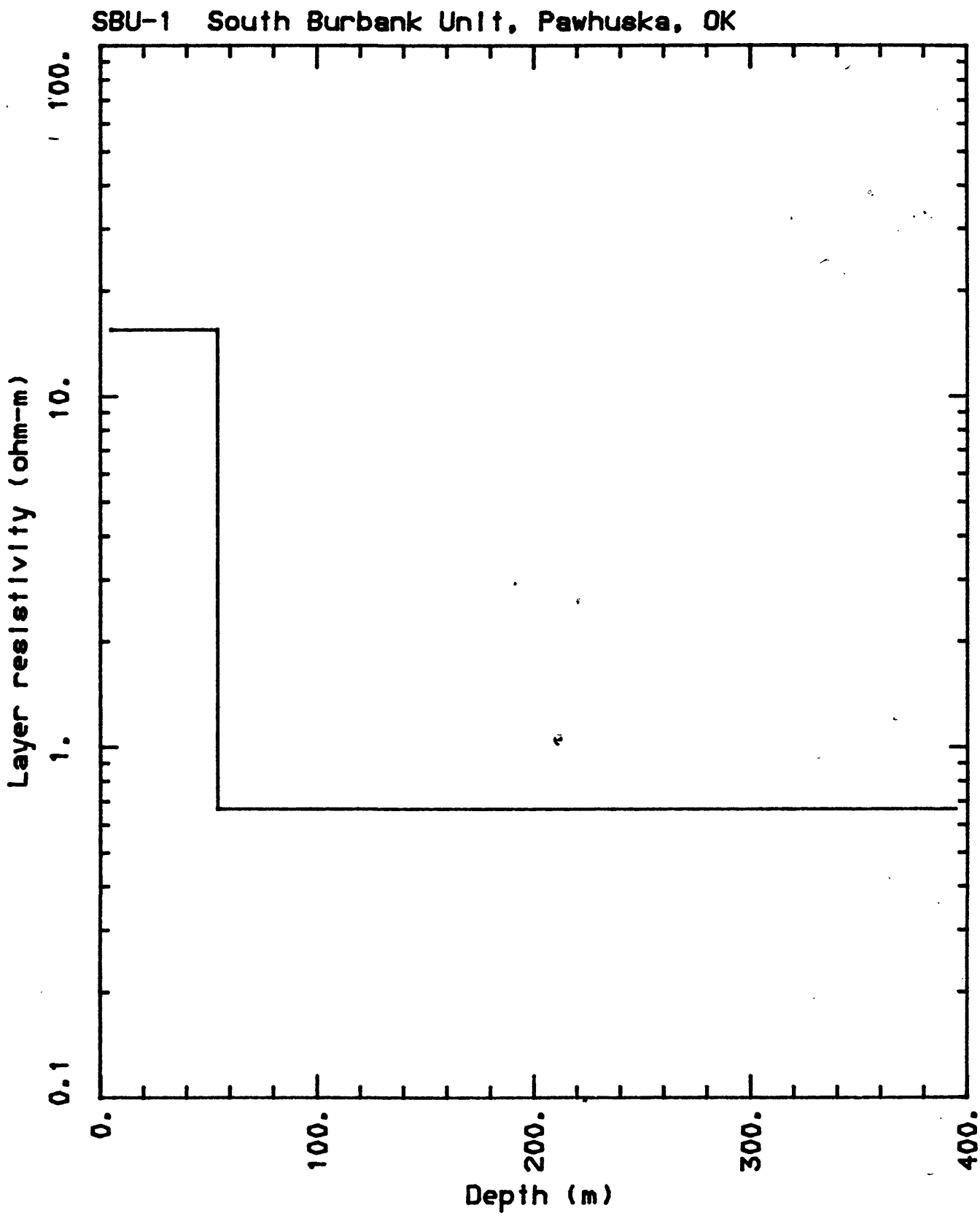
SBU-1 South Burbank Unit, Pawhuska, OK
Layer resistivity (ohm-m)
100.
10.
1.
0.1
0.
100.
200.
300.
400.
Depth (m)

Figure 2c

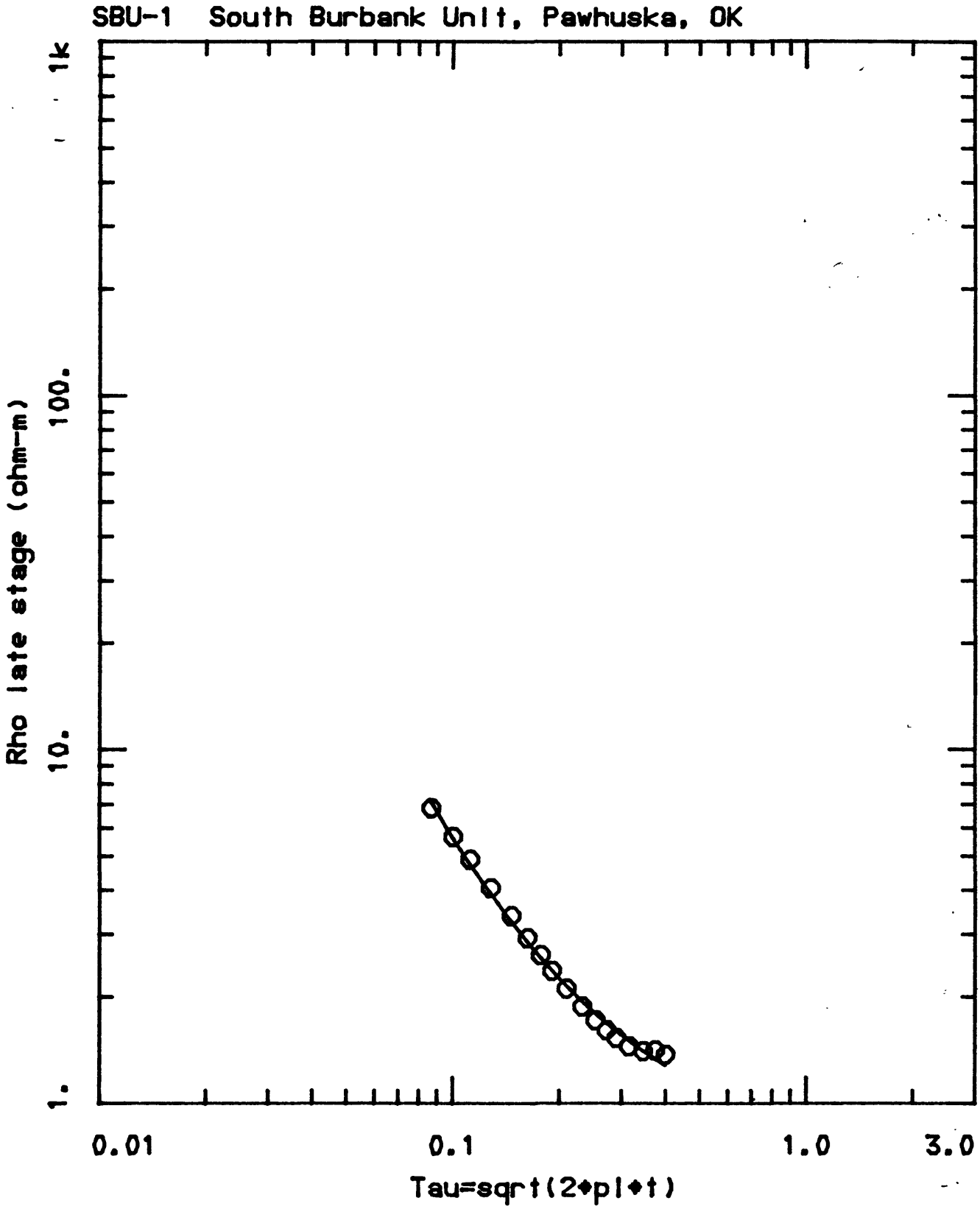
SBU-1 South Burbank Unit, Pawhuska, OK
Rho late stage (ohm-m)
1k
100.
10.
1.
0.01
0.1
1.0
3.0
Tau=sqrt(2*pi*t)

Figure 3a

```
<NLSTCO>:     SBU-6  South Burbank Unit, Pawhuska, OK

***** X-CONVERGENCE *****                    LOOP RADIUS=  43.0

  I     OBS.Y(I)        CAL             RES          %RES.ERR       X(I,1)
  1  0.743910E+01  0.764350E+01 -0.204E+00 -0.267412E+01  0.800000E-03
  2  0.580990E+01  0.574443E+01  0.655E-01  0.113962E+01  0.120000E-02
  3  0.487550E+01  0.478375E+01  0.918E-01  0.191805E+01  0.160000E-02
  4  0.428430E+01  0.420437E+01  0.799E-01  0.190116E+01  0.200000E-02
  5  0.368240E+01  0.365757E+01  0.248E-01  0.678777E+00  0.260000E-02
  6  0.324820E+01  0.321695E+01  0.313E-01  0.971454E+00  0.340000E-02
  7  0.296270E+01  0.293706E+01  0.256E-01  0.873064E+00  0.420000E-02
  8  0.275420E+01  0.273903E+01  0.152E-01  0.553701E+00  0.500000E-02
  9  0.261580E+01  0.258999E+01  0.258E-01  0.996669E+00  0.580000E-02
 10  0.241540E+01  0.242853E+01 -0.131E-01 -0.540762E+00  0.700000E-02
 11  0.226890E+01  0.227733E+01 -0.843E-02 -0.370025E+00  0.860000E-02
 12  0.207030E+01  0.216412E+01 -0.938E-01 -0.433538E+01  0.102000E-01
 13  0.205570E+01  0.208133E+01 -0.256E-01 -0.123133E+01  0.118000E-01
** RMSERR=  0.81865393E-01

CORRELATION MATRIX
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 3  0.8077E+00  0.1000E+01

  **PARM_SOL.    STD_ERROR    REL_ERROR     % ERROR **

 2  0.8332E+00  0.2976E-02  0.3572E-02  0.3572E+00
 3  0.3979E+02  0.1129E-02  0.2837E-04  0.2837E-02

********  E N D  ********     SBU-6  South Burbank Unit, Pawhuska, OK

PARAMETER NAME       FINAL SOLUTION        RESISTIVITY   LAYER DEPTH

   1 * SIGMA( 1) =  0.33300001E-01    1  0.30030029E+02
   2   SIGMA( 2) =  0.83316588E+00    2  0.12002412E+01
   3   THICK( 1) =  0.39791378E+02                      1  0.39791378E+02
   4 * SHIFT     =  0.10000000E+01

     * FIXED
```

Figure 3b

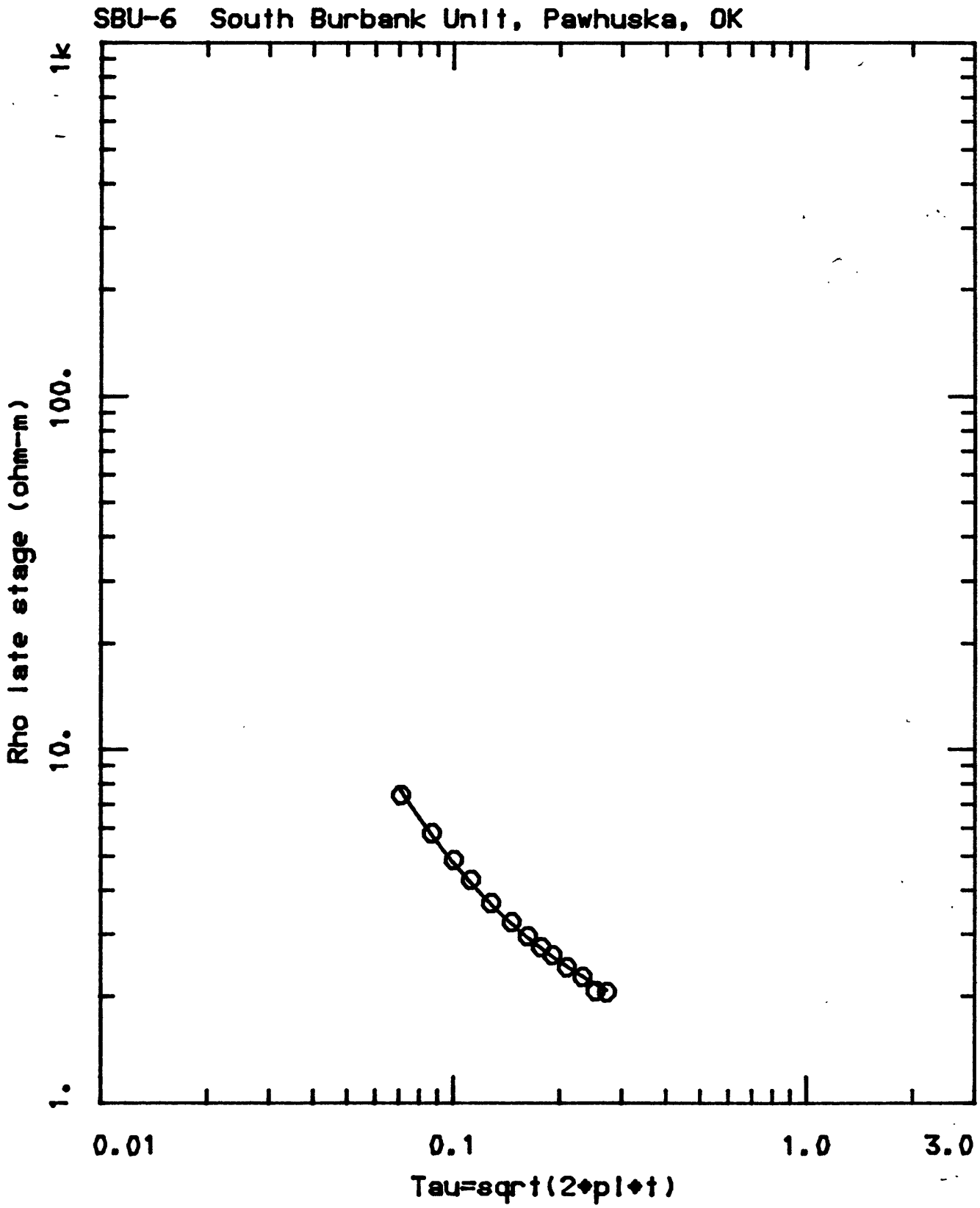

SBU-6 South Burbank Unit, Pawhuska, OK
Rho late stage (ohm-m)
1k
100.
10.
1.
0.01
0.1
1.0
3.0
Tau=sqrt(2*pi*t)

Figure 3c

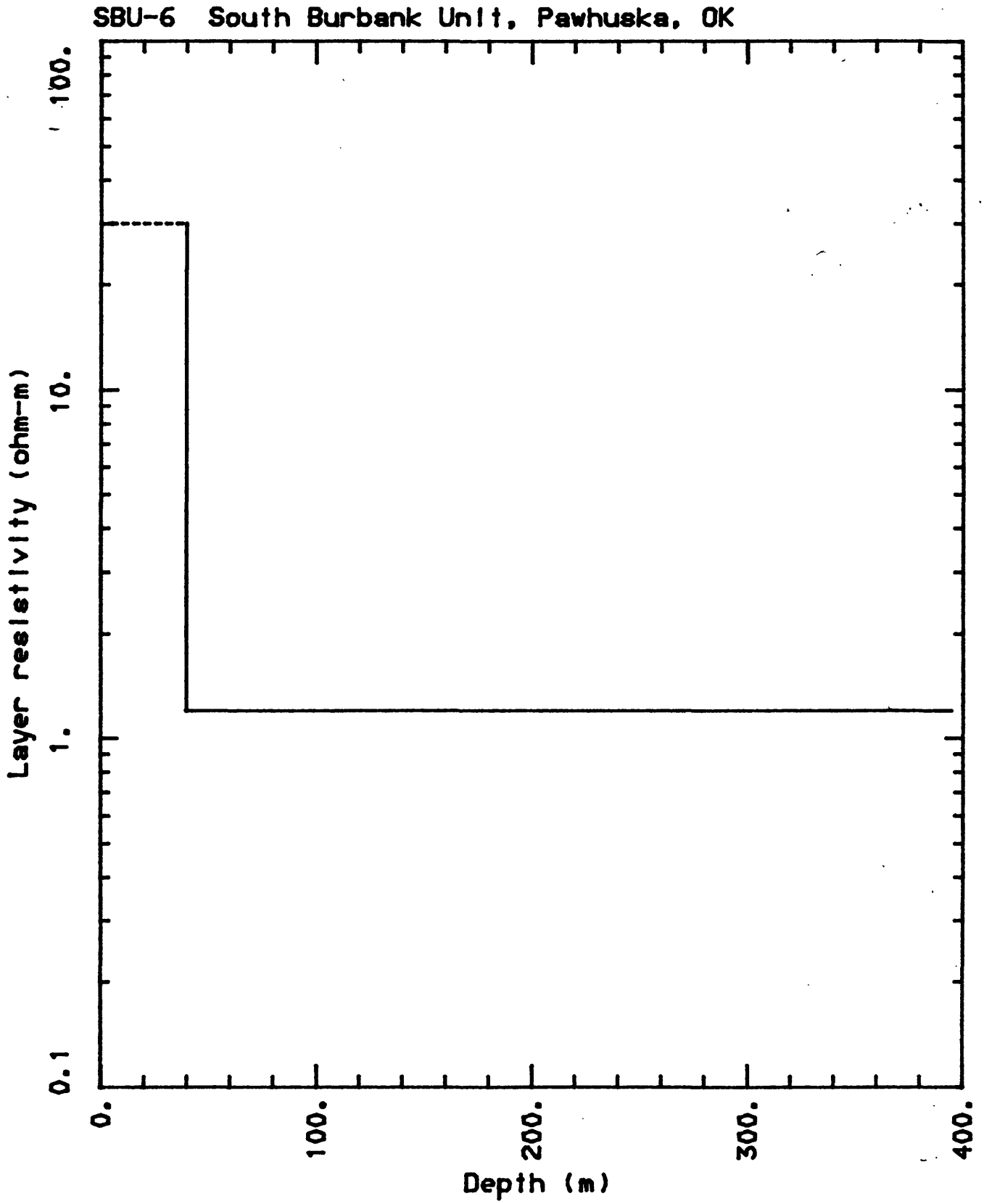

SBU-6 South Burbank Unit, Pawhuska, OK
Layer resistivity (ohm-m)
100.
10.
1.
0.1
0.
100.
200.
300.
400.
Depth (m)

Figure 4a

```
<NLSTCO>:      SBU-7  South Burbank Unit, Pawhuska, OK

***** X-CONVERGENCE *****                    LOOP RADIUS=  43.0

  I     OBS.Y(I)        CAL             RES         %RES.ERR       X(I,1)
  1  0.596840E+01  0.554683E+01  0.422E+00  0.760017E+01  0.120000E-02
  2  0.524490E+01  0.493893E+01  0.306E+00  0.619503E+01  0.160000E-02
  3  0.484280E+01  0.465467E+01  0.188E+00  0.404181E+01  0.200000E-02
  4  0.446840E+01  0.447413E+01 -0.573E-02 -0.128094E+00  0.260000E-02
  5  0.433390E+01  0.447954E+01 -0.146E+00 -0.325122E+01  0.340000E-02
  6  0.433100E+01  0.460377E+01 -0.273E+00 -0.592488E+01  0.420000E-02
  7  0.442570E+01  0.475216E+01 -0.326E+00 -0.686971E+01  0.500000E-02
  8  0.459740E+01  0.492630E+01 -0.329E+00 -0.667650E+01  0.580000E-02
  9  0.484960E+01  0.530678E+01 -0.457E+00 -0.861503E+01  0.700000E-02
 10  0.537790E+01  0.582226E+01 -0.444E+00 -0.763210E+01  0.860000E-02
 11  0.602340E+01  0.622019E+01 -0.197E+00 -0.316372E+01  0.102000E-01
 12  0.676870E+01  0.676432E+01  0.438E-02  0.647549E-01  0.118000E-01
 13  0.771990E+01  0.740038E+01  0.320E+00  0.431760E+01  0.134000E-01
 14  0.992740E+01  0.825130E+01  0.168E+01  0.203131E+02  0.158000E-01
** RMSERR=  0.6644746lE+00

CORRELATION MATRIX
 1  0.1000E+01
 2 -0.3482E+00  0.1000E+01
 3 -0.3137E+00  0.8561E+00  0.1000E+01
 4 -0.7585E+00  0.1361E+00 -0.1509E+00  0.1000E+01
 5  0.1307E+00 -0.9631E+00 -0.8564E+00  0.6236E-01  0.1000E+01

  **PARM_SOL.    STD_ERROR    REL_ERROR     % ERROR **

 1  0.9790E-02  0.7058E-03  0.7210E-01  0.7210E+01
 2  0.4991E+00  0.8225E-02  0.1648E-01  0.1648E+01
 3  0.2562E-03  0.2157E-02  0.8416E+01  0.8416E+03
 4  0.3240E+02  0.4948E-02  0.1527E-03  0.1527E-01
 5  0.5081E+02  0.131oE-01  0.2590E-03  0.2590E-01

********  E N D  ********      SBU-7  South Burbank Unit, Pawhuska, OK

PARAMETER NAME       FINAL SOLUTION        RESISTIVITY   LAYER DEPTH

   1    SIGMA( 1) =  0.97897109E-02   1  0.10214806E+03
   2    SIGMA( 2) =  0.49910814E+00   2  0.20035739E+01
   3    SIGMA( 3) =  0.25623519E-03   3  0.39026646E+04
   4    THICK( 1) =  0.32400368E+02                      1  0.32400368E+02
   5    THICK( 2) =  0.50811131E+02                      2  0.83211502E+02
   6  * SHIFT     =  0.10000000E+01

     * FIXED
```

