UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Time-Domain Electromagnetic Soundings of Newberry Volcano, Deschutes County, Oregon

by

David V. Fitterman

Open-File Report 83-832

4 November 1983

Introduction

A time-domain electromagnetic (TDEM) survey of Newberry Volcano, Oregon was carried out during July 1983 as part of a research project funded by Department of Energy in conjunction with the USGS Geothermal Program. Nineteen TDEM soundings were made using a central induction loop configuration at locations shown in Figure 1. This report describes the results of layered earth inversions.

Newberry Volcano is a large Quaternary volcano located about 40 km south of Bend, Oregon (MacLeod and Sammel, 1982). The flanks of the volcano are composed of basaltic flows, andesitic to rhyolitic tuffs, and alluvial sediments. The summit caldera, which contains Paulina and East Lakes, is interpreted as being a collapse feature formed after the eruption of large volumes of tephra.

In 1981 the USGS completed a 932 m deep drill hole in the caldera; temperatures as high as 265°C were encountered (Sammel, 1981; MacLeod and Sammel, 1982). The demonstrated occurrence of such high-temperature water has caused an increase in geothermal exploration activity in the vicinity of Newberry Volcano.

Field Procedure and Equipment

TDEM measurements were made using a SIROTEM II system (Buselli and O'Neill, 1977). The SIROTEM system injects a bipolar, square-wave current into a transmitter loop. When the current is turned off, the voltage induced in a receiving coil located at the center of the transmitter loop is recorded. The SIROTEM system records and stacks the transients from a large number of current turn-offs, and reports the averaged voltage-current ratios.

Square transmitter loops 457 m, 229 m, and 152 m on a side were used. The receiver coil was an eight turn 38 m x 38 m loop (receiver coil moment M_r = 11,613 turn-m^2) situated at the center of the transmitter loop. Four to six runs, consisting of 2,048 transients per run, were made at each site. The polarity of the receiver coil was reversed on alternate runs to reduce instrumental noise.

At several locations, an external transmitter built by the USGS was used to increase transmitter current to about 12 amperes, which is about three times the current delivered by the SIROTEM transmitter. The higher current made it possible to record the transient with an acceptable signal-to-noise ratio at later times, thereby gathering information from greater depths.

Data Preparation

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

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

where μ_o is the free space permeability, L is the length of a side of the transmitter loop, M_r is the receiver loop moment, t is time since current shutoff, and V/I is the voltage-current ratio (all in SI units). Data from several runs were averaged and converted to apparent resistivity. Data from the first two SIROTEM channels were not used because they appeared to be noisy. Late-time data were rejected when the data appeared to be noisy and the apparent resistivity curves no longer behaved smoothly. Data obtained using the external transmitter were combined with data from the internal transmitter to obtain longer data records with less noise.

Inversion of Soundings

Initial models for the data were obtained by curve matching using a catalog of two-layer models (Kaufmann and Keller, 1983). These models served as starting points for a non-linear least squares inversion by computer (Anderson, 1982). Best-fit two and three layer models were found for each sounding. If the three layer model did not provide a significantly better fit than the two-layer model, then the three-layer model was rejected.

Results

Results of the inversions are presented in Figures 2 through 19. Figures 2a through 19a contain the output from the inversion program. This consists of the sounding title, the effective transmitter loop radius ($A = \pi^{-1/2}L$), and a list of the model parameters held fixed. For all models the SHIFT parameter, which is a scaling factor, has been set to 1.0. The next line of the output specifies the type of convergence criteria which terminated the inversion. See Dennis et al. (1979) for a discussion of the convergence criteria.

The first table 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 time. The line following this table gives the RMS error of the fit.

The next table is the parameter correlation matrix. This provides a measure of the interdependence of the model parameter estimates. A high correlation between parameters indicates that only their ratio 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 columns of integers in the following two tables. As an example, if we consider the second entry in the first column of any given correlation matrix, this will be the correlation between the second and first unconstrained model parameters.

The third table gives the model parameter estimate (PARM SOL.), the standard deviation in the parameter estimate (STD ERROR), the relative error which is the standard deviation divided by the model parameter (REL ERROR), 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.

Figure 2b through 19b present the observed apparent resistivity (circles) and the computed model apparent resistivity (solid line) as a function of time. The actual model resistivities as a function of depth are given in Figures 2c through 19c.

The RMS error of the models ranges from 1 to 14% with most errors less than 10%. The percentage error of the layer thickness estimates is smaller than the percentage error of the conductivity estimates. The second layer conductivity is usually resolved to better than 5%. In a few cases, the first layer conductivity is not well resolved, most often when the first layer is very resistive.

Using the inversion results, three cross sections were constructed (AA', BB', and CC'; see Figure 1). The first (A-A', Figure 20) runs along an east-west line through the caldera. The second (B-B', Figure 21) goes north-south just west of the western edge of the caldera. The third (C-C', Figure 22) goes north-south just to the west of the eastern caldera wall.

Discussion

The east-west profile A-A' (Figure 20) can be divided into three regions. The western boundary, which lies between stations 5 and 18, is slightly west of the caldera rim and a probable ring fracture (MacLeod and Summel, 1982). The eastern boundary, lying between stations 17 and 16, corresponds to the inner caldera rim and the caldera rim fracture (MacLeod and Sammel, 1982).

The western region is characterized by a resistive (>300 ohm-m) near-surface zone with a thickness of 300 to 500 m, underlain by a conductive basement with resistivities in the range 16 to 61 ohm-m. The basement becomes more conductive in the direction of the caldera.

The eastern region, which is near or outside of the caldera, has a very resistive first layer (2,500 to 4,300 ohm-m). The resistive zone thickens from 440 m at station 16 on the west to 500 m at station 11 on the east. The second layer is a conductive zone with resistivities of 39-53 ohm-m; this zone is similar to the near-surface layer on the eastern edge of the caldera. The electrical basement below station 16 is even more conductive (10 ohm-m).

The central region, which roughly corresponds to the caldera, is composed of a first layer that has resistivities of 56 to 190 ohm-m and which varies in depth from 270 to 430 m. Station 17 was interpreted as a three-layer section, but the first two layers are comparable to the first layer at the other intra-caldera stations. A conductor having resistivities of 2 to 31 ohm-m underlies the caldera floor and bulges upward between stations 1 and 4. The first layer corresponds with the fragmental rocks seen to a depth of 500 m in USGS test hole Newberry 2; the deeper conductor corresponds to the flows and associated breccia below 500 m depth (MacLeod and Sammel, 1982).

The western profile B-B′ (Figure 21) is similar to the western end of the east-west profile. A resistive surface layer (210 to 730 ohm-m) overlies a conductor (12 to 62 ohm-m). The depth of the conductor varies from 430 to 690 m. The conductor rises below station 2, which is near a hole being drilled by Union Oil Company.

The eastern profile C-C′ (Figure 22) is more complicated. The interpreted section at station 12 resembles the intra-caldera sections shown in figure 20. Stations 16 and 13 show a very resistive first layer underlain by progressively more conductive material; a section similar to that of station 11 (Figure 20), which is located east of the caldera. The electrical section at station 10 is similar to the section to the west of the caldera (see Figure 20).

The TDEM soundings at Newberry Volcano indicate the presence of a conductor at depth which becomes shallowest within the caldera. The overlying material is more resistive, but falls into three categories: moderately conductive inside the caldera, moderately resistive to the west of the caldera, and very resistive to the east of the caldera.

Acknowledgements

This work was funded by Department of Energy under Interagency Agreement DE-AI01-79RA50294. Permission to conduct the field work was granted by the Deschutes National Forest, Bend, Oregon. The field work was accomplished with the help of Jerry Bradley, Roger Grette, and Clark Grose. Discussions concerning data interpretation with Walter Anderson, Frank Frischknecht, and Alexander Kaufman are gratefully acknowledged.

References

Anderson, W. L., 1982, Nonlinear least-squares inversion of transient soundings for a central induction loop system (Program NLSTCI): U.S. Geological Survey Open-File Report 82-1129, 85 p.

Buselli, G., and O'Neill, G., 1977, SIROTEM--a new portable instrument for multichannel electromagnetic measurements: Bull. Aust. Soc. Expl. Geophys., 8, 82-87.

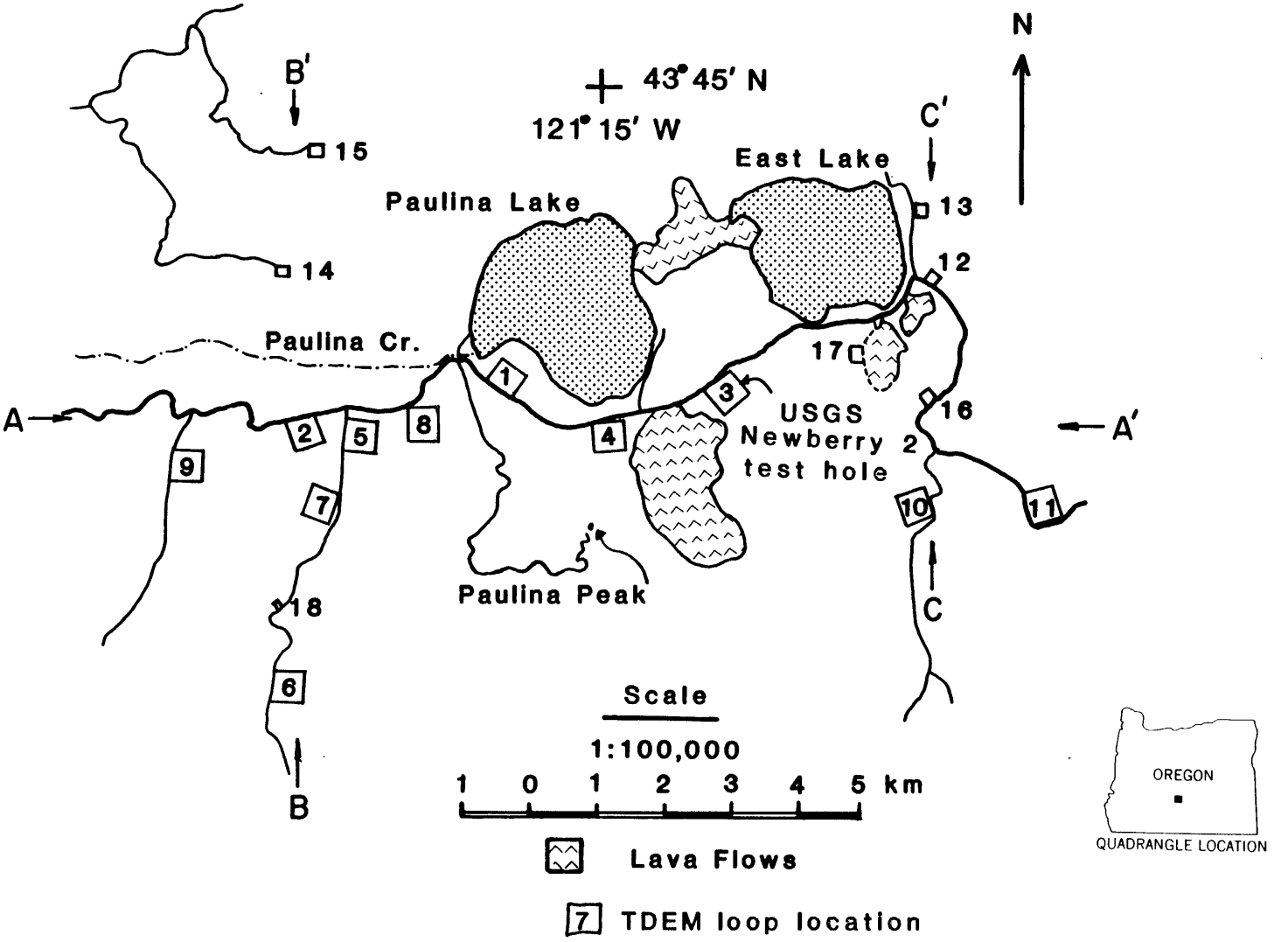
Dennis, J. E., Gay, D. M., and Welsch, R. E., 1979, An adaptive nonlinear least-squares algorithm: Univ. of Wisconsin MRC Tech. Sum. Rept. 2010 (also available as NTIS Rept. AD-A079-716), 40 p.

Kaufman, A. A., and Keller, G. R., 1983, Frequency and Transient Sounding: Amsterdam, Elsevier, 687 p.

MacLeod, N. S., and Sammel, E. A., 1982, Newberry Volcano, Oregon--a Cascade Range geothermal prospect: California Geology, 35, 235-244.

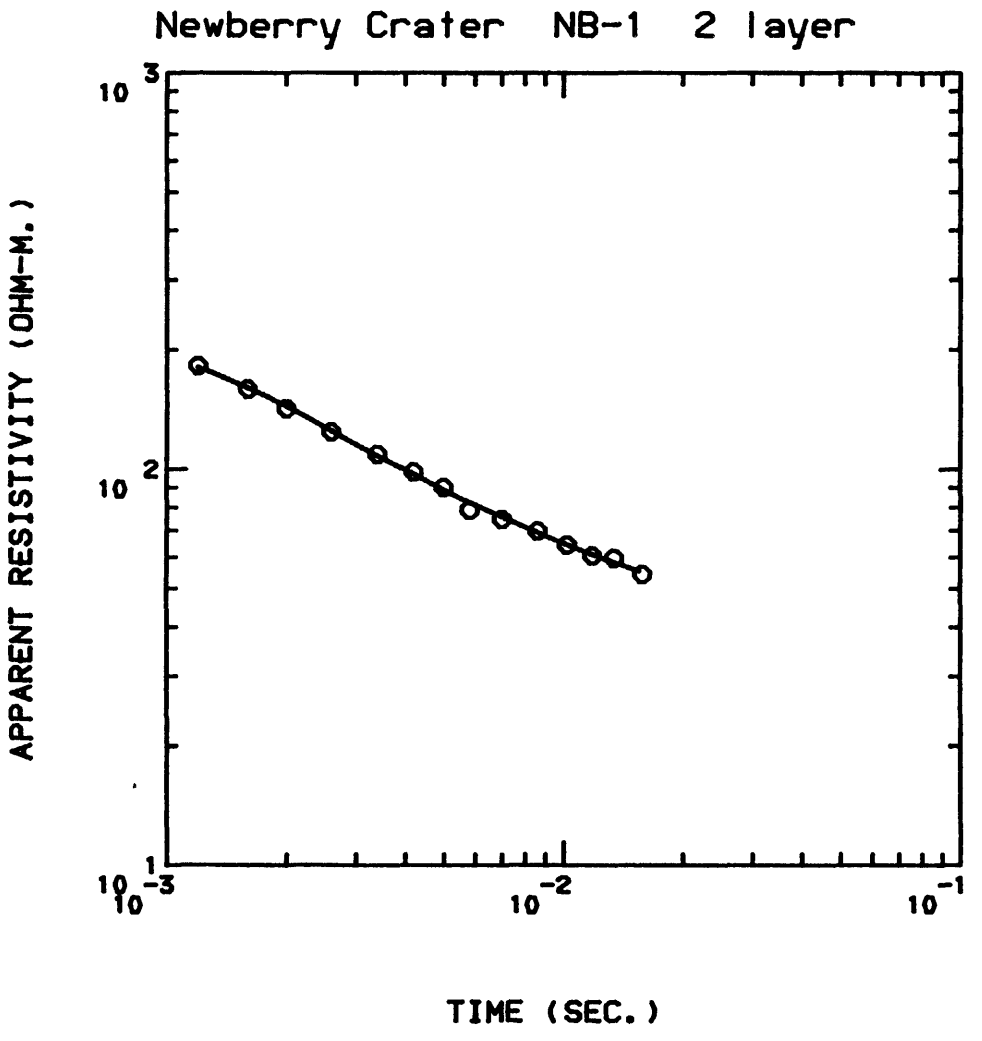
Sammel, E. A., 1981, Results of test drilling at Newberry Volcano, Oregon, and some implications for geothermal prospects in the Cascades: Geothermal Resources Council Bulletin, 10 3-8.

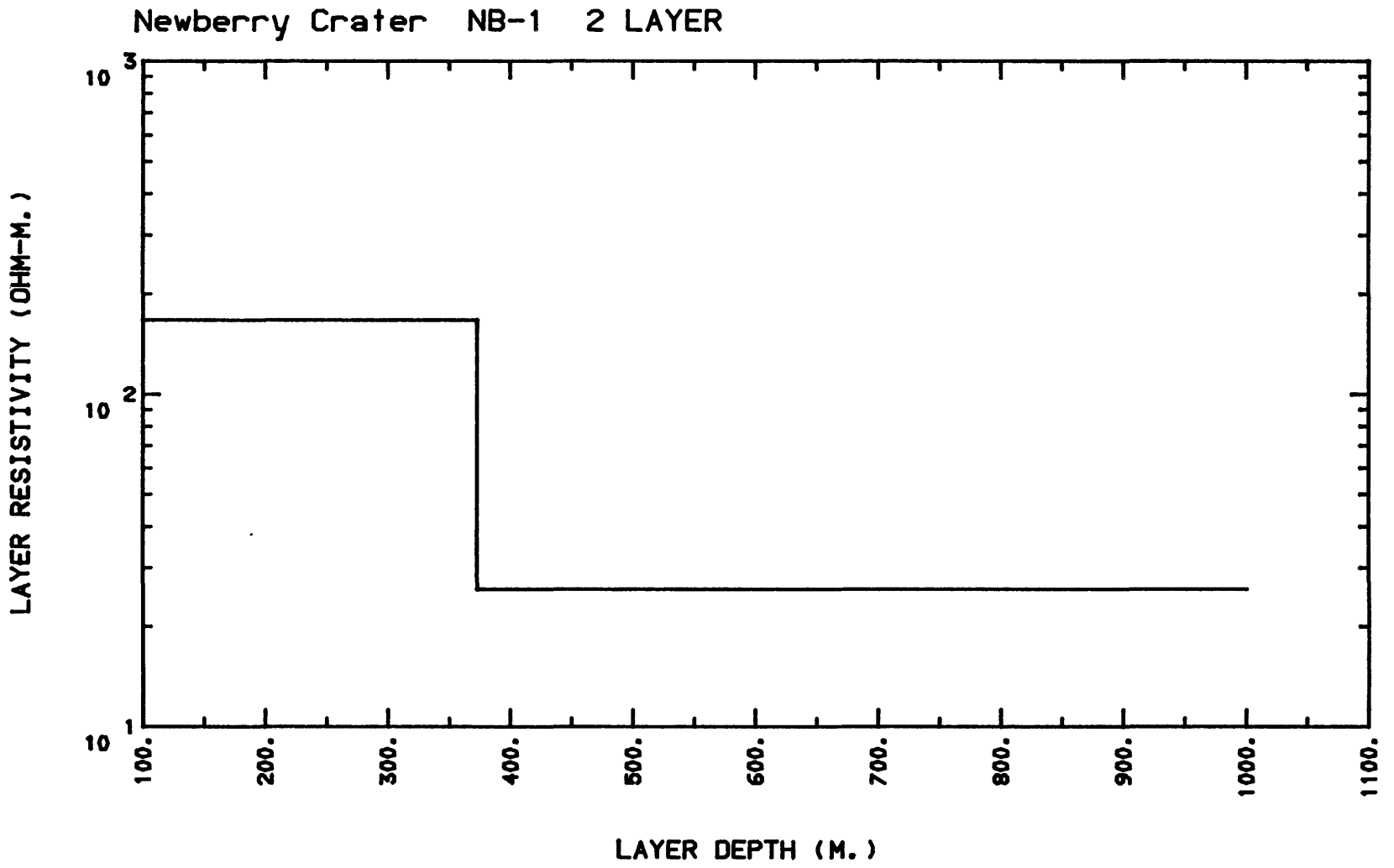
NEWBERRY CRATER



```
<NLSTCI2>:    Newberry Crater  NB-1  2 layer
A= 0.257900E+03
PARAMETERS HELD FIXED: IB=  4
***** X-CONVERGENCE *****

  I     OBS.Y(I)        CAL             RES         %RES.ERR       X(I,1)
  1   0.182000E+03  0.180539E+03  0.146E+01  0.809157E+00  0.120000E-02
  2   0.159000E+03  0.159708E+03 -0.708E+00 -0.443076E+00  0.160000E-02
  3   0.142000E+03  0.143564E+03 -0.156E+01 -0.108944E+01  0.200000E-02
  4   0.124000E+03  0.124469E+03 -0.469E+00 -0.377156E+00  0.260000E-02
  5   0.109000E+03  0.107754E+03  0.125E+01  0.115602E+01  0.340000E-02
  6   0.983000E+02  0.969028E+02  0.140E+01  0.144185E+01  0.420000E-02
  7   0.900000E+02  0.884078E+02  0.159E+01  0.180095E+01  0.500000E-02
  8   0.788000E+02  0.821539E+02 -0.335E+01 -0.408248E+01  0.580000E-02
  9   0.747000E+02  0.756246E+02 -0.925E+00 -0.122269E+01  0.700000E-02
 10   0.698000E+02  0.690392E+02  0.761E+00  0.110199E+01  0.860000E-02
 11   0.644000E+02  0.643324E+02  0.676E-01  0.105062E+00  0.102000E-01
 12   0.605000E+02  0.608401E+02 -0.340E+00 -0.558980E+00  0.118000E-01
 13   0.597000E+02  0.580973E+02  0.160E+01  0.275868E+01  0.134000E-01
 14   0.543000E+02  0.548513E+02 -0.551E+00 -0.100503E+01  0.158000E-01
** RMSERR=  0.15671540E+01

CORRELATION MATRIX
 1  0.1000E+01
 2  0.3587E+00  0.1000E+01
 3  0.5697E+00  0.7172E+00  0.1000E+01

  **PARM_SOL.    STD_ERROR    REL_ERROR     % ERROR **
 1  0.5998E-02  0.1449E-03  0.2416E-01  0.2416E+01
 2  0.3872E-01  0.6775E-03  0.1750E-01  0.1750E+01
 3  0.3730E+03  0.2166E-02  0.5806E-05  0.5806E-03

PARAMETER NAME       FINAL SOLUTION        RESISTIVITY   LAYER DEPTH
   1   SIGMA( 1) =  0.59982953E-02   1  0.16671404E+03
   2   SIGMA( 2) =  0.38715161E-01   2  0.25829674E+02
   3   THICK( 1) =  0.37302838E+03                      1  0.37302838E+03
   4   SHIFT     =  0.10000000E+01
```


2a

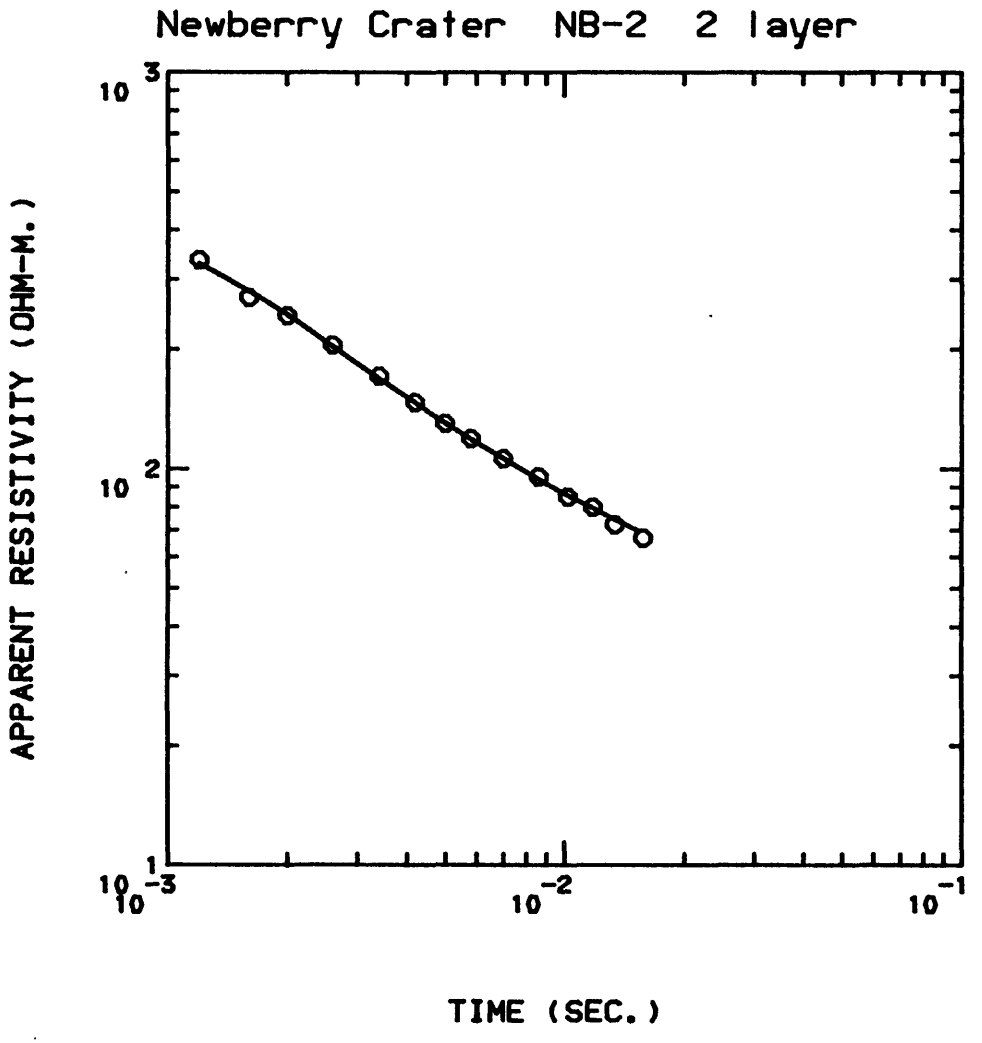

Newberry Crater NB-1 2 layer
APPARENT RESISTIVITY (OHM-M.)
10 3
10 2
10 1
10 -3
10 -2
10 -1
TIME (SEC.)