Figure 4b

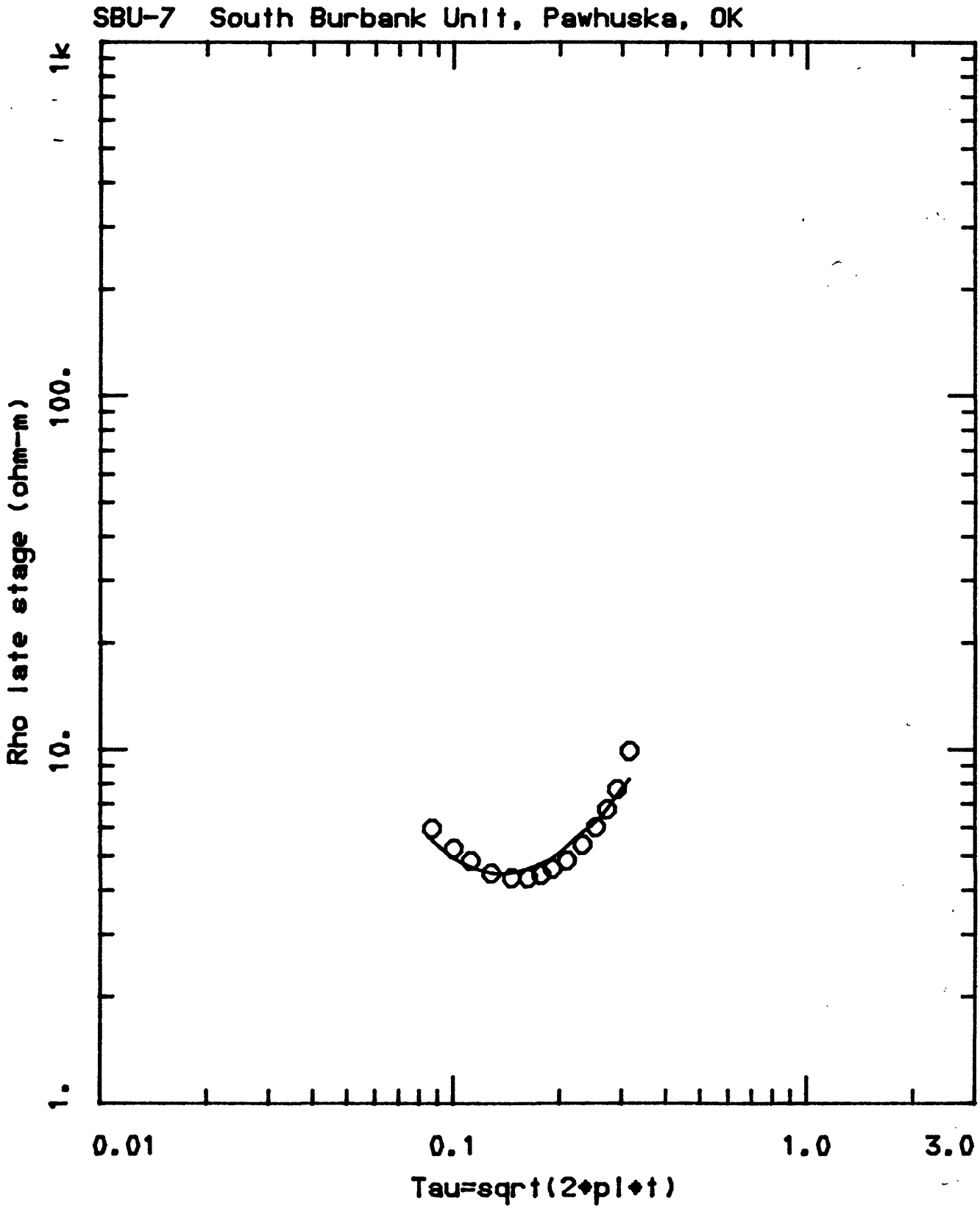

SBU-7 South Burbank Unit, Pawhuska, OK
1k
100.
10.
1.
Rho late stage (ohm-m)
0.01
0.1
1.0
3.0
Tau=sqrt(2*pi*t)

Figure 4c

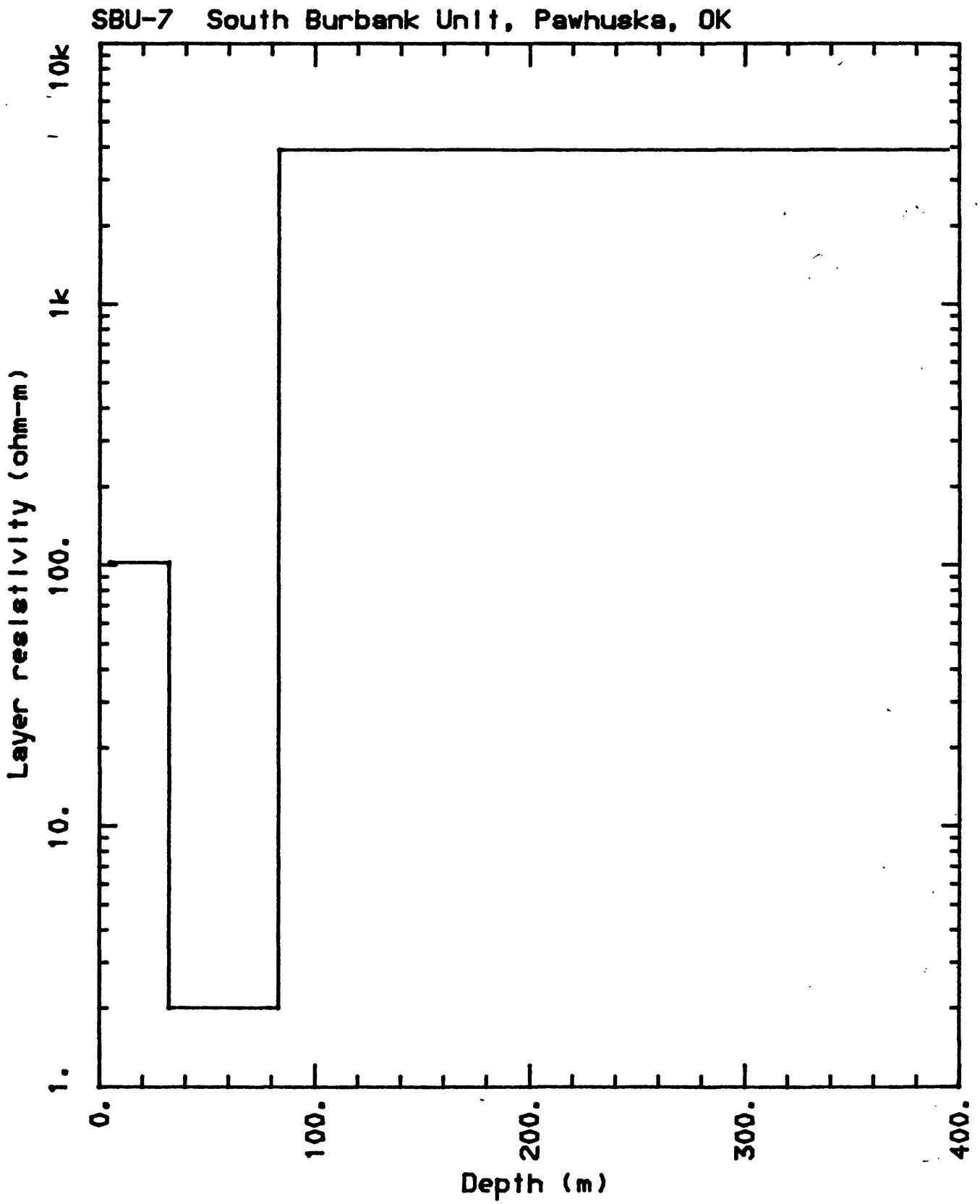

SBU-7 South Burbank Unit, Pawhuska, OK
Layer resistivity (ohm-m)
10k
1k
100.
10.
1.
0.
100.
200.
300.
400.
Depth (m)

Figure 5a

```
<NLSTCO>:      SBU-8  South Burbank Unit, Pawhuska, OK

***** X-CONVERGENCE *****                    LOOP RADIUS=  43.0

  I     OBS.Y(I)        CAL             RES         %RES.ERR       X(I,1)
  1  0.554960E+01  0.545326E+01  0.963E-01  0.176658E+01  0.120000E-02
  2  0.486150E+01  0.483493E+01  0.266E-01  0.549520E+00  0.160000E-02
  3  0.444820E+01  0.446269E+01 -0.145E-01 -0.324663E+00  0.200000E-02
  4  0.405480E+01  0.416762E+01 -0.113E+00 -0.270710E+01  0.260000E-02
  5  0.385580E+01  0.394002E+01 -0.842E-01 -0.213760E+01  0.340000E-02
  6  0.376430E+01  0.381929E+01 -0.550E-01 -0.143989E+01  0.420000E-02
  7  0.374720E+01  0.375875E+01 -0.116E-01 -0.307414E+00  0.500000E-02
  8  0.374510E+01  0.372557E+01  0.195E-01  0.524204E+00  0.580000E-02
  9  0.372650E+01  0.369501E+01  0.315E-01  0.852363E+00  0.700000E-02
 10  0.379690E+01  0.367130E+01  0.126E+00  0.342111E+01  0.860000E-02
 11  0.375850E+01  0.368911E+01  0.694E-01  0.188105E+01  0.102000E-01
 12  0.377990E+01  0.370584E+01  0.741E-01  0.199860E+01  0.118000E-01
 13  0.363110E+01  0.371369E+01 -0.826E-01 -0.222393E+01  0.134000E-01
 14  0.374750E+01  0.372466E+01  0.228E-01  0.613147E+00  0.158000E-01
** RMSERR=  0.86902706E-01

CORRELATION MATRIX
 1  0.1000E+01
 2 -0.7890E+00  0.1000E+01
 3 -0.4404E-01 -0.3090E+00  0.1000E+01
 4 -0.1180E+00  0.5488E+00 -0.5800E+00  0.1000E+01
 5  0.2582E+00 -0.2329E+00 -0.7213E+00  0.5504E-01  0.1000E+01

  **PARM_SOL.    STD_ERROR    REL_ERROR     % ERROR **

 1  0.1421E+00  0.1997E-02  0.1405E-01  0.1405E+01
 2  0.4980E+00  0.3047E-02  0.6118E-02  0.6118E+00
 3  0.2316E+00  0.3689E-02  0.1593E-01  0.1593E+01
 4  0.4364E+02  0.2270E-02  0.5202E-04  0.5202E-02
 5  0.4237E+02  0.4694E-02  0.1108E-03  0.1108E-01

********  E N D  ********      SBU-8  South Burbank Unit, Pawhuska, OK

PARAMETER NAME        FINAL SOLUTION        RESISTIVITY   LAYER DEPTH

   1    SIGMA( 1) =  0.14214765E+00    1  0.70349388E+01
   2    SIGMA( 2) =  0.49801409E+00    2  0.20079753E+01
   3    SIGMA( 3) =  0.23163451E+00    3  0.43171458E+01
   4    THICK( 1) =  0.43642319E+02                        1  0.43642319E+02
   5    THICK( 2) =  0.42368977E+02                        2  0.86011299E+02
   6  * SHIFT     =  0.10000000E+01

     * FIXED
```

Figure 5b

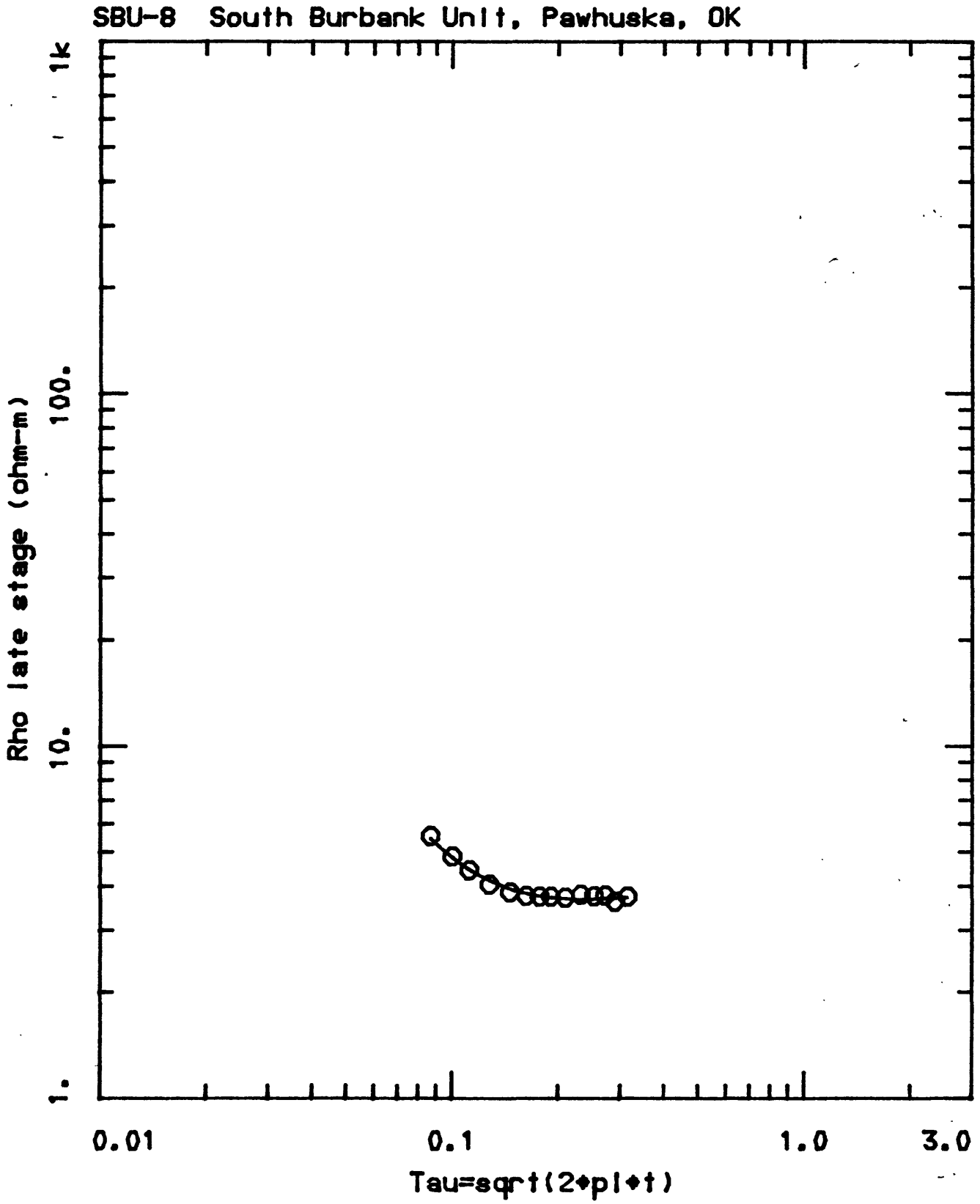

SBU-8 South Burbank Unit, Pawhuska, OK
Rho late stage (ohm-m)
1k
100.
10.
1.
0.01
0.1
1.0
3.0
Tau=sqrt(2*pi*t)

Figure 5c

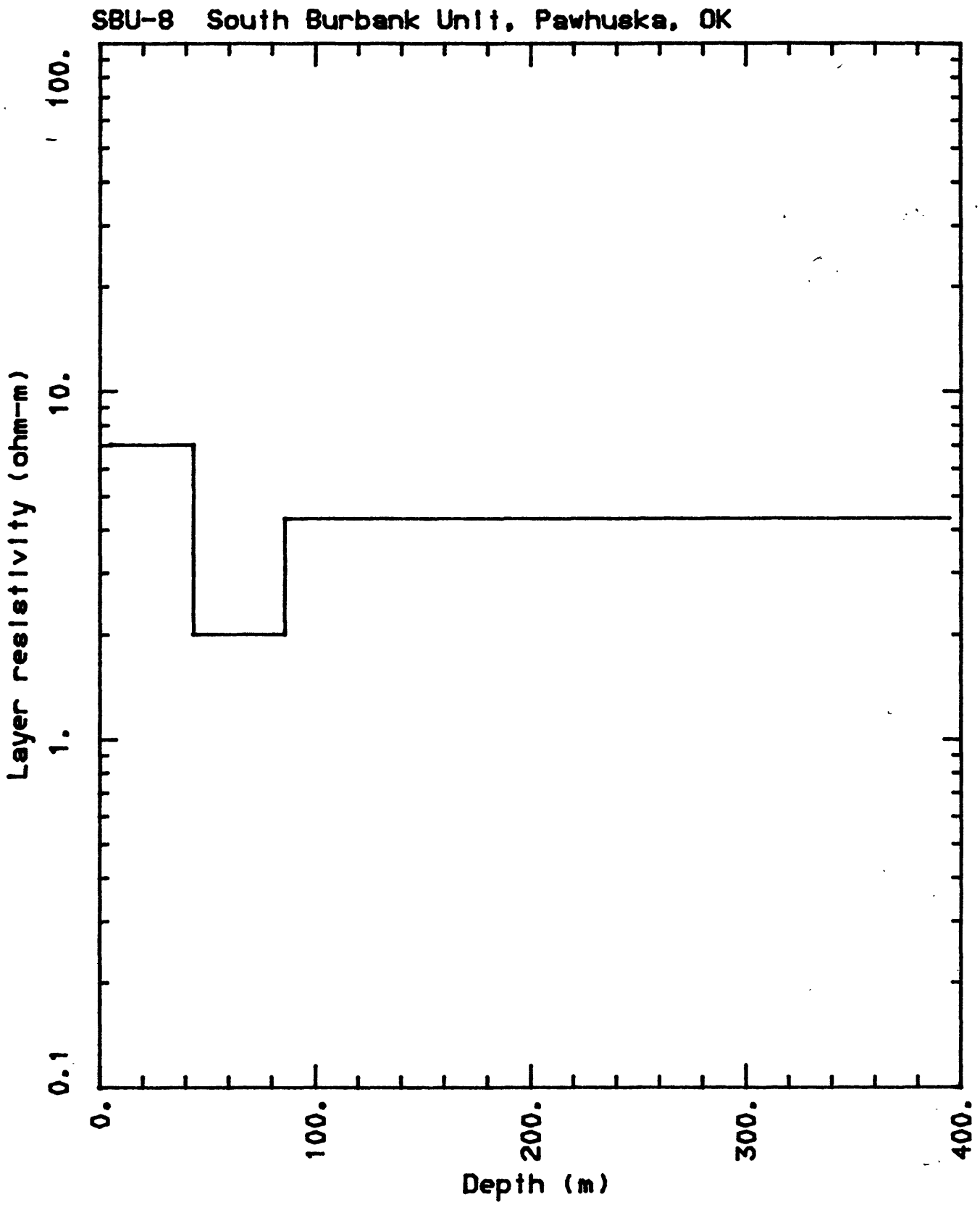

SBU-8 South Burbank Unit, Pawhuska, OK
Layer resistivity (ohm-m)
100.
10.
1.
0.1
0.
100.
200.
300.
400.
Depth (m)

Figure 6a

```
<NLSTCO>:      SBU-9  South Burbank Unit, Pawhuska, OK

***** X-CONVERGENCE *****                    LOOP RADIUS=  86.0

  I     OBS.Y(I)        CAL             RES         %RES.ERR       X(I,1)
  1  0.768150E+01  0.790653E+01 -0.225E+00 -0.284608E+01  0.120000E-02
  2  0.671520E+01  0.661813E+01  0.971E-01  0.146676E+01  0.160000E-02
  3  0.613030E+01  0.596125E+01  0.169E+00  0.283590E+01  0.200000E-02
  4  0.557070E+01  0.548235E+01  0.883E-01  0.161147E+01  0.260000E-02
  5  0.527500E+01  0.520809E+01  0.669E-01  0.128480E+01  0.340000E-02
  6  0.516700E+01  0.514123E+01  0.258E-01  0.501329E+00  0.420000E-02
  7  0.513790E+01  0.517754E+01 -0.396E-01 -0.765586E+00  0.500000E-02
  8  0.519330E+01  0.523586E+01 -0.426E-01 -0.812948E+00  0.580000E-02
  9  0.525750E+01  0.529820E+01 -0.407E-01 -0.768158E+00  0.700000E-02
 10  0.541110E+01  0.538287E+01  0.282E-01  0.524490E+00  0.860000E-02
 11  0.550030E+01  0.550751E+01 -0.721E-02 -0.130899E+00  0.102000E-01
 12  0.555070E+01  0.554011E+01  0.106E-01  0.191110E+00  0.118000E-01
 13  0.549220E+01  0.549446E+01 -0.226E-02 -0.412055E-01  0.134000E-01
 14  0.533750E+01  0.540255E+01 -0.651E-01 -0.120406E+01  0.158000E-01
 15  0.521720E+01  0.534436E+01 -0.127E+00 -0.237929E+01  0.190000E-01
 16  0.511300E+01  0.523190E+01 -0.119E+00 -0.227264E+01  0.222000E-01
 17  0.509980E+01  0.510100E+01 -0.120E-02 -0.235567E-01  0.254000E-01
 18  0.509240E+01  0.496431E+01  0.128E+00  0.258026E+01  0.286000E-01
 19  0.486700E+01  0.477889E+01  0.108E+00  0.226225E+01  0.334000E-01
 20  0.468700E+01  0.463578E+01  0.512E-01  0.110491E+01  0.398000E-01
** RMSERR=  0.11530920E+00

CORRELATION MATRIX
 1  0.1000E+01
 2 -0.7159E+00  0.1000E+01
 3  0.1151E-01 -0.1595E+00  0.1000E+01
 4 -0.5270E+00  0.2897E+00 -0.1181E+00  0.1000E+01
 5 -0.6198E+00  0.8437E+00 -0.7109E-02 -0.1007E-02  0.1000E+01
 6  0.7210E+00 -0.9478E+00  0.1840E+00 -0.4427E+00 -0.7358E+00  0.1000E+01
 7  0.3992E-01  0.3234E+00 -0.1281E+00  0.7566E-01  0.1829E+00 -0.1972E+00

  **PARM_SOL.    STD_ERROR    REL_ERROR     % ERROR **

 1  0.1932E-01  0.1168E-02  0.6044E-01  0.6044E+01
 2  0.3935E+00  0.3078E-02  0.7822E-02  0.7822E+00
 3  0.3239E-02  0.2215E-01  0.6838E+01  0.6838E+03
 4  0.4002E+00  0.2399E-02  0.5995E-02  0.5995E+00
 5  0.2940E+02  0.2477E-02  0.8427E-04  0.8427E-02
 6  0.6978E+02  0.5569E-02  0.7981E-04  0.7981E-02
 7  0.1020E+03  0.3855E-02  0.3779E-04  0.3779E-02

********  E N D  ********      SBU-9  South Burbank Unit, Pawhuska, OK

PARAMETER NAME        FINAL SOLUTION        RESISTIVITY   LAYER DEPTH

   1    SIGMA( 1) =  0.19317815E-01    1  0.51765690E+02
   2    SIGMA( 2) =  0.39353812E+00    2  0.25410500E+01
   3    SIGMA( 3) =  0.32387706E-02    3  0.30875912E+03
   4    SIGMA( 4) =  0.40020269E+00    4  0.24987338E+01
   5    THICK( 1) =  0.29397203E+02                      1  0.29397203E+02
   6    THICK( 2) =  0.69780289E+02                      2  0.99177490E+02
   7    THICK( 3) =  0.10203135E+03                      3  0.20120885E+03
   8  * SHIFT     =  0.10000000E+01

     * FIXED
```