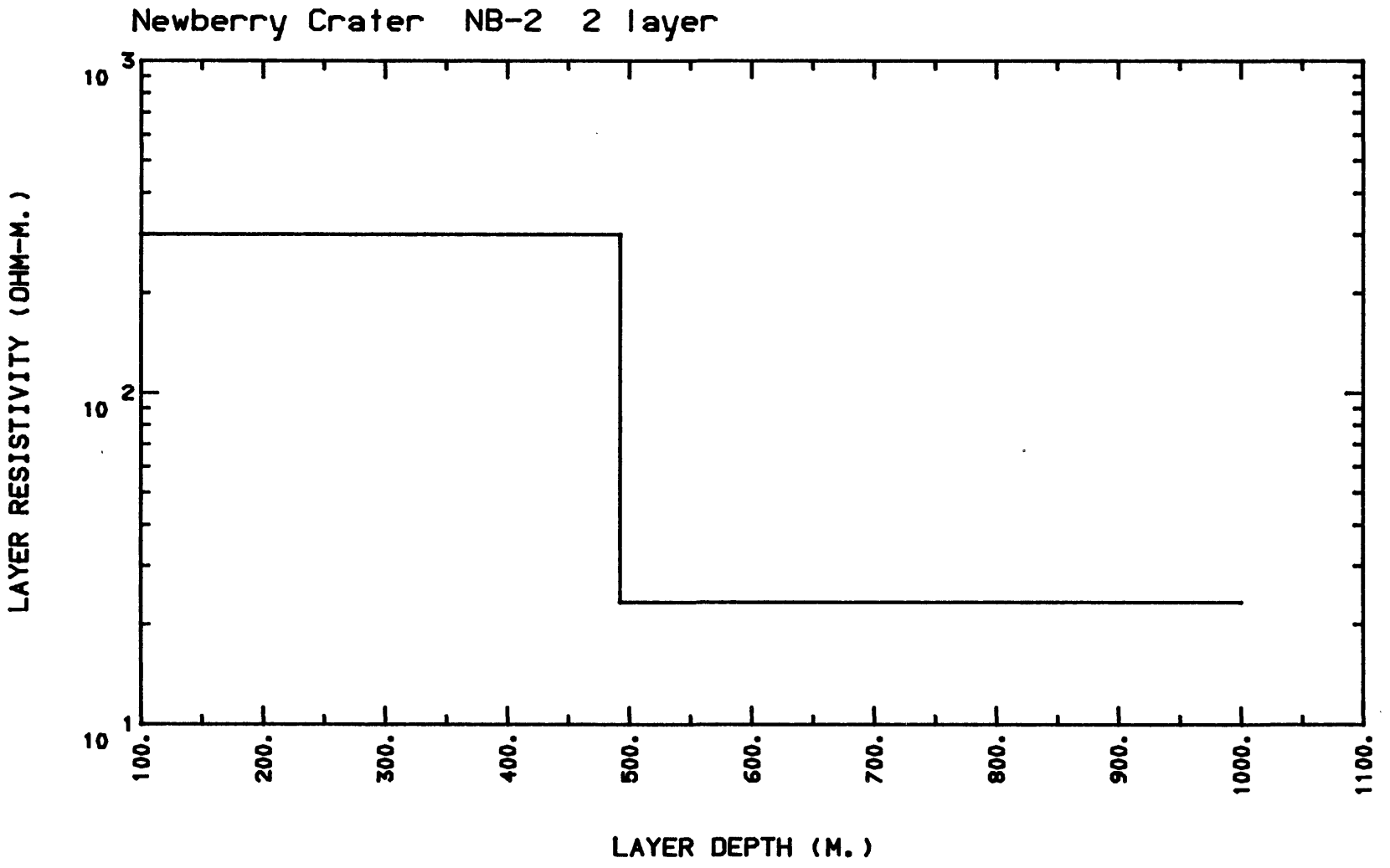

Newberry Crater NB-1 2 LAYER
LAYER RESISTIVITY (OHM-M.)
10 3
10 2
10 1
100.
200.
300.
400.
500.
600.
700.
800.
900.
1000.
1100.
LAYER DEPTH (M.)

2c

```
<NLSTCI2>:    Newberry Crater  NB-2  2 layer
A= 0.257900E+03
PARAMETERS HELD FIXED: IB=  4
***** X-CONVERGENCE *****

  I     OBS.Y(I)        CAL             RES          %RES.ERR       X(I,1)
  1   0.336000E+03  0.328380E+03  0.762E+01  0.232039E+01  0.120000E-02
  2   0.270000E+03  0.279927E+03 -0.993E+01 -0.354645E+01  0.160000E-02
  3   0.243000E+03  0.243790E+03 -0.790E+00 -0.323934E+00  0.200000E-02
  4   0.205000E+03  0.202656E+03  0.234E+01  0.115665E+01  0.260000E-02
  5   0.171000E+03  0.168195E+03  0.281E+01  0.166785E+01  0.340000E-02
  6   0.147000E+03  0.146398E+03  0.602E+00  0.411096E+00  0.420000E-02
  7   0.130000E+03  0.130043E+03 -0.430E-01 -0.330302E-01  0.500000E-02
  8   0.119000E+03  0.118268E+03  0.732E+00  0.618799E+00  0.580000E-02
  9   0.106000E+03  0.105851E+03  0.149E+00  0.140463E+00  0.700000E-02
 10   0.954000E+02  0.938310E+02  0.157E+01  0.167216E+01  0.860000E-02
 11   0.849000E+02  0.854220E+02 -0.522E+00 -0.611043E+00  0.102000E-01
 12   0.799000E+02  0.792177E+02  0.682E+00  0.861254E+00  0.118000E-01
 13   0.722000E+02  0.743712E+02 -0.217E+01 -0.291943E+01  0.134000E-01
 14   0.669000E+02  0.687234E+02 -0.182E+01 -0.265319E+01  0.158000E-01
** RMSERR=  0.40761223E+01

CORRELATION MATRIX
 1  0.1000E+01
 2 -0.4530E-01  0.1000E+01
 3  0.4387E+00  0.3108E+00  0.1000E+01

  **PARM_SOL.   STD_ERROR   REL_ERROR    % ERROR **
 1  0.3334E-02  0.1098E-03  0.3294E-01  0.3294E+01
 2  0.4288E-01  0.1030E-02  0.2402E-01  0.2402E+01
 3  0.4925E+03  0.1621E-02  0.3291E-05  0.3291E-03

PARAMETER NAME       FINAL SOLUTION        RESISTIVITY   LAYER DEPTH
   1   SIGMA( 1) =  0.33337125E-02   1  0.29996588E+03
   2   SIGMA( 2) =  0.42883433E-01   2  0.23319029E+02
   3   THICK( 1) =  0.49249362E+03                      1  0.49249362E+03
   4   SHIFT     =  0.10000000E+01
```

3a

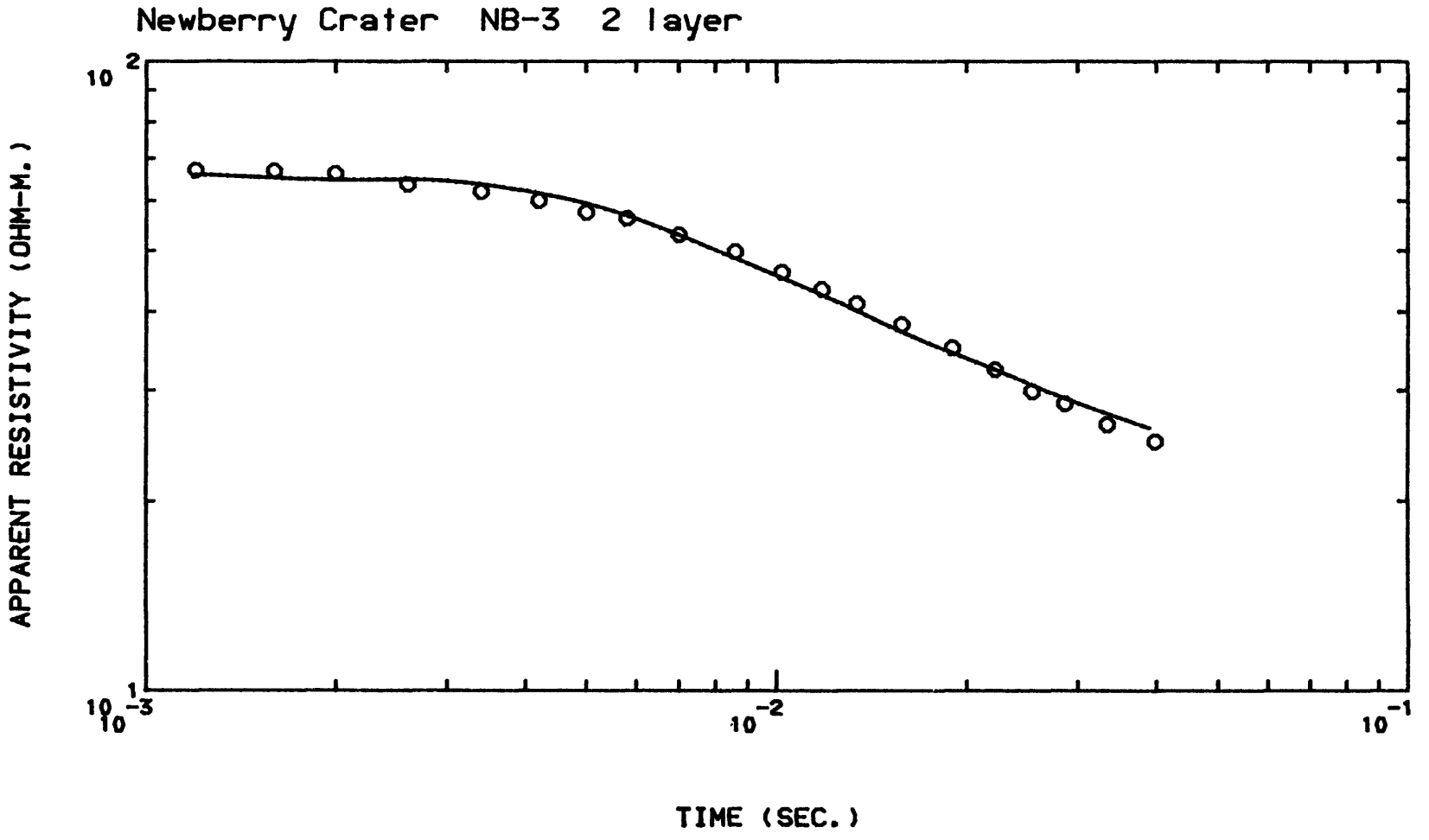

Newberry Crater NB-2 2 layer
APPARENT RESISTIVITY (OHM-M.)
10^3
10^2
10^1
10^-3
10^-2
10^-1
TIME (SEC.)


Newberry Crater NB-2 2 layer
LAYER RESISTIVITY (OHM-M.)
10 3
10 2
10 1
100.
200.
300.
400.
500.
600.
700.
800.
900.
1000.
1100.
LAYER DEPTH (M.)

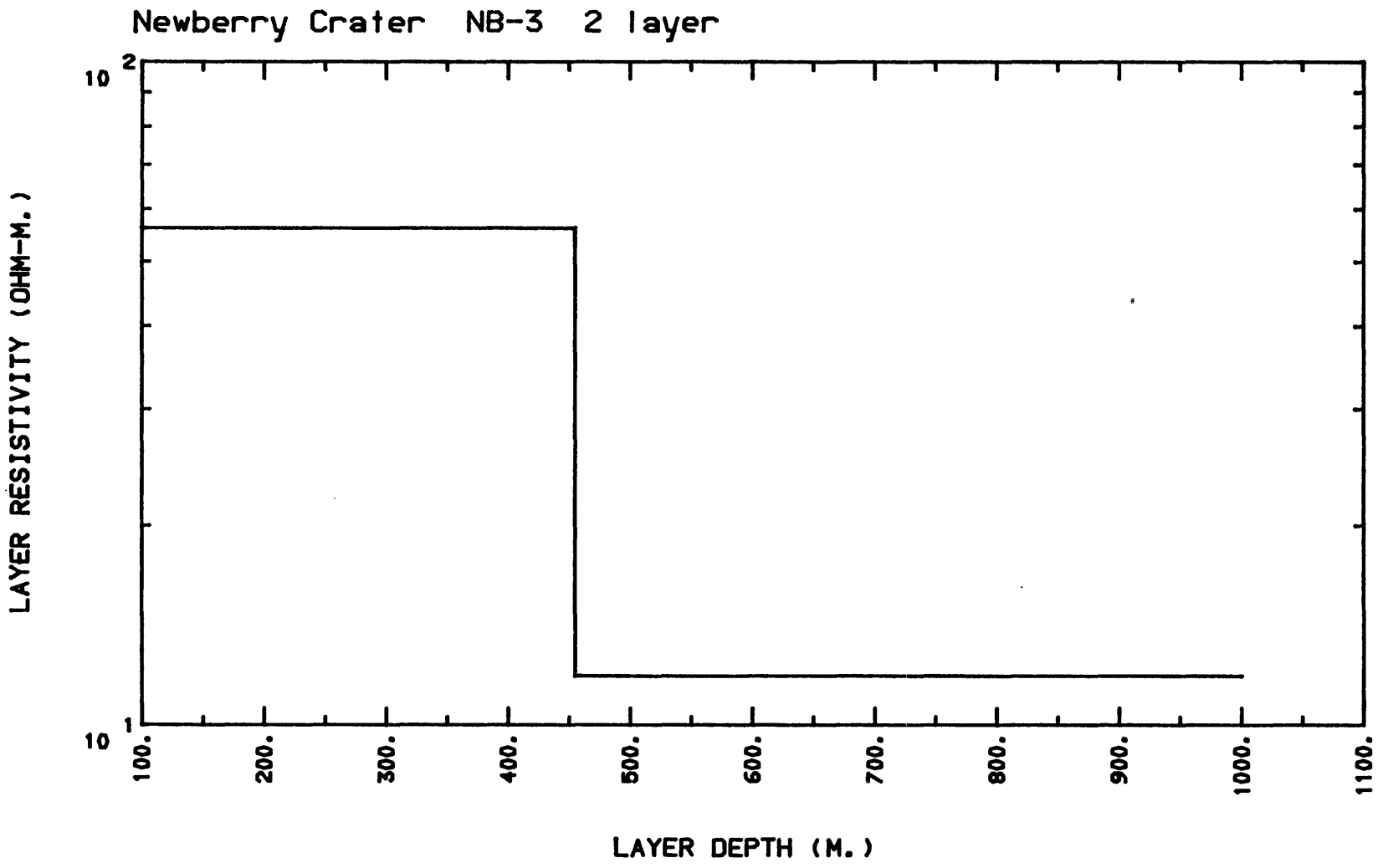
3c

```
<NLSTCI2>:    Newberry Crater  NB-3  2 layer
A= 0.257900E+03
PARAMETERS HELD FIXED: IB=  4
***** VARIABILITY CONVERGENCE *****

  I     OBS.Y(I)        CAL             RES          %RES.ERR       X(I,1)
  1  0.671000E+02  0.660378E+02  0.106E+01  0.160854E+01  0.120000E-02
  2  0.669000E+02  0.652104E+02  0.169E+01  0.259093E+01  0.160000E-02
  3  0.663000E+02  0.647156E+02  0.158E+01  0.244823E+01  0.200000E-02
  4  0.637000E+02  0.648072E+02 -0.111E+01 -0.170849E+01  0.260000E-02
  5  0.620000E+02  0.636003E+02 -0.160E+01 -0.251615E+01  0.340000E-02
  6  0.600000E+02  0.615260E+02 -0.153E+01 -0.248028E+01  0.420000E-02
  7  0.575000E+02  0.593285E+02 -0.183E+01 -0.308201E+01  0.500000E-02
  8  0.563000E+02  0.567574E+02 -0.457E+00 -0.805928E+00  0.580000E-02
  9  0.530000E+02  0.528882E+02  0.112E+00  0.211305E+00  0.700000E-02
 10  0.496000E+02  0.485370E+02  0.126E+01  0.260217E+01  0.860000E-02
 11  0.462000E+02  0.452112E+02  0.989E+00  0.218714E+01  0.102000E-01
 12  0.434000E+02  0.424898E+02  0.910E+00  0.214228E+01  0.118000E-01
 13  0.412000E+02  0.400854E+02  0.111E+01  0.278051E+01  0.134000E-01
 14  0.382000E+02  0.371044E+02  0.110E+01  0.295270E+01  0.158000E-01
 15  0.351000E+02  0.344064E+02  0.694E+00  0.201581E+01  0.190000E-01
 16  0.324000E+02  0.323341E+02  0.659E-01  0.203877E+00  0.222000E-01
 17  0.299000E+02  0.305756E+02 -0.676E+00 -0.220949E+01  0.254000E-01
 18  0.286000E+02  0.291289E+02 -0.529E+00 -0.181566E+01  0.286000E-01
 19  0.265000E+02  0.275415E+02 -0.104E+01 -0.378153E+01  0.334000E-01
 20  0.249000E+02  0.259293E+02 -0.103E+01 -0.396955E+01  0.398000E-01
** RMSERR=  0.12219495E+01

CORRELATION MATRIX
 1  0.1000E+01
 2  0.2307E+00  0.1000E+01
 3  0.2442E+00  0.7058E+00  0.1000E+01

  **PARM_SOL.   STD_ERROR   REL_ERROR    % ERROR **
 1  0.1781E-01  0.1672E-03  0.9389E-02  0.9389E+00
 2  0.8440E-01  0.1959E-02  0.2321E-01  0.2321E+01
 3  0.4553E+03  0.3160E-02  0.6940E-05  0.6940E-03

PARAMETER NAME       FINAL SOLUTION        RESISTIVITY   LAYER DEPTH
   1   SIGMA( 1) =  0.17807685E-01   1  0.56155533E+02
   2   SIGMA( 2) =  0.84403656E-01   2  0.11847828E+02
   3   THICK( 1) =  0.45531293E+03                      1  0.45531293E+03
   4   SHIFT     =  0.10000000E+01
```

4a


Newberry Crater NB-3 2 layer
APPARENT RESISTIVITY (OHM-M.)
TIME (SEC.)
10 2
10 1
10 -3
10 -2
10 -1

4b


Newberry Crater NB-3 2 layer
LAYER RESISTIVITY (OHM-M.)
10 2
10 1
100.
200.
300.
400.
500.
600.
700.
800.
900.
1000.
1100.
LAYER DEPTH (M.)

4c

<NLSTCI2>: Newberry Crater NB-4 2 layer
A= 0.257900E+03
PARAMETERS HELD FIXED: IB= 4
***** VARIABILITY CONVERGENCE *****

I	OBS.Y(I)	CAL	RES	%RES.ERR	X(I,1)
1	0.124000E+03	0.123296E+03	0.704E+00	0.570923E+00	0.120000E-02
2	0.118000E+03	0.118845E+03	-0.845E+00	-0.711317E+00	0.160000E-02
3	0.111000E+03	0.111500E+03	-0.500E+00	-0.448676E+00	0.200000E-02
4	0.996000E+02	0.101860E+03	-0.226E+01	-0.221831E+01	0.260000E-02
5	0.905000E+02	0.909406E+02	-0.441E+00	-0.484514E+00	0.340000E-02
6	0.832000E+02	0.821203E+02	0.108E+01	0.131480E+01	0.420000E-02
7	0.769000E+02	0.755689E+02	0.133E+01	0.176144E+01	0.500000E-02
8	0.718000E+02	0.707651E+02	0.103E+01	0.146248E+01	0.580000E-02
9	0.647000E+02	0.650146E+02	-0.315E+00	-0.483853E+00	0.700000E-02
10	0.599000E+02	0.590745E+02	0.825E+00	0.139732E+01	0.860000E-02
11	0.562000E+02	0.551483E+02	0.105E+01	0.190713E+01	0.102000E-01
12	0.518000E+02	0.520977E+02	-0.298E+00	-0.571381E+00	0.118000E-01
13	0.488000E+02	0.495726E+02	-0.773E+00	-0.155859E+01	0.134000E-01
14	0.464000E+02	0.465781E+02	-0.178E+00	-0.382345E+00	0.158000E-01
15	0.421000E+02	0.437467E+02	-0.165E+01	-0.376413E+01	0.190000E-01

** RMSERR= 0.11577367E+01

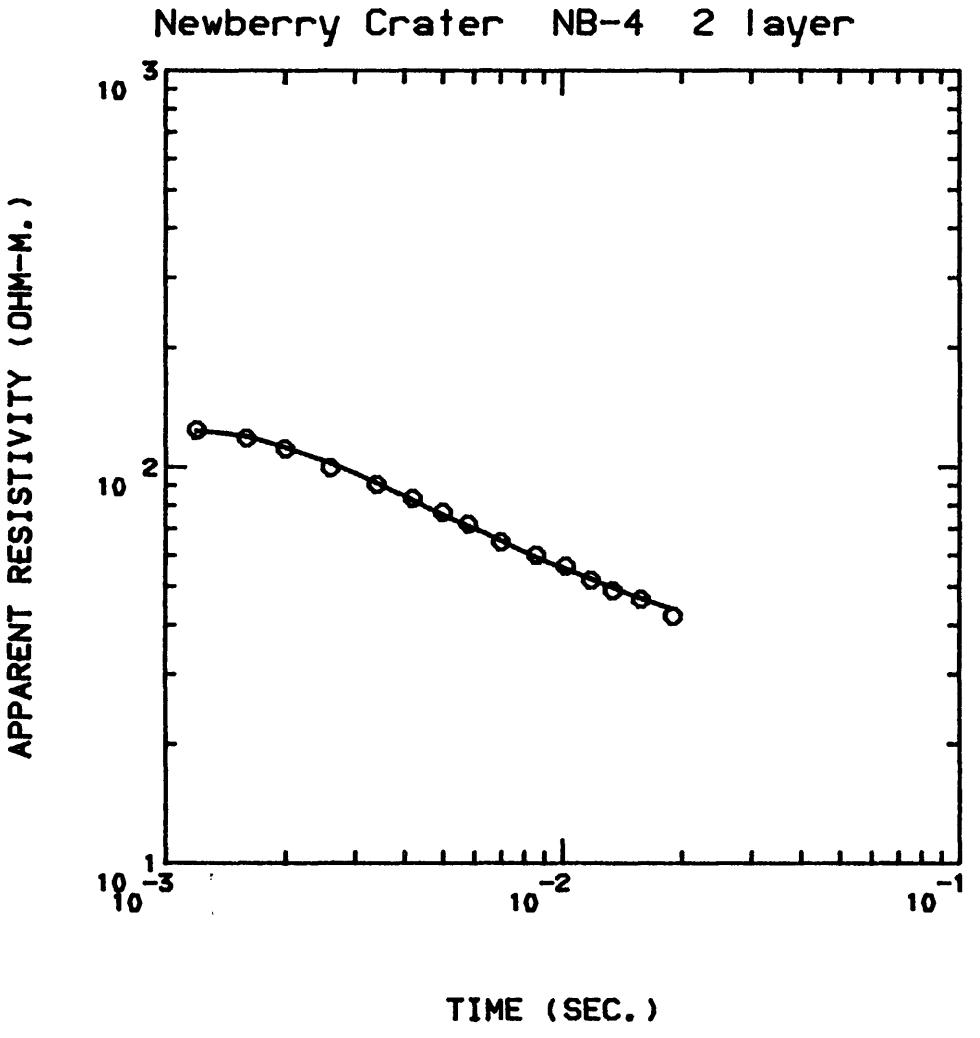
CORRELATION MATRIX

1	0.1000E+01		
2	0.7853E+00	0.1000E+01	
3	0.8616E+00	0.9171E+00	0.1000E+01

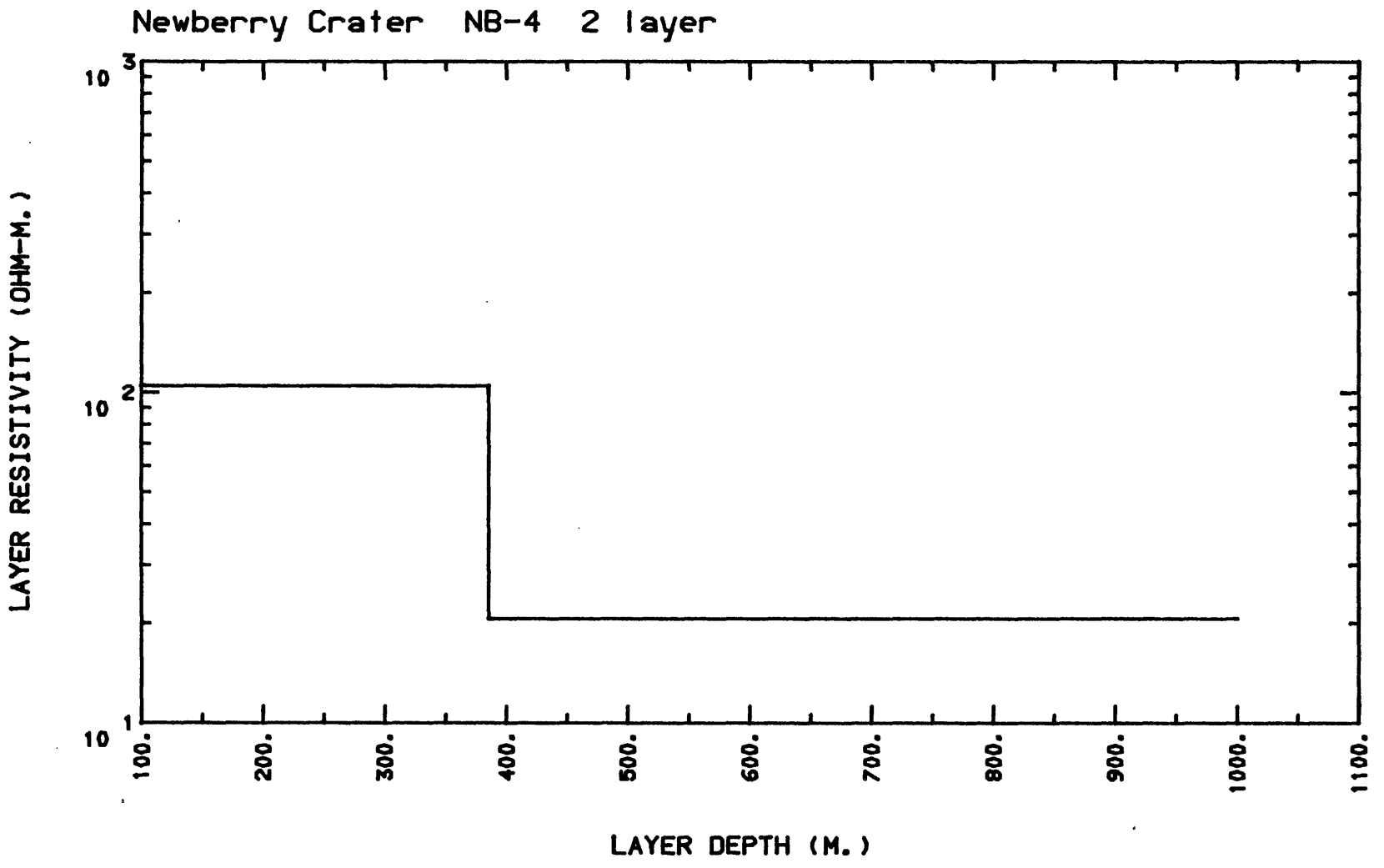
	**PARM_SOL.	STD_ERROR	REL_ERROR	% ERROR **
1	0.9541E-02	0.2090E-03	0.2190E-01	0.2190E+01
2	0.4840E-01	0.1793E-02	0.3704E-01	0.3704E+01
3	0.3856E+03	0.4702E-02	0.1219E-04	0.1219E-02