Figure 6b

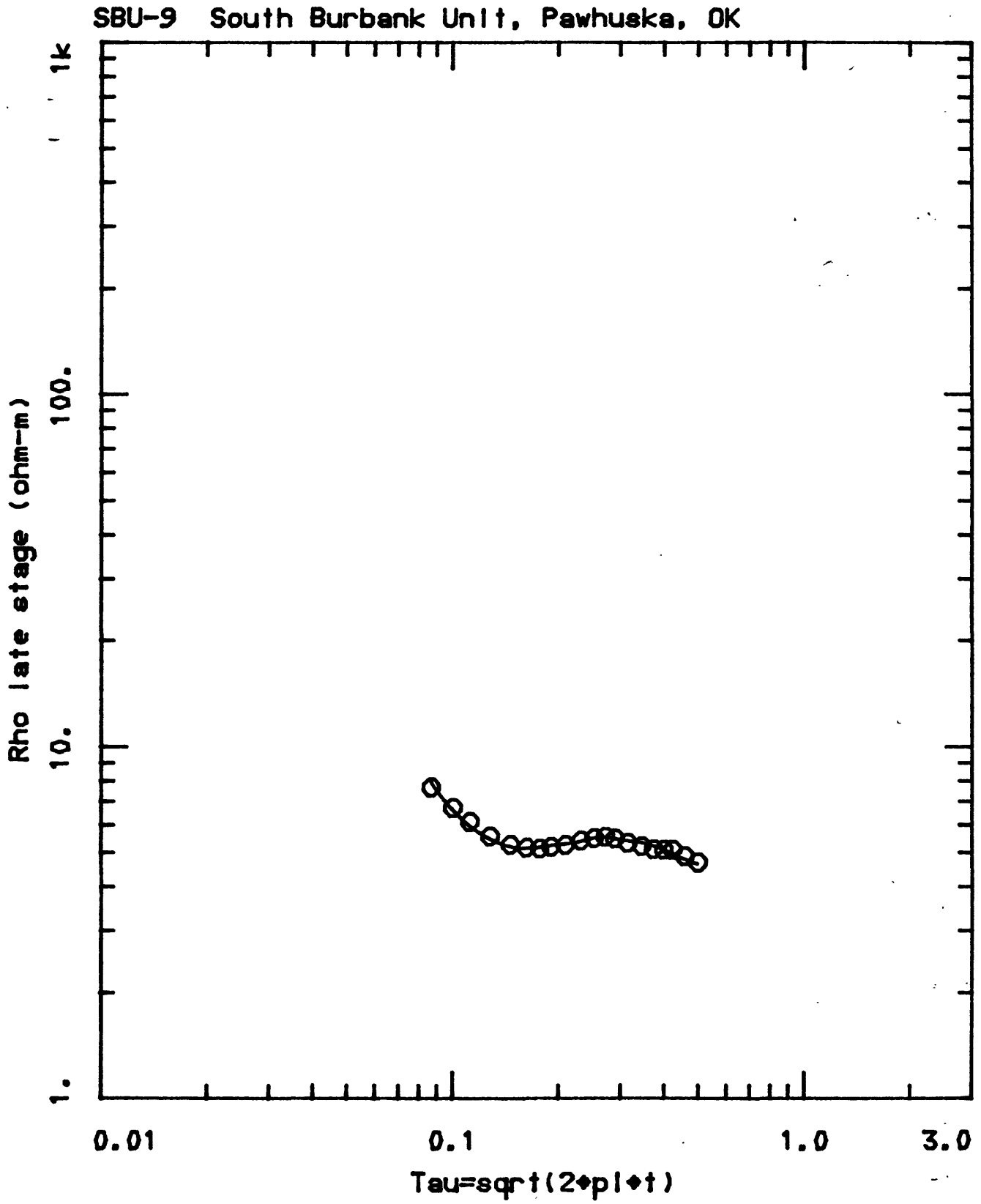

SBU-9 South Burbank Unit, Pawhuska, OK
Rho late stage (ohm-m)
1k
100.
10.
1.
0.01
0.1
1.0
3.0
Tau=sqrt(2*pi*t)

Figure 6c

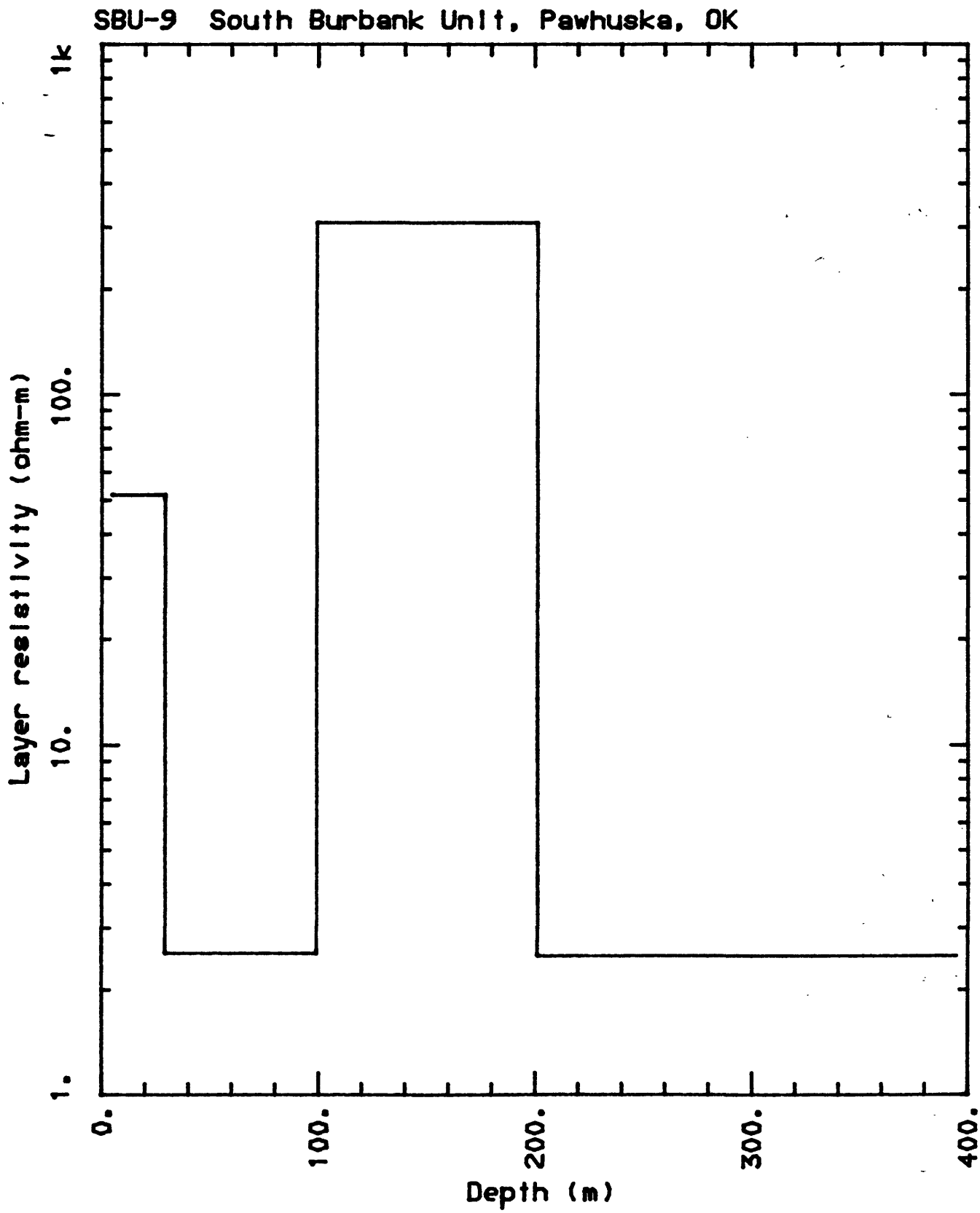

SBU-9 South Burbank Unit, Pawhuska, OK
Layer resistivity (ohm-m)
1k
100.
10.
1.
0.
100.
200.
300.
400.
Depth (m)

Figure 7a

```
<NLSTCO>:     SBU-10  South Burbank Unit, Pawhuska, OK

***** VARIABILITY CONVERGENCE *****      LOOP RADIUS=  43.0

  I     OBS.Y(I)       CAL            RES         %RES.ERR      X(I,1)
  1  0.654610E+01  0.696083E+01 -0.415E+00 -0.595805E+01  0.120000E-02
  2  0.561130E+01  0.562190E+01 -0.106E-01 -0.188618E+00  0.160000E-02
  3  0.497940E+01  0.482472E+01  0.155E+00  0.320601E+01  0.200000E-02
  4  0.427790E+01  0.407950E+01  0.198E+00  0.486344E+01  0.260000E-02
  5  0.369340E+01  0.348861E+01  0.205E+00  0.587036E+01  0.340000E-02
  6  0.327750E+01  0.311487E+01  0.163E+00  0.522122E+01  0.420000E-02
  7  0.297720E+01  0.285432E+01  0.123E+00  0.430497E+01  0.500000E-02
  8  0.274270E+01  0.266184E+01  0.809E-01  0.303788E+01  0.580000E-02
  9  0.243550E+01  0.245185E+01 -0.164E-01 -0.667048E+00  0.700000E-02
 10  0.217660E+01  0.225603E+01 -0.794E-01 -0.352087E+01  0.860000E-02
 11  0.202100E+01  0.211435E+01 -0.934E-01 -0.441516E+01  0.102000E-01
 12  0.189420E+01  0.201047E+01 -0.116E+00 -0.578333E+01  0.118000E-01
 13  0.184590E+01  0.193016E+01 -0.843E-01 -0.436538E+01  0.134000E-01
** RMSERR=  0.18124364E+00

CORRELATION MATRIX
 2  0.1000E+01
 3  0.7793E+00  0.1000E+01

  **PARM_SOL.    STD_ERROR    REL_ERROR     % ERROR **

 2  0.1038E+01  0.9230E-02  0.8890E-02  0.8890E+00
 3  0.4942E+02  0.2413E-02  0.4883E-04  0.4883E-02

********  E N D  ********      SBU-10  South Burbank Unit, Pawhuska, OK

PARAMETER NAME        FINAL SOLUTION        RESISTIVITY   LAYER DEPTH

   1 * SIGMA( 1) =  0.33300001E-01    1  0.30030029E+02
   2   SIGMA( 2) =  0.10383208E+01    2  0.96309352E+00
   3   THICK( 1) =  0.49418266E+02                        1  0.49418266E+02
   4 * SHIFT     =  0.10000000E+01

     * FIXED
```

Figure 7b

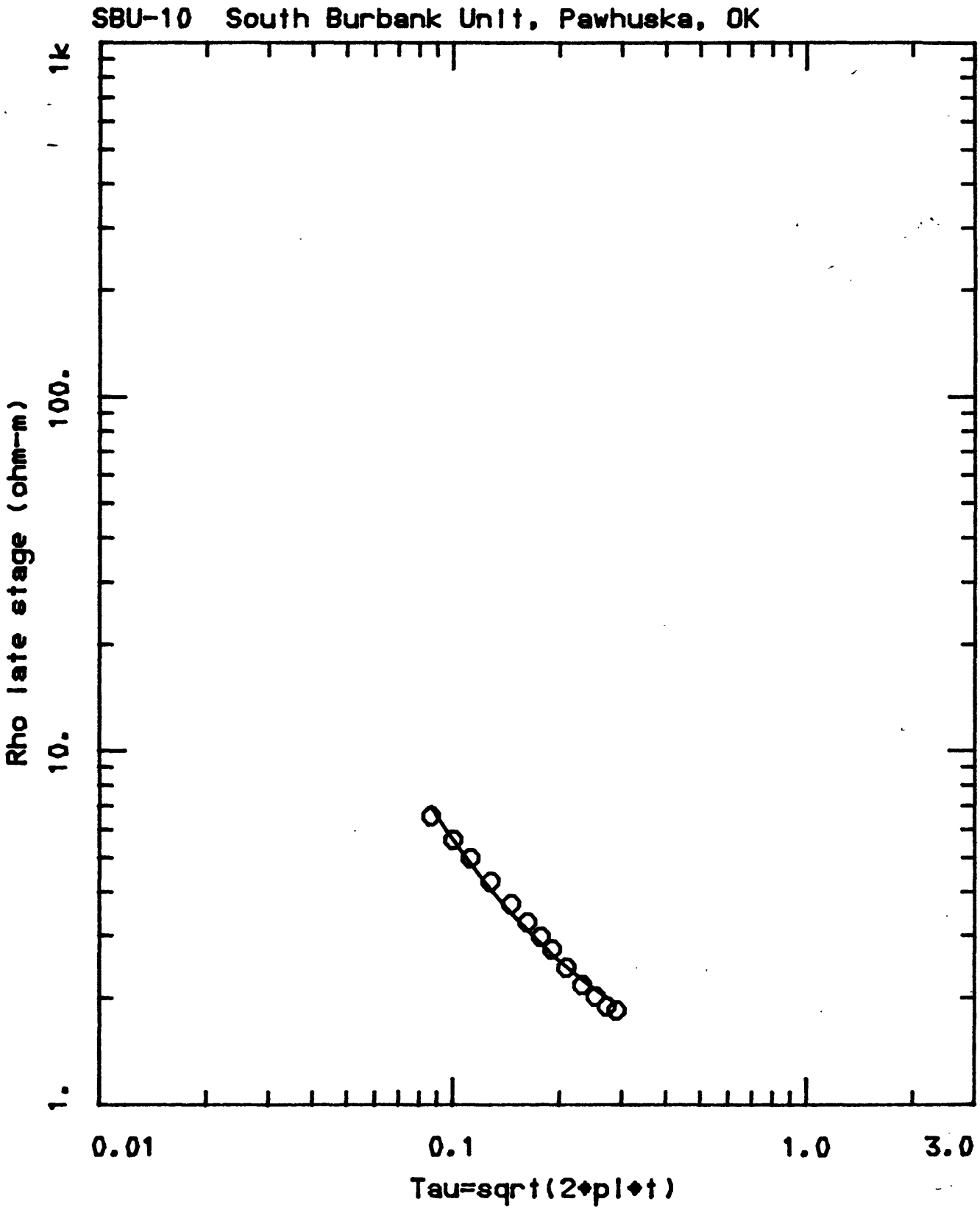

SBU-10 South Burbank Unit, Pawhuska, OK
Rho late stage (ohm-m)
1k
100.
10.
1.
0.01
0.1
1.0
3.0
Tau=sqrt(2*pi*t)

Figure 7c

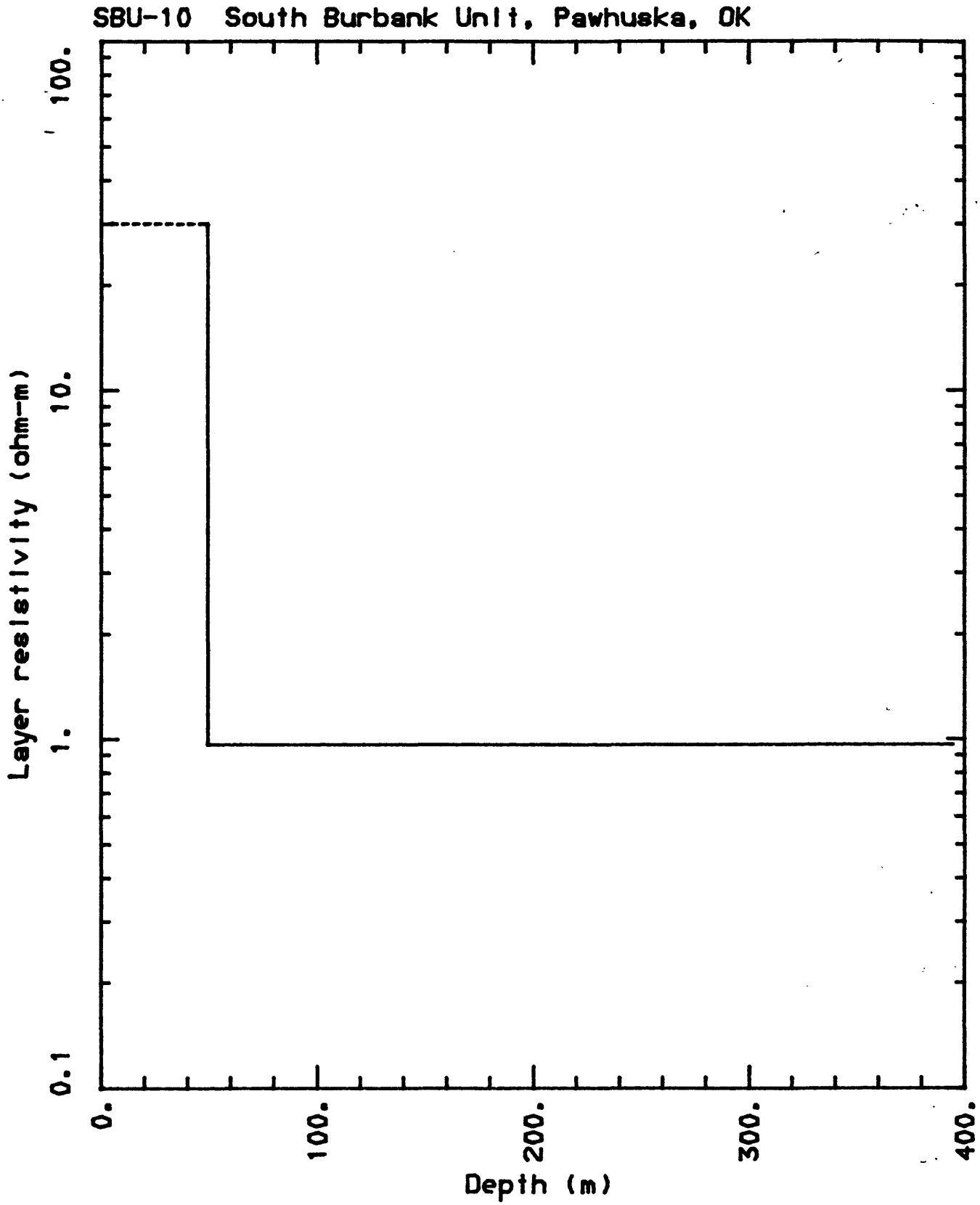

SBU-10 South Burbank Unit, Pawhuska, OK
Layer resistivity (ohm-m)
100.
10.
1.
0.1
0.
100.
200.
300.
400.
Depth (m)

Figure 8a

```
<NLSTCO>:      SBU-11  South Burbank Unit, Pawhuska, OK

***** X-CONVERGENCE *****                    LOOP RADIUS=  86.0

  I     OBS.Y(I)        CAL             RES          %RES.ERR       X(I,1)
  1  0.878290E+01  0.874560E+01  0.373E-01  0.426469E+00  0.120000E-02
  2  0.783660E+01  0.783257E+01  0.403E-02  0.514547E-01  0.160000E-02
  3  0.726270E+01  0.727480E+01 -0.121E-01 -0.166304E+00  0.200000E-02
  4  0.660340E+01  0.673477E+01 -0.131E+00 -0.195066E+01  0.260000E-02
  5  0.617460E+01  0.622890E+01 -0.543E-01 -0.871748E+00  0.340000E-02
  6  0.586330E+01  0.581565E+01  0.477E-01  0.819405E+00  0.420000E-02
  7  0.561660E+01  0.549122E+01  0.125E+00  0.228327E+01  0.500000E-02
  8  0.534040E+01  0.523208E+01  0.108E+00  0.207039E+01  0.580000E-02
  9  0.495720E+01  0.489370E+01  0.635E-01  0.129759E+01  0.700000E-02
 10  0.451060E+01  0.453271E+01 -0.221E-01 -0.487829E+00  0.860000E-02
 11  0.418430E+01  0.426831E+01 -0.840E-01 -0.196815E+01  0.102000E-01
 12  0.404710E+01  0.405836E+01 -0.113E-01 -0.277394E+00  0.118000E-01
 13  0.382340E+01  0.388633E+01 -0.629E-01 -0.161920E+01  0.134000E-01
 14  0.363740E+01  0.367689E+01 -0.395E-01 -0.107392E+01  0.158000E-01
 15  0.341790E+01  0.346265E+01 -0.448E-01 -0.129240E+01  0.190000E-01
 16  0.324570E+01  0.330511E+01 -0.594E-01 -0.179756E+01  0.222000E-01
 17  0.321150E+01  0.318226E+01  0.292E-01  0.918886E+00  0.254000E-01
 18  0.303730E+01  0.307929E+01 -0.420E-01 -0.136376E+01  0.286000E-01
 19  0.308680E+01  0.295309E+01  0.134E+00  0.452796E+01  0.334000E-01
 20  0.288470E+01  0.282791E+01  0.568E-01  0.200803E+01  0.398000E-01
** RMSERR=  0.80814704E-01

CORRELATION MATRIX
 1  0.1000E+01
 2 -0.8150E+00  0.1000E+01
 3  0.1656E-03 -0.3445E+00  0.1000E+01
 4  0.2554E+00  0.2134E+00 -0.5833E+00  0.1000E+01
 5 -0.6335E+00  0.3731E+00  0.5164E+00 -0.6254E+00  0.1000E+01

  **PARM_SOL.    STD_ERROR    REL_ERROR     % ERROR **

 1  0.1081E+00  0.2830E-02  0.2619E-01  0.2619E+01
 2  0.2655E+00  0.2032E-02  0.7651E-02  0.7651E+00
 3  0.6016E+00  0.2944E-02  0.4894E-02  0.4894E+00
 4  0.3516E+02  0.2812E-02  0.7997E-04  0.7997E-02
 5  0.9368E+02  0.5902E-02  0.6300E-04  0.6300E-02

********  E N D  ********      SBU-11  South Burbank Unit, Pawhuska, OK

PARAMETER NAME        FINAL SOLUTION        RESISTIVITY   LAYER DEPTH

   1    SIGMA( 1) =  0.10806824E+00    1  0.92534132E+01
   2    SIGMA( 2) =  0.26552361E+00    2  0.37661433E+01
   3    SIGMA( 3) =  0.60155159E+00    3  0.16623678E+01
   4    THICK( 1) =  0.35157269E+02                      1  0.35157269E+02
   5    THICK( 2) =  0.93684113E+02                      2  0.12884138E+03
   6  * SHIFT     =  0.10000000E+01

     * FIXED
```