PARAMETER NAME		FINAL SOLUTION		RESISTIVITY	LAYER DEPTH	
1	SIGMA(1) =	0.95408158E-02	1	0.10481284E+03		
2	SIGMA(2) =	0.48400078E-01	2	0.20661123E+02		
3	THICK(1) =	0.38564847E+03			1	0.38564847E+03
4	SHIFT =	0.10000000E+01				

5a


Newberry Crater NB-4 2 layer
APPARENT RESISTIVITY (OHM-M.)
10^3
10^2
10^1
10^-3
10^-2
10^-1
TIME (SEC.)

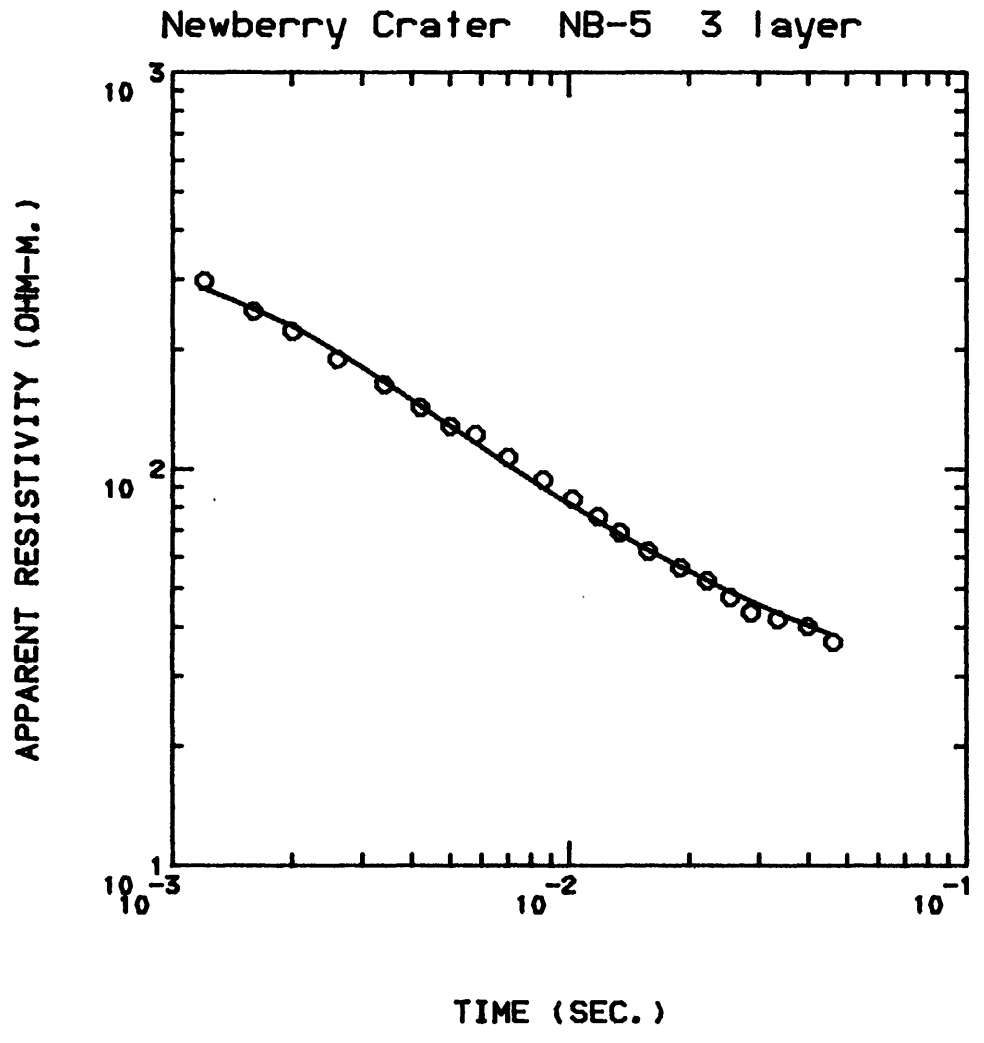
5b


Newberry Crater NB-4 2 layer
LAYER RESISTIVITY (OHM-M.)
10 3
10 2
10 1
100.
200.
300.
400.
500.
600.
700.
800.
900.
1000.
1100.
LAYER DEPTH (M.)

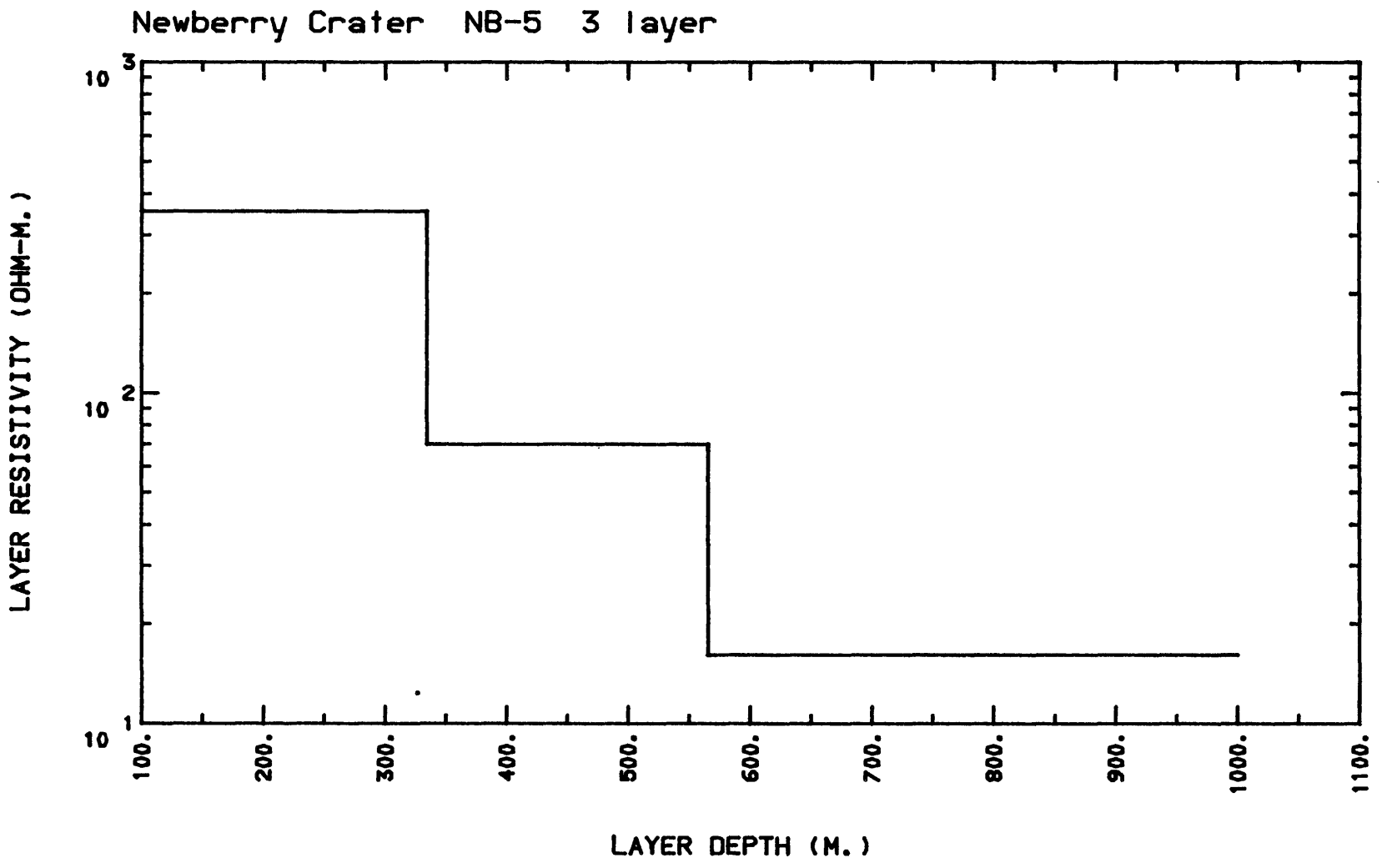
5c

```
<NLSTCI2>:    Newberry Crater  NB-5  3 layer
A= 0.257900E+03
PARAMETERS HELD FIXED: IB=  6
***** X-CONVERGENCE *****

  I     OBS.Y(I)        CAL             RES         %RES.ERR       X(I,1)
  1  0.298000E+03  0.284898E+03  0.131E+02  0.459875E+01  0.120000E-02
  2  0.250000E+03  0.252716E+03 -0.272E+01 -0.107472E+01  0.160000E-02
  3  0.222000E+03  0.228278E+03 -0.628E+01 -0.275008E+01  0.200000E-02
  4  0.189000E+03  0.196463E+03 -0.746E+01 -0.379862E+01  0.260000E-02
  5  0.163000E+03  0.165631E+03 -0.263E+01 -0.158869E+01  0.340000E-02
  6  0.143000E+03  0.143776E+03 -0.776E+00 -0.540056E+00  0.420000E-02
  7  0.128000E+03  0.127957E+03  0.430E-01  0.336045E-01  0.500000E-02
  8  0.122000E+03  0.115827E+03  0.617E+01  0.532940E+01  0.580000E-02
  9  0.107000E+03  0.102141E+03  0.486E+01  0.475761E+01  0.700000E-02
 10  0.937000E+02  0.894113E+02  0.429E+01  0.479661E+01  0.860000E-02
 11  0.839000E+02  0.805051E+02  0.339E+01  0.421696E+01  0.102000E-01
 12  0.758000E+02  0.737343E+02  0.207E+01  0.280159E+01  0.118000E-01
 13  0.693000E+02  0.684333E+02  0.867E+00  0.126654E+01  0.134000E-01
 14  0.621000E+02  0.623905E+02 -0.291E+00 -0.465641E+00  0.158000E-01
 15  0.564000E+02  0.566014E+02 -0.201E+00 -0.355823E+00  0.190000E-01
 16  0.523000E+02  0.523013E+02 -0.132E-02 -0.251632E-02  0.222000E-01
 17  0.475000E+02  0.490090E+02 -0.151E+01 -0.307902E+01  0.254000E-01
 18  0.434000E+02  0.463933E+02 -0.299E+01 -0.645197E+01  0.286000E-01
 19  0.418000E+02  0.433341E+02 -0.153E+01 -0.354024E+01  0.334000E-01
 20  0.401000E+02  0.403164E+02 -0.216E+00 -0.536726E+00  0.398000E-01
 21  0.366000E+02  0.380452E+02 -0.145E+01 -0.379860E+01  0.462000E-01
** RMSERR=  0.49634480E+01

CORRELATION MATRIX
 1  0.1000E+01
 2  0.2227E+00  0.1000E+01
 3  0.4656E+00  0.5078E+00  0.1000E+01
 4  0.4974E+00  0.8203E+00  0.5011E+00  0.1000E+01
 5  0.2213E+00 -0.1408E+00  0.3189E+00 -0.2769E+00  0.1000E+01

  **PARM_SOL.   STD_ERROR   REL_ERROR    % ERROR **
 1  0.2826E-02  0.2385E-03  0.8440E-01  0.8440E+01
 2  0.1430E-01  0.1086E-02  0.7597E-01  0.7597E+01
 3  0.6202E-01  0.1689E-02  0.2723E-01  0.2723E+01
 4  0.3344E+03  0.5220E-02  0.1561E-04  0.1561E-02
 5  0.2313E+03  0.6684E-02  0.2890E-04  0.2890E-02

PARAMETER NAME       FINAL SOLUTION        RESISTIVITY   LAYER DEPTH
   1   SIGMA( 1) =  0.28262159E-02   1  0.35383002E+03
   2   SIGMA( 2) =  0.14299732E-01   2  0.69931381E+02
   3   SIGMA( 3) =  0.62019791E-01   3  0.16123886E+02
   4   THICK( 1) =  0.33438226E+03                      1  0.33438226E+03
   5   THICK( 2) =  0.23125919E+03                      2  0.56564148E+03
   6   SHIFT     =  0.10000000E+01
```

6a


Newberry Crater NB-5 3 layer
APPARENT RESISTIVITY (OHM-M.)
TIME (SEC.)
10^3
10^2
10^1
10^-3
10^-2
10^-1

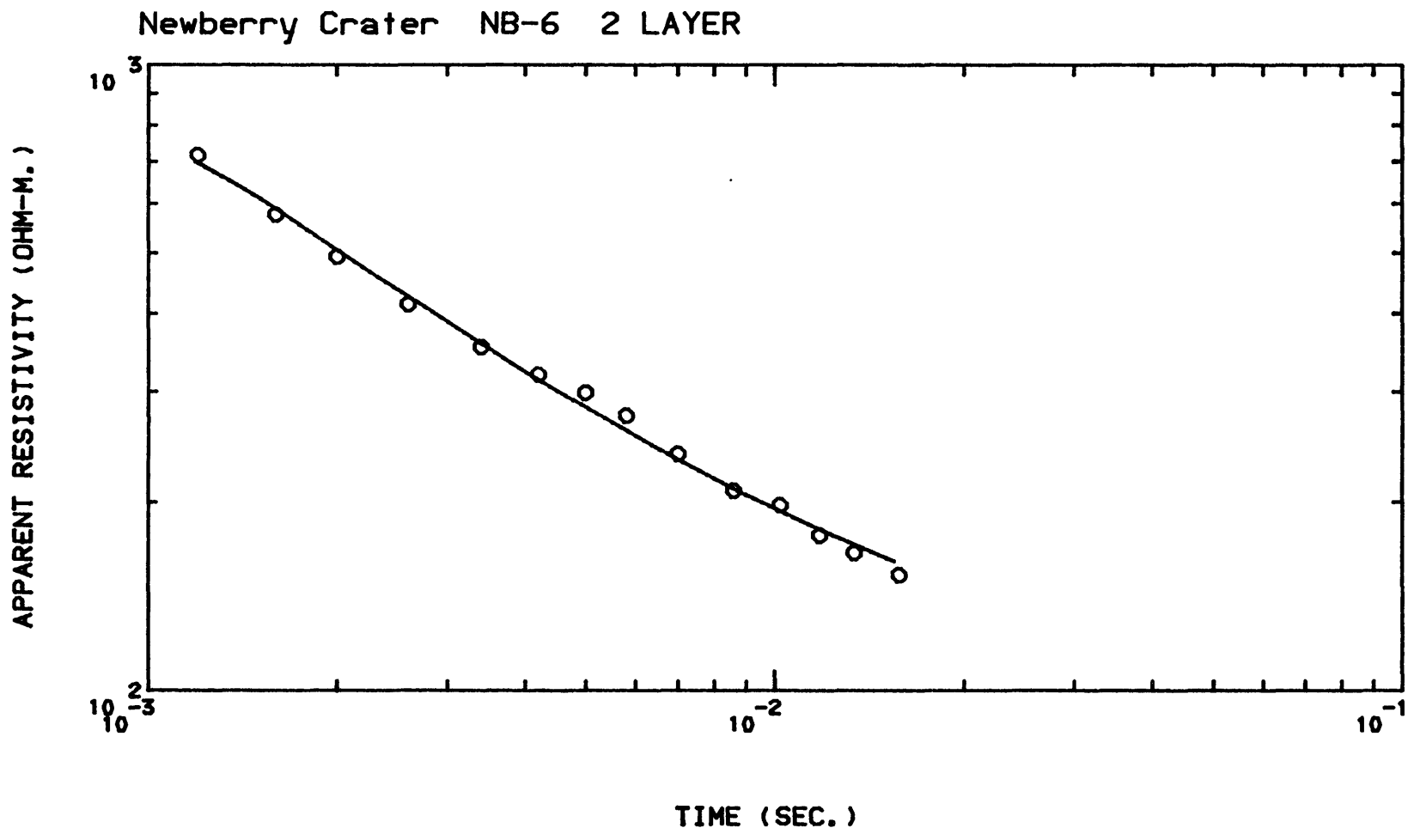
6b


Newberry Crater NB-5 3 layer
LAYER RESISTIVITY (OHM-M.)
10 3
10 2
10 1
100.
200.
300.
400.
500.
600.
700.
800.
900.
1000.
1100.
LAYER DEPTH (M.)

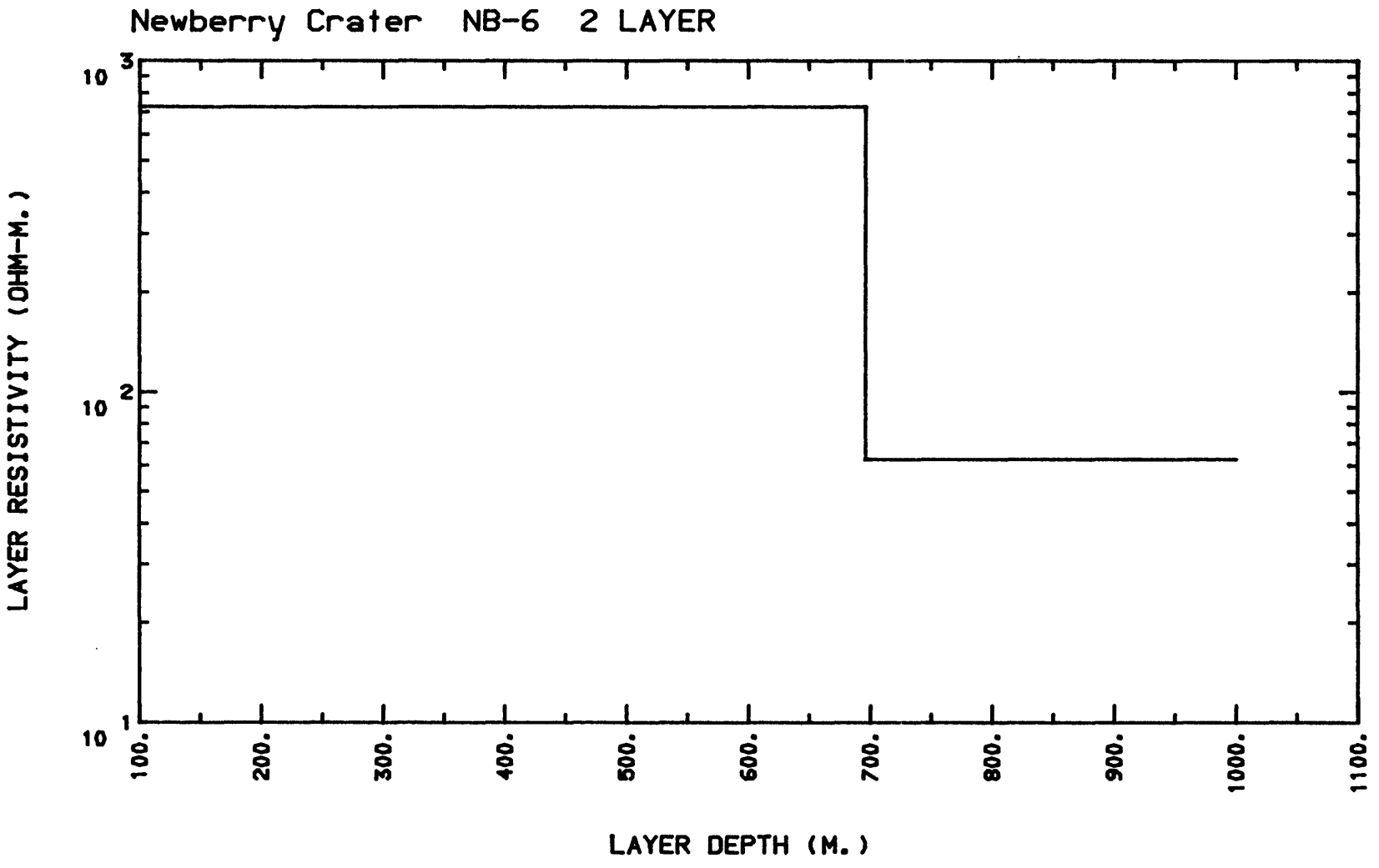
6c

```
<NLSTCI2>:    Newberry Crater  NB-6  2 layer
A= 0.257900E+03
PARAMETERS HELD FIXED: IB=  4
***** X-CONVERGENCE *****

  I     OBS.Y(I)        CAL             RES         %RES.ERR       X(I,1)
  1   0.717000E+03  0.696352E+03  0.206E+02  0.296523E+01  0.120000E-02
  2   0.576000E+03  0.587895E+03 -0.119E+02 -0.202332E+01  0.160000E-02
  3   0.493000E+03  0.504980E+03 -0.120E+02 -0.237233E+01  0.200000E-02
  4   0.414000E+03  0.425888E+03 -0.119E+02 -0.279132E+01  0.260000E-02
  5   0.354000E+03  0.358043E+03 -0.404E+01 -0.112908E+01  0.340000E-02
  6   0.320000E+03  0.313197E+03  0.680E+01  0.217227E+01  0.420000E-02
  7   0.299000E+03  0.283220E+03  0.158E+02  0.557172E+01  0.500000E-02
  8   0.275000E+03  0.260098E+03  0.149E+02  0.572957E+01  0.580000E-02
  9   0.239000E+03  0.233931E+03  0.507E+01  0.216708E+01  0.700000E-02
 10   0.209000E+03  0.210254E+03 -0.125E+01 -0.596204E+00  0.860000E-02
 11   0.198000E+03  0.193326E+03  0.467E+01  0.241751E+01  0.102000E-01
 12   0.177000E+03  0.180750E+03 -0.375E+01 -0.207490E+01  0.118000E-01
 13   0.166000E+03  0.170953E+03 -0.495E+01 -0.289706E+01  0.134000E-01
 14   0.153000E+03  0.159560E+03 -0.656E+01 -0.411132E+01  0.158000E-01
** RMSERR=  0.11744075E+02

CORRELATION MATRIX
 1  0.1000E+01
 2 -0.4264E+00  0.1000E+01
 3 -0.5542E+00  0.3028E+00  0.1000E+01

  **PARM_SOL.   STD_ERROR   REL_ERROR    % ERROR **
 1  0.1377E-02  0.4998E-04  0.3630E-01  0.3630E+01
 2  0.1601E-01  0.4325E-03  0.2702E-01  0.2702E+01
 3  0.6964E+03  0.2608E-02  0.3745E-05  0.3745E-03

PARAMETER NAME       FINAL SOLUTION        RESISTIVITY   LAYER DEPTH
   1   SIGMA( 1) =  0.13767633E-02   1  0.72634125E+03
   2   SIGMA( 2) =  0.16007731E-01   2  0.62469818E+02
   3   THICK( 1) =  0.69639349E+03                      1  0.69639349E+03
   4   SHIFT     =  0.10000000E+01
```

7a


Newberry Crater NB-6 2 LAYER
APPARENT RESISTIVITY (OHM-M.)
10^3
10^2
10^{-3}
10^{-2}
10^{-1}
TIME (SEC.)