Figure 8b

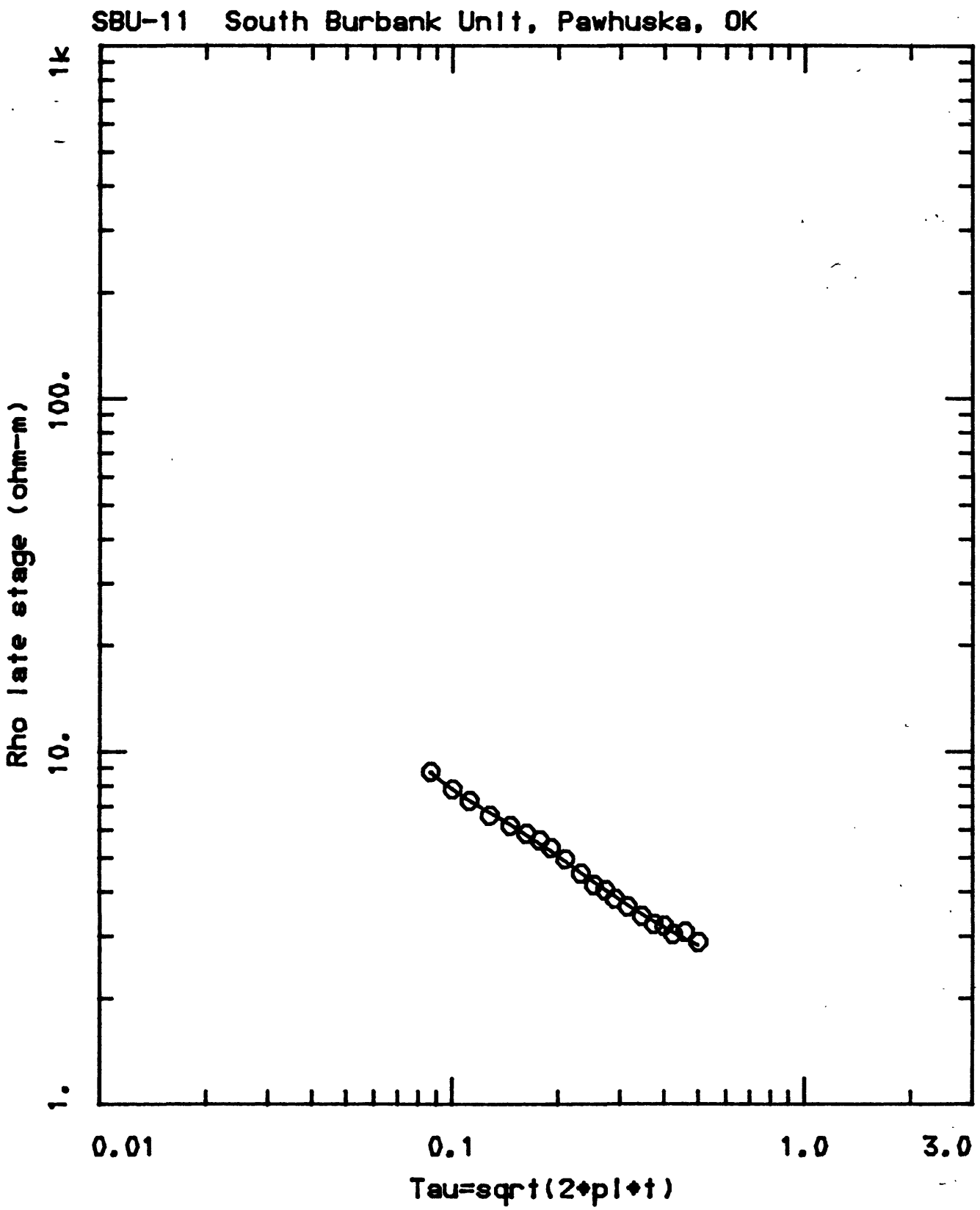

SBU-11 South Burbank Unit, Pawhuska, OK
Rho late stage (ohm-m)
1k
100.
10.
1.
0.01
0.1
1.0
3.0
Tau=sqrt(2*pi*t)

Figure 8c

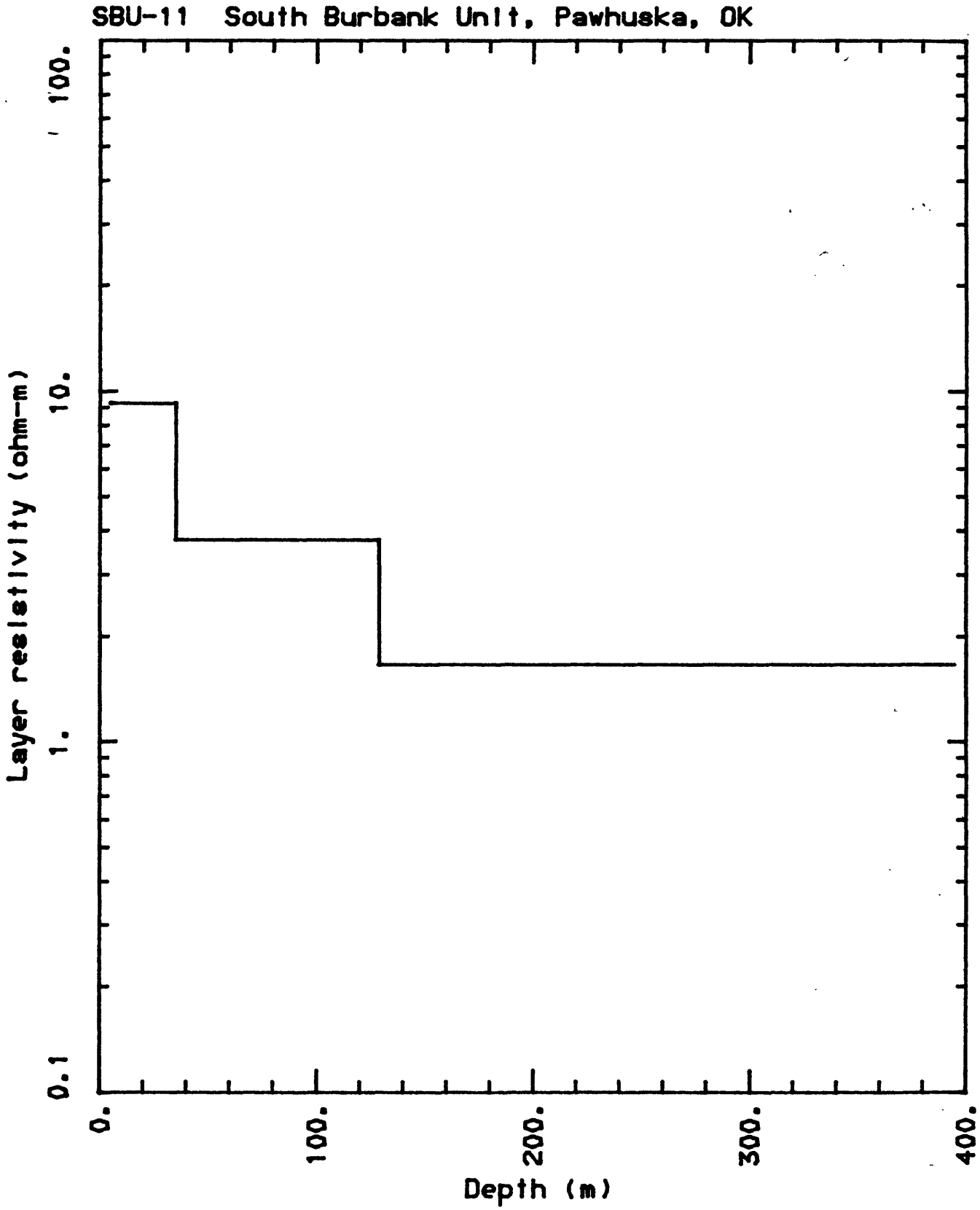

SBU-11 South Burbank Unit, Pawhuska, OK
Layer resistivity (ohm-m)
100.
10.
1.
0.1
0.
100.
200.
300.
400.
Depth (m)

Figure 9a

```
<NLSTCO>:      SBU-12  South Burbank Unit,  Pawhuska, OK

***** X-CONVERGENCE *****                    LOOP RADIUS=  86.0

  I     OBS.Y(I)       CAL            RES          %RES.ERR       X(I,1)
  1  0.943320E+01  0.954259E+01 -0.109E+00 -0.114630E+01  0.120000E-02
  2  0.840080E+01  0.834497E+01  0.558E-01  0.669072E+00  0.160000E-02
  3  0.770770E+01  0.762767E+01  0.800E-01  0.104922E+01  0.200000E-02
  4  0.700760E+01  0.697903E+01  0.286E-01  0.409420E+00  0.260000E-02
  5  0.651200E+01  0.647033E+01  0.417E-01  0.644059E+00  0.340000E-02
  6  0.615990E+01  0.614922E+01  0.107E-01  0.173645E+00  0.420000E-02
  7  0.588660E+01  0.591847E+01 -0.317E-01 -0.535186E+00  0.500000E-02
  8  0.567450E+01  0.571915E+01 -0.447E-01 -0.780712E+00  0.580000E-02
  9  0.538660E+01  0.543637E+01 -0.498E-01 -0.915577E+00  0.700000E-02
 10  0.508890E+01  0.508604E+01  0.286E-02  0.562243E-01  0.860000E-02
 11  0.479250E+01  0.479750E+01 -0.500E-02 -0.104203E+00  0.102000E-01
 12  0.452780E+01  0.454325E+01 -0.155E-01 -0.340096E+00  0.118000E-01
 13  0.431150E+01  0.430710E+01  0.434E-02  0.100711E+00  0.134000E-01
 14  0.400920E+01  0.399514E+01  0.141E-01  0.351904E+00  0.158000E-01
 15  0.370840E+01  0.367937E+01  0.290E-01  0.788976E+00  0.190000E-01
 16  0.345160E+01  0.343306E+01  0.185E-01  0.539935E+00  0.222000E-01
 17  0.324750E+01  0.323476E+01  0.127E-01  0.393984E+00  0.254000E-01
 18  0.307600E+01  0.306860E+01  0.740E-02  0.241068E+00  0.286000E-01
 19  0.287580E+01  0.286481E+01  0.110E-01  0.383634E+00  0.334000E-01
 20  0.267290E+01  0.266171E+01  0.112E-01  0.420494E+00  0.398000E-01
 21  0.250930E+01  0.251139E+01 -0.209E-02 -0.831251E-01  0.462000E-01
 22  0.238270E+01  0.239027E+01 -0.757E-02 -0.316602E+00  0.526000E-01
 23  0.226960E+01  0.228706E+01 -0.175E-01 -0.763265E+00  0.590000E-01
 24  0.214460E+01  0.216607E+01 -0.215E-01 -0.991395E+00  0.686000E-01
 25  0.203020E+01  0.204730E+01 -0.171E-01 -0.835020E+00  0.814000E-01
 26  0.197770E+01  0.195558E+01  0.221E-01  0.113131E+01  0.942000E-01
** RMSERR=  0.398666786E-01

CORRELATION MATRIX
 1  0.1000E+01
 2 -0.5490E+00  0.1000E+01
 3 -0.1130E+00 -0.2207E+00  0.1000E+01
 4  0.1090E+00  0.5046E+00 -0.2149E+00  0.1000E+01
 5 -0.3243E+00 -0.1071E-02 -0.1867E+00 -0.5132E+00  0.1000E+01

  **PARM_SOL.    STD_ERROR    REL_ERROR     % ERROR **

 1  0.1164E+00  0.3966E-03  0.3408E-02  0.3408E+00
 2  0.3109E+00  0.5234E-03  0.1683E-02  0.1683E+00
 3  0.1042E+01  0.9462E-03  0.9081E-03  0.9081E-01
 4  0.5344E+02  0.6307E-03  0.1180E-04  0.1180E-02
 5  0.1244E+03  0.9357E-03  0.7521E-05  0.7521E-03

********  E N D  ********      SBU-12  South Burbank Unit,  Pawhuska, OK

PARAMETER NAME       FINAL SOLUTION        RESISTIVITY   LAYER DEPTH

   1    SIGMA( 1) =  0.11635237E+00    1  0.85945816E+01
   2    SIGMA( 2) =  0.31092480E+00    2  0.32162118E+01
   3    SIGMA( 3) =  0.10419223E+01    3  0.95976442E+00
   4    THICK( 1) =  0.53437042E+02                      1  0.53437042E+02
   5    THICK( 2) =  0.12441553E+03                      2  0.17785258E+03
   6  * SHIFT     =  0.10000000E+01

     * FIXED
```

Figure 9b

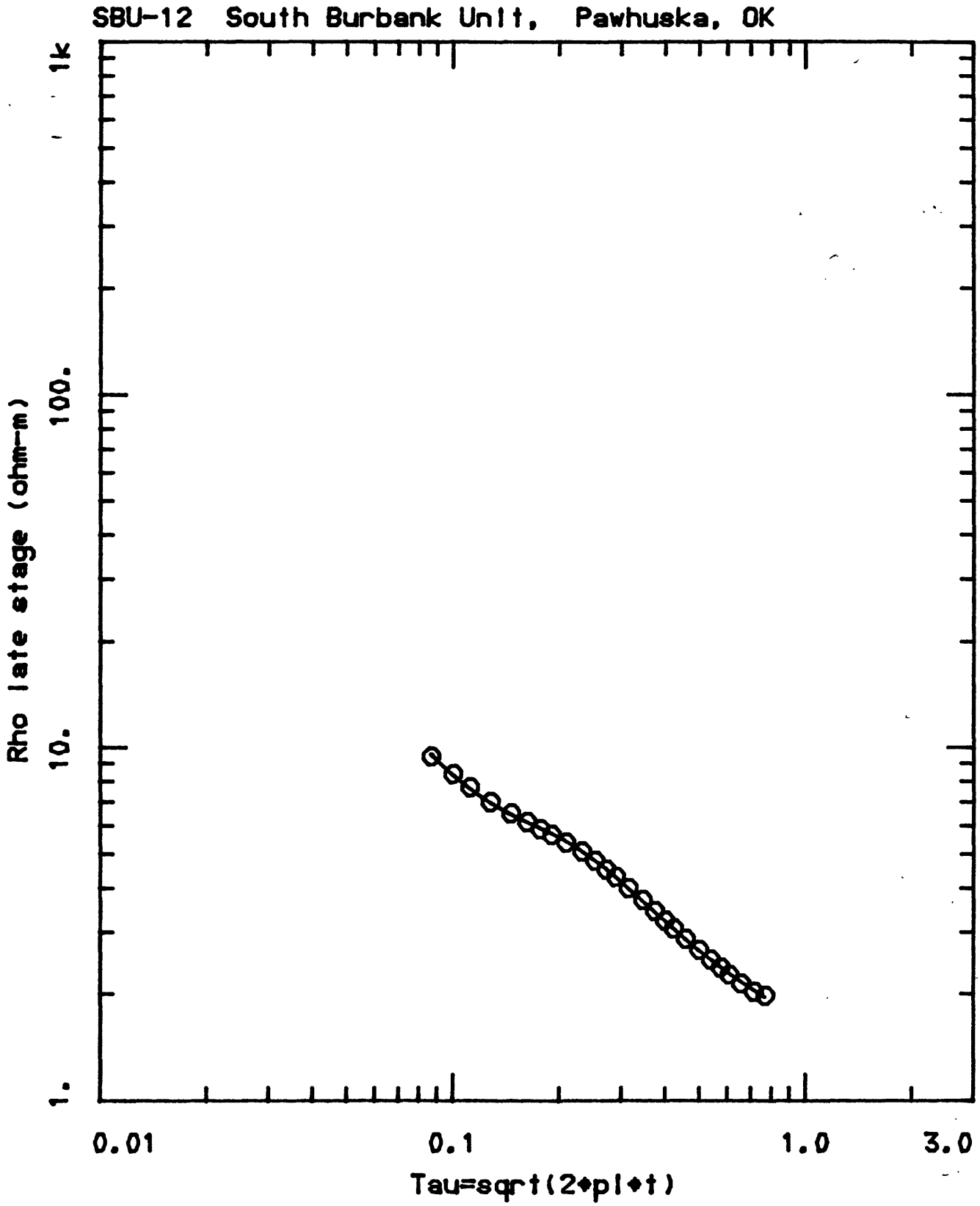

SBU-12 South Burbank Unit, Pawhuska, OK
Rho late stage (ohm-m)
1k
100.
10.
1.
0.01
0.1
1.0
3.0
Tau=sqrt(2*pi*t)

Figure 9c

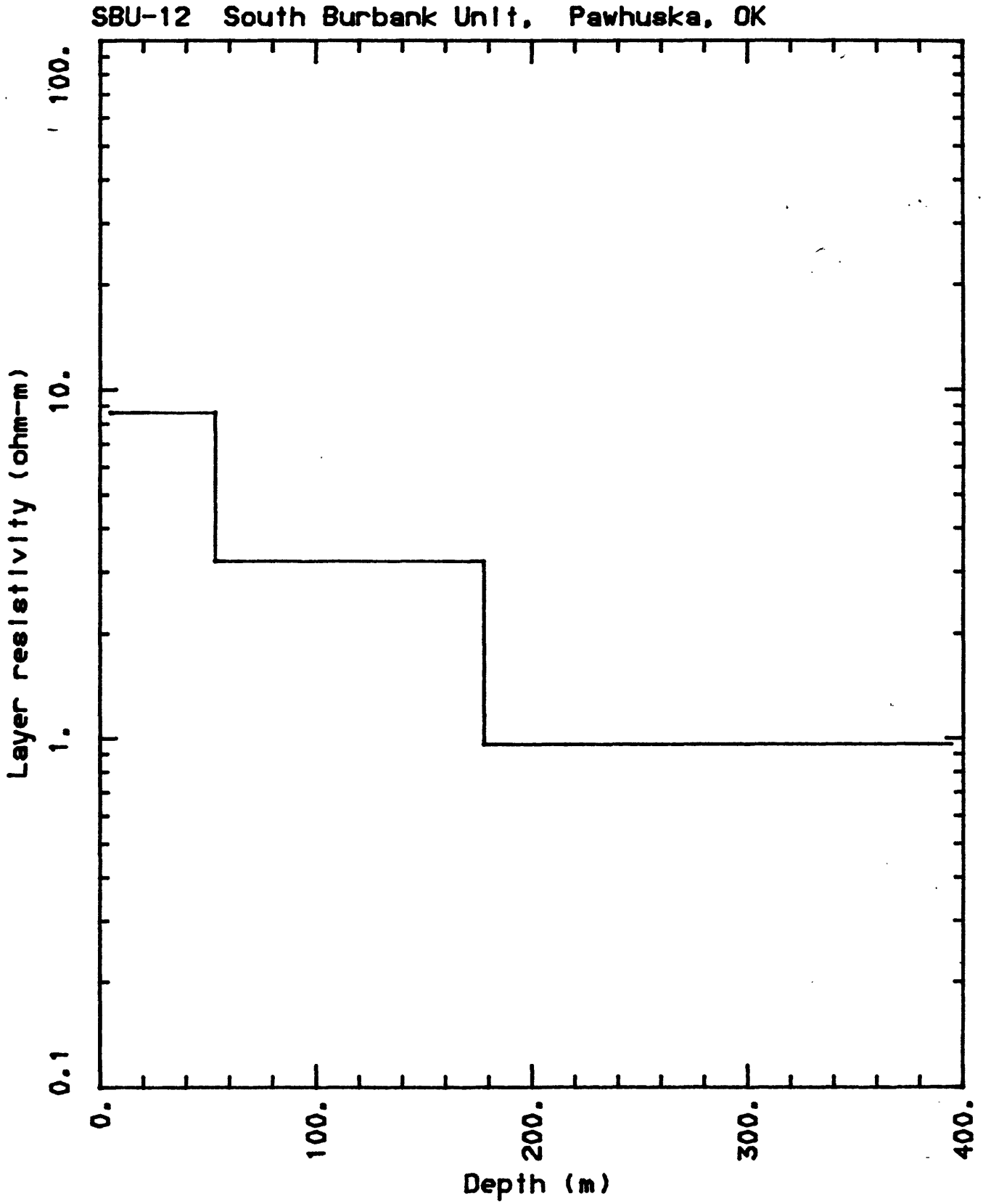

SBU-12 South Burbank Unit, Pawhuska, OK
Layer resistivity (ohm-m)
100.
10.
1.
0.1
0.
100.
200.
300.
400.
Depth (m)

Figure 10a

```
<NLSTCO>:     SBU-13  South Burbank Unit,  Pawhuska, OK

***** X-CONVERGENCE *****                    LOOP RADIUS=  86.0

  I     OBS.Y(I)        CAL             RES          %RES.ERR       X(I,1)
  1  0.969310E+01  0.967170E+01  0.214E-01  0.221298E+00  0.120000E-02
  2  0.882690E+01  0.879654E+01  0.304E-01  0.345127E+00  0.160000E-02
  3  0.828510E+01  0.827582E+01  0.928E-02  0.112171E+00  0.200000E-02
  4  0.772770E+01  0.783693E+01 -0.109E+00 -0.139383E+01  0.260000E-02
  5  0.744350E+01  0.750825E+01 -0.647E-01 -0.862324E+00  0.340000E-02
  6  0.727940E+01  0.730485E+01 -0.254E-01 -0.348369E+00  0.420000E-02
  7  0.716900E+01  0.716802E+01  0.983E-03  0.137170E-01  0.500000E-02
  8  0.706050E+01  0.702567E+01  0.348E-01  0.495741E+00  0.580000E-02
  9  0.685640E+01  0.680956E+01  0.468E-01  0.687887E+00  0.700000E-02
 10  0.667020E+01  0.657583E+01  0.944E-01  0.143505E+01  0.860000E-02
 11  0.643250E+01  0.633250E+01  0.100E+00  0.157916E+01  0.102000E-01
 12  0.619010E+01  0.608636E+01  0.104E+00  0.170439E+01  0.118000E-01
 13  0.594210E+01  0.586631E+01  0.758E-01  0.129203E+01  0.134000E-01
 14  0.557120E+01  0.559011E+01 -0.189E-01 -0.338300E+00  0.158000E-01
 15  0.521000E+01  0.528604E+01 -0.760E-01 -0.143859E+01  0.190000E-01
 16  0.493850E+01  0.503009E+01 -0.916E-01 -0.182092E+01  0.222000E-01
 17  0.475530E+01  0.480993E+01 -0.546E-01 -0.113571E+01  0.254000E-01
 18  0.458250E+01  0.462374E+01 -0.412E-01 -0.891841E+00  0.286000E-01
 19  0.436110E+01  0.440956E+01 -0.485E-01 -0.109938E+01  0.334000E-01
 20  0.417620E+01  0.419144E+01 -0.132E-01 -0.315924E+00  0.398000E-01
 21  0.410160E+01  0.400920E+01  0.924E-01  0.230459E+01  0.462000E-01
 22  0.390670E+01  0.385859E+01  0.481E-01  0.124677E+01  0.526000E-01
 23  0.384510E+01  0.374312E+01  0.102E+00  0.272458E+01  0.590000E-01
 24  0.360820E+01  0.360575E+01  0.245E-02  0.680724E-01  0.686000E-01
 25  0.340220E+01  0.345661E+01 -0.544E-01 -0.157396E+01  0.814000E-01
 26  0.328000E+01  0.333696E+01 -0.570E-01 -0.170703E+01  0.942000E-01
** RMSERR=  0.71133547E-01

CORRELATION MATRIX
 1  0.1000E+01
 2 -0.3114E+00  0.1000E+01
 3 -0.5257E-01 -0.1425E+00  0.1000E+01
 4 -0.2204E+00  0.2753E+00 -0.5081E+00  0.1000E+01
 5 -0.5920E+00  0.1863E+00  0.2405E+00 -0.5036E+00  0.1000E+01

  **PARM_SOL.    STD_ERROR    REL_ERROR     % ERROR **

 1  0.9337E-01  0.4476E-03  0.4794E-02  0.4794E+00
 2  0.1882E+00  0.3639E-03  0.1934E-02  0.1934E+00
 3  0.5021E+00  0.8971E-03  0.1787E-02  0.1787E+00
 4  0.3100E+02  0.7398E-03  0.2386E-04  0.2386E-02
 5  0.1790E+03  0.2013E-02  0.1124E-04  0.1124E-02

********  E N D  ********     SBU-13  South Burbank Unit,  Pawhuska, OK

PARAMETER NAME       FINAL SOLUTION        RESISTIVITY   LAYER DEPTH

   1   SIGMA( 1) =  0.93367033E-01   1  0.10710419E+02
   2   SIGMA( 2) =  0.18816715E+00   2  0.53138590E+01
   3   SIGMA( 3) =  0.50212036E+00   3  0.19915543E+01
   4   THICK( 1) =  0.31000862E+02                      1  0.31000862E+02
   5   THICK( 2) =  0.17904349E+03                      2  0.21004436E+03
   6 * SHIFT     =  0.10000000E+01

     * FIXED
```