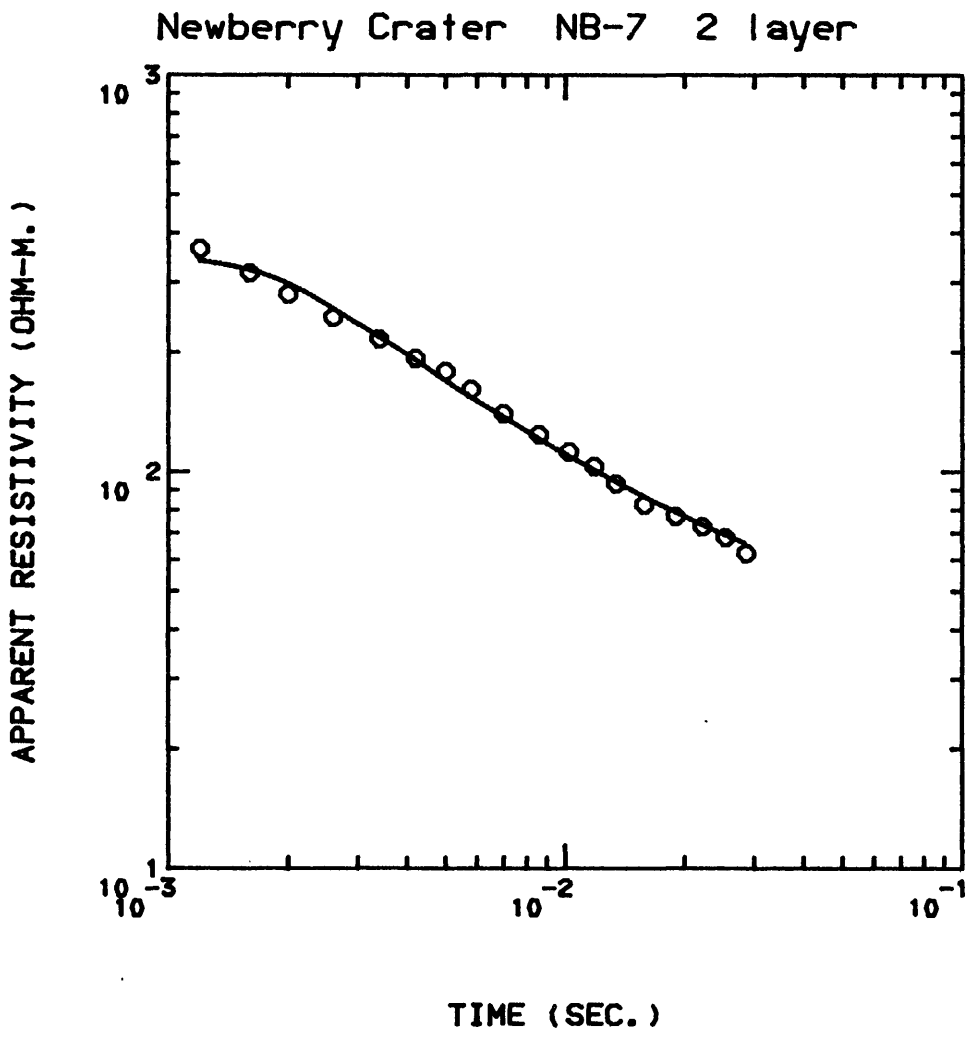
7b

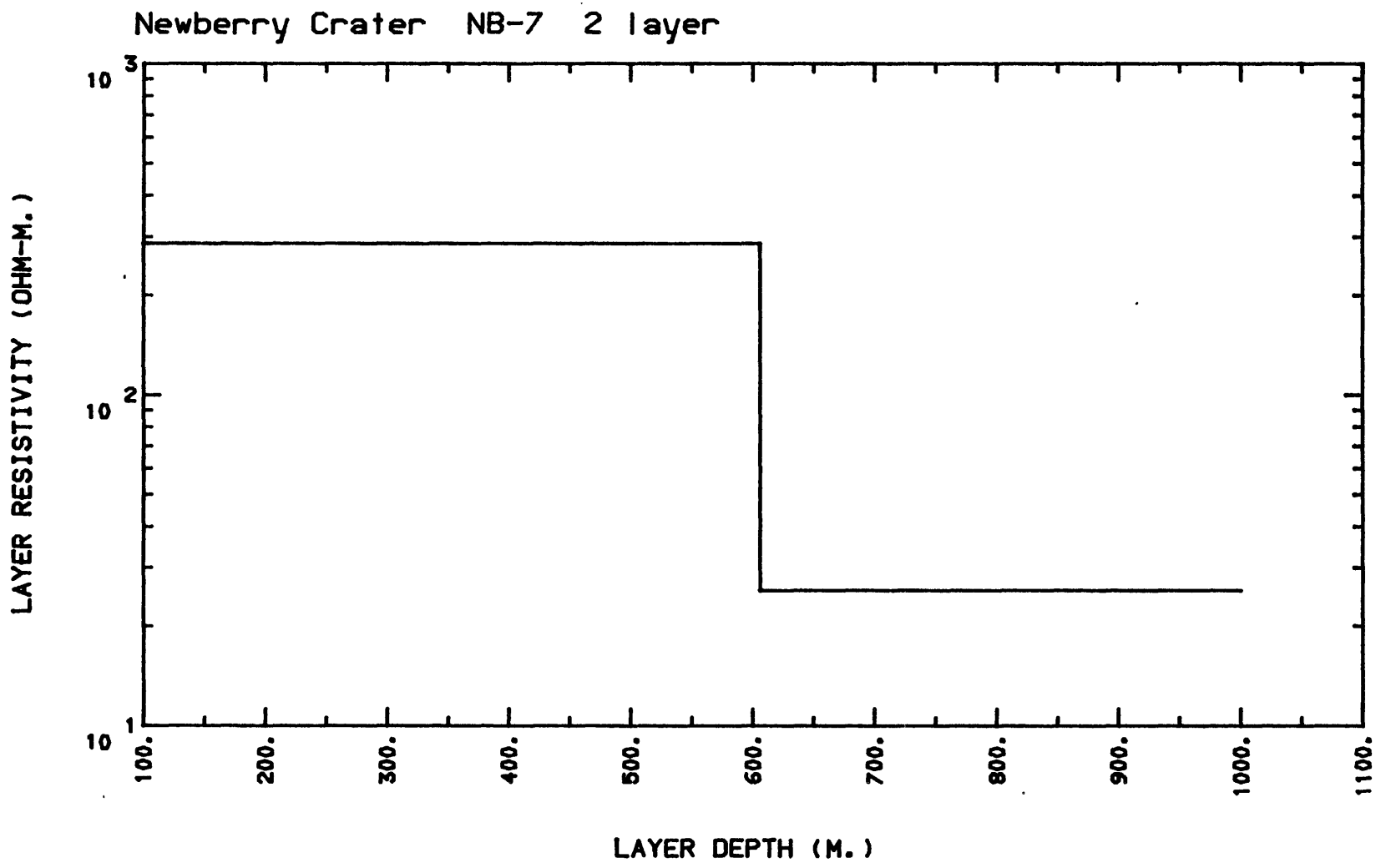

Newberry Crater NB-6 2 LAYER
LAYER RESISTIVITY (OHM-M.)
10 3
10 2
10 1
100.
200.
300.
400.
500.
600.
700.
800.
900.
1000.
1100.
LAYER DEPTH (M.)

7c

```
<NLSTCI2>:    Newberry Crater  N8-7  2 layer
A= 0.257900E+03
PARAMETERS HELD FIXED: IB=  4
***** X-CONVERGENCE *****

  I     OBS.Y(I)        CAL             RES         %RES.ERR       X(I,1)
  1   0.365000E+03  0.340598E+03  0.244E+02  0.716436E+01  0.120000E-02
  2   0.317000E+03  0.322120E+03 -0.512E+01 -0.158943E+01  0.160000E-02
  3   0.280000E+03  0.296954E+03 -0.170E+02 -0.570931E+01  0.200000E-02
  4   0.245000E+03  0.257525E+03 -0.125E+02 -0.486360E+01  0.260000E-02
  5   0.216000E+03  0.217986E+03 -0.199E+01 -0.910842E+00  0.340000E-02
  6   0.193000E+03  0.190756E+03  0.224E+01  0.117613E+01  0.420000E-02
  7   0.179000E+03  0.169297E+03  0.970E+01  0.573129E+01  0.500000E-02
  8   0.161000E+03  0.153409E+03  0.759E+01  0.494834E+01  0.580000E-02
  9   0.140000E+03  0.137047E+03  0.295E+01  0.215456E+01  0.700000E-02
 10   0.124000E+03  0.120792E+03  0.321E+01  0.265570E+01  0.860000E-02
 11   0.112000E+03  0.109103E+03  0.290E+01  0.265520E+01  0.102000E-01
 12   0.103000E+03  0.100724E+03  0.228E+01  0.225954E+01  0.118000E-01
 13   0.932000E+02  0.941709E+02 -0.971E+00 -0.103098E+01  0.134000E-01
 14   0.825000E+02  0.863864E+02 -0.389E+01 -0.449882E+01  0.158000E-01
 15   0.771000E+02  0.788546E+02 -0.175E+01 -0.222507E+01  0.190000E-01
 16   0.727000E+02  0.733393E+02 -0.639E+00 -0.871760E+00  0.222000E-01
 17   0.683000E+02  0.691490E+02 -0.849E+00 -0.122773E+01  0.254000E-01
 18   0.623000E+02  0.658117E+02 -0.351E+01 -0.533605E+01  0.286000E-01
** RMSERR=  0.92804003E+01

CORRELATION MATRIX
 1  0.1000E+01
 2 -0.2126E+00  0.1000E+01
 3 -0.6523E-01  0.2364E+00  0.1000E+01

  **PARM_SOL.    STD_ERROR    REL_ERROR     % ERROR **
 1  0.3494E-02  0.1181E-03  0.3381E-01  0.3381E+01
 2  0.3908E-01  0.1251E-02  0.3200E-01  0.3200E+01
 3  0.6062E+03  0.3365E-02  0.5551E-05  0.5551E-03

PARAMETER NAME        FINAL SOLUTION          RESISTIVITY   LAYER DEPTH
   1   SIGMA( 1) =  0.34938017E-02   1  0.28622116E+03
   2   SIGMA( 2) =  0.39084874E-01   2  0.25585346E+02
   3   THICK( 1) =  0.60620282E+03                        1  0.60620282E+03
   4   SHIFT     =  0.10000000E+01
```

8a

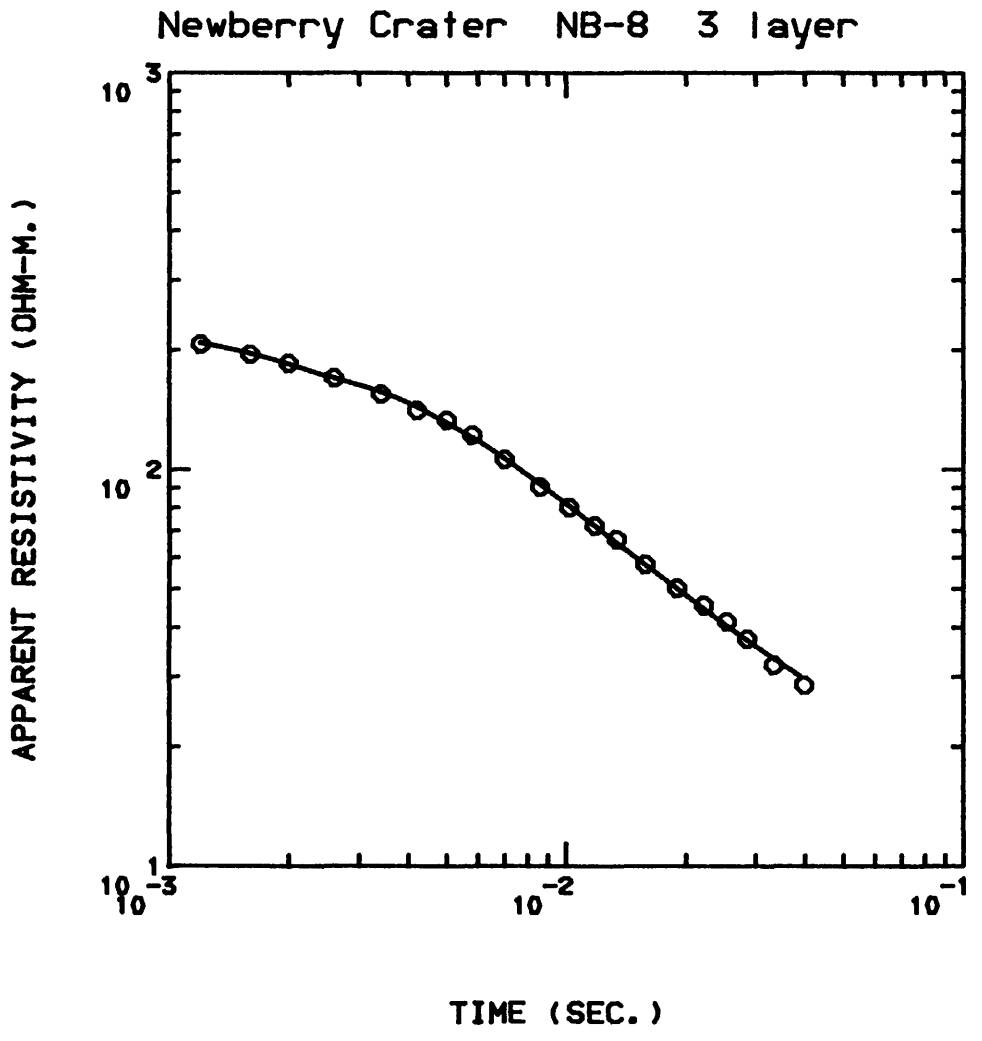

Newberry Crater NB-7 2 layer
APPARENT RESISTIVITY (OHM-M.)
TIME (SEC.)
10^3
10^2
10^1
10^-3
10^-2
10^-1


Newberry Crater NB-7 2 layer
LAYER RESISTIVITY (OHM-M.)
10 3
10 2
10 1
100.
200.
300.
400.
500.
600.
700.
800.
900.
1000.
1100.
LAYER DEPTH (M.)

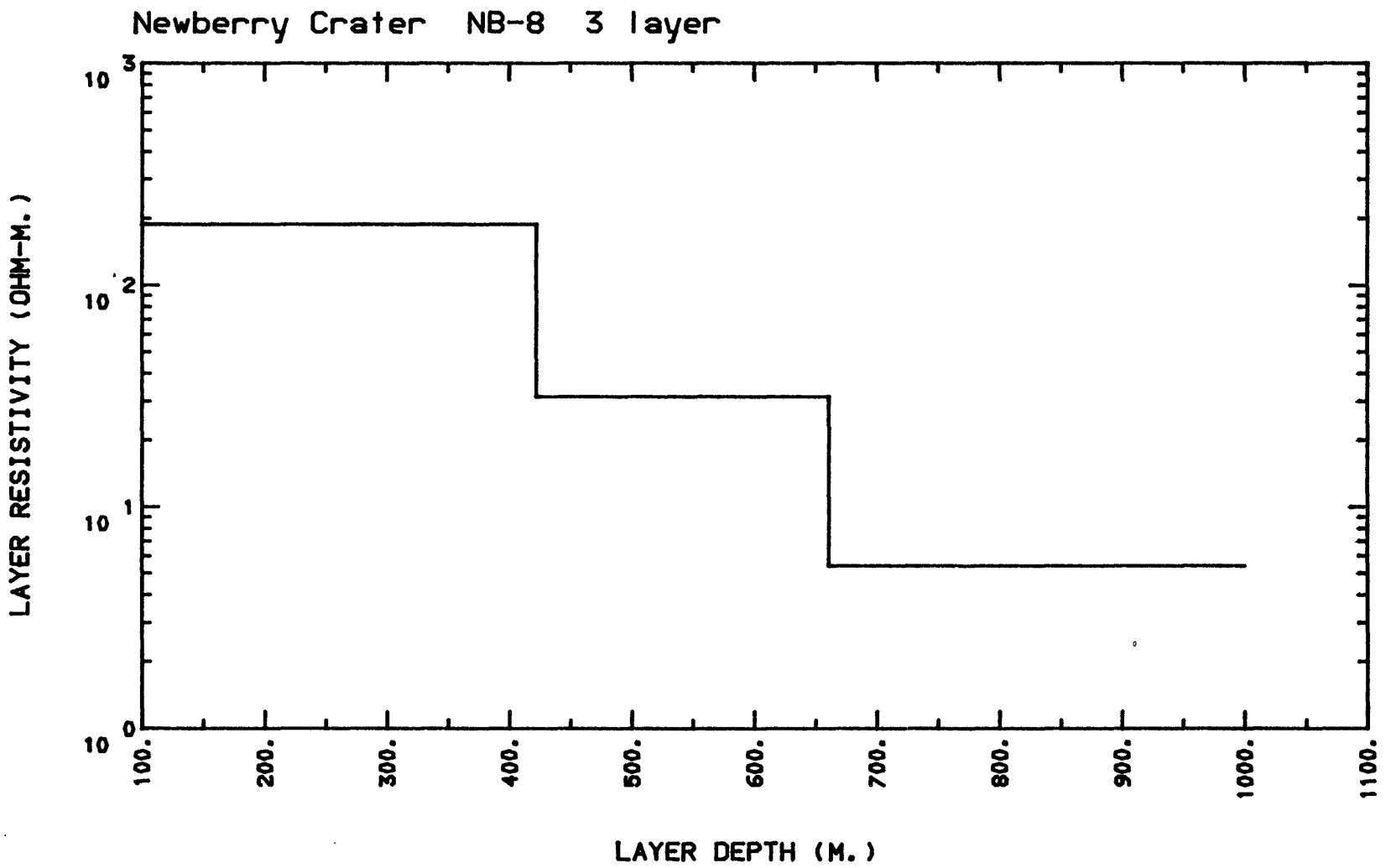
8c

```
<NLSICI2>:    Newberry Crater  NB-8  3 layer
A= 0.257900E+03
PARAMETERS HELD FIXED: IB=  6
***** X-CONVERGENCE *****

  I     OBS.Y(I)        CAL            RES         %RES.ERR       X(I,1)
  1   0.207000E+03  0.208521E+03 -0.152E+01 -0.729298E+00  0.120000E-02
  2   0.195000E+03  0.195564E+03 -0.564E+00 -0.288635E+00  0.160000E-02
  3   0.185000E+03  0.183844E+03  0.116E+01  0.628739E+00  0.200000E-02
  4   0.170000E+03  0.169514E+03  0.486E+00  0.286526E+00  0.260000E-02
  5   0.155000E+03  0.156531E+03 -0.153E+01 -0.978046E+00  0.340000E-02
  6   0.141000E+03  0.143422E+03 -0.242E+01 -0.168875E+01  0.420000E-02
  7   0.133000E+03  0.130678E+03  0.232E+01  0.177680E+01  0.500000E-02
  8   0.122000E+03  0.120044E+03  0.196E+01  0.162948E+01  0.580000E-02
  9   0.106000E+03  0.106303E+03 -0.303E+00 -0.285043E+00  0.700000E-02
 10   0.904000E+02  0.916297E+02 -0.123E+01 -0.134203E+01  0.860000E-02
 11   0.801000E+02  0.805847E+02 -0.485E+00 -0.601492E+00  0.102000E-01
 12   0.721000E+02  0.719589E+02  0.141E+00  0.196135E+00  0.118000E-01
 13   0.667000E+02  0.651686E+02  0.153E+01  0.234992E+01  0.134000E-01
 14   0.576000E+02  0.574299E+02  0.170E+00  0.296109E+00  0.158000E-01
 15   0.502000E+02  0.499901E+02  0.210E+00  0.419845E+00  0.190000E-01
 16   0.455000E+02  0.445012E+02  0.999E+00  0.224438E+01  0.222000E-01
 17   0.414000E+02  0.403118E+02  0.109E+01  0.269952E+01  0.254000E-01
 18   0.374000E+02  0.370399E+02  0.360E+00  0.972163E+00  0.286000E-01
 19   0.321000E+02  0.333070E+02 -0.121E+01 -0.362377E+01  0.334000E-01
 20   0.286000E+02  0.296327E+02 -0.103E+01 -0.348509E+01  0.398000E-01
** RMSERR=  0.14316093E+01

CORRELATION MATRIX
 1  0.1000E+01
 2  0.8378E+00  0.1000E+01
 3 -0.1353E+00 -0.3102E+00  0.1000E+01
 4  0.8603E+00  0.9619E+00 -0.3672E+00  0.1000E+01
 5 -0.8210E+00 -0.8589E+00  0.2387E+00 -0.8981E+00  0.1000E+01

  **PARM_SOL.    STD_ERROR    REL_ERROR     % ERROR **
 1  0.5327E-02  0.1623E-03  0.3046E-01  0.3046E+01
 2  0.3183E-01  0.1355E-02  0.4256E-01  0.4256E+01
 3  0.1853E+00  0.1662E-02  0.8974E-02  0.8974E+00
 4  0.4222E+03  0.4436E-02  0.1051E-04  0.1051E-02
 5  0.2387E+03  0.5186E-02  0.2173E-04  0.2173E-02

PARAMETER NAME        FINAL SOLUTION          RESISTIVITY    LAYER DEPTH
   1   SIGMA( 1) =  0.53270226E-02    1  0.18772212E+03
   2   SIGMA( 2) =  0.31825010E-01    2  0.31421829E+02
   3   SIGMA( 3) =  0.18526085E+00    3  0.53977947E+01
   4   THICK( 1) =  0.42220587E+03                        1  0.42220587E+03
   5   THICK( 2) =  0.23867612E+03                        2  0.66088202E+03
   6   SHIFT     =  0.10000000E+01
```

9a

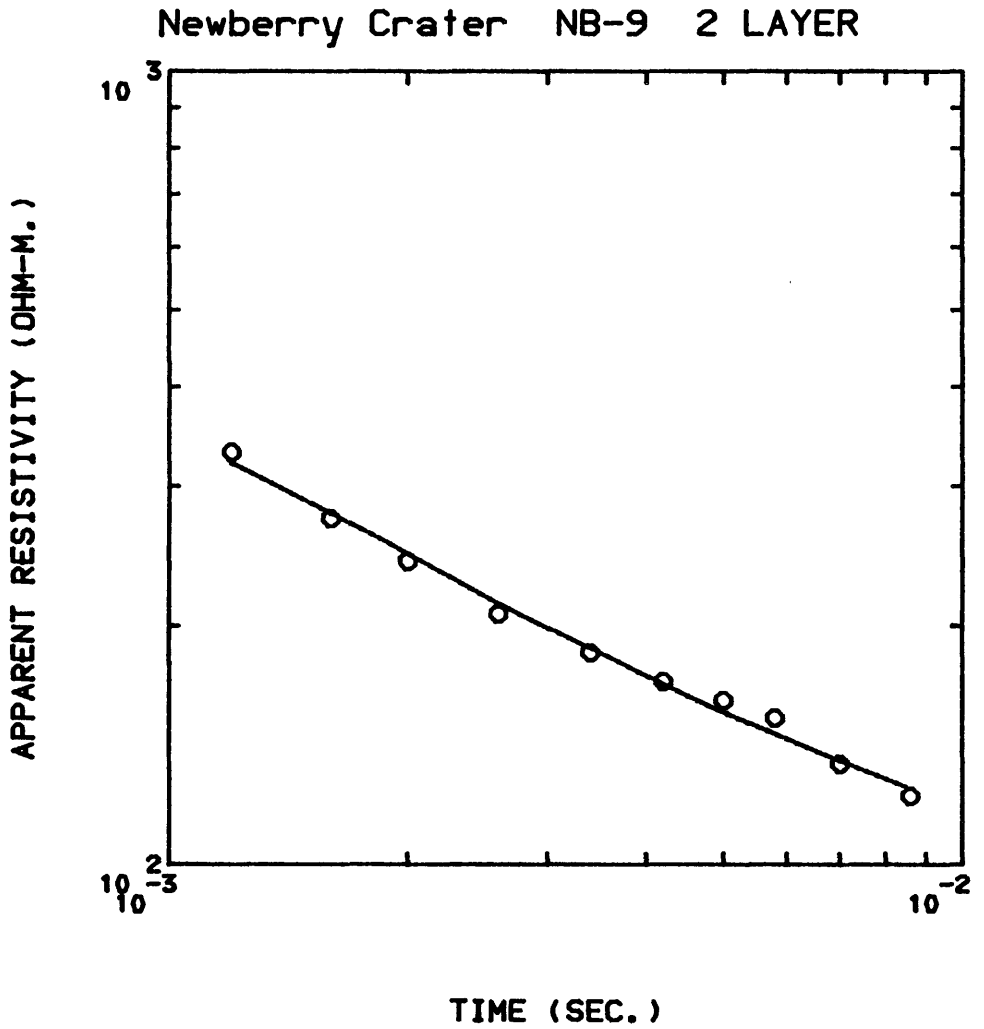

Newberry Crater NB-8 3 layer
APPARENT RESISTIVITY (OHM-M.)
TIME (SEC.)
10^3
10^2
10^1
10^-3
10^-2
10^-1