Figure 10b

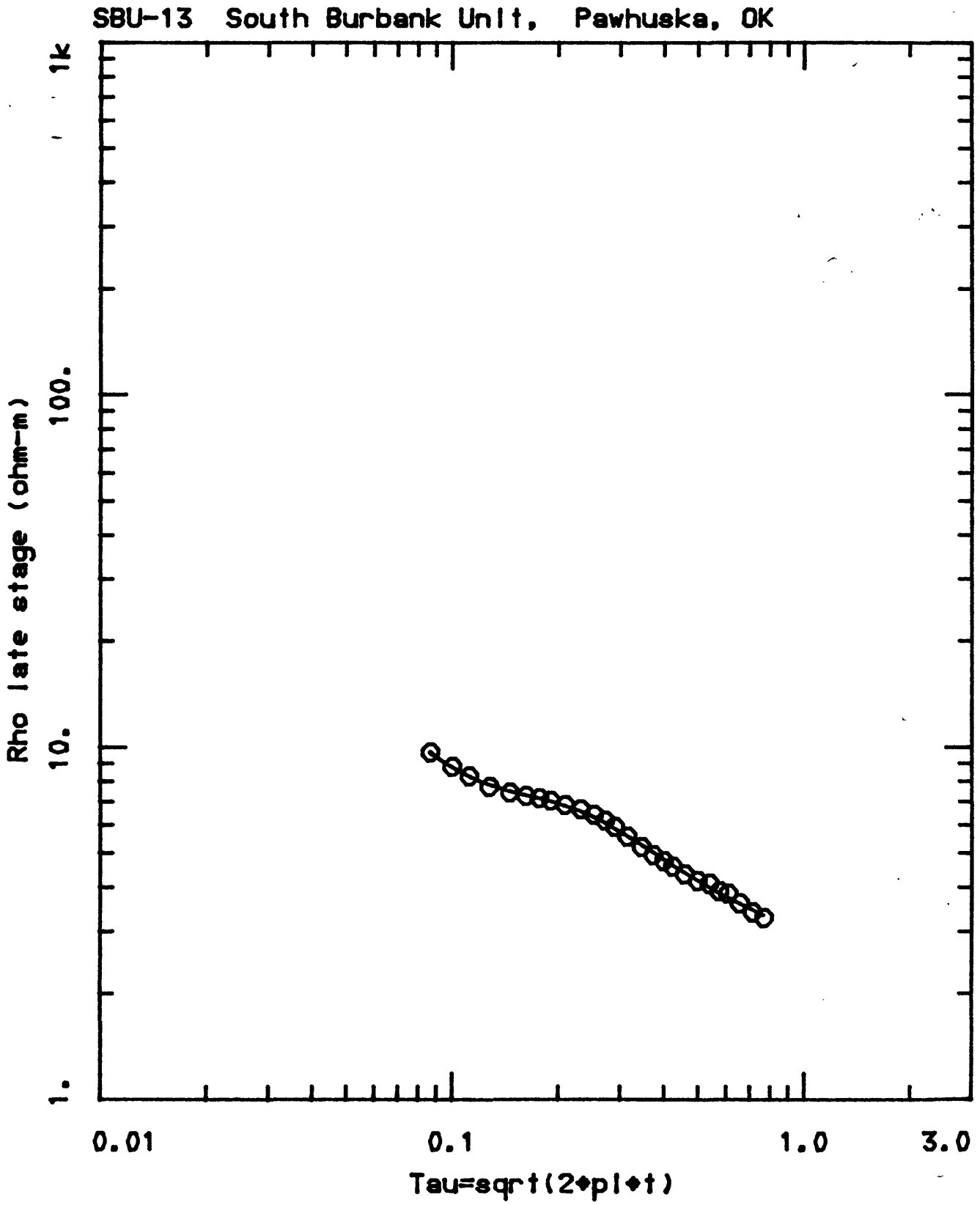

SBU-13 South Burbank Unit, Pawhuska, OK
Rho late stage (ohm-m)
1k
100.
10.
1.
0.01
0.1
1.0
3.0
Tau=sqrt(2*pi*t)

Figure 10c

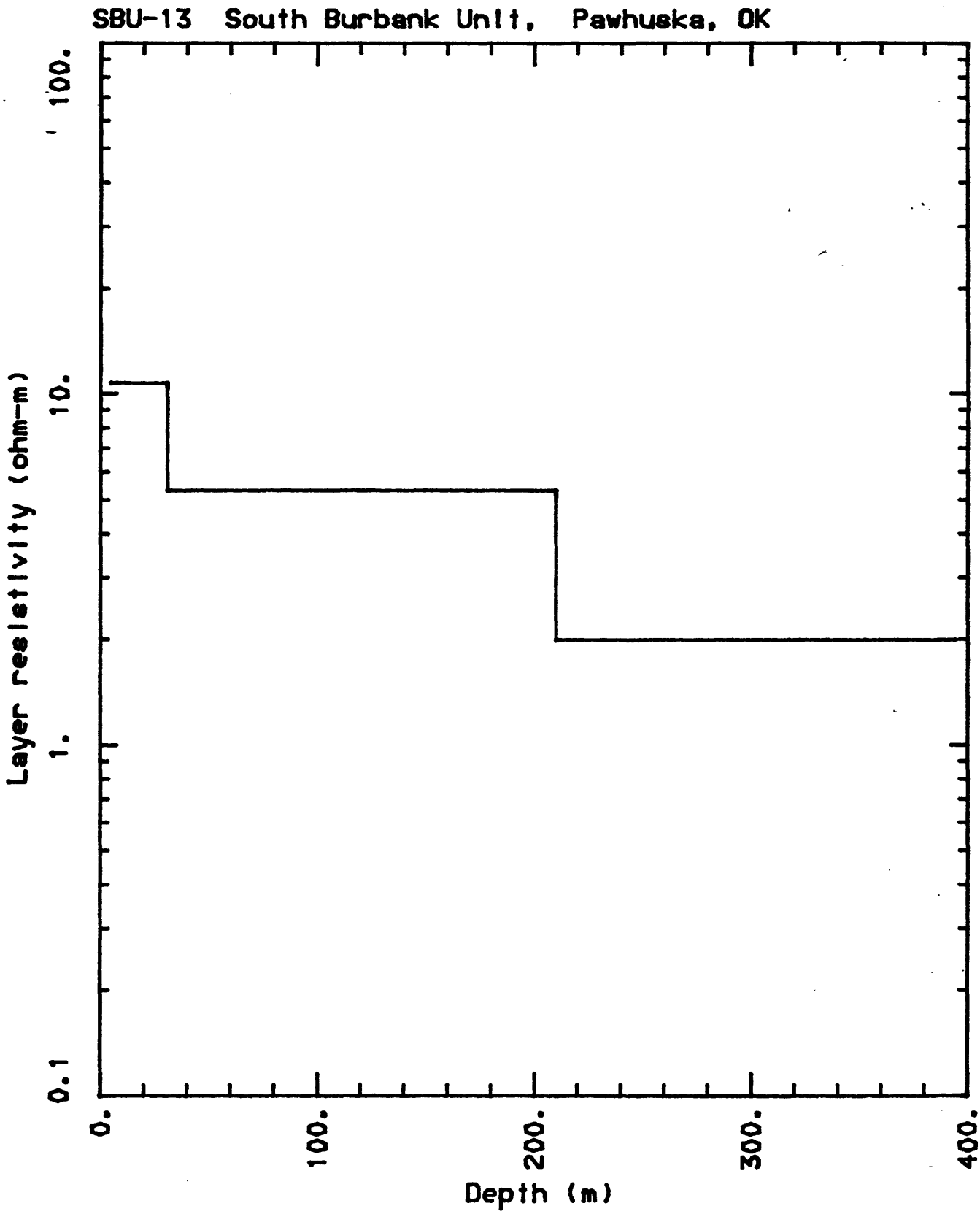

SBU-13 South Burbank Unit, Pawhuska, OK
Layer resistivity (ohm-m)
100.
10.
1.
0.1
0.
100.
200.
300.
400.
Depth (m)

Figure 11a

```
<NLSTCO>:     SBU-14  South Burbank Unit,  Pawhuska, OK

***** X-CONVERGENCE *****                    LOOP RADIUS=  86.0

  I     OBS.Y(I)       CAL            RES        %RES.ERR      X(I,1)
  1  0.956260E+01  0.956979E+01 -0.719E-02 -0.751297E-01  0.120000E-02
  2  0.860730E+01  0.854962E+01  0.577E-01  0.674674E+00  0.160000E-02
  3  0.799840E+01  0.797171E+01  0.267E-01  0.334797E+00  0.200000E-02
  4  0.735940E+01  0.744801E+01 -0.886E-01 -0.118975E+01  0.260000E-02
  5  0.692600E+01  0.699740E+01 -0.714E-01 -0.102037E+01  0.340000E-02
  6  0.663260E+01  0.669262E+01 -0.600E-01 -0.896794E+00  0.420000E-02
  7  0.640120E+01  0.641550E+01 -0.143E-01 -0.222970E+00  0.500000E-02
  8  0.621530E+01  0.615218E+01  0.631E-01  0.102594E+01  0.580000E-02
  9  0.591750E+01  0.584527E+01  0.722E-01  0.123572E+01  0.700000E-02
 10  0.559870E+01  0.550943E+01  0.893E-01  0.162030E+01  0.860000E-02
 11  0.529050E+01  0.520006E+01  0.904E-01  0.173925E+01  0.102000E-01
 12  0.501420E+01  0.495249E+01  0.617E-01  0.124605E+01  0.118000E-01
 13  0.477230E+01  0.475153E+01  0.208E-01  0.437104E+00  0.134000E-01
 14  0.445400E+01  0.450381E+01 -0.498E-01 -0.110592E+01  0.158000E-01
 15  0.415030E+01  0.424571E+01 -0.954E-01 -0.224713E+01  0.190000E-01
 16  0.393310E+01  0.403763E+01 -0.105E+00 -0.258898E+01  0.222000E-01
 17  0.377720E+01  0.387108E+01 -0.939E-01 -0.242522E+01  0.254000E-01
 18  0.367770E+01  0.373803E+01 -0.603E-01 -0.161393E+01  0.286000E-01
 19  0.363870E+01  0.358559E+01 -0.469E-01 -0.130785E+01  0.334000E-01
 20  0.342320E+01  0.341719E+01  0.601E-02  0.176010E+00  0.398000E-01
 21  0.333920E+01  0.328690E+01  0.523E-01  0.159132E+01  0.462000E-01
 22  0.326550E+01  0.318649E+01  0.790E-01  0.247954E+01  0.526000E-01
 23  0.319110E+01  0.310429E+01  0.868E-01  0.279640E+01  0.590000E-01
 24  0.304380E+01  0.300506E+01  0.387E-01  0.128926E+01  0.686000E-01
 25  0.291090E+01  0.290038E+01  0.105E-01  0.362735E+00  0.814000E-01
 26  0.278940E+01  0.281871E+01 -0.293E-01 -0.103979E+01  0.942000E-01
** RMSERR=  0.71254715E-01

CORRELATION MATRIX
 1  0.1000E+01
 2 -0.2488E+00  0.1000E+01
 3  0.4143E+00 -0.1111E+00  0.1000E+01
 4 -0.4515E+00  0.5178E+00 -0.1073E+00  0.1000E+01
 5  0.4535E+00 -0.1595E+00  0.1811E+00 -0.5551E+00  0.1000E+01

  **PARM_SOL.    STD_ERROR    REL_ERROR     % ERROR **

 1  0.2570E-01  0.3129E-03  0.1217E-01  0.1217E+01
 2  0.2258E+00  0.4380E-03  0.1940E-02  0.1940E+00
 3  0.5374E+00  0.1870E-02  0.3480E-02  0.3480E+00
 4  0.2315E+02  0.9165E-03  0.3959E-04  0.3959E-02
 5  0.1383E+03  0.2125E-02  0.1536E-04  0.1536E-02

********  E N D  ********     SBU-14  South Burbank Unit,  Pawhuska, OK

PARAMETER NAME       FINAL SOLUTION        RESISTIVITY   LAYER DEPTH

   1    SIGMA( 1) =  0.25703171E-01    1  0.38905704E+02
   2    SIGMA( 2) =  0.22580598E+00    2  0.44285808E+01
   3    SIGMA( 3) =  0.53736484E+00    3  0.18609331E+01
   4    THICK( 1) =  0.23149033E+02                      1  0.23149033E+02
   5    THICK( 2) =  0.13829535E+03                      2  0.16144438E+03
   6  * SHIFT     =  0.10000000E+01

     * FIXED
```

Figure 11b

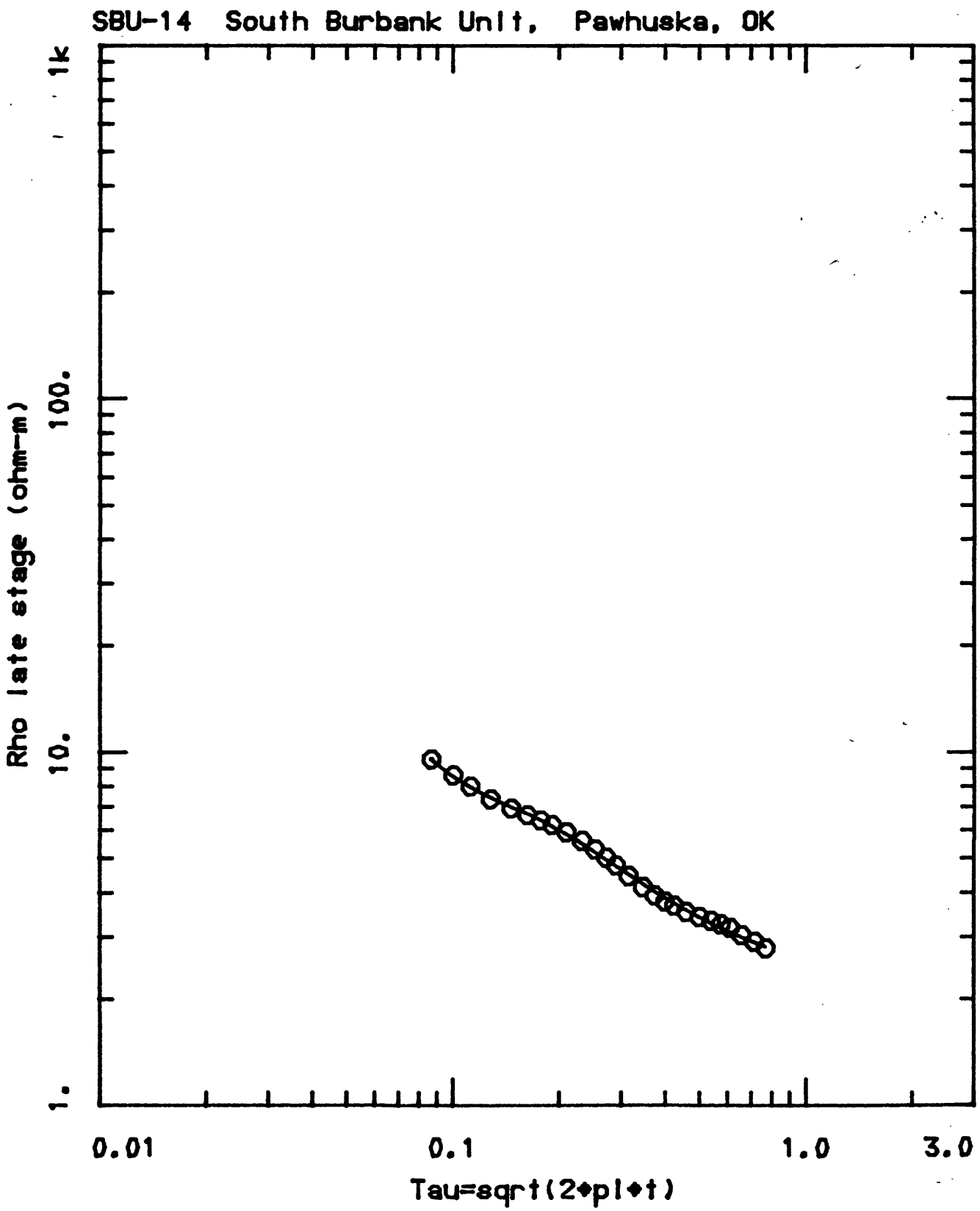

SBU-14 South Burbank Unit, Pawhuska, OK
Rho late stage (ohm-m)
1k
100.
10.
1.
0.01
0.1
1.0
3.0
Tau=sqrt(2*pi*t)

Figure 11c

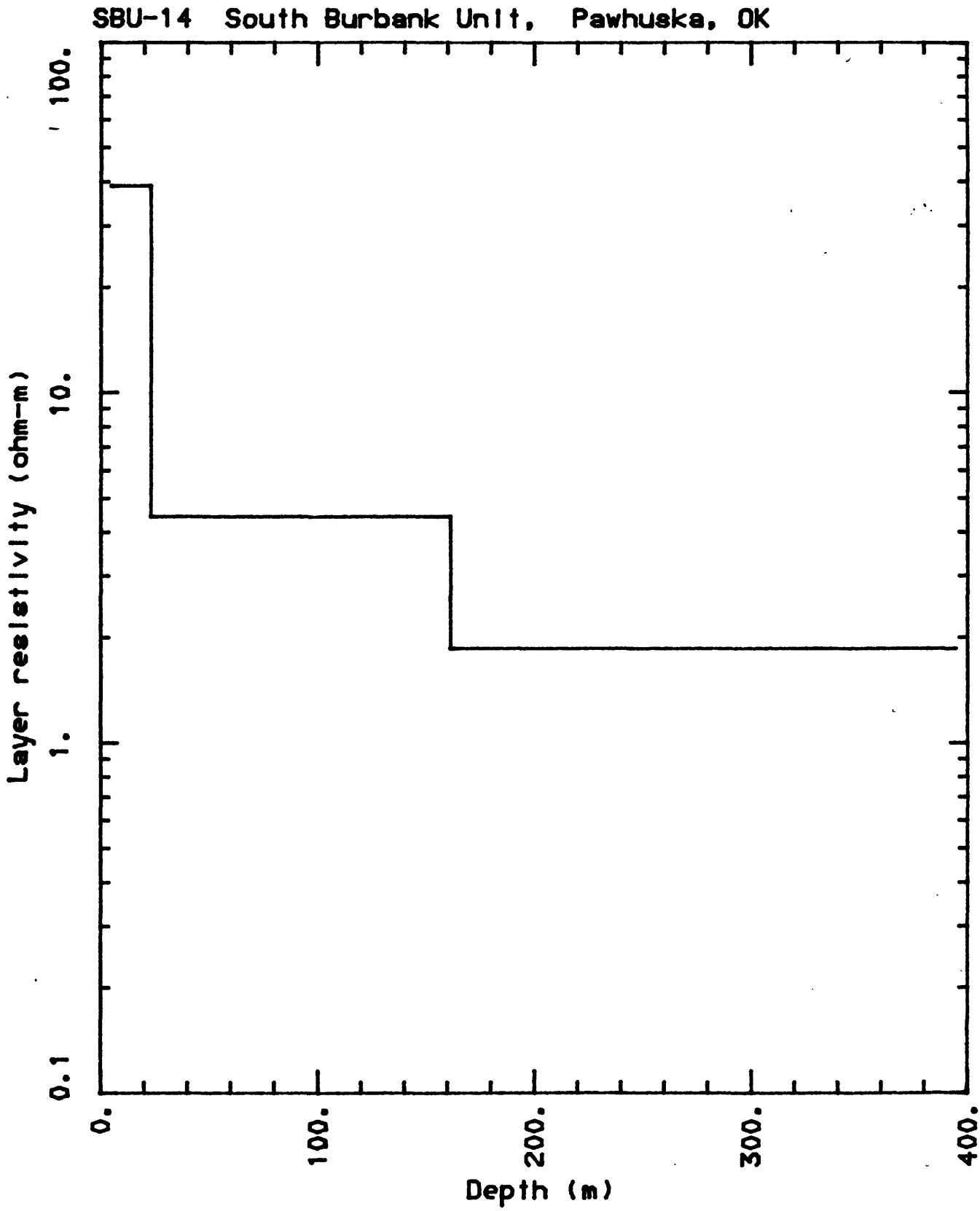

SBU-14 South Burbank Unit, Pawhuska, OK
Layer resistivity (ohm-m)
100.
10.
1.
0.1
0.
100.
200.
300.
400.
Depth (m)