9b

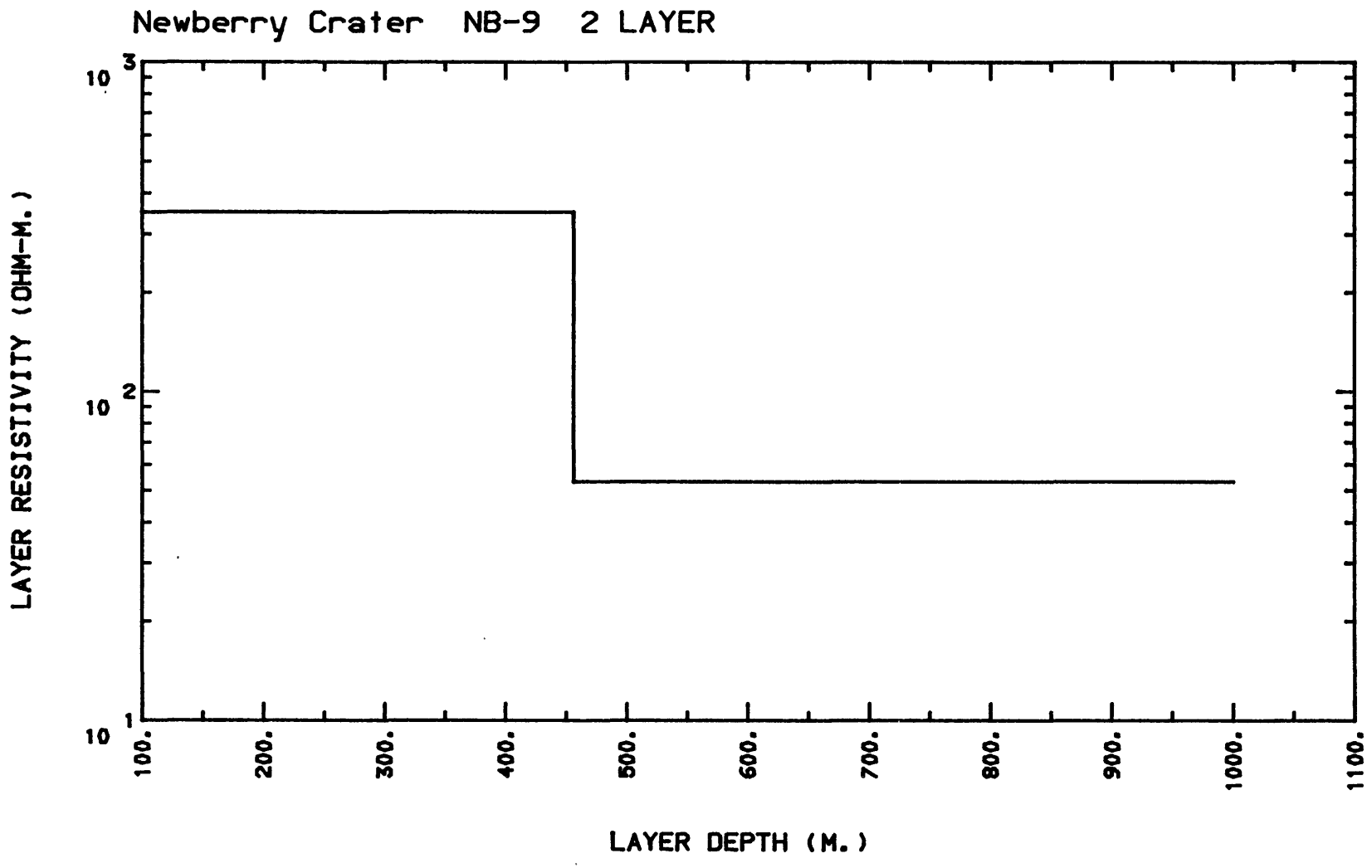

Newberry Crater NB-8 3 layer
LAYER RESISTIVITY (OHM-M.)
10 3
10 2
10 1
10 0
100.
200.
300.
400.
500.
600.
700.
800.
900.
1000.
1100.
LAYER DEPTH (M.)

```
<NLSTCI2>:    Newberry Crater  NB-9  3 layer
A= 0.257900E+03
PARAMETERS HELD FIXED: IB=  6
***** X-CONVERGENCE *****

  I     OBS.Y(I)        CAL             RES         %RES.ERR       X(I,1)
  1  0.331000E+03  0.328833E+03  0.217E+01  0.659051E+00  0.120000E-02
  2  0.273000E+03  0.275666E+03 -0.267E+01 -0.967107E+00  0.160000E-02
  3  0.241000E+03  0.242536E+03 -0.154E+01 -0.633244E+00  0.200000E-02
  4  0.207000E+03  0.210931E+03 -0.393E+01 -0.186361E+01  0.260000E-02
  5  0.185000E+03  0.184592E+03  0.408E+00  0.220757E+00  0.340000E-02
  6  0.170000E+03  0.167674E+03  0.233E+01  0.138740E+01  0.420000E-02
  7  0.161000E+03  0.155699E+03  0.530E+01  0.340489E+01  0.500000E-02
  8  0.153000E+03  0.146641E+03  0.636E+01  0.433638E+01  0.580000E-02
  9  0.134000E+03  0.136456E+03 -0.246E+01 -0.179961E+01  0.700000E-02
 10  0.122000E+03  0.127028E+03 -0.503E+01 -0.395841E+01  0.860000E-02
** RMSERR=  0.51970654E+01

CORRELATION MATRIX
 1  0.1000E+01
 2 -0.3382E+00  0.1000E+01
 3 -0.6829E+00 -0.2451E+00  0.1000E+01
 4 -0.2077E+00  0.4342E-02  0.3834E+00  0.1000E+01
 5 -0.2688E+00  0.3347E+00  0.6868E-01 -0.6915E+00  0.1000E+01

  **PARM_SOL.    STD_ERROR    REL_ERROR     % ERROR **
 1  0.1113E-02  0.5115E-03  0.4595E+00  0.4595E+02
 2  0.5592E-02  0.1418E-02  0.2535E+00  0.2535E+02
 3  0.1645E-01  0.1588E-02  0.9654E-01  0.9654E+01
 4  0.2855E+03  0.5506E-02  0.1929E-04  0.1929E-02
 5  0.1249E+03  0.1284E-01  0.1029E-03  0.1029E-01

PARAMETER NAME       FINAL SOLUTION        RESISTIVITY   LAYER DEPTH
   1   SIGMA( 1) =  0.11131888E-02   1  0.89832019E+03
   2   SIGMA( 2) =  0.55924091E-02   2  0.17881381E+03
   3   SIGMA( 3) =  0.16453654E-01   3  0.60776775E+02
   4   THICK( 1) =  0.28549359E+03                      1  0.28549359E+03
   5   THICK( 2) =  0.12487097E+03                      2  0.41036456E+03
   6   SHIFT     =  0.10000000E+01
```

10a


Newberry Crater NB-9 2 LAYER
APPARENT RESISTIVITY (OHM-M.)
10 3
10 2
10 -3
10 -2
TIME (SEC.)

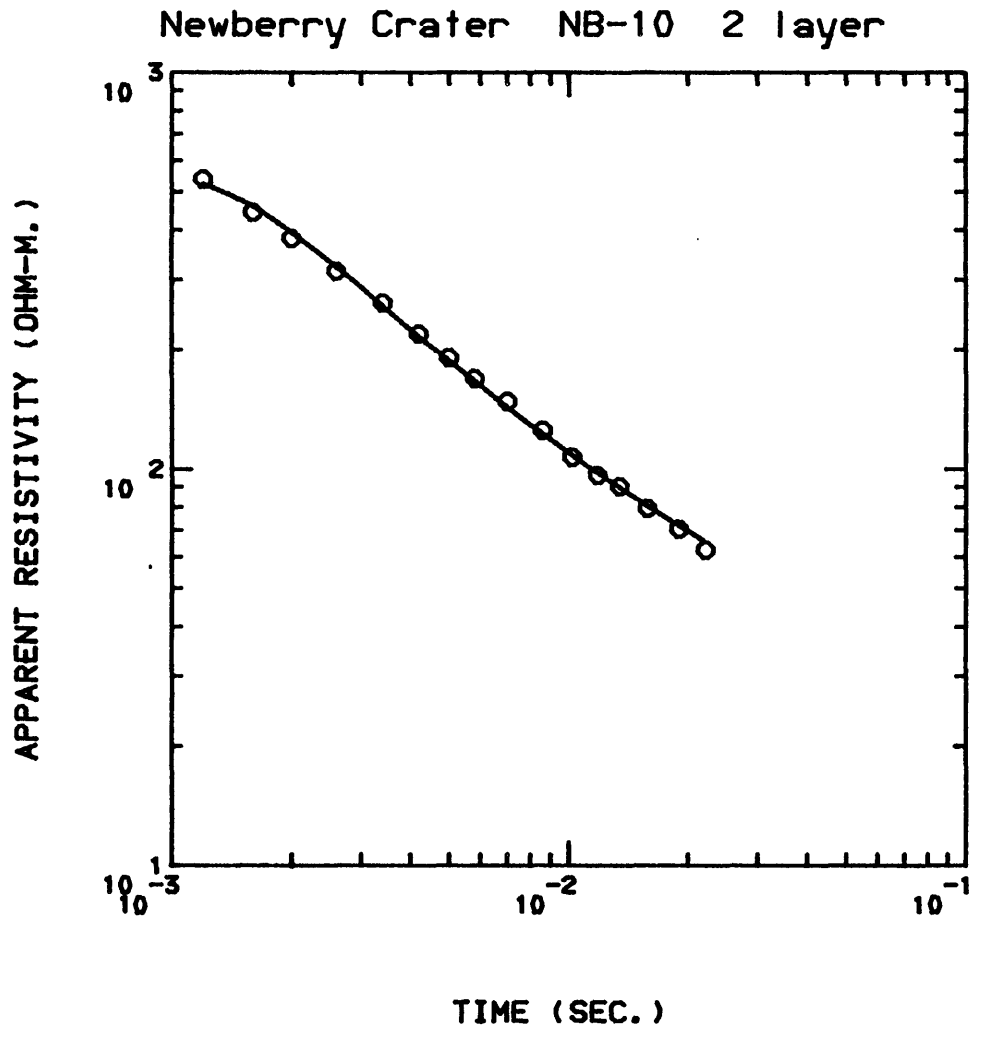
10b


Newberry Crater NB-9 2 LAYER
LAYER RESISTIVITY (OHM-M.)
10 3
10 2
10 1
100.
200.
300.
400.
500.
600.
700.
800.
900.
1000.
1100.
LAYER DEPTH (M.)

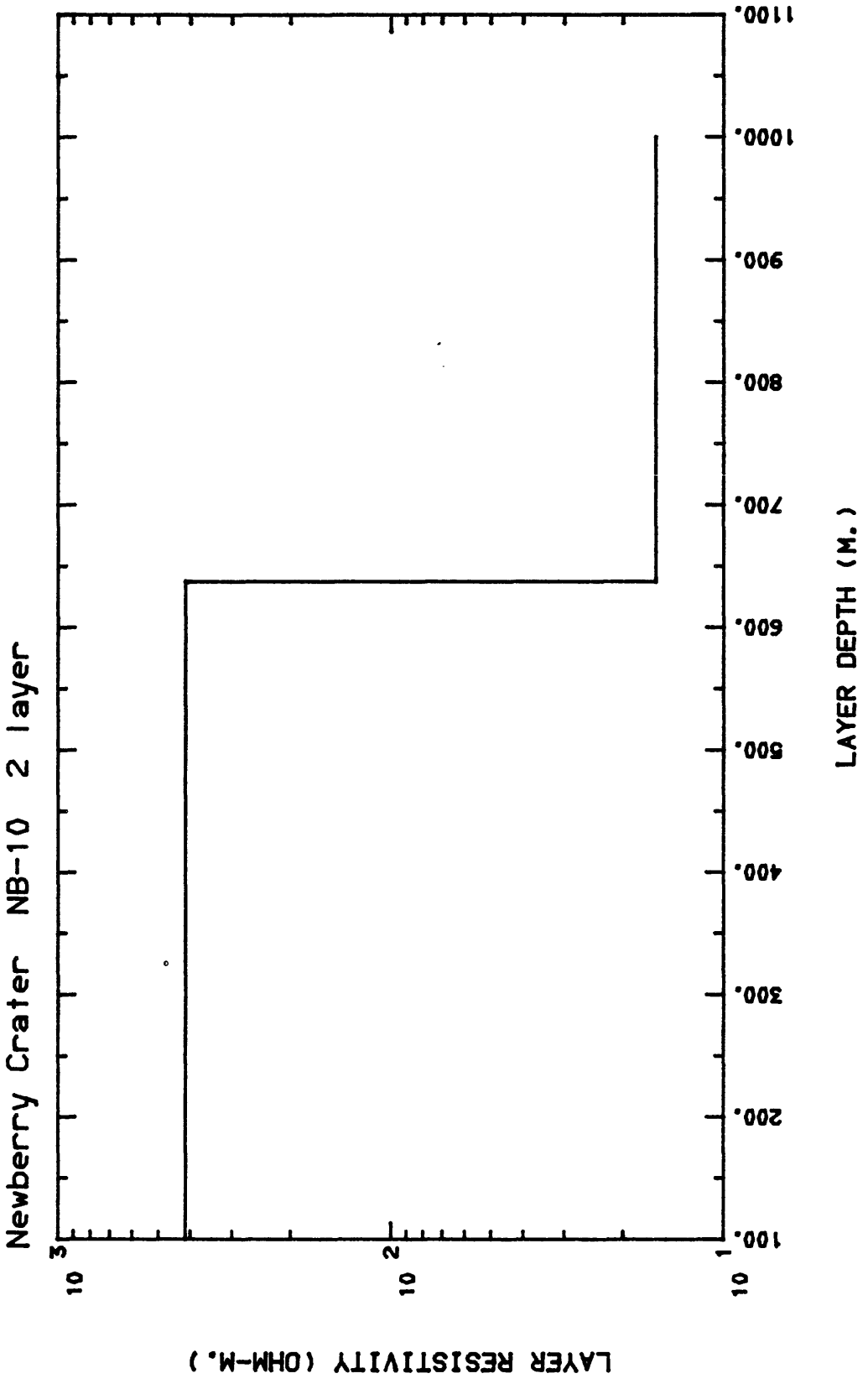
10c

```
<NLSTCI2>:    Newberry Crater  NB-10  2 layer
A= 0.257900E+03
PARAMETERS HELD FIXED: IB=  4
***** VARIABILITY CONVERGENCE *****

  I     OBS.Y(I)        CAL             RES         %RES.ERR       X(I,1)
  1   0.539000E+03  0.523273E+03  0.157E+02  0.300541E+01  0.120000E-02
  2   0.443000E+03  0.457858E+03 -0.149E+02 -0.324510E+01  0.160000E-02
  3   0.381000E+03  0.393085E+03 -0.121E+02 -0.307434E+01  0.200000E-02
  4   0.315000E+03  0.322468E+03 -0.747E+01 -0.231587E+01  0.260000E-02
  5   0.262000E+03  0.256666E+03  0.533E+01  0.207836E+01  0.340000E-02
  6   0.219000E+03  0.215065E+03  0.394E+01  0.182989E+01  0.420000E-02
  7   0.191000E+03  0.187299E+03  0.370E+01  0.197580E+01  0.500000E-02
  8   0.169000E+03  0.166005E+03  0.299E+01  0.180404E+01  0.580000E-02
  9   0.148000E+03  0.142660E+03  0.534E+01  0.374319E+01  0.700000E-02
 10   0.125000E+03  0.122390E+03  0.261E+01  0.213232E+01  0.860000E-02
 11   0.107000E+03  0.108043E+03 -0.104E+01 -0.965572E+00  0.102000E-01
 12   0.962000E+02  0.974934E+02 -0.129E+01 -0.132664E+01  0.118000E-01
 13   0.902000E+02  0.894735E+02  0.726E+00  0.811957E+00  0.134000E-01
 14   0.794000E+02  0.804204E+02 -0.102E+01 -0.126885E+01  0.158000E-01
 15   0.704000E+02  0.717131E+02 -0.131E+01 -0.183098E+01  0.190000E-01
 16   0.624000E+02  0.653913E+02 -0.299E+01 -0.457447E+01  0.222000E-01
** RMSERR=  0.77798038E+01

CORRELATION MATRIX
 1  0.1000E+01
 2 -0.6231E-01  0.1000E+01
 3  0.1745E+00 -0.6711E-01  0.1000E+01

  **PARM_SOL.    STD_ERROR    REL_ERROR     % ERROR **
 1  0.2416E-02  0.7581E-04  0.3138E-01  0.3138E+01
 2  0.6271E-01  0.1437E-02  0.2292E-01  0.2292E+01
 3  0.6375E+03  0.1853E-02  0.2907E-05  0.2907E-03

PARAMETER NAME       FINAL SOLUTION        RESISTIVITY   LAYER DEPTH
   1   SIGMA( 1) =  0.24156065E-02   1  0.41397470E+03
   2   SIGMA( 2) =  0.62712103E-01   2  0.15945886E+02
   3   THICK( 1) =  0.63750897E+03                      1  0.63750897E+03
   4   SHIFT     =  0.10000000E+01
```

11a

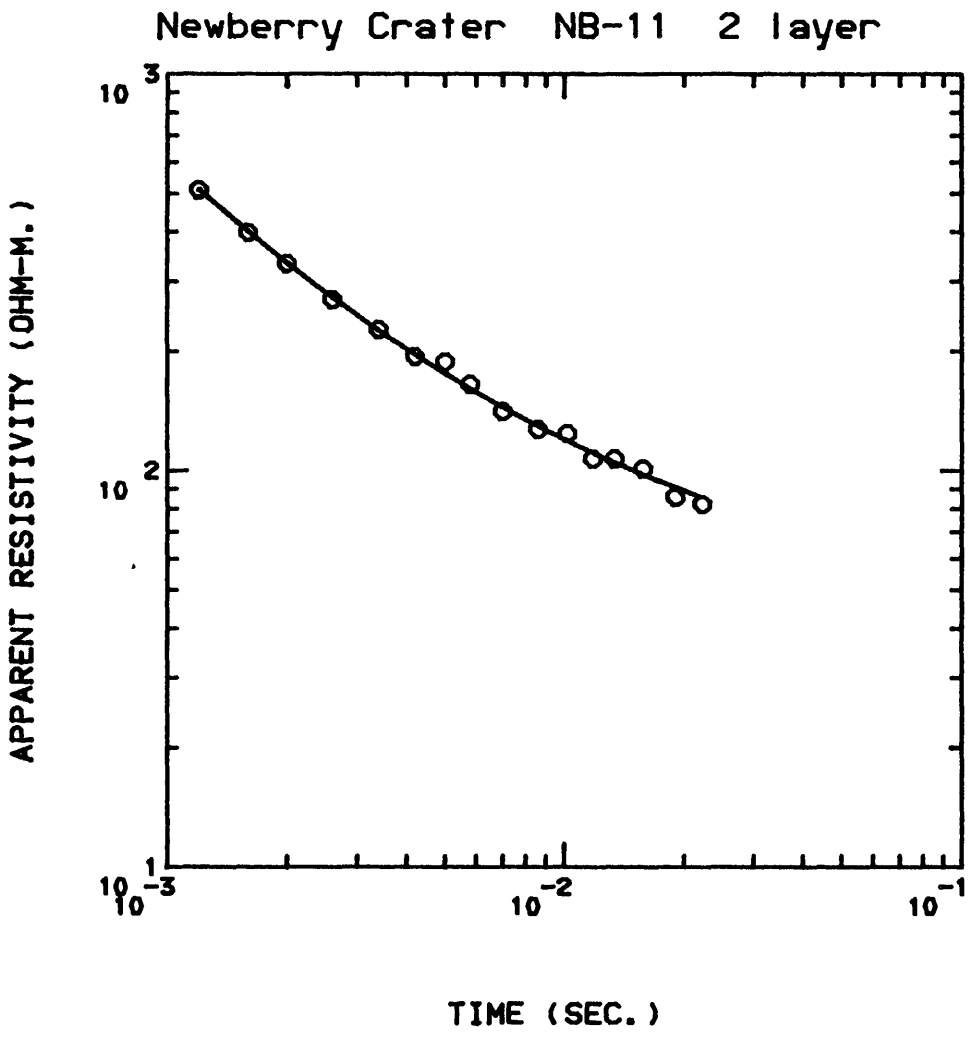

Newberry Crater NB-10 2 layer
APPARENT RESISTIVITY (OHM-M.)
10^3
10^2
10^1
10^-3
10^-2
10^-1
TIME (SEC.)