Figure 12a

```
<NLSTCO>:     SBU-15  South Burbank Unit, Pawhuska, OK

***** X-CONVERGENCE *****                    LOOP RADIUS=  86.0

  I     OBS.Y(I)       CAL            RES         %RES.ERR       X(I,1)
  1  0.103290E+02  0.104208E+02 -0.918E-01 -0.880746E+00  0.120000E-02
  2  0.918730E+01  0.919030E+01 -0.300E-02 -0.326252E-01  0.160000E-02
  3  0.846280E+01  0.845847E+01  0.433E-02  0.512101E-01  0.200000E-02
  4  0.779970E+01  0.782075E+01 -0.210E-01 -0.269119E+00  0.260000E-02
  5  0.735220E+01  0.734503E+01  0.717E-02  0.975678E-01  0.340000E-02
  6  0.709120E+01  0.707408E+01  0.171E-01  0.241988E+00  0.420000E-02
  7  0.696640E+01  0.690639E+01  0.600E-01  0.868891E+00  0.500000E-02
  8  0.686930E+01  0.676242E+01  0.107E+00  0.158049E+01  0.580000E-02
  9  0.649700E+01  0.657399E+01 -0.770E-01 -0.117118E+01  0.700000E-02
 10  0.639310E+01  0.636880E+01  0.243E-01  0.381519E+00  0.860000E-02
 11  0.589880E+01  0.612513E+01 -0.226E+00 -0.369506E+01  0.102000E-01
 12  0.588590E+01  0.587187E+01  0.140E-01  0.238887E+00  0.118000E-01
 13  0.564350E+01  0.564475E+01 -0.125E-02 -0.220732E-01  0.134000E-01
 14  0.534710E+01  0.534898E+01 -0.188E-02 -0.350788E-01  0.158000E-01
 15  0.518860E+01  0.498906E+01  0.200E+00  0.399960E+01  0.190000E-01
 16  0.463020E+01  0.467222E+01 -0.420E-01 -0.899406E+00  0.222000E-01
 17  0.443160E+01  0.441078E+01  0.208E-01  0.472083E+00  0.254000E-01
 18  0.417260E+01  0.419543E+01 -0.226E-01 -0.539322E+00  0.286000E-01
 19  0.390660E+01  0.393774E+01 -0.311E-01 -0.790775E+00  0.334000E-01
** RMSERR=  0.94757348E-01

CORRELATION MATRIX
 1  0.1000E+01
 2 -0.5603E+00  0.1000E+01
 3 -0.1616E+00 -0.2119E-02  0.1000E+01
 4 -0.3276E+00  0.7633E+00 -0.2777E+00  0.1000E+01
 5 -0.4989E+00  0.1079E+00  0.6319E-01 -0.2846E-01  0.1000E+01

  **PARM_SOL.    STD_ERROR    REL_ERROR     % ERROR **

 1  0.2913E-01  0.9403E-03  0.3228E-01  0.3228E+01
 2  0.2227E+00  0.7156E-03  0.3213E-02  0.3213E+00
 3  0.8044E+00  0.3866E-02  0.4807E-02  0.4807E+00
 4  0.2924E+02  0.1666E-02  0.5700E-04  0.5700E-02
 5  0.1940E+03  0.4503E-02  0.2321E-04  0.2321E-02

********  E N D  ********     SBU-15  South Burbank Unit, Pawhuska, OK

PARAMETER NAME       FINAL SOLUTION        RESISTIVITY   LAYER DEPTH

   1    SIGMA( 1) =  0.29130632E-01    1  0.34328125E+02
   2    SIGMA( 2) =  0.22272427E+00    2  0.44898562E+01
   3    SIGMA( 3) =  0.80437565E+00    3  0.12432002E+01
   4    THICK( 1) =  0.29235945E+02                      1  0.29235945E+02
   5    THICK( 2) =  0.19402982E+03                      2  0.22326576E+03
   6  * SHIFT     =  0.10000000E+01

     * FIXED
```

Figure 12b

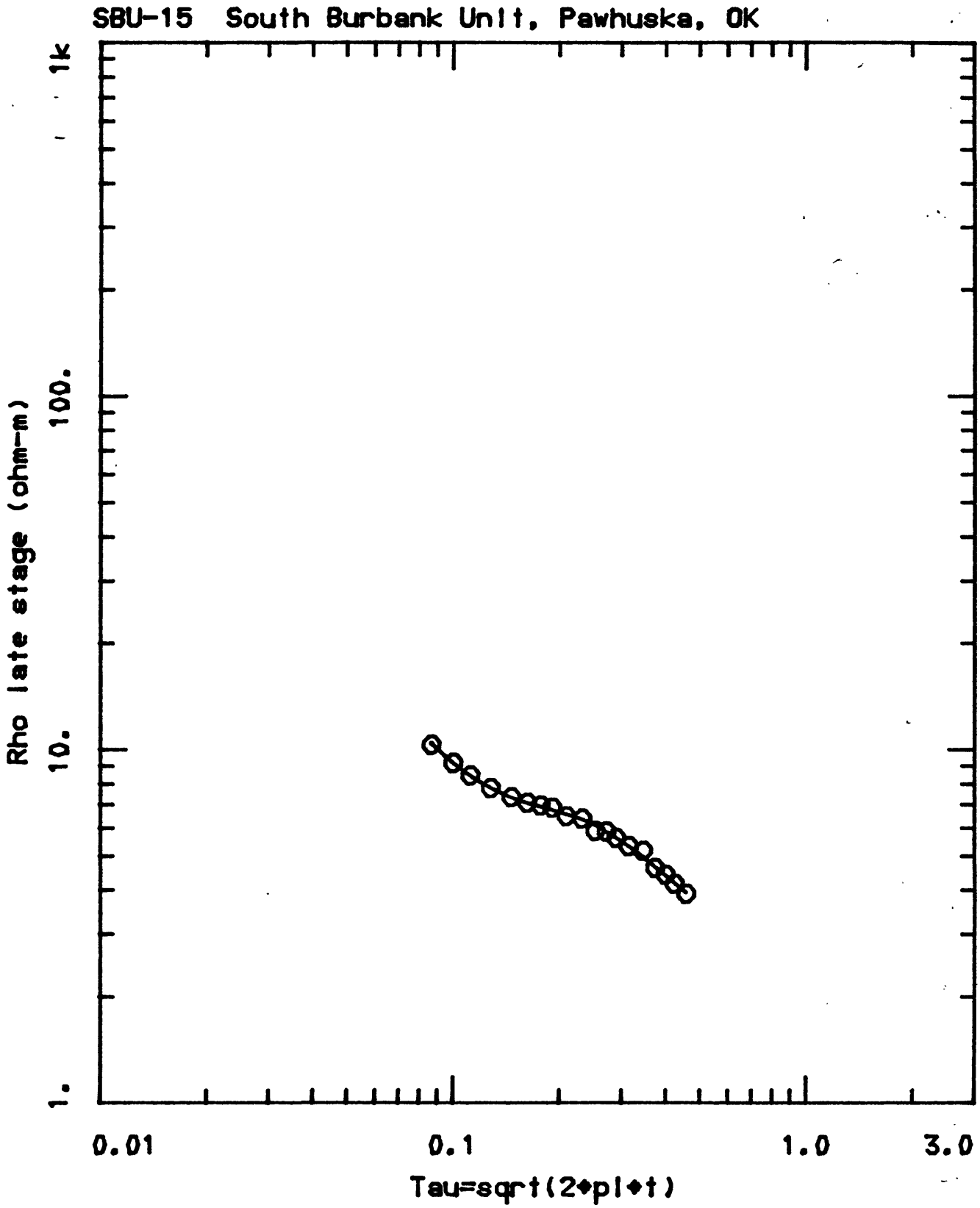

SBU-15 South Burbank Unit, Pawhuska, OK
Rho late stage (ohm-m)
1k
100.
10.
1.
0.01
0.1
1.0
3.0
Tau=sqrt(2*pi*t)

Figure 12c

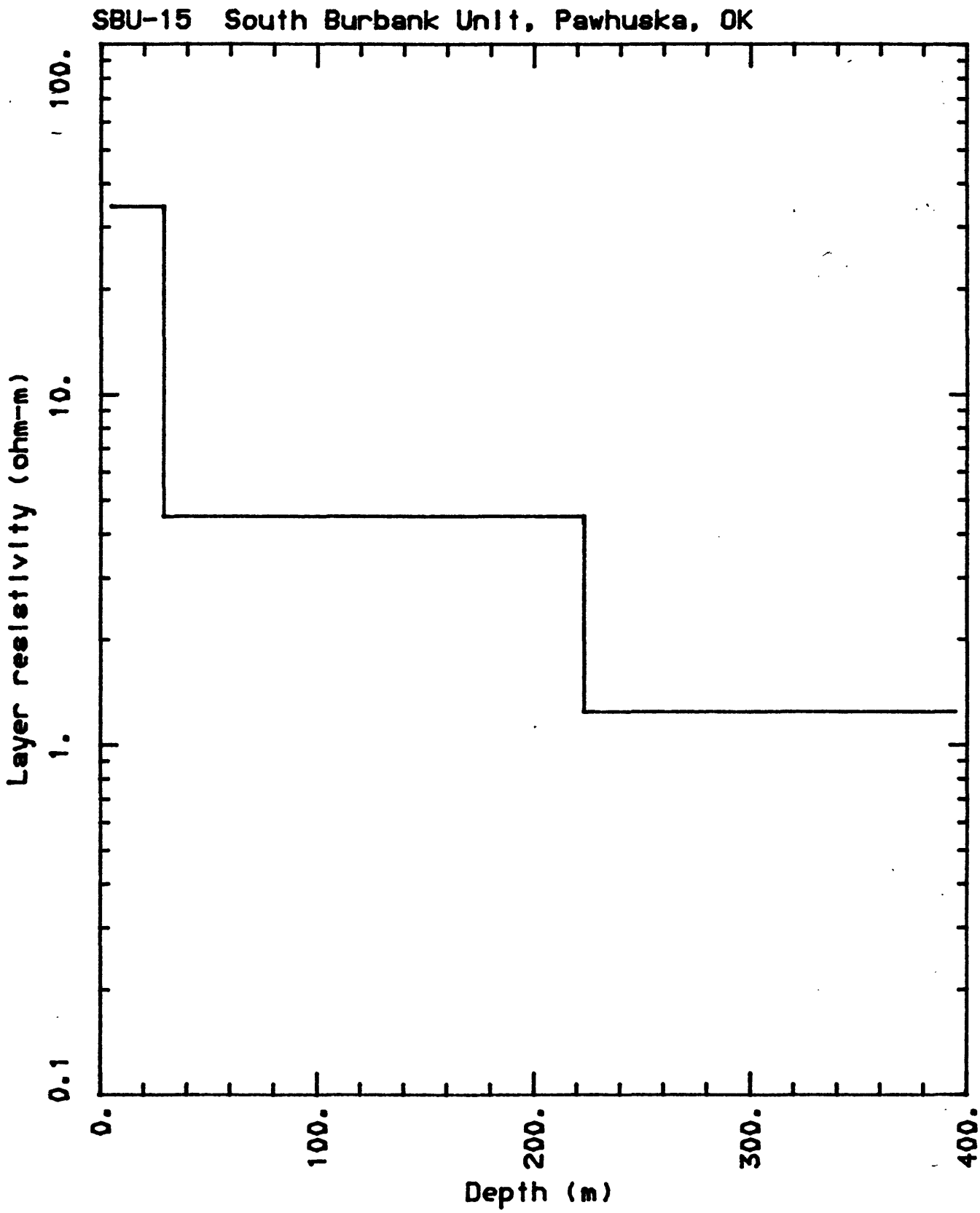

SBU-15 South Burbank Unit, Pawhuska, OK
Layer resistivity (ohm-m)
100.
10.
1.
0.1
0.
100.
200.
300.
400.
Depth (m)

Figure 13a

<NLSTCO>: SBU-16 South Burbank Unit, Pawhuska, OK

***** X-CONVERGENCE ***** LOOP RADIUS= 86.0

I	OBS.Y(I)	CAL	RES	%RES.ERR	X(I,1)
1	0.796140E+01	0.797344E+01	-0.120E-01	-0.151015E+00	0.120000E-02
2	0.730630E+01	0.730816E+01	-0.186E-02	-0.253942E-01	0.160000E-02
3	0.695200E+01	0.692711E+01	0.249E-01	0.359284E+00	0.200000E-02
4	0.652640E+01	0.663049E+01	-0.104E+00	-0.156990E+01	0.260000E-02
5	0.637020E+01	0.640697E+01	-0.368E-01	-0.573830E+00	0.340000E-02
6	0.624860E+01	0.625948E+01	-0.109E-01	-0.173748E+00	0.420000E-02
7	0.614150E+01	0.615635E+01	-0.149E-01	-0.241263E+00	0.500000E-02
8	0.607540E+01	0.602877E+01	0.466E-01	0.773456E+00	0.580000E-02
9	0.590120E+01	0.582592E+01	0.753E-01	0.129209E+01	0.700000E-02
10	0.569780E+01	0.562480E+01	0.730E-01	0.129781E+01	0.860000E-02
11	0.547560E+01	0.542977E+01	0.458E-01	0.844020E+00	0.102000E-01
12	0.526840E+01	0.524095E+01	0.275E-01	0.523807E+00	0.118000E-01
13	0.507520E+01	0.507541E+01	-0.207E-03	-0.407745E-02	0.134000E-01
14	0.482660E+01	0.487319E+01	-0.466E-01	-0.956015E+00	0.158000E-01
15	0.457660E+01	0.466234E+01	-0.857E-01	-0.183895E+01	0.190000E-01
16	0.437050E+01	0.447861E+01	-0.108E+00	-0.241381E+01	0.222000E-01
17	0.419810E+01	0.430001E+01	-0.102E+00	-0.237011E+01	0.254000E-01
18	0.406040E+01	0.413224E+01	-0.718E-01	-0.173859E+01	0.286000E-01
19	0.390660E+01	0.392254E+01	-0.159E-01	-0.406277E+00	0.334000E-01
20	0.375840E+01	0.368513E+01	0.733E-01	0.198821E+01	0.398000E-01
21	0.355190E+01	0.347217E+01	0.797E-01	0.229626E+01	0.462000E-01
22	0.342910E+01	0.328579E+01	0.143E+00	0.436139E+01	0.526000E-01
23	0.321400E+01	0.312995E+01	0.840E-01	0.268527E+01	0.590000E-01
24	0.293150E+01	0.293105E+01	0.447E-03	0.152435E-01	0.686000E-01
25	0.258870E+01	0.271323E+01	-0.125E+00	-0.458989E+01	0.814000E-01
26	0.234400E+01	0.254391E+01	-0.200E+00	-0.785823E+01	0.942000E-01

** RMSERR= 0.92088245E-01

Figure 13a cont.

```
CORRELATION MATRIX
 1  0.1000E+01
 2 -0.2120E+00  0.1000E+01
 3 -0.2651E+00 -0.4156E+00  0.1000E+01
 4  0.6228E-01 -0.2059E+00  0.4613E+00  0.1000E+01
 5 -0.1168E+00  0.4004E+00 -0.8473E+00 -0.5140E+00  0.1000E+01
 6 -0.1085E+00  0.2972E+00 -0.3471E+00 -0.5515E+00  0.2771E+00  0.1000E+01
 7 -0.3840E+00  0.1155E-01 -0.2055E+00 -0.6590E-01  0.4103E+00 -0.4130E+00

  **PARM_SOL.    STD_ERROR    REL_ERROR     % ERROR **

 1  0.1646E-01   0.6336E-03   0.3850E-01   0.3850E+01
 2  0.2039E+00   0.5252E-03   0.2576E-02   0.2576E+00
 3  0.5639E+00   0.4971E-02   0.8815E-02   0.8815E+00
 4  0.1352E+01   0.1200E-01   0.8875E-02   0.8875E+00
 5  0.7352E+01   0.1524E-02   0.2073E-03   0.2073E-01
 6  0.1727E+03   0.3494E-02   0.2023E-04   0.2023E-02
 7  0.1497E+03   0.5008E-02   0.3346E-04   0.3346E-02

******** E N D ********     SBU-16  South Burbank Unit, Pawhuska, OK

PARAMETER NAME       FINAL SOLUTION        RESISTIVITY   LAYER DEPTH

   1   SIGMA( 1) =  0.16457368E-01   1  0.60763058E+02
   2   SIGMA( 2) =  0.20388266E+00   2  0.49047818E+01
   3   SIGMA( 3) =  0.56388646E+00   3  0.17734066E+01
   4   SIGMA( 4) =  0.13516598E+01   4  0.73983115E+00
   5   THICK( 1) =  0.73522301E+01                      1  0.73522301E+01
   6   THICK( 2) =  0.17272446E+03                      2  0.18007669E+03
   7   THICK( 3) =  0.14966387E+03                      3  0.32976056E+03
   8 * SHIFT     =  0.10000000E+01

     * FIXED
```

Figure 13b

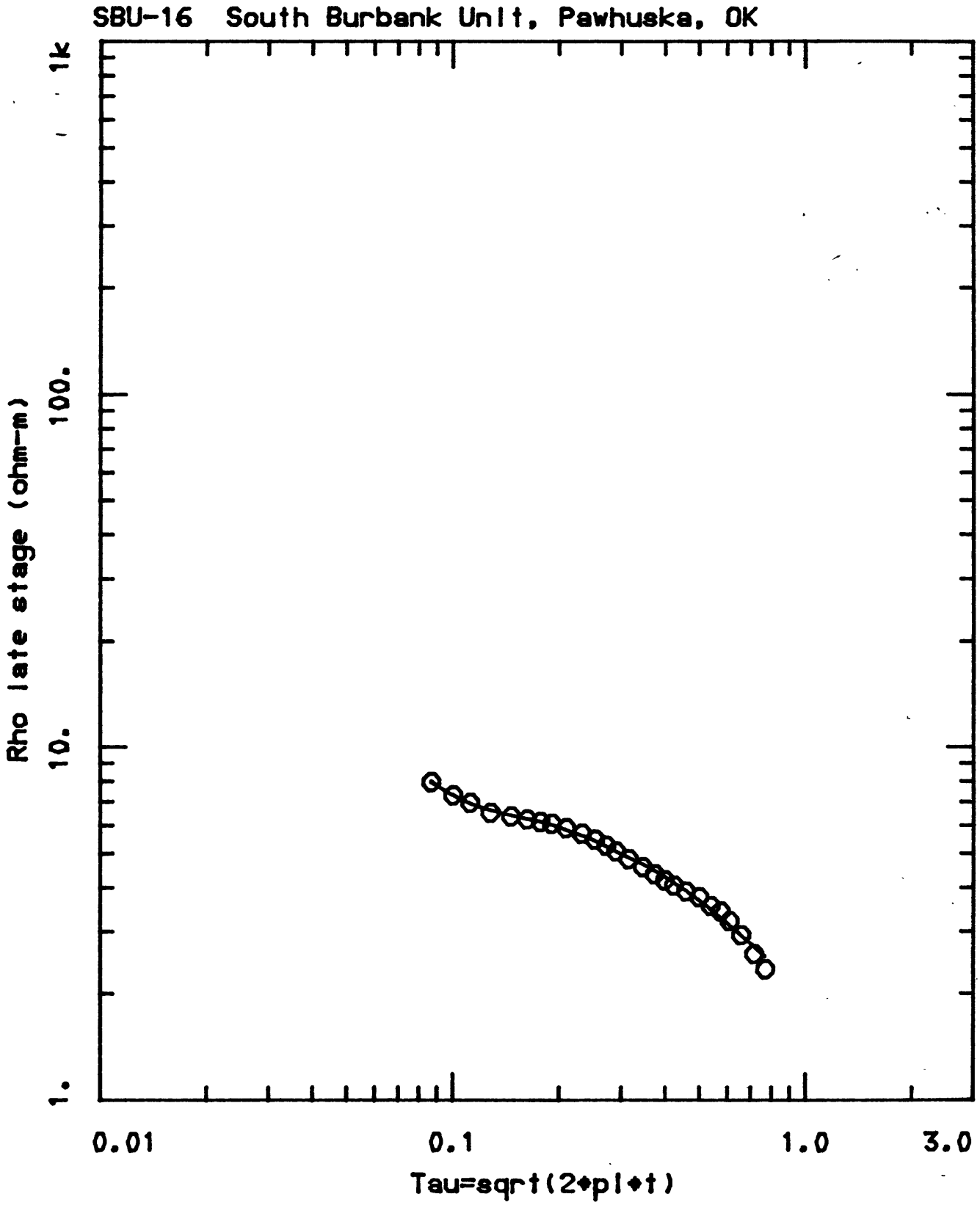

SBU-16 South Burbank Unit, Pawhuska, OK
Rho late stage (ohm-m)
1k
100.
10.
1.
0.01
0.1
1.0
3.0
Tau=sqrt(2*pi*t)

Figure 13c

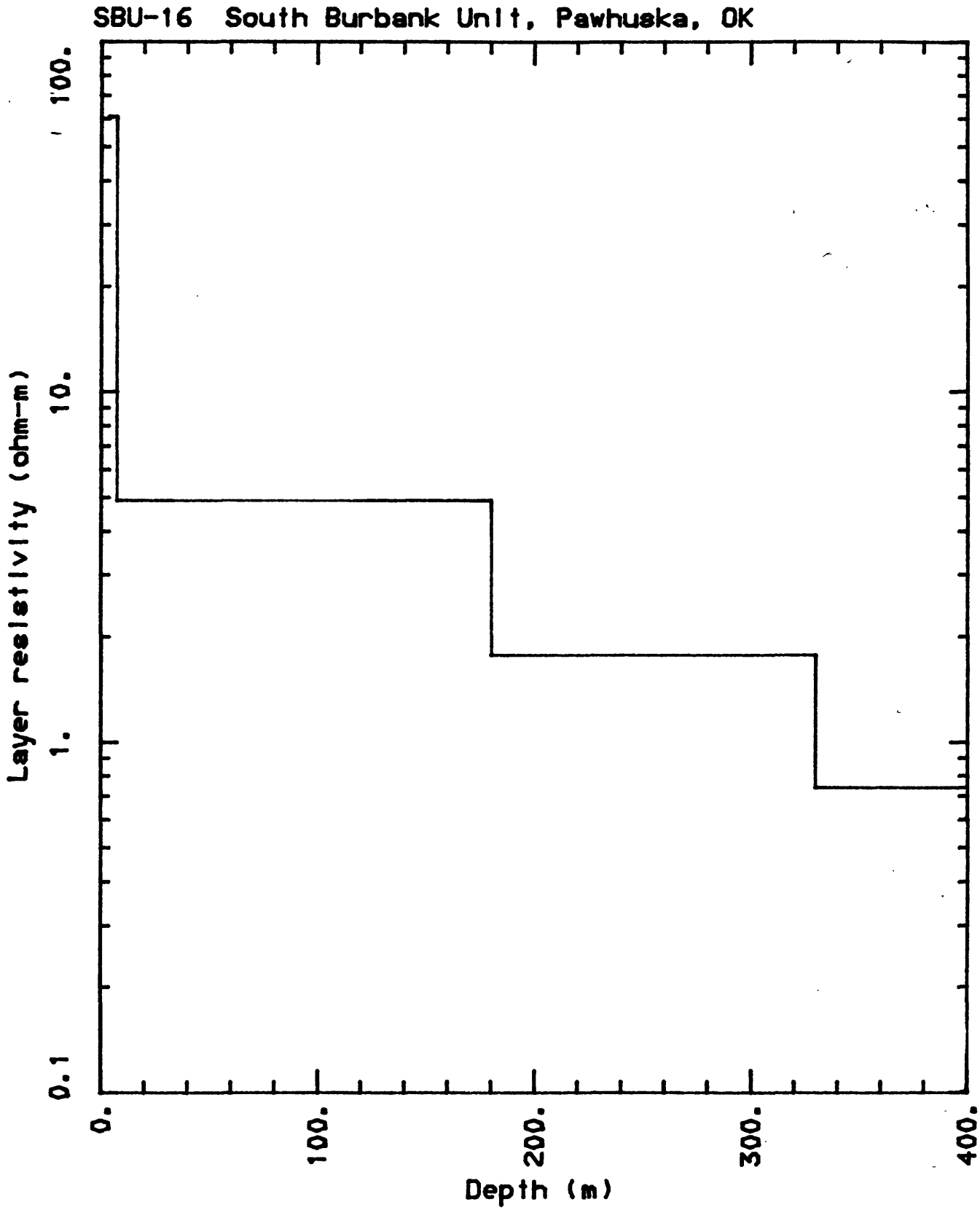

SBU-16 South Burbank Unit, Pawhuska, OK
Layer resistivity (ohm-m)
100.
10.
1.
0.1
0.
100.
200.
300.
400.
Depth (m)

Figure 14a

<NLSTCO>: SBU-17 South Burbank Unit, Pawhuska, OK

***** X-CONVERGENCE ***** LOOP RADIUS= 86.0

I	OBS.Y(I)	CAL	RES	%RES.ERR	X(I,1)
1	0.794000E+01	0.781356E+01	0.126E+00	0.161817E+01	0.120000E-02
2	0.744000E+01	0.741881E+01	0.212E-01	0.285602E+00	0.160000E-02
3	0.726000E+01	0.726276E+01	-0.276E-02	-0.380602E-01	0.200000E-02
4	0.695000E+01	0.712959E+01	-0.180E+00	-0.251894E+01	0.260000E-02
5	0.694000E+01	0.704194E+01	-0.102E+00	-0.144759E+01	0.340000E-02
6	0.695000E+01	0.699817E+01	-0.482E-01	-0.688324E+00	0.420000E-02
7	0.696000E+01	0.690695E+01	0.531E-01	0.768068E+00	0.500000E-02
8	0.695000E+01	0.683371E+01	0.116E+00	0.170175E+01	0.580000E-02
9	0.682000E+01	0.675591E+01	0.641E-01	0.948669E+00	0.700000E-02
10	0.669000E+01	0.661983E+01	0.702E-01	0.106002E+01	0.860000E-02
11	0.648000E+01	0.647198E+01	0.802E-02	0.123947E+00	0.102000E-01
12	0.628000E+01	0.632940E+01	-0.494E-01	-0.780430E+00	0.118000E-01
13	0.608000E+01	0.620717E+01	-0.127E+00	-0.204870E+01	0.134000E-01
14	0.578000E+01	0.603463E+01	-0.255E+00	-0.421947E+01	0.158000E-01
15	0.551000E+01	0.576211E+01	-0.252E+00	-0.437536E+01	0.190000E-01
16	0.532000E+01	0.548720E+01	-0.167E+00	-0.304704E+01	0.222000E-01
17	0.515000E+01	0.526256E+01	-0.113E+00	-0.213883E+01	0.254000E-01
18	0.501000E+01	0.506042E+01	-0.504E-01	-0.996431E+00	0.286000E-01
19	0.484000E+01	0.476070E+01	0.793E-01	0.166566E+01	0.334000E-01
20	0.461000E+01	0.442632E+01	0.184E+00	0.414977E+01	0.398000E-01
21	0.446000E+01	0.417098E+01	0.289E+00	0.692930E+01	0.462000E-01
22	0.424000E+01	0.395805E+01	0.282E+00	0.712350E+01	0.526000E-01
23	0.395000E+01	0.376516E+01	0.185E+00	0.490935E+01	0.590000E-01
24	0.365000E+01	0.352850E+01	0.121E+00	0.344334E+01	0.686000E-01
25	0.311000E+01	0.329307E+01	-0.183E+00	-0.555936E+01	0.814000E-01
26	0.260000E+01	0.311186E+01	-0.512E+00	-0.164487E+02	0.942000E-01

** RMSERR= 0.20831640E+00

Figure 14a cont.

```
CORRELATION MATRIX
 1  0.1000E+01
 2 -0.6920E+00  0.1000E+01
 3 -0.6799E+00  0.2719E+00  0.1000E+01
 4  0.1758E+00  0.1335E+00 -0.2462E+00  0.1000E+01
 5 -0.3628E+00  0.2989E-01  0.2377E+00 -0.8182E+00  0.1000E+01
 6 -0.6560E+00  0.4260E+00  0.4371E+00 -0.6847E+00  0.6636E+00  0.1000E+01
 7 -0.6199E+00 -0.6525E+00 -0.2709E+00  0.1326E+00 -0.3164E+00 -0.7179E+00

  **PARM_SOL.    STD_ERROR    REL_ERROR     % ERROR **

 1  0.2216E+00  0.3634E-02  0.1640E-01  0.1640E+01
 2  0.1531E+00  0.1407E-02  0.9185E-02  0.9185E+00
 3  0.3433E+00  0.2458E-02  0.7160E-02  0.7160E+00
 4  0.8678E+00  0.1342E-01  0.1547E-01  0.1547E+01
 5  0.1511E+02  0.4059E-02  0.2686E-03  0.2686E-01
 6  0.1659E+03  0.9807E-02  0.5910E-04  0.5910E-02
 7  0.1305E+03  0.1367E-01  0.1048E-03  0.1048E-01

******** E N D ********     SBU-17  South Burbank Unit, Pawhuska, OK

PARAMETER NAME       FINAL SOLUTION        RESISTIVITY   LAYER DEPTH

   1   SIGMA( 1) =  0.22164911E+00   1  0.45116353E+01
   2   SIGMA( 2) =  0.15313751E+00   2  0.65300789E+01
   3   SIGMA( 3) =  0.34334826E+00   3  0.29124947E+01
   4   SIGMA( 4) =  0.86779600E+00   4  0.11523446E+01
   5   THICK( 1) =  0.15112526E+02                      1  0.15112526E+02
   6   THICK( 2) =  0.16592747E+03                      2  0.18104001E+03
   7   THICK( 3) =  0.13051894E+03                      3  0.31155896E+03
   8 * SHIFT     =  0.10000000E+01

     * FIXED
```

Figure 14b

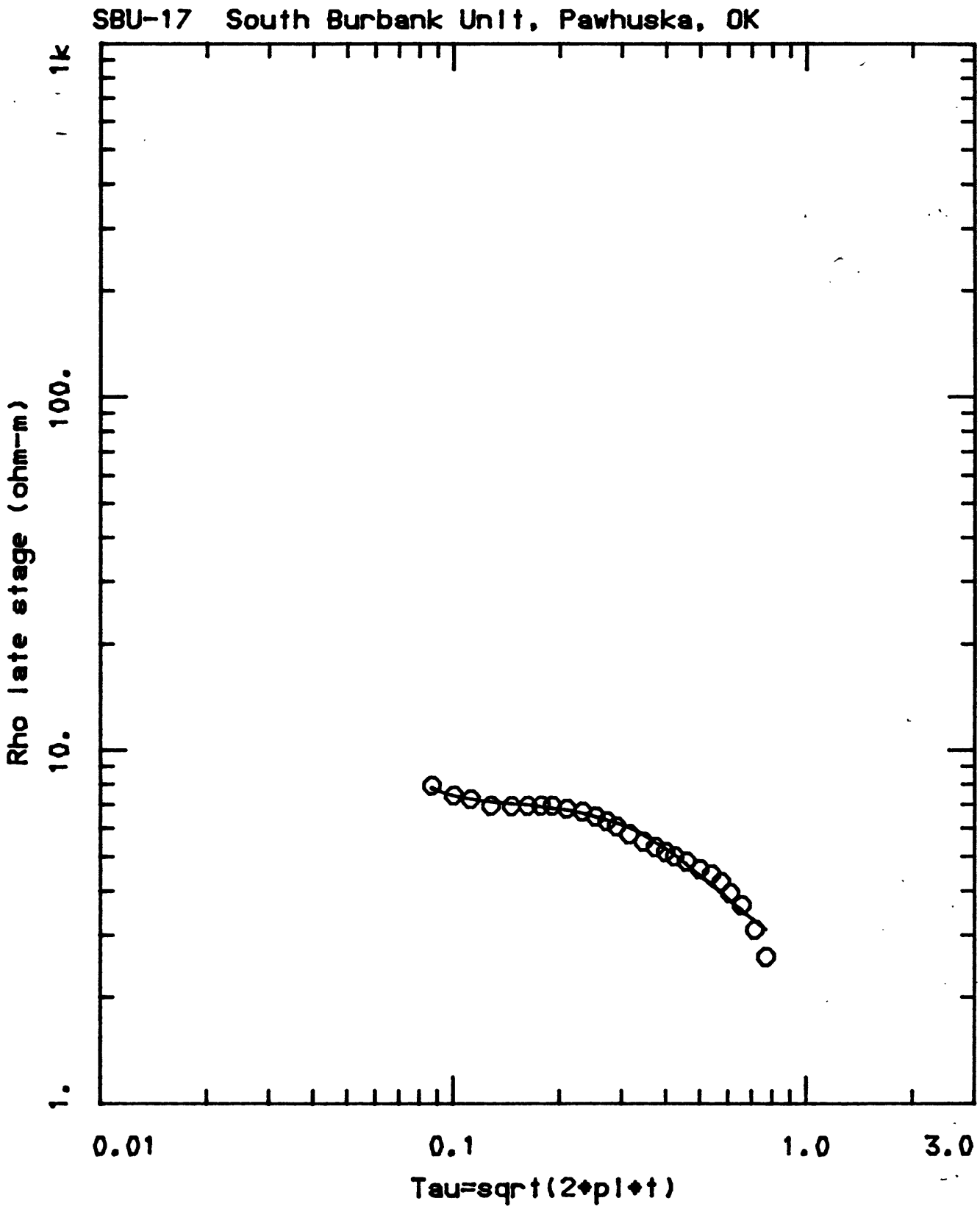

SBU-17 South Burbank Unit, Pawhuska, OK
Rho late stage (ohm-m)
1k
100.
10.
1.
0.01
0.1
1.0
3.0
Tau=sqrt(2*pi*t)

Figure 14c

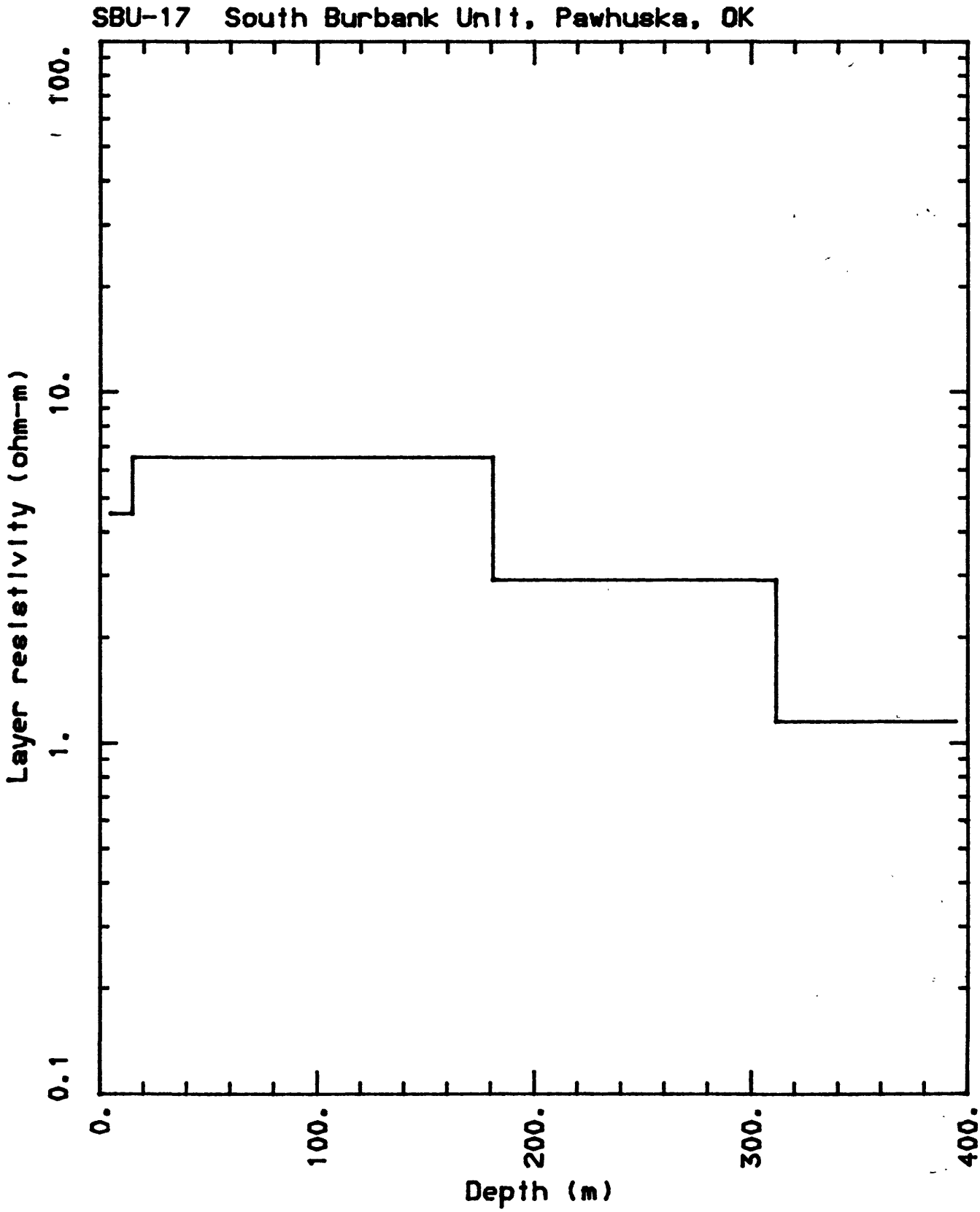

SBU-17 South Burbank Unit, Pawhuska, OK
Layer resistivity (ohm-m)
100.
10.
1.
0.1
0.
100.
200.
300.
400.
Depth (m)

Figure 15a

<NLSTCO>: SBU-18 South Burbank Unit, Pawhuska, OK

***** X-CONVERGENCE ***** LOOP RADIUS= 86.0

I	OBS.Y(I)	CAL	RES	%RES.ERR	X(I,1)
1	0.833000E+01	0.847176E+01	-0.142E+00	-0.167333E+01	0.120000E-02
2	0.761000E+01	0.767316E+01	-0.632E-01	-0.823116E+00	0.160000E-02
3	0.719000E+01	0.720255E+01	-0.125E-01	-0.174229E+00	0.200000E-02
4	0.670000E+01	0.678967E+01	-0.897E-01	-0.132072E+01	0.260000E-02
5	0.645000E+01	0.647473E+01	-0.247E-01	-0.382016E+00	0.340000E-02
6	0.628000E+01	0.625190E+01	0.281E-01	0.449479E+00	0.420000E-02
7	0.614000E+01	0.610627E+01	0.337E-01	0.552454E+00	0.500000E-02
8	0.604000E+01	0.598061E+01	0.594E-01	0.993116E+00	0.580000E-02
9	0.583000E+01	0.578484E+01	0.452E-01	0.780608E+00	0.700000E-02
10	0.565000E+01	0.559409E+01	0.559E-01	0.999364E+00	0.860000E-02
11	0.548000E+01	0.544464E+01	0.352E-01	0.645838E+00	0.102000E-01
12	0.534000E+01	0.530164E+01	0.384E-01	0.723561E+00	0.118000E-01
13	0.522000E+01	0.517256E+01	0.474E-01	0.917055E+00	0.134000E-01
14	0.499000E+01	0.500833E+01	-0.183E-01	-0.365992E+00	0.158000E-01
15	0.479000E+01	0.483006E+01	-0.401E-01	-0.829899E+00	0.190000E-01
16	0.462000E+01	0.468451E+01	-0.645E-01	-0.137700E+01	0.222000E-01
17	0.448000E+01	0.455211E+01	-0.721E-01	-0.158410E+01	0.254000E-01
18	0.437000E+01	0.442680E+01	-0.568E-01	-0.128314E+01	0.286000E-01
19	0.425000E+01	0.426606E+01	-0.161E-01	-0.376435E+00	0.334000E-01
20	0.410000E+01	0.409941E+01	0.159E-02	0.388017E-01	0.398000E-01
21	0.394000E+01	0.395188E+01	-0.119E-01	-0.300705E+00	0.462000E-01
22	0.391000E+01	0.381938E+01	0.906E-01	0.237251E+01	0.526000E-01
23	0.367000E+01	0.370860E+01	-0.386E-01	-0.104082E+01	0.590000E-01
24	0.360000E+01	0.357594E+01	0.241E-01	0.672871E+00	0.686000E-01
25	0.350000E+01	0.343009E+01	0.699E-01	0.203827E+01	0.814000E-01
26	0.334000E+01	0.330659E+01	0.334E-01	0.101042E+01	0.942000E-01

** RMSERR= 0.64762644E-01

Figure 15a cont.

```
CORRELATION MATRIX
 1  0.1000E+01
 2 -0.3798E+00  0.1000E+01
 3 -0.3444E+00 -0.2586E+00  0.1000E+01
 4 -0.3947E+00  0.4767E+00 -0.1332E+00  0.1000E+01
 5 -0.4218E+00  0.3721E+00 -0.1024E+00  0.2880E+00  0.1000E+01
 6  0.3532E+00 -0.3186E+00 -0.1393E-01 -0.3448E-01 -0.6826E+00  0.1000E+01
 7 -0.2979E+00  0.3452E+00  0.6486E-02  0.8899E+00  0.2262E-01  0.2661E+00

  **PARM_SOL.    STD_ERROR    REL_ERROR     % ERROR **

 1  0.3170E-01  0.2833E-03  0.8937E-02  0.8937E+00
 2  0.2118E+00  0.2855E-03  0.1348E-02  0.1348E+00
 3  0.3811E+00  0.7435E-03  0.1951E-02  0.1951E+00
 4  0.5634E+00  0.1214E-01  0.2155E-01  0.2155E+01
 5  0.1364E+02  0.6298E-03  0.4618E-04  0.4618E-02
 6  0.1672E+03  0.1497E-02  0.8951E-05  0.8951E-03
 7  0.1583E+03  0.7109E-02  0.4491E-04  0.4491E-02

******** E N D ********     SBU-18  South Burbank Unit, Pawhuska, OK

PARAMETER NAME       FINAL SOLUTION        RESISTIVITY   LAYER DEPTH

   1   SIGMA( 1) =  0.31696048E-01   1  0.31549675E+02
   2   SIGMA( 2) =  0.21176198E+00   2  0.47222829E+01
   3   SIGMA( 3) =  0.38111901E+00   3  0.26238523E+01
   4   SIGMA( 4) =  0.56343776E+00   4  0.17748189E+01
   5   THICK( 1) =  0.13637238E+02                      1  0.13637238E+02
   6   THICK( 2) =  0.18719476E+03                      2  0.18083200E+03
   7   THICK( 3) =  0.15831523E+03                      3  0.33914725E+03
   8 * SHIFT     =  0.10000000E+01

     * FIXED
```

Figure 15b

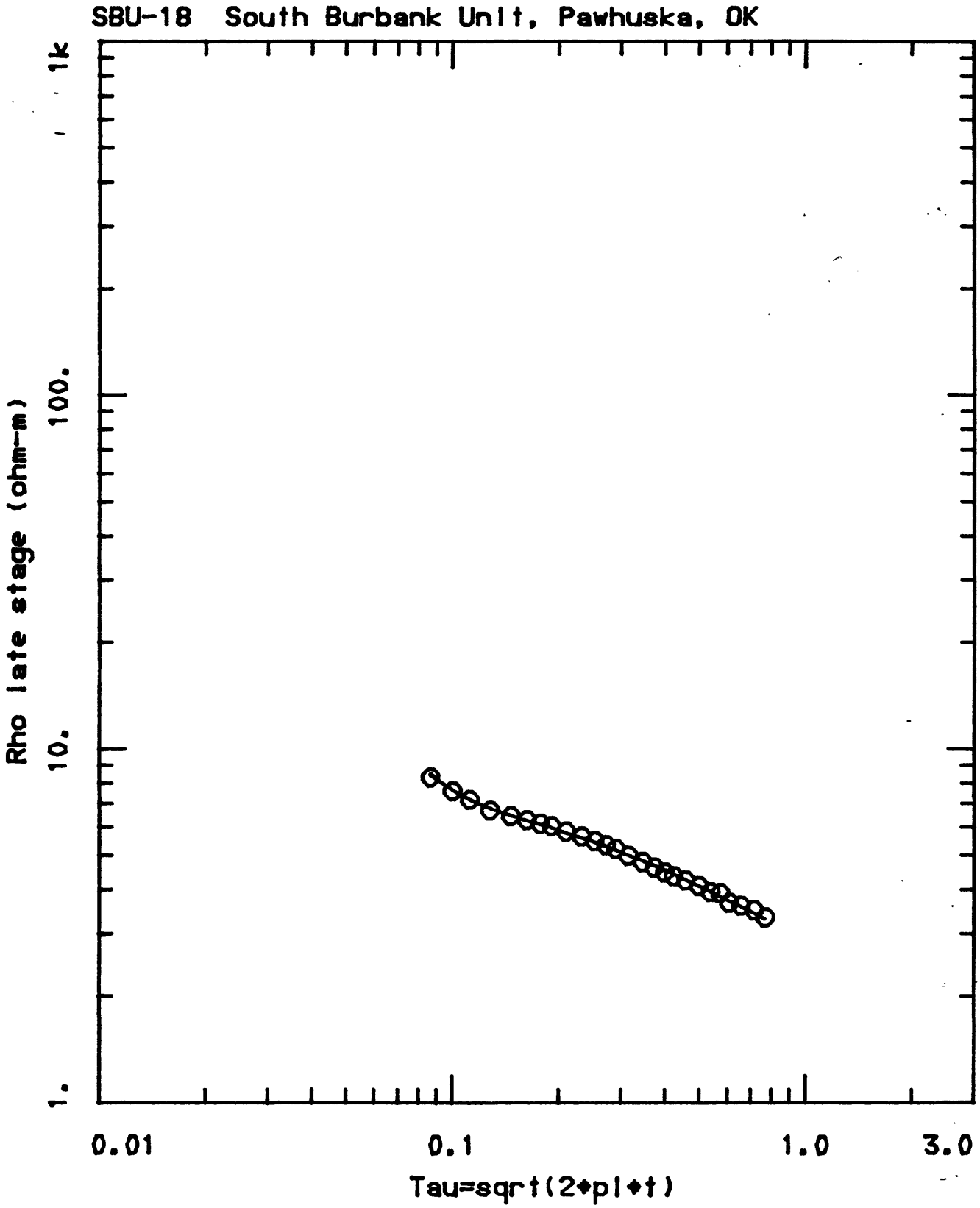

SBU-18 South Burbank Unit, Pawhuska, OK
Rho late stage (ohm-m)
1k
100.
10.
1.
0.01
0.1
1.0
3.0
Tau=sqrt(2*pi*t)