11C

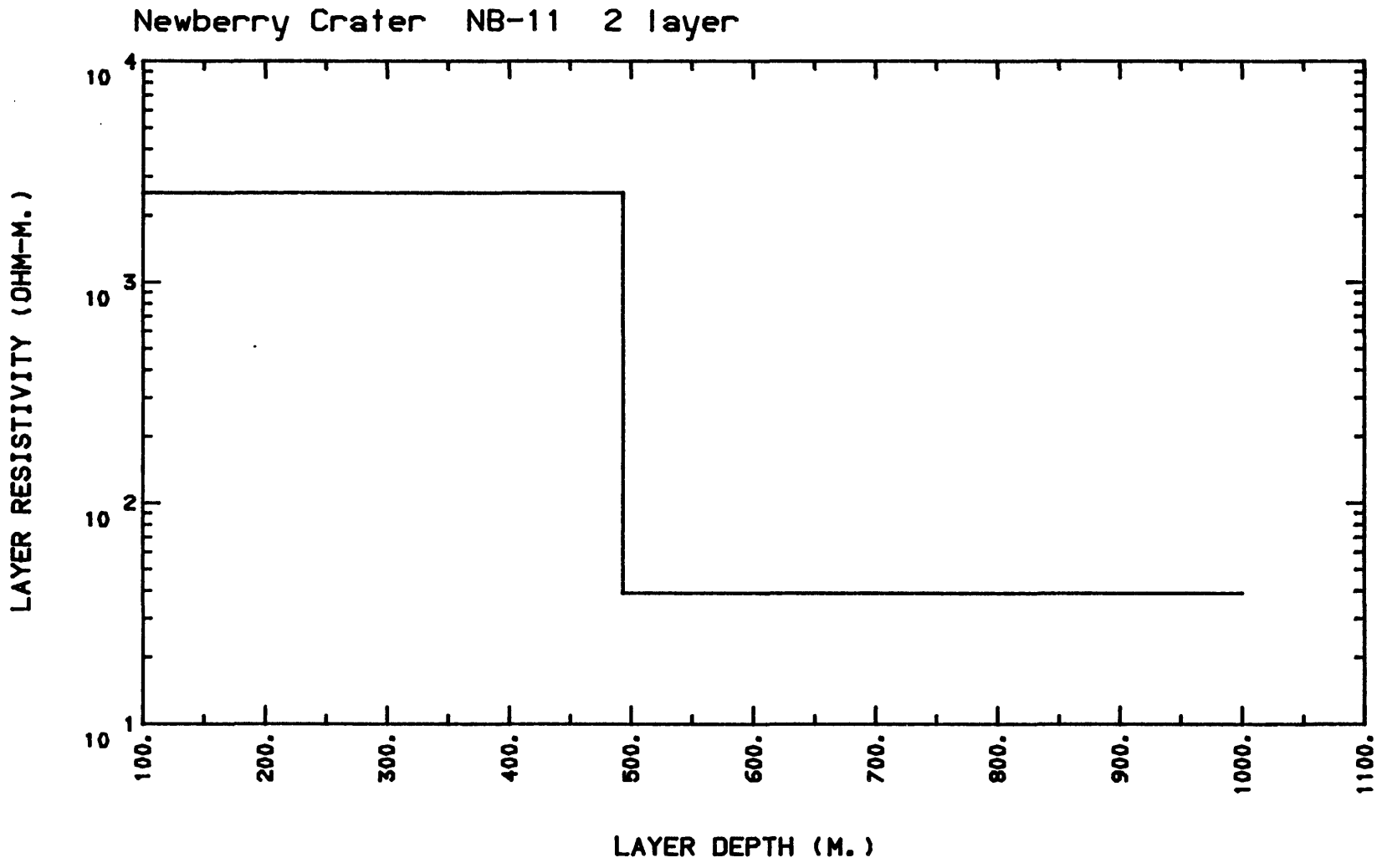

Newberry Crater NB-10 2 layer
LAYER RESISTIVITY (OHM-M.)
LAYER DEPTH (M.)
100.
200.
300.
400.
500.
600.
700.
800.
900.
1000.
1100.
10^1
10^2
10^3

```
<VLSTCI2>:    Newberry Crater  NB-11  2 layer
A= 0.257900E+03
PARAMETERS HELD FIXED: IB=  4
**** X-CONVERGENCE *****

  I     OBS.Y(I)        CAL             RES          %RES.ERR       X(I,1)
  1   0.511000E+03  0.511044E+03 -0.441E-01 -0.863495E-02  0.120000E-02
  2   0.398000E+03  0.400054E+03 -0.205E+01 -0.513450E+00  0.160000E-02
  3   0.333000E+03  0.333795E+03 -0.795E+00 -0.238119E+00  0.200000E-02
  4   0.270000E+03  0.273230E+03 -0.323E+01 -0.118199E+01  0.260000E-02
  5   0.227000E+03  0.225479E+03  0.152E+01  0.674392E+00  0.340000E-02
  6   0.194000E+03  0.195854E+03 -0.185E+01 -0.946533E+00  0.420000E-02
  7   0.188000E+03  0.175486E+03  0.125E+02  0.713130E+01  0.500000E-02
  8   0.165000E+03  0.160469E+03  0.453E+01  0.282360E+01  0.580000E-02
  9   0.141000E+03  0.144145E+03 -0.315E+01 -0.218194E+01  0.700000E-02
 10   0.127000E+03  0.129199E+03 -0.220E+01 -0.170174E+01  0.860000E-02
 11   0.124000E+03  0.118645E+03  0.536E+01  0.451360E+01  0.102000E-01
 12   0.107000E+03  0.110743E+03 -0.374E+01 -0.337975E+01  0.118000E-01
 13   0.107000E+03  0.104595E+03  0.240E+01  0.229900E+01  0.134000E-01
 14   0.101000E+03  0.975181E+02  0.348E+01  0.357051E+01  0.158000E-01
 15   0.856000E+02  0.906268E+02 -0.503E+01 -0.554673E+01  0.190000E-01
 16   0.822000E+02  0.854293E+02 -0.323E+01 -0.378006E+01  0.222000E-01
** RMSERR=  0.48768506E+01

CORRELATION MATRIX
 1  0.1000E+01
 2  0.1796E-01  0.1000E+01
 3  0.2936E+00  0.6251E+00  0.1000E+01

  **PARM_SOL.   STD_ERROR   REL_ERROR    % ERROR **
 1  0.3953E-03  0.7494E-04  0.1896E+00  0.1896E+02
 2  0.2566E-01  0.6324E-03  0.2464E-01  0.2464E+01
 3  0.4935E+03  0.2192E-02  0.4441E-05  0.4441E-03

PARAMETER NAME       FINAL SOLUTION        RESISTIVITY   LAYER DEPTH
   1   SIGMA( 1) =  0.39529626E-03   1  0.25297483E+04
   2   SIGMA( 2) =  0.25664145E-01   2  0.38964867E+02
   3   THICK( 1) =  0.49351880E+03                      1  0.49351880E+03
   4   SHIFT     =  0.10000000E+01
```

12a

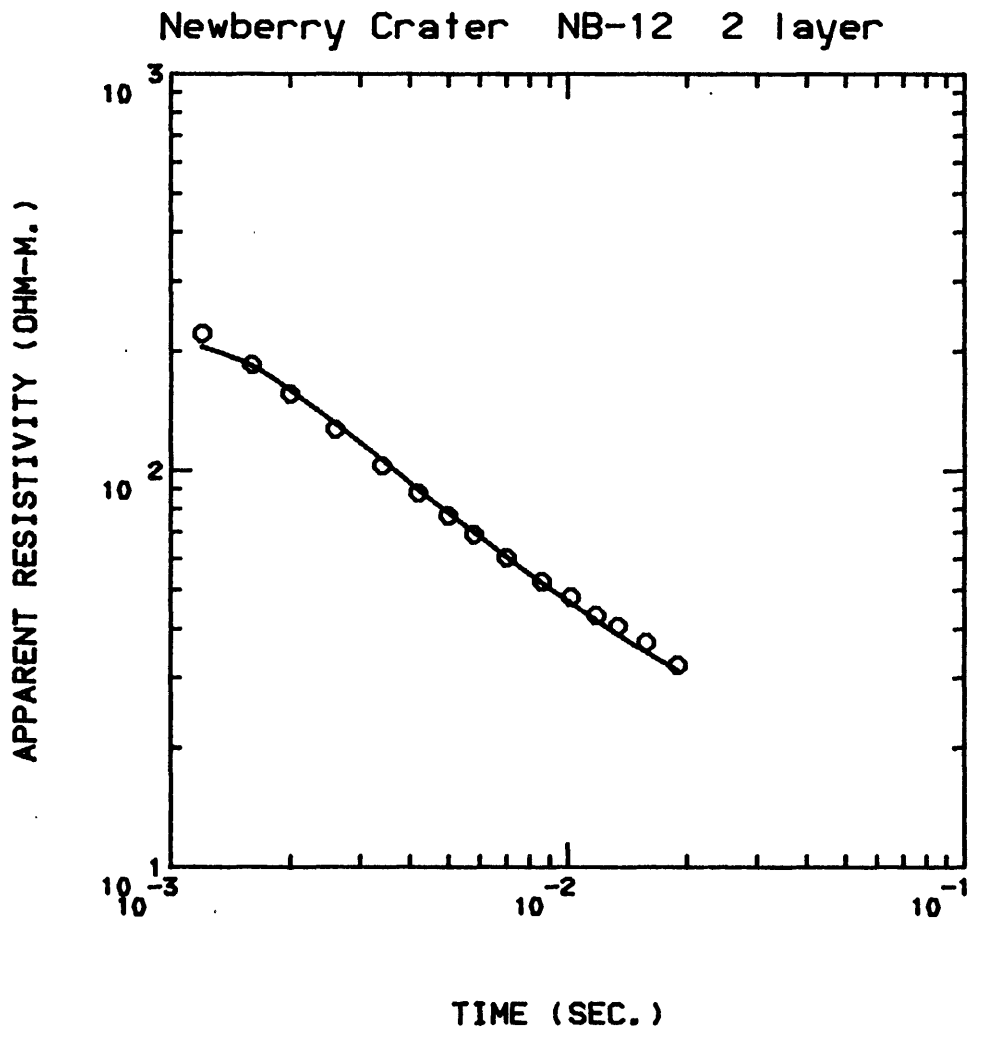

Newberry Crater NB-11 2 layer
APPARENT RESISTIVITY (OHM-M.)
10^3
10^2
10^1
10^-3
10^-2
10^-1
TIME (SEC.)

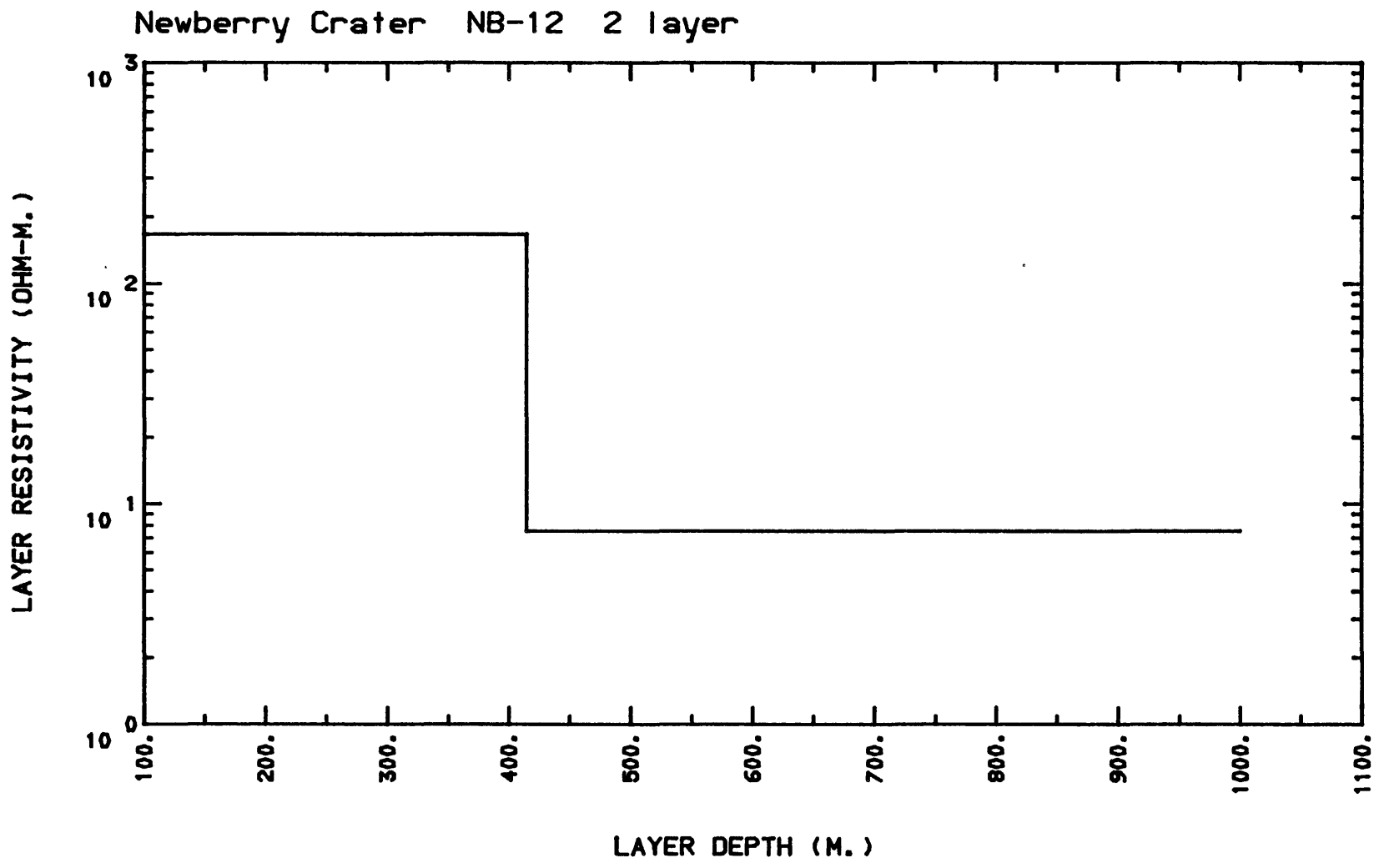
12b


Newberry Crater NB-11 2 layer
LAYER RESISTIVITY (OHM-M.)
10 4
10 3
10 2
10 1
100.
200.
300.
400.
500.
600.
700.
800.
900.
1000.
1100.
LAYER DEPTH (M.)

```
<NLSTCI2>:    Newberry Crater  NB-12  2 layer
A= 0.129000E+03
PARAMETERS HELD FIXED: IB=  4
***** X-CONVERGENCE *****

  I     OBS.Y(I)        CAL             RES          %RES.ERR       X(I,1)
  1   0.222000E+03  0.205097E+03  0.169E+02  0.824121E+01  0.120000E-02
  2   0.185000E+03  0.183050E+03  0.195E+01  0.106537E+01  0.160000E-02
  3   0.156000E+03  0.158874E+03 -0.287E+01 -0.180923E+01  0.200000E-02
  4   0.127000E+03  0.131147E+03 -0.415E+01 -0.316236E+01  0.260000E-02
  5   0.103000E+03  0.106417E+03 -0.342E+01 -0.321052E+01  0.340000E-02
  6   0.879000E+02  0.893017E+02 -0.140E+01 -0.156963E+01  0.420000E-02
  7   0.770000E+02  0.780401E+02 -0.104E+01 -0.133277E+01  0.500000E-02
  8   0.690000E+02  0.698488E+02 -0.849E+00 -0.121518E+01  0.580000E-02
  9   0.603000E+02  0.603924E+02 -0.924E-01 -0.152967E+00  0.700000E-02
 10   0.525000E+02  0.520053E+02  0.495E+00  0.951281E+00  0.860000E-02
 11   0.480000E+02  0.462502E+02  0.175E+01  0.378337E+01  0.102000E-01
 12   0.432000E+02  0.419067E+02  0.129E+01  0.308620E+01  0.118000E-01
 13   0.406000E+02  0.385644E+02  0.204E+01  0.527852E+01  0.134000E-01
 14   0.369000E+02  0.348168E+02  0.208E+01  0.598340E+01  0.158000E-01
 15   0.323000E+02  0.312262E+02  0.107E+01  0.343866E+01  0.190000E-01
** RMSERR=  0.53620958E+01

CORRELATION MATRIX
 1  0.1000E+01
 2  0.2146E+00  0.1000E+01
 3 -0.6170E+00  0.9738E-01  0.1000E+01

  **PARM_SOL.   STD_ERROR   REL_ERROR    % ERROR **
 1  0.6000E-02  0.1981E-03  0.3302E-01  0.3302E+01
 2  0.1330E+00  0.3297E-02  0.2478E-01  0.2478E+01
 3  0.4147E+03  0.2822E-02  0.6807E-05  0.6807E-03

PARAMETER NAME       FINAL SOLUTION        RESISTIVITY   LAYER DEPTH
   1   SIGMA( 1) =  0.59996559E-02   1  0.16667622E+03
   2   SIGMA( 2) =  0.13302813E+00   2  0.75172067E+01
   3   THICK( 1) =  0.41465356E+03                      1  0.41465356E+03
   4   SHIFT     =  0.10000000E+01
```

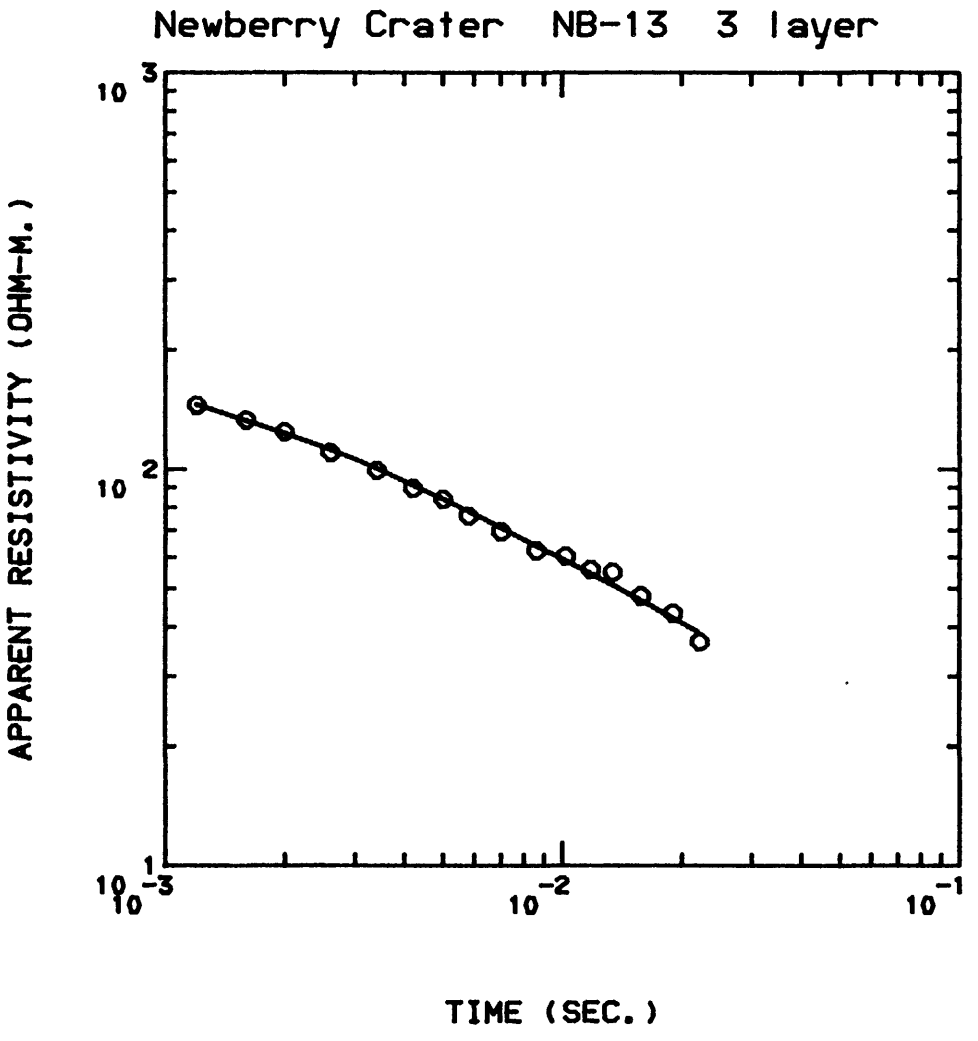
13a

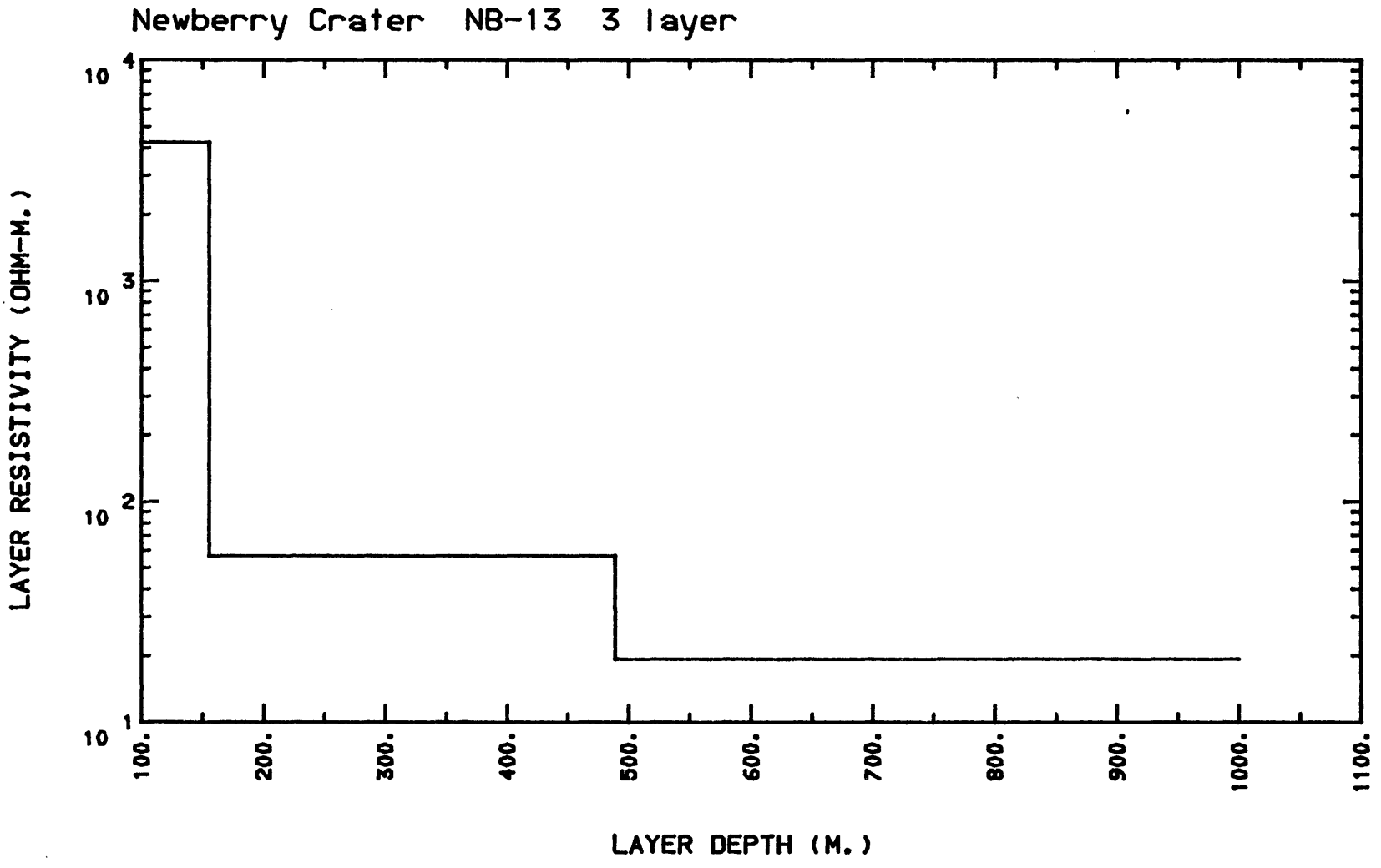

Newberry Crater NB-12 2 layer
APPARENT RESISTIVITY (OHM-M.)
TIME (SEC.)
10^3
10^2
10^1
10^-3
10^-2
10^-1


Newberry Crater NB-12 2 layer
LAYER RESISTIVITY (OHM-M.)
10 3
10 2
10 1
10 0
100.
200.
300.
400.
500.
600.
700.
800.
900.
1000.
1100.
LAYER DEPTH (M.)

```
<NLSTCI2>:    Newberry Crater  NB-13  3 layer
A= 0.129000E+03
PARAMETERS HELD FIXED: IB=  6
***** X-CONVERGENCE *****

  I     OBS.Y(I)        CAL             RES          %RES.ERR       X(I,1)
  1   0.145000E+03  0.145252E+03 -0.252E+00 -0.173659E+00  0.120000E-02
  2   0.133000E+03  0.132123E+03  0.877E+00  0.663670E+00  0.160000E-02
  3   0.124000E+03  0.122460E+03  0.154E+01  0.125743E+01  0.200000E-02
  4   0.110000E+03  0.111647E+03 -0.165E+01 -0.147520E+01  0.260000E-02
  5   0.992000E+02  0.100071E+03 -0.871E+00 -0.870052E+00  0.340000E-02
  6   0.894000E+02  0.907704E+02 -0.137E+01 -0.150974E+01  0.420000E-02
  7   0.840000E+02  0.837284E+02  0.272E+00  0.324390E+00  0.500000E-02
  8   0.761000E+02  0.779535E+02 -0.185E+01 -0.237766E+01  0.580000E-02
  9   0.695000E+02  0.708854E+02 -0.139E+01 -0.195437E+01  0.700000E-02
 10   0.623000E+02  0.638322E+02 -0.153E+01 -0.240033E+01  0.860000E-02
 11   0.603000E+02  0.585505E+02  0.175E+01  0.298807E+01  0.102000E-01
 12   0.558000E+02  0.543315E+02  0.147E+01  0.270278E+01  0.118000E-01
 13   0.549000E+02  0.508654E+02  0.403E+01  0.793187E+01  0.134000E-01
 14   0.479000E+02  0.465727E+02  0.133E+01  0.284992E+01  0.158000E-01
 15   0.433000E+02  0.420429E+02  0.126E+01  0.299014E+01  0.190000E-01
 16   0.367000E+02  0.386602E+02 -0.196E+01 -0.507042E+01  0.222000E-01
** RMSERR=  0.20227797E+01

CORRELATION MATRIX
 1  0.1000E+01
 2 -0.6194E+00  0.1000E+01
 3 -0.1043E+00 -0.4634E+00  0.1000E+01
 4 -0.5828E+00  0.9288E+00 -0.5044E+00  0.1000E+01
 5  0.5709E+00 -0.8789E+00  0.1984E+00 -0.8589E+00  0.1000E+01

  **PARM_SOL.    STD_ERROR    REL_ERROR     % ERROR **
 1  0.2360E-03  0.6390E-04  0.2707E+00  0.2707E+02
 2  0.1770E-01  0.6303E-03  0.3560E-01  0.3560E+01
 3  0.5187E-01  0.1506E-02  0.2904E-01  0.2904E+01
 4  0.1557E+03  0.5029E-02  0.3229E-04  0.3229E-02
 5  0.3333E+03  0.1019E-01  0.3056E-04  0.3056E-02

PARAMETER NAME        FINAL SOLUTION          RESISTIVITY   LAYER DEPTH
   1   SIGMA( 1) =  0.23603022E-03   1  0.42367456E+04
   2   SIGMA( 2) =  0.17703634E-01   2  0.56485580E+02
   3   SIGMA( 3) =  0.51869310E-01   3  0.19279222E+02
   4   THICK( 1) =  0.15571378E+03                      1  0.15571378E+03
   5   THICK( 2) =  0.33328336E+03                      2  0.48899713E+03
   6   SHIFT     =  0.10000000E+01
```

14a

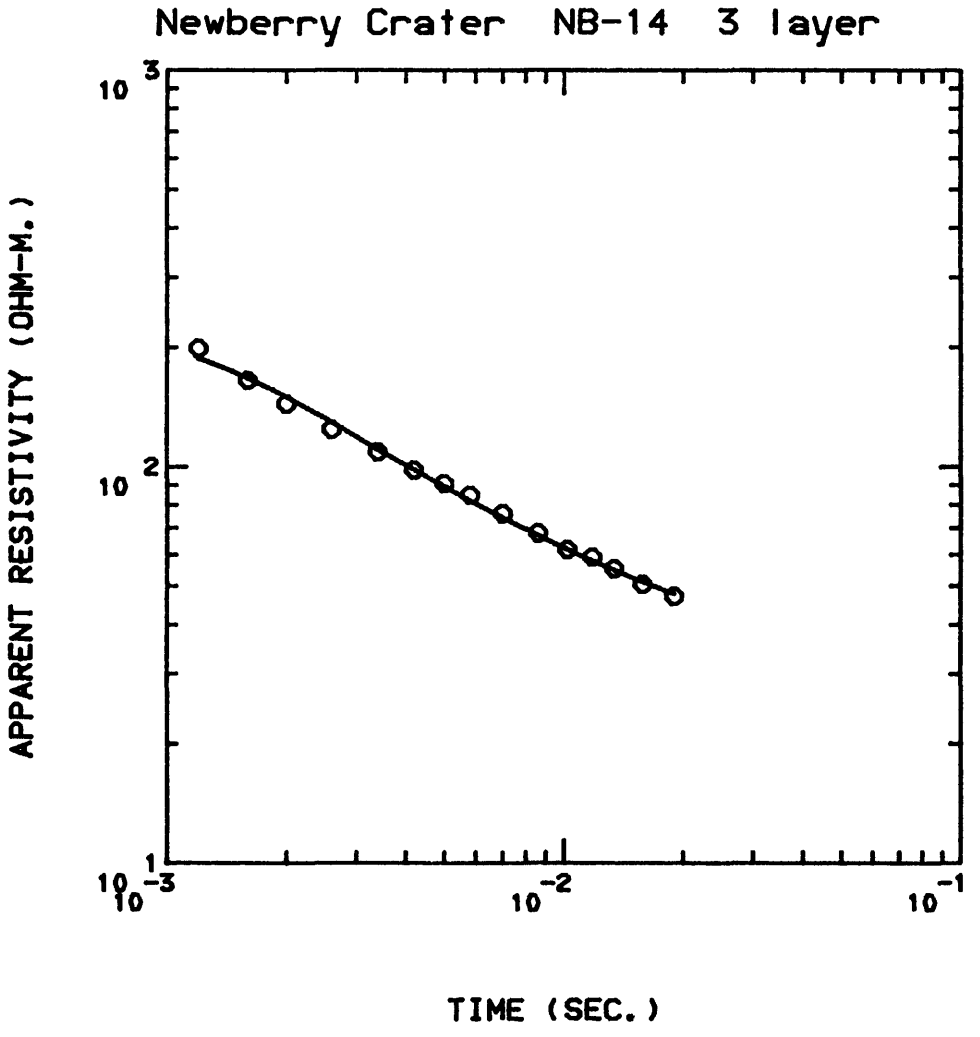

Newberry Crater NB-13 3 layer
APPARENT RESISTIVITY (OHM-M.)
TIME (SEC.)
10^3
10^2
10^1
10^-3
10^-2
10^-1

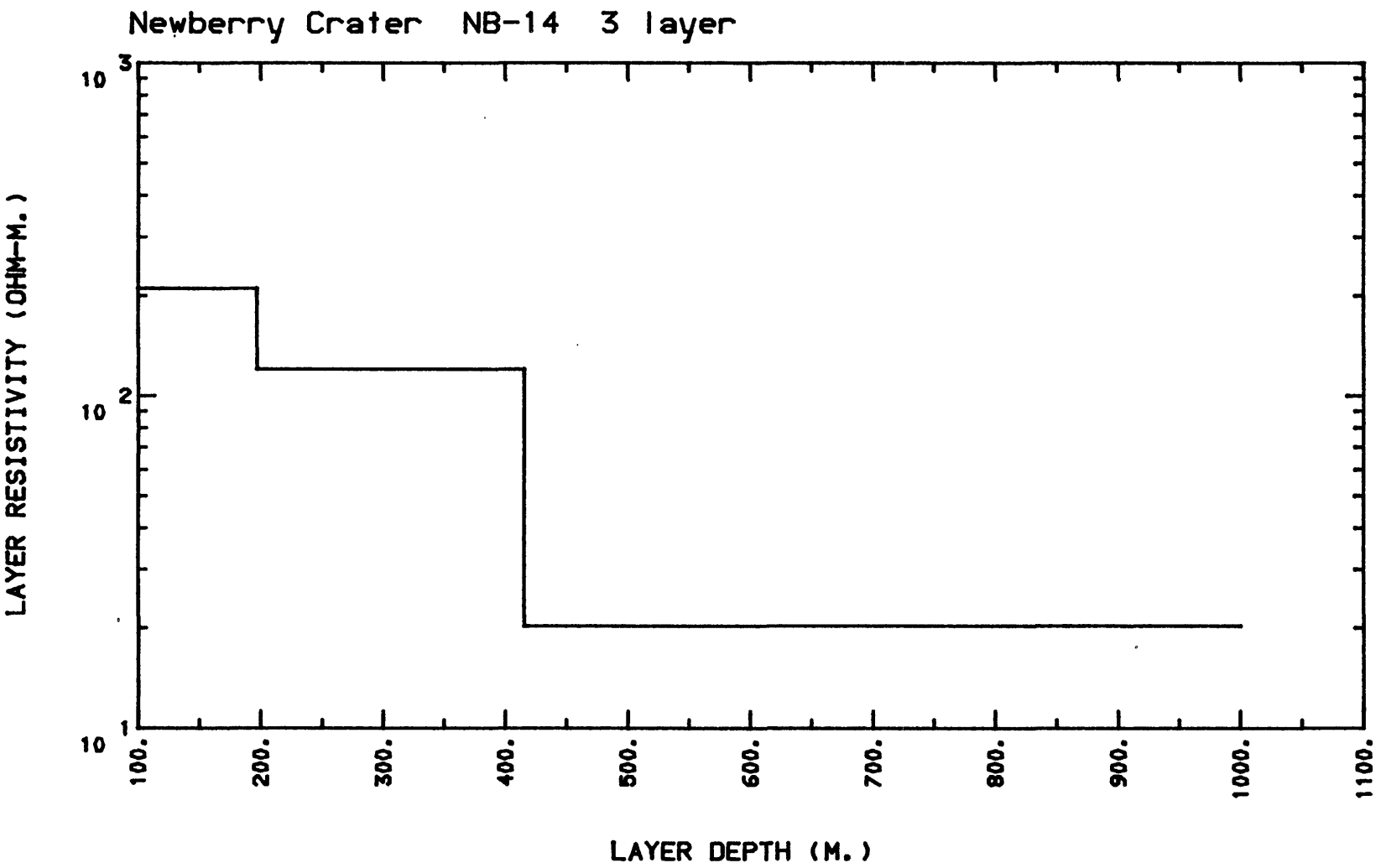

Newberry Crater NB-13 3 layer
LAYER RESISTIVITY (OHM-M.)
10 4
10 3
10 2
10 1
100.
200.
300.
400.
500.
600.
700.
800.
900.
1000.
1100.
LAYER DEPTH (M.)

14c

```
<NLSTCI2>:    Newberry Crater  NB-14  3 layer
A= 0.129000E+03
PARAMETERS HELD FIXED: IB=  6
***** X-CONVERGENCE *****

  I     OBS.Y(I)        CAL             RES         %RES.ERR       X(I,1)
  1   0.199000E+03  0.187446E+03  0.116E+02  0.616379E+01  0.120000E-02
  2   0.165000E+03  0.166806E+03 -0.181E+01 -0.108241E+01  0.160000E-02
  3   0.144000E+03  0.149318E+03 -0.532E+01 -0.356172E+01  0.200000E-02
  4   0.124000E+03  0.129179E+03 -0.518E+01 -0.400936E+01  0.260000E-02
  5   0.109000E+03  0.110290E+03 -0.129E+01 -0.116925E+01  0.340000E-02
  6   0.981000E+02  0.981234E+02 -0.234E-01 -0.238080E-01  0.420000E-02
  7   0.908000E+02  0.890088E+02  0.179E+01  0.201238E+01  0.500000E-02
  8   0.848000E+02  0.818478E+02  0.295E+01  0.360688E+01  0.580000E-02
  9   0.761000E+02  0.741803E+02  0.192E+01  0.258784E+01  0.700000E-02
 10   0.680000E+02  0.670097E+02  0.990E+00  0.147782E+01  0.860000E-02
 11   0.618000E+02  0.617186E+02  0.812E-01  0.131502E+00  0.102000E-01
 12   0.592000E+02  0.577922E+02  0.141E+01  0.243600E+01  0.118000E-01
 13   0.553000E+02  0.547372E+02  0.563E+00  0.102815E+01  0.134000E-01
 14   0.506000E+02  0.511800E+02 -0.580E+00 -0.113323E+01  0.158000E-01
 15   0.472000E+02  0.477131E+02 -0.513E+00 -0.107538E+01  0.190000E-01
** RMSERR=  0.46153741E+01

CORRELATION MATRIX
 1  0.1000E+01
 2  0.1015E-01  0.1000E+01
 3 -0.1733E+00 -0.5940E+00  0.1000E+01
 4 -0.1797E-01  0.3896E+00 -0.2776E+00  0.1000E+01
 5  0.6491E-01 -0.5181E+00  0.2617E+00 -0.8175E+00  0.1000E+01

  **PARM_SOL.    STD_ERROR    REL_ERROR     % ERROR **
 1  0.4759E-02  0.9058E-04  0.1903E-01  0.1903E+01
 2  0.8331E-02  0.4777E-03  0.5735E-01  0.5735E+01
 3  0.4932E-01  0.9405E-03  0.1907E-01  0.1907E+01
 4  0.1971E+03  0.3820E-02  0.1938E-04  0.1938E-02
 5  0.2184E+03  0.4690E-02  0.2147E-04  0.2147E-02

PARAMETER NAME        FINAL SOLUTION          RESISTIVITY    LAYER DEPTH
   1   SIGMA( 1) =  0.47591785E-02    1  0.21012030E+03
   2   SIGMA( 2) =  0.83308360E-02    2  0.12003597E+03
   3   SIGMA( 3) =  0.49321495E-01    3  0.20275135E+02
   4   THICK( 1) =  0.19714076E+03                      1  0.19714076E+03
   5   THICK( 2) =  0.21840993E+03                      2  0.41555069E+03
   6   SHIFT     =  0.10000000E+01
```

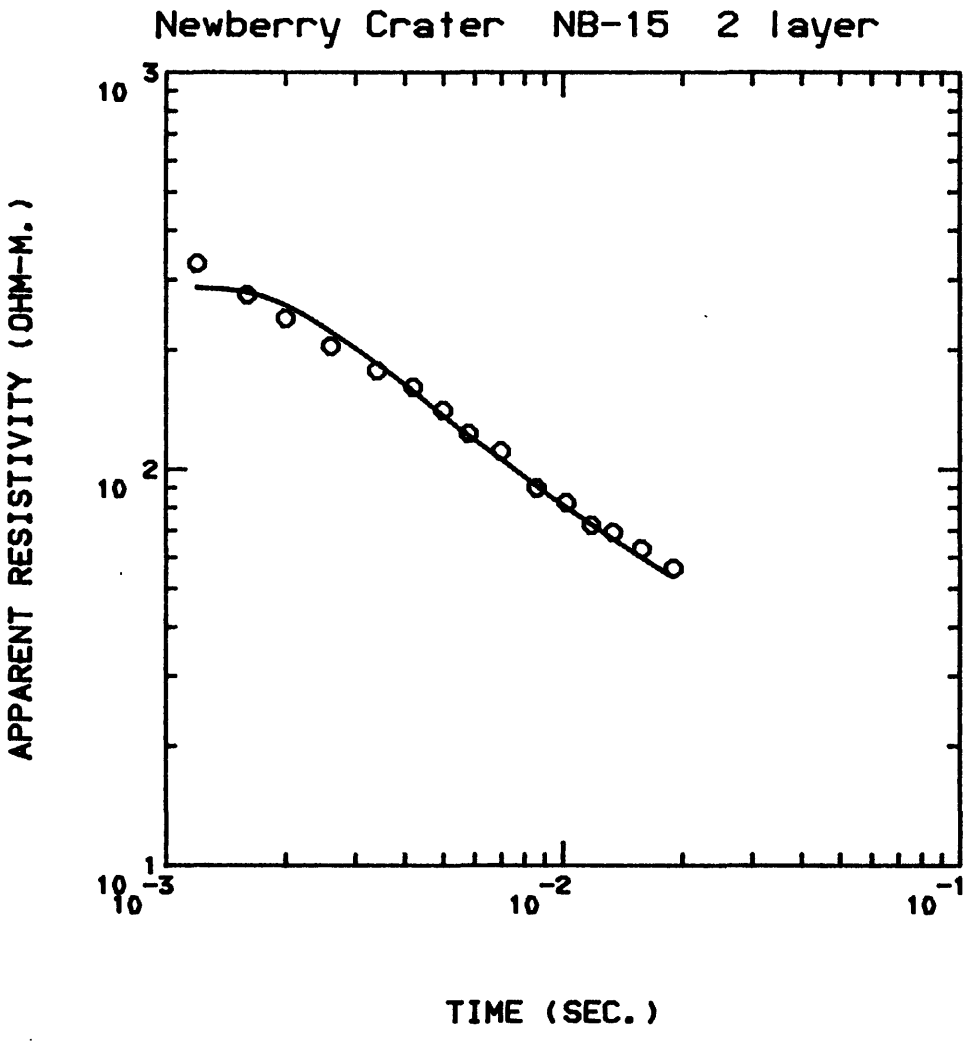
15a


Newberry Crater NB-14 3 layer
APPARENT RESISTIVITY (OHM-M.)
10^3
10^2
10^1
10^-3
10^-2
10^-1
TIME (SEC.)

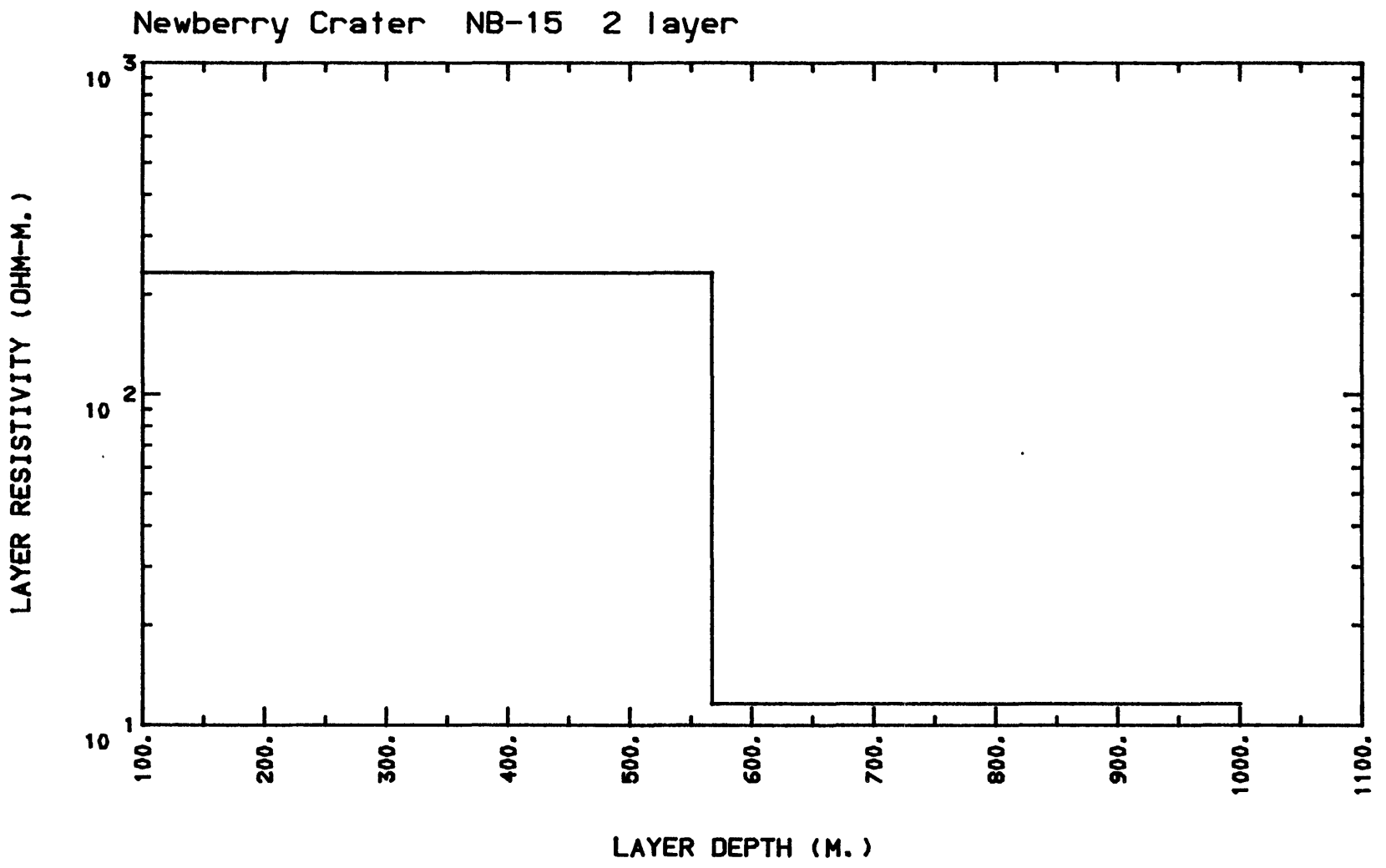

Newberry Crater NB-14 3 layer
LAYER RESISTIVITY (OHM-M.)
10 3
10 2
10 1
100.
200.
300.
400.
500.
600.
700.
800.
900.
1000.
1100.
LAYER DEPTH (M.)

```
<NLSTCI2>:    Newberry Crater  NB-15  2 layer
A= 0.129000E+03
PARAMETERS HELD FIXED: IB=  4
***** X-CONVERGENCE *****

  I     OBS.Y(I)       CAL            RES         %RES.ERR       X(I,1)
  1  0.330000E+03  0.286423E+03  0.436E+02  0.152142E+02  0.120000E-02
  2  0.275000E+03  0.278239E+03 -0.324E+01 -0.116421E+01  0.160000E-02
  3  0.240000E+03  0.258164E+03 -0.182E+02 -0.703567E+01  0.200000E-02
  4  0.204000E+03  0.221843E+03 -0.178E+02 -0.804305E+01  0.260000E-02
  5  0.177000E+03  0.184055E+03 -0.706E+01 -0.383316E+01  0.340000E-02
  6  0.161000E+03  0.157122E+03  0.388E+01  0.246810E+01  0.420000E-02
  7  0.141000E+03  0.136316E+03  0.468E+01  0.343587E+01  0.500000E-02
  8  0.123000E+03  0.121359E+03  0.164E+01  0.135216E+01  0.580000E-02
  9  0.111000E+03  0.105800E+03  0.520E+01  0.491459E+01  0.700000E-02
 10  0.897000E+02  0.905564E+02 -0.856E+00 -0.945700E+00  0.860000E-02
 11  0.824000E+02  0.799727E+02  0.243E+01  0.303516E+01  0.102000E-01
 12  0.722000E+02  0.724338E+02 -0.234E+00 -0.322792E+00  0.118000E-01
 13  0.693000E+02  0.665638E+02  0.274E+01  0.411068E+01  0.134000E-01
 14  0.630000E+02  0.597228E+02  0.328E+01  0.548733E+01  0.158000E-01
 15  0.563000E+02  0.532646E+02  0.304E+01  0.569878E+01  0.190000E-01
** RMSERR=  0.15023120E+02

CORRELATION MATRIX
 1  0.1000E+01
 2 -0.1627E+00  0.1000E+01
 3  0.1351E+00 -0.8361E-01  0.1000E+01

  **PARM_SOL.    STD_ERROR    REL_ERROR     % ERROR **
 1  0.4304E-02  0.1858E-03  0.4317E-01  0.4317E+01
 2  0.8631E-01  0.2860E-02  0.3314E-01  0.3314E+01
 3  0.5672E+03  0.3545E-02  0.6250E-05  0.6250E-03

PARAMETER NAME       FINAL SOLUTION         RESISTIVITY   LAYER DEPTH
   1   SIGMA( 1) =  0.43036090E-02   1  0.23236311E+03
   2   SIGMA( 2) =  0.86310074E-01   2  0.11586133E+02
   3   THICK( 1) =  0.56717145E+03                      1  0.56717145E+03
   4   SHIFT     =  0.10000000E+01
```

16a

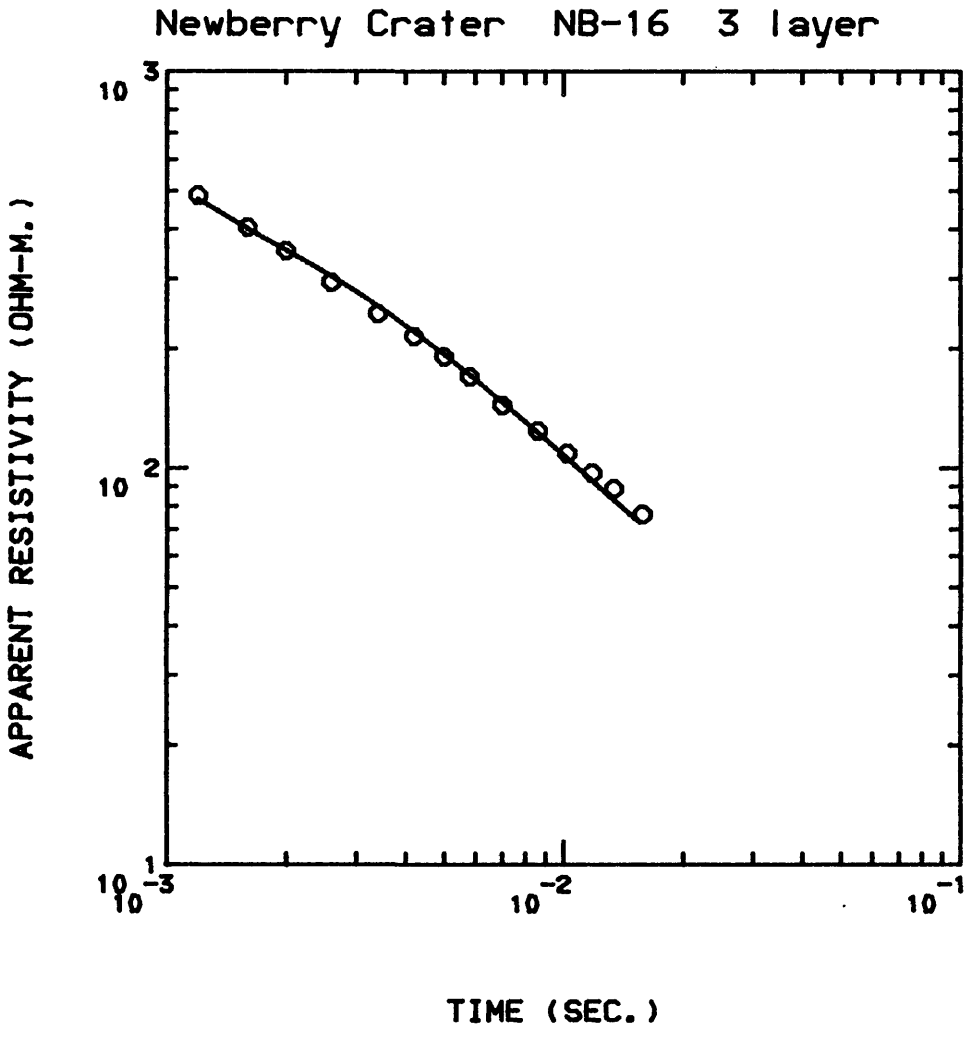

Newberry Crater NB-15 2 layer
APPARENT RESISTIVITY (OHM-M.)
TIME (SEC.)
10^3
10^2
10^1
10^-3
10^-2
10^-1