Figure 15c

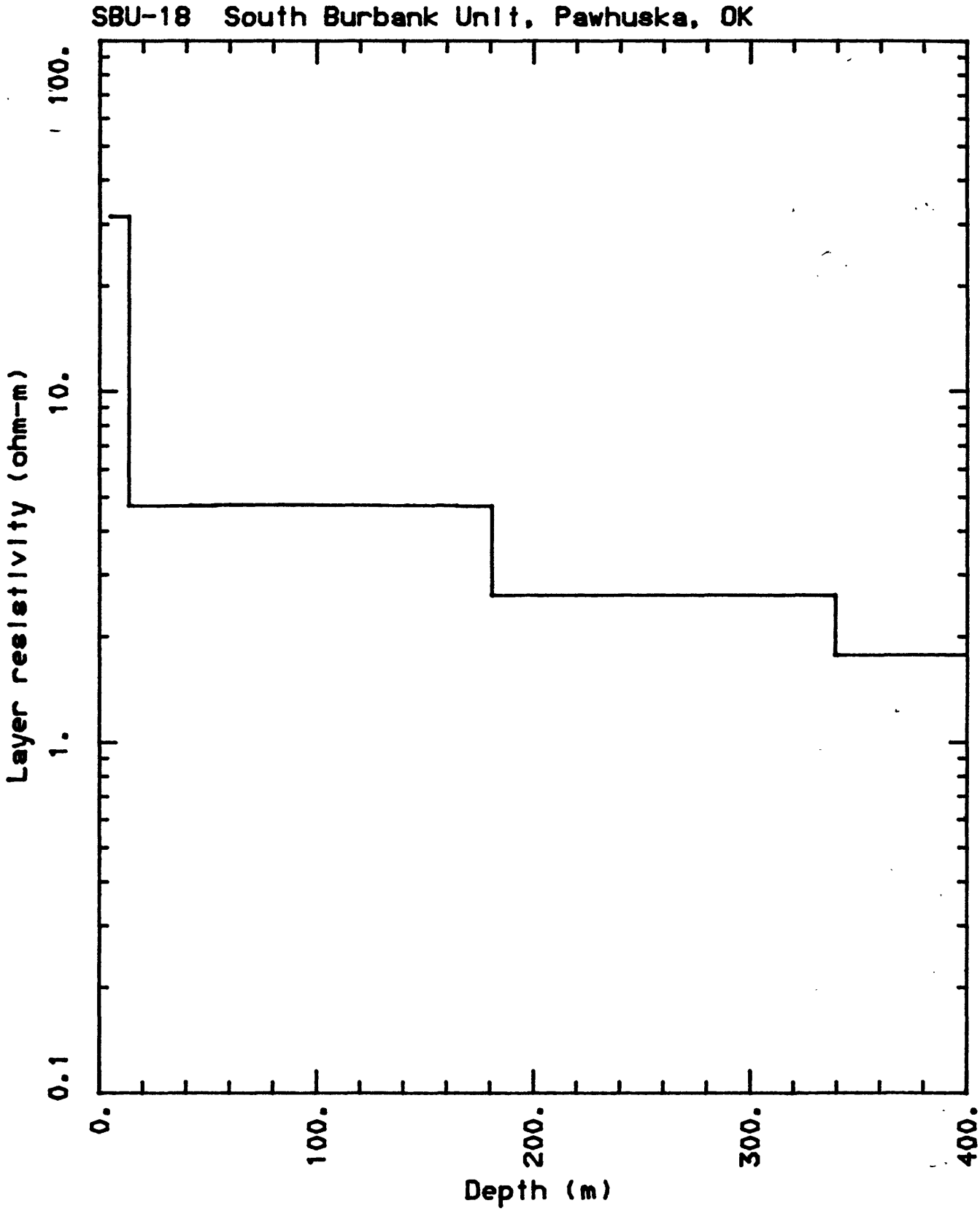

SBU-18 South Burbank Unit, Pawhuska, OK
Layer resistivity (ohm-m)
100.
10.
1.
0.1
0.
100.
200.
300.
400.
Depth (m)

Figure 16a

```
<NLSTCO>:     SBU-19  South Burbank Unit,  Pawhuska, OK

***** X-CONVERGENCE *****                    LOOP RADIUS=  43.0

  I     OBS.Y(I)       CAL            RES         %RES.ERR      X(I,1)
  1  0.793280E+01  0.792000E+01  0.128E-01  0.161649E+00  0.120000E-02
  2  0.741070E+01  0.743807E+01 -0.274E-01 -0.367940E+00  0.160000E-02
  3  0.714040E+01  0.715027E+01 -0.987E-02 -0.138011E+00  0.200000E-02
  4  0.675140E+01  0.680492E+01 -0.535E-01 -0.786472E+00  0.260000E-02
  5  0.644210E+01  0.646089E+01 -0.188E-01 -0.290882E+00  0.340000E-02
  6  0.616660E+01  0.612236E+01  0.442E-01  0.722534E+00  0.420000E-02
  7  0.589670E+01  0.582294E+01  0.738E-01  0.126672E+01  0.500000E-02
  8  0.564870E+01  0.558026E+01  0.684E-01  0.122647E+01  0.580000E-02
  9  0.526810E+01  0.526394E+01  0.416E-02  0.790994E-01  0.700000E-02
 10  0.488110E+01  0.490910E+01 -0.280E-01 -0.570463E+00  0.860000E-02
 11  0.458590E+01  0.463152E+01 -0.456E-01 -0.985091E+00  0.102000E-01
 12  0.437240E+01  0.441502E+01 -0.426E-01 -0.965377E+00  0.118000E-01
 13  0.422370E+01  0.424226E+01 -0.186E-01 -0.437579E+00  0.134000E-01
** RMSERR=  0.51664330E-01

CORRELATION MATRIX
 1  0.1000E+01
 2 -0.7439E+00  0.1000E+01
 3 -0.2792E+00 -0.1354E+00  0.1000E+01
 4 -0.5676E+00  0.7910E+00 -0.2782E+00  0.1000E+01
 5 -0.4950E+00  0.1719E+00  0.6257E+00  0.2000E+00  0.1000E+01

  **PARM_SOL.    STD_ERROR    REL_ERROR     % ERROR **

 1  0.4422E-01  0.4871E-03  0.1102E-01  0.1102E+01
 2  0.2227E+00  0.4612E-03  0.2071E-02  0.2071E+00
 3  0.5541E+00  0.2267E-02  0.4091E-02  0.4091E+00
 4  0.2620E+02  0.9093E-03  0.3471E-04  0.3471E-02
 5  0.1117E+03  0.1660E-02  0.1486E-04  0.1486E-02

********  E N D  ********     SBU-19  South Burbank Unit,  Pawhuska, OK

PARAMETER NAME       FINAL SOLUTION        RESISTIVITY   LAYER DEPTH

   1   SIGMA( 1) =  0.44217955E-01    1  0.22615248E+02
   2   SIGMA( 2) =  0.22273345E+00    2  0.44896712E+01
   3   SIGMA( 3) =  0.55409324E+00    3  0.18047504E+01
   4   THICK( 1) =  0.26198971E+02                      1  0.26198971E+02
   5   THICK( 2) =  0.11168083E+03                      2  0.13787981E+03
   6 * SHIFT     =  0.10000000E+01

     * FIXED
```

Figure 16b

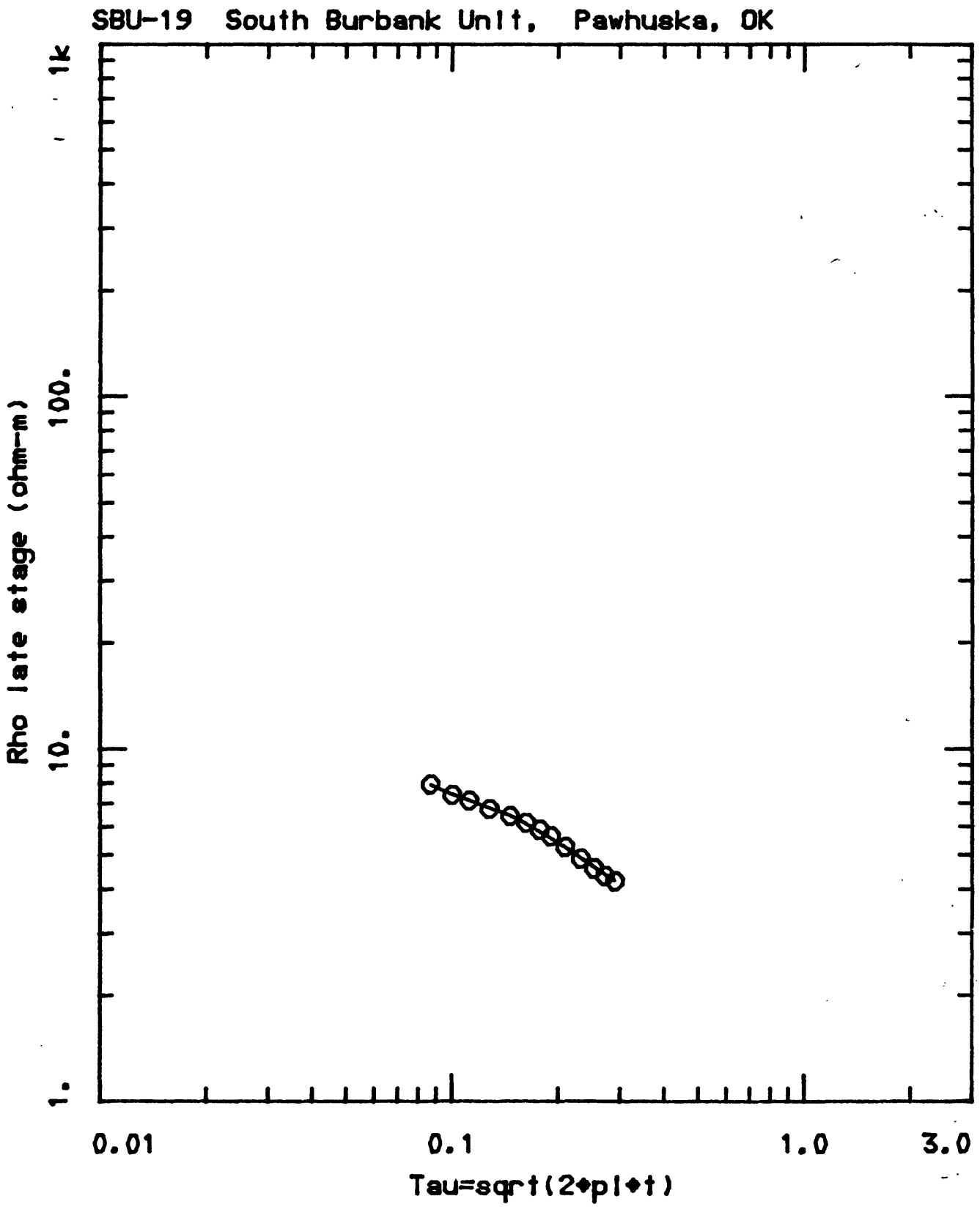
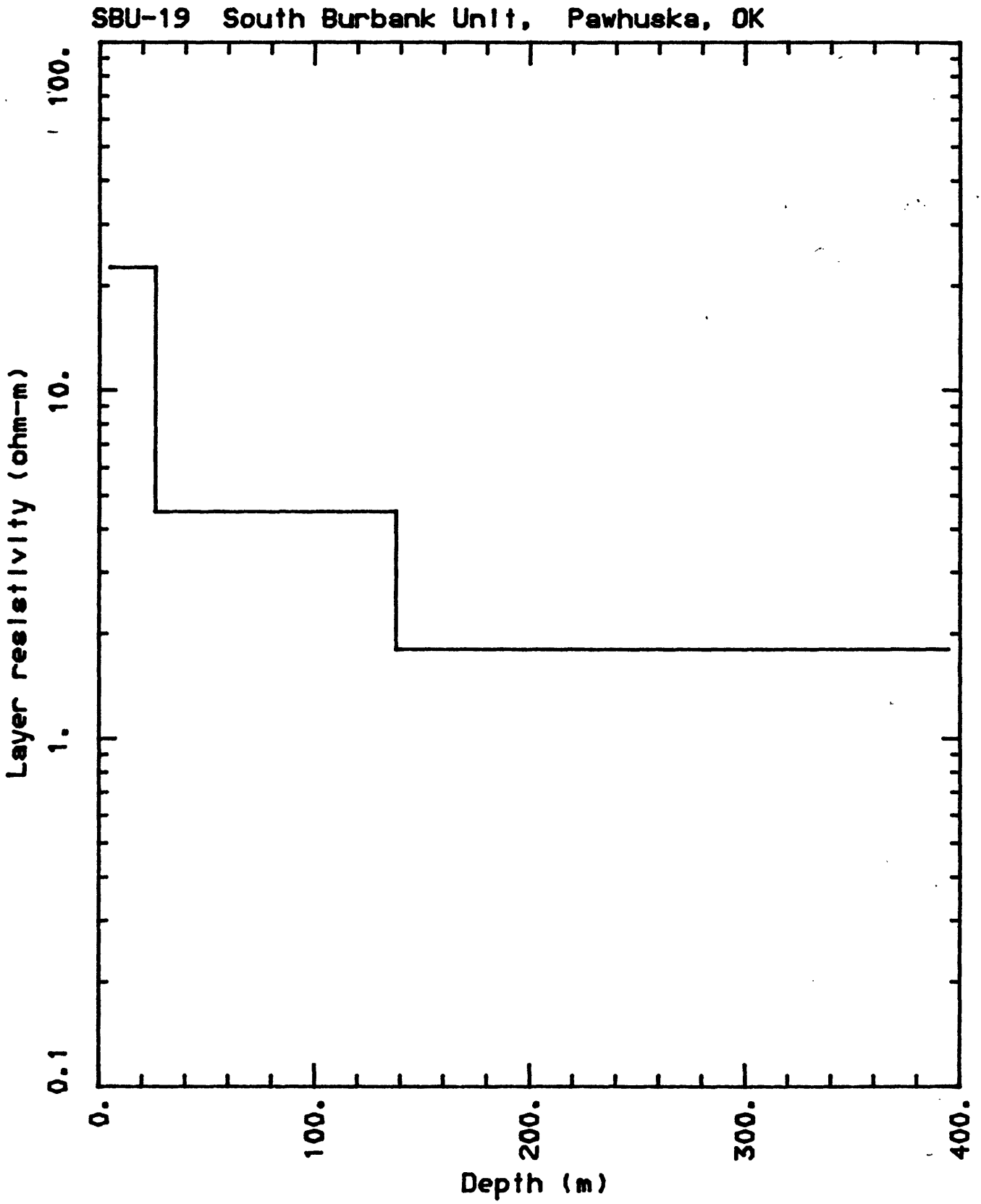
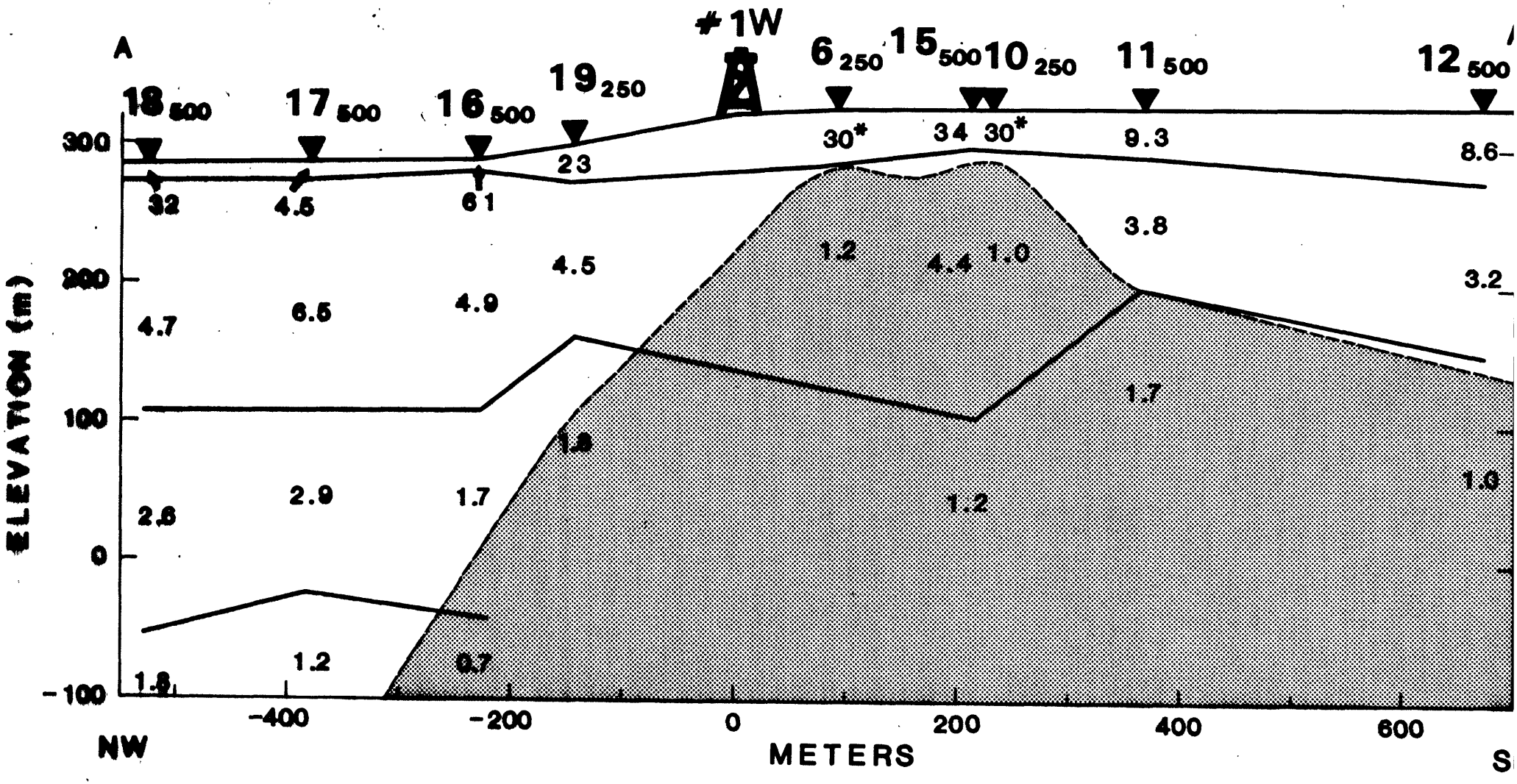

SBU-19 South Burbank Unit, Pawhuska, OK
Rho late stage (ohm-m)
1k
100.
10.
1.
0.01
0.1
1.0
3.0
Tau=sqrt(2*pi*t)

Figure 16c


SBU-19 South Burbank Unit, Pawhuska, OK
Layer resistivity (ohm-m)
100.
10.
1.
0.1
0.
100.
200.
300.
400.
Depth (m)

Section A – A′



Sounding Number — 10_{250} — Loopside length (ft.)

▼ Location of transient sounding

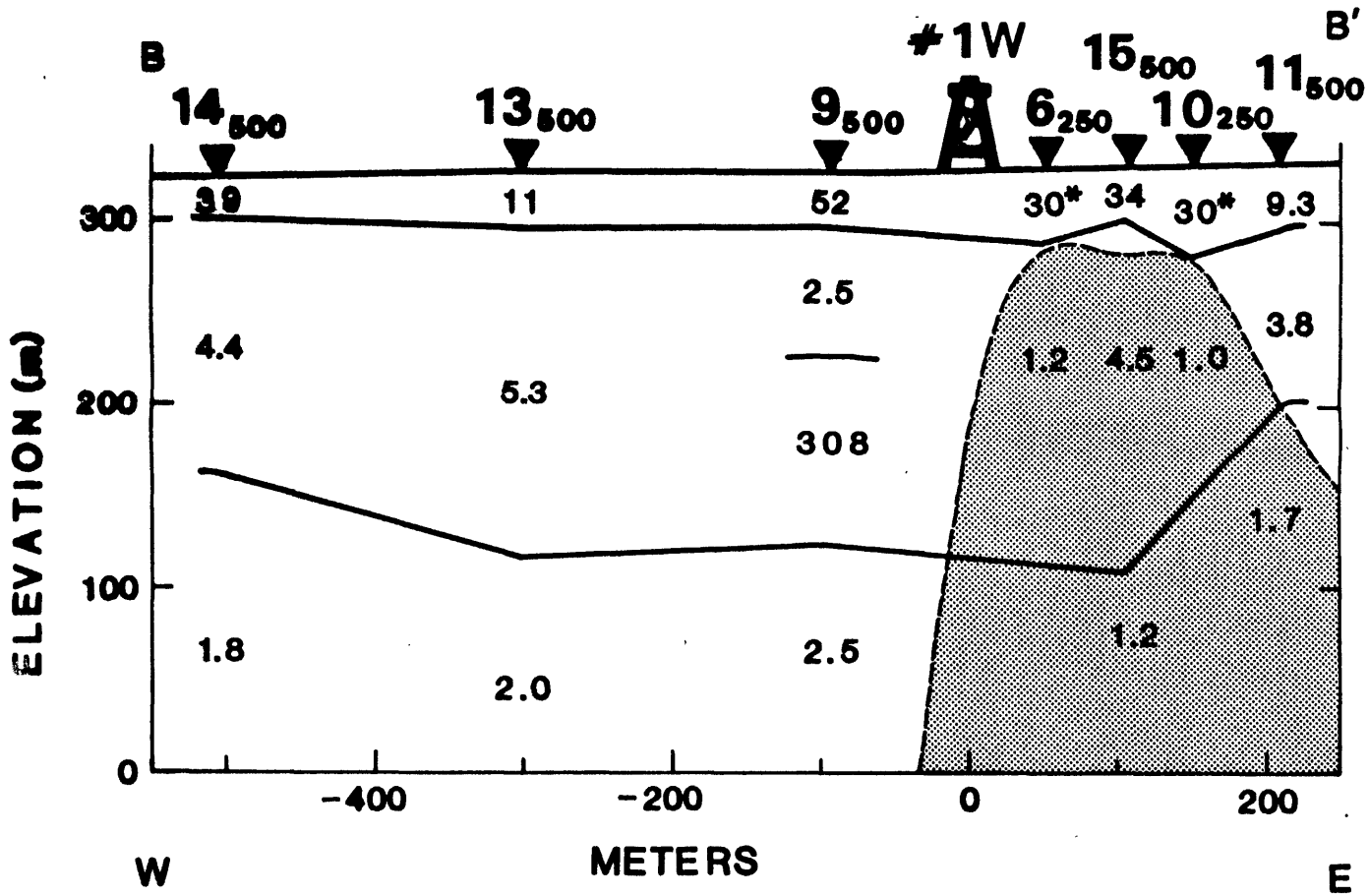
Resistivities in ohm-m

* Indicates resistivity fixed in inversion

Interpreted extent of brine contamination

Figure 17

Section B - B'



Sounding Number — 13_{250} — Loopside of length (ft.)

▼ Location of transient sounding

Resistivities in ohm-m

* Indicates resistivity fixed in inversion

Interpreted extent of brine contamination

Figure 18