16b

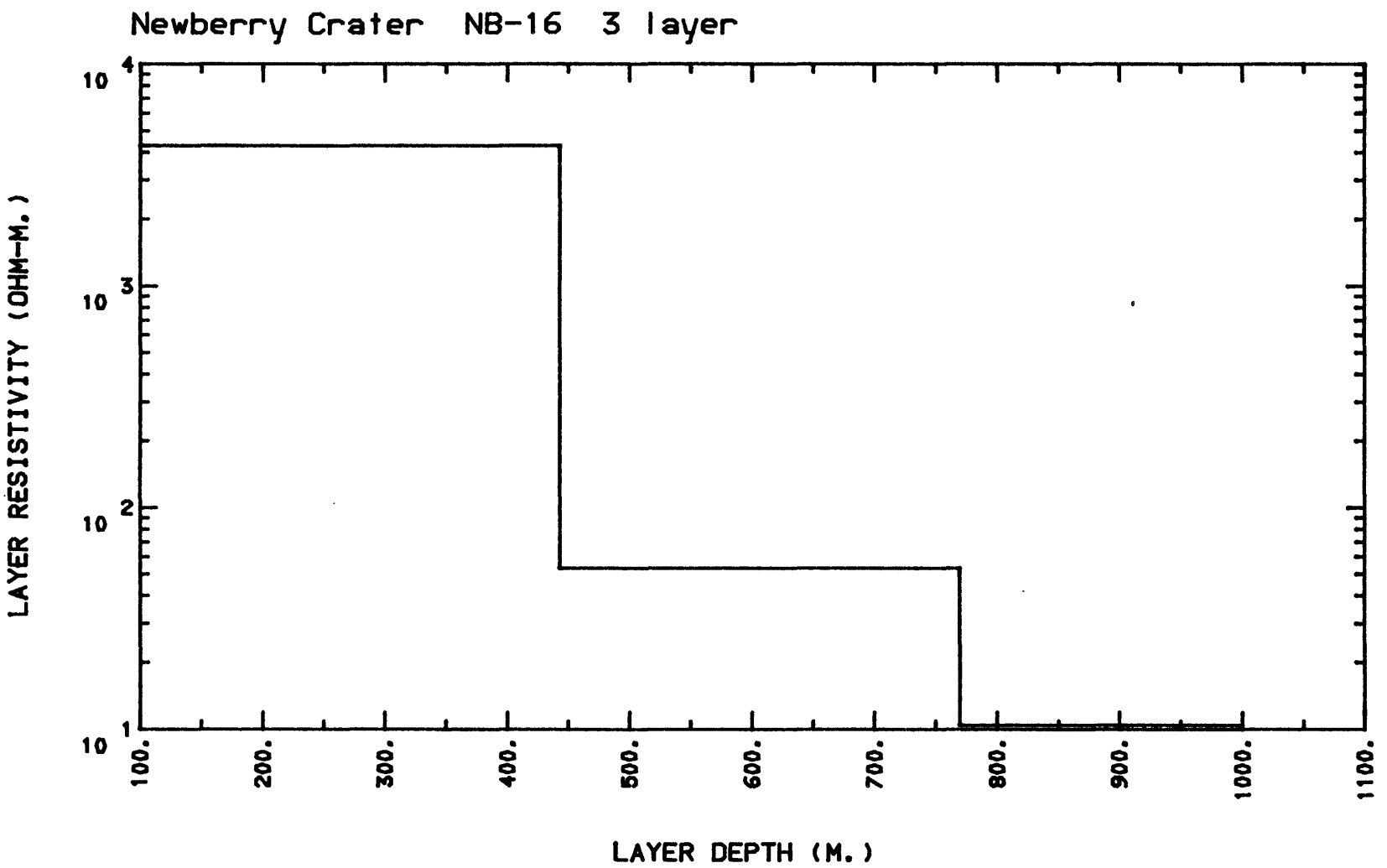

Newberry Crater NB-15 2 layer
LAYER RESISTIVITY (OHM-M.)
10 3
10 2
10 1
100.
200.
300.
400.
500.
600.
700.
800.
900.
1000.
1100.
LAYER DEPTH (M.)

```
<NLSTCI2>:    Newberry Crater  NB-16  3 layer
A= 0.129000E+03
PARAMETERS HELD FIXED: IB=  6
***** X-CONVERGENCE *****

  I     OBS.Y(I)        CAL             RES          %RES.ERR       X(I,1)
  1   0.487000E+03  0.475804E+03  0.112E+02  0.235300E+01  0.120000E-02
  2   0.404000E+03  0.399945E+03  0.405E+01  0.101380E+01  0.160000E-02
  3   0.353000E+03  0.353157E+03 -0.157E+00 -0.443302E-01  0.200000E-02
  4   0.294000E+03  0.303925E+03 -0.992E+01 -0.326556E+01  0.260000E-02
  5   0.245000E+03  0.255699E+03 -0.107E+02 -0.418405E+01  0.340000E-02
  6   0.215000E+03  0.220194E+03 -0.519E+01 -0.235905E+01  0.420000E-02
  7   0.191000E+03  0.193154E+03 -0.215E+01 -0.111529E+01  0.500000E-02
  8   0.170000E+03  0.171463E+03 -0.146E+01 -0.853279E+00  0.580000E-02
  9   0.144000E+03  0.146226E+03 -0.223E+01 -0.152241E+01  0.700000E-02
 10   0.124000E+03  0.122622E+03  0.138E+01  0.112376E+01  0.860000E-02
 11   0.109000E+03  0.105664E+03  0.334E+01  0.315670E+01  0.102000E-01
 12   0.973000E+02  0.927126E+02  0.459E+01  0.494793E+01  0.118000E-01
 13   0.888000E+02  0.827934E+02  0.601E+01  0.725497E+01  0.134000E-01
 14   0.764000E+02  0.714898E+02  0.491E+01  0.686846E+01  0.158000E-01
** RMSERR=  0.73616719E+01

CORRELATION MATRIX
 1  0.1000E+01
 2 -0.7277E+00  0.1000E+01
 3 -0.8195E+00  0.5012E+00  0.1000E+01
 4 -0.2315E+00  0.5397E+00 -0.1860E-01  0.1000E+01
 5  0.2992E+00 -0.6481E+00 -0.1194E+00 -0.6639E+00  0.1000E+01

  **PARM_SOL.    STD_ERROR    REL_ERROR     % ERROR **
 1  0.2334E-03  0.3555E-04  0.1523E+00  0.1523E+02
 2  0.1881E-01  0.5441E-03  0.2893E-01  0.2893E+01
 3  0.9594E-01  0.1294E-02  0.1348E-01  0.1348E+01
 4  0.4431E+03  0.2345E-02  0.5293E-05  0.5293E-03
 5  0.3264E+03  0.3344E-02  0.1025E-04  0.1025E-02

PARAMETER NAME        FINAL SOLUTION          RESISTIVITY   LAYER DEPTH
   1   SIGMA( 1) =  0.23338229E-03    1  0.42848154E+04
   2   SIGMA( 2) =  0.18810613E-01    2  0.53161480E+02
   3   SIGMA( 3) =  0.95942847E-01    3  0.10422872E+02
   4   THICK( 1) =  0.44313925E+03                        1  0.44313925E+03
   5   THICK( 2) =  0.32636188E+03                        2  0.76950116E+03
   6   SHIFT     =  0.10000000E+01
```

17a


Newberry Crater NB-16 3 layer
APPARENT RESISTIVITY (OHM-M.)
TIME (SEC.)
10^3
10^2
10^1
10^-3
10^-2
10^-1

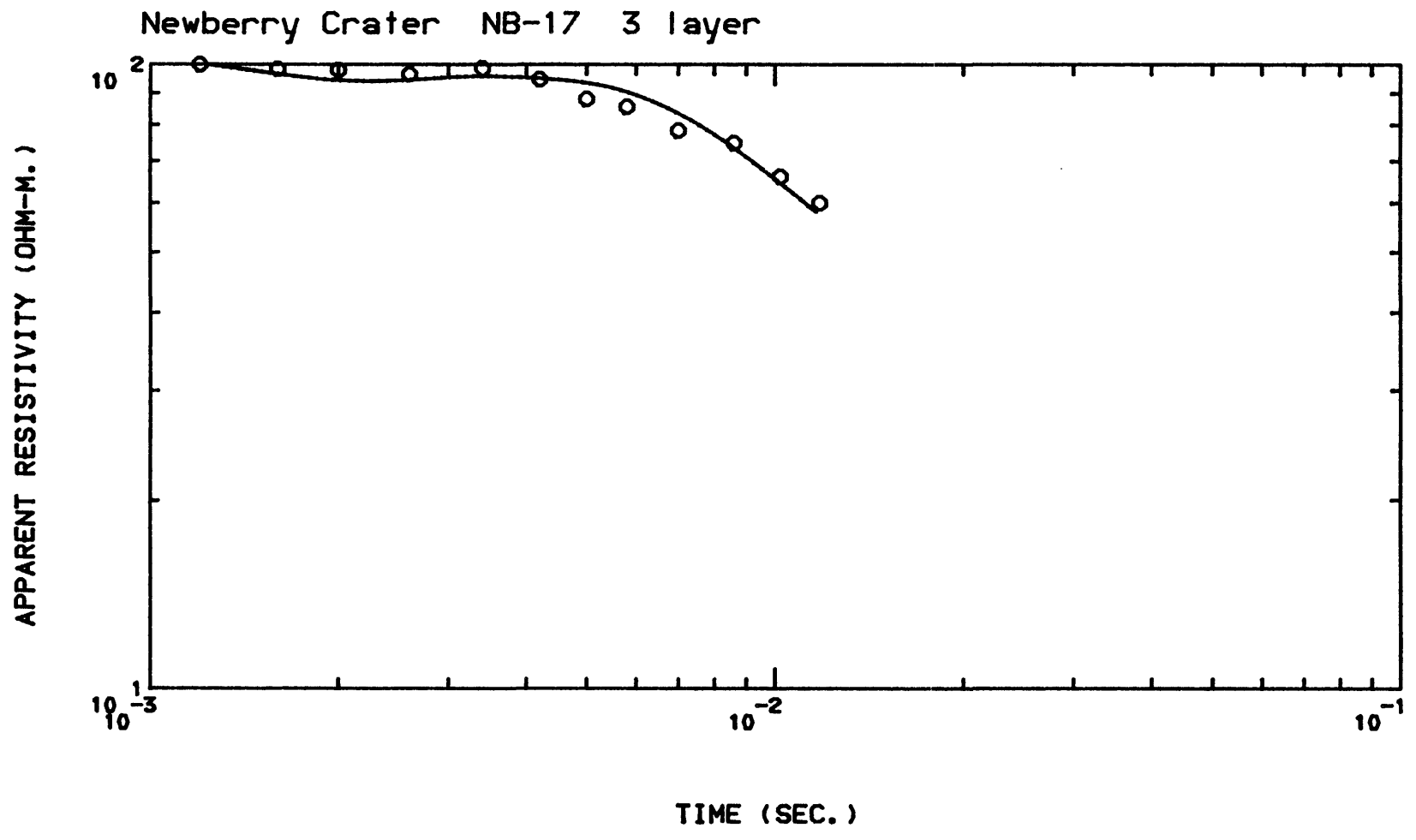
17b

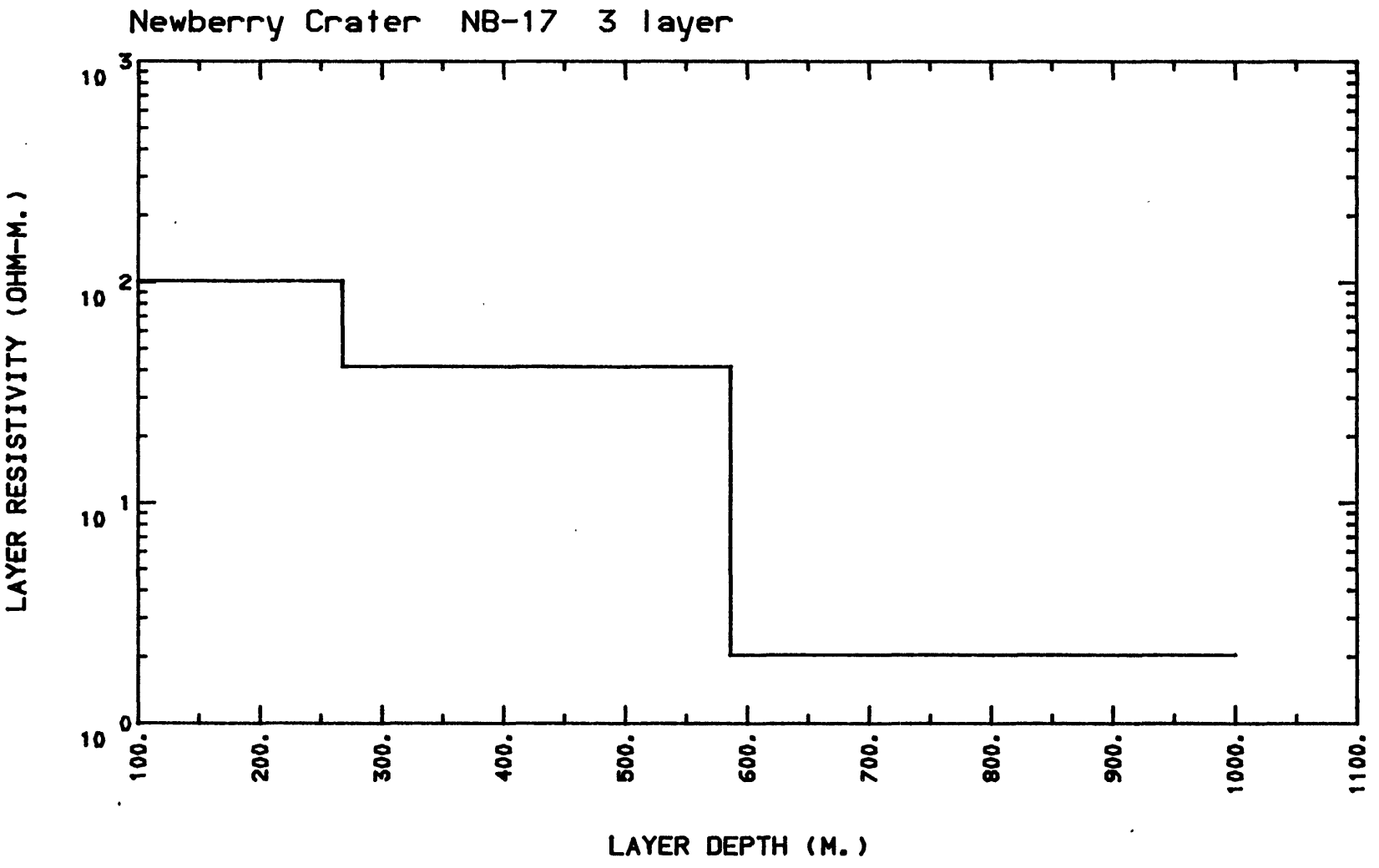

Newberry Crater NB-16 3 layer
LAYER RESISTIVITY (OHM-M.)
10 4
10 3
10 2
10 1
100.
200.
300.
400.
500.
600.
700.
800.
900.
1000.
1100.
LAYER DEPTH (M.)

17c

```
<NLSTCI2>:    Newberry Crater  NB-17  3 layer
A= 0.129000E+03
PARAMETERS HELD FIXED: IB=  6
***** VARIABILITY CONVERGENCE *****

  I     OBS.Y(I)        CAL             RES          %RES.ERR       X(I,1)
  1   0.100000E+03  0.100371E+03 -0.371E+00 -0.370017E+00  0.120000E-02
  2   0.983000E+02  0.964696E+02  0.183E+01  0.189740E+01  0.160000E-02
  3   0.979000E+02  0.942440E+02  0.366E+01  0.387925E+01  0.200000E-02
  4   0.965000E+02  0.945513E+02  0.195E+01  0.206099E+01  0.260000E-02
  5   0.987000E+02  0.958641E+02  0.284E+01  0.295824E+01  0.340000E-02
  6   0.947000E+02  0.949352E+02 -0.235E+00 -0.247699E+00  0.420000E-02
  7   0.880000E+02  0.933353E+02 -0.534E+01 -0.571623E+01  0.500000E-02
  8   0.856000E+02  0.902201E+02 -0.462E+01 -0.512091E+01  0.580000E-02
  9   0.783000E+02  0.834095E+02 -0.511E+01 -0.612585E+01  0.700000E-02
 10   0.748000E+02  0.733851E+02  0.141E+01  0.192805E+01  0.860000E-02
 11   0.661000E+02  0.644609E+02  0.164E+01  0.254271E+01  0.102000E-01
 12   0.600000E+02  0.573557E+02  0.264E+01  0.461030E+01  0.118000E-01
** RMSERR=  0.40768962E+01

CORRELATION MATRIX
 1  0.1000E+01
 2  0.5903E+00  0.1000E+01
 3  0.4247E+00  0.7590E-01  0.1000E+01
 4  0.6423E+00  0.6753E+00  0.3354E+00  0.1000E+01
 5  0.3025E+00 -0.2995E+00  0.5040E+00  0.2862E+00  0.1000E+01

  **PARM_SOL.    STD_ERROR    REL_ERROR     % ERROR **
 1  0.9863E-02  0.2772E-03  0.2811E-01  0.2811E+01
 2  0.2414E-01  0.1447E-02  0.5996E-01  0.5996E+01
 3  0.4898E+00  0.8245E-02  0.1683E-01  0.1683E+01
 4  0.2679E+03  0.9751E-02  0.3640E-04  0.3640E-02
 5  0.3185E+03  0.9323E-02  0.2927E-04  0.2927E-02

PARAMETER NAME       FINAL SOLUTION        RESISTIVITY   LAYER DEPTH
   1   SIGMA( 1) =  0.98628579E-02   1  0.10139049E+03
   2   SIGMA( 2) =  0.24136271E-01   2  0.41431419E+02
   3   SIGMA( 3) =  0.48984161E+00   3  0.20414762E+01
   4   THICK( 1) =  0.26787317E+03                      1  0.26787317E+03
   5   THICK( 2) =  0.31850494E+03                      2  0.58637811E+03
   6   SHIFT     =  0.10000000E+01
```

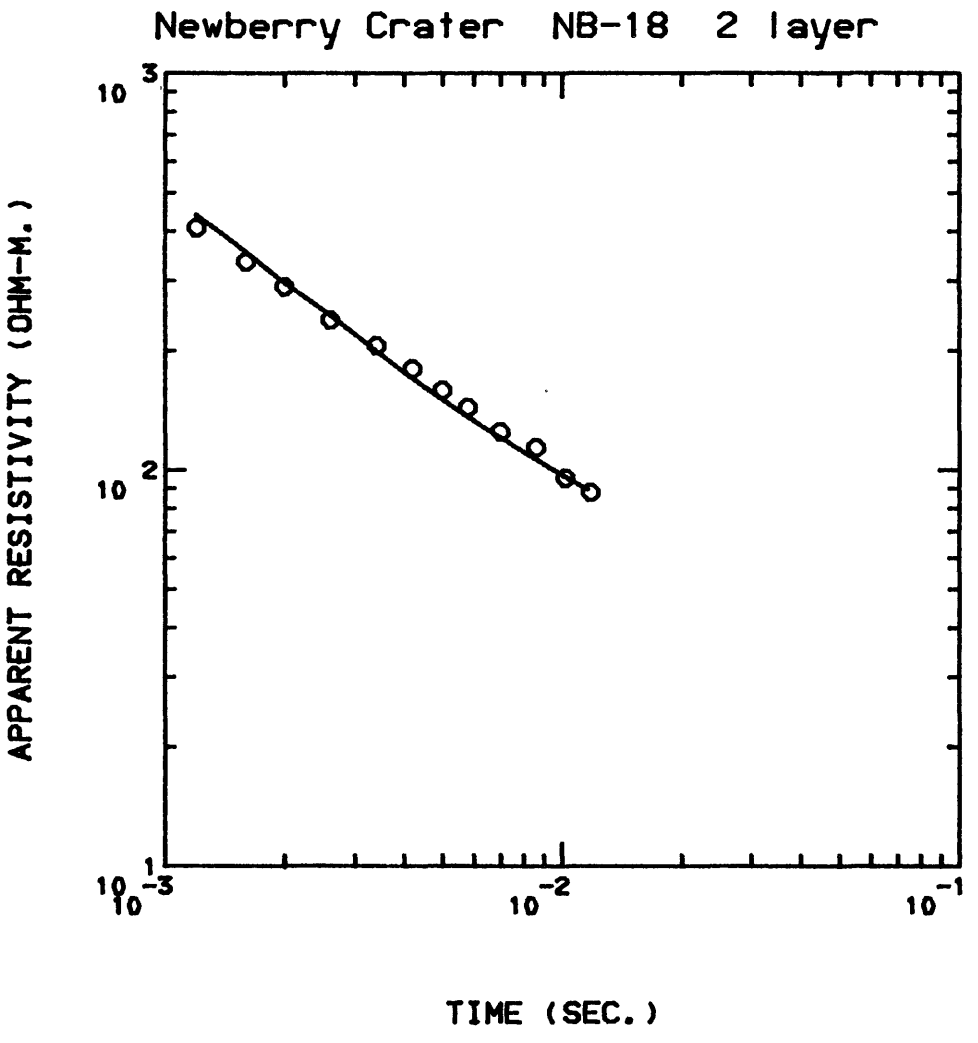
18a

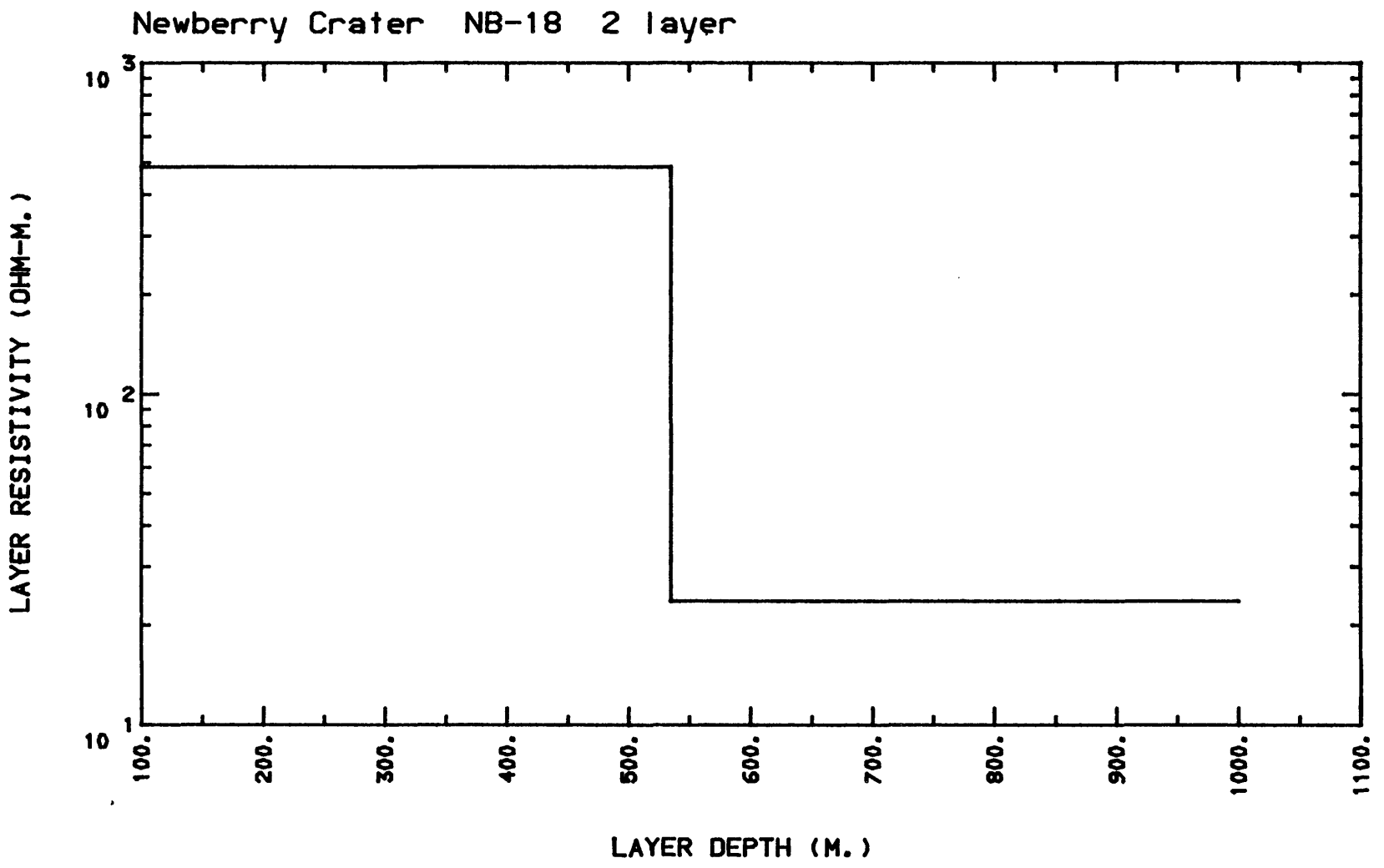

Newberry Crater NB-17 3 layer
APPARENT RESISTIVITY (OHM-M.)
10^2
10^1
10^{-3}
10^{-2}
10^{-1}
TIME (SEC.)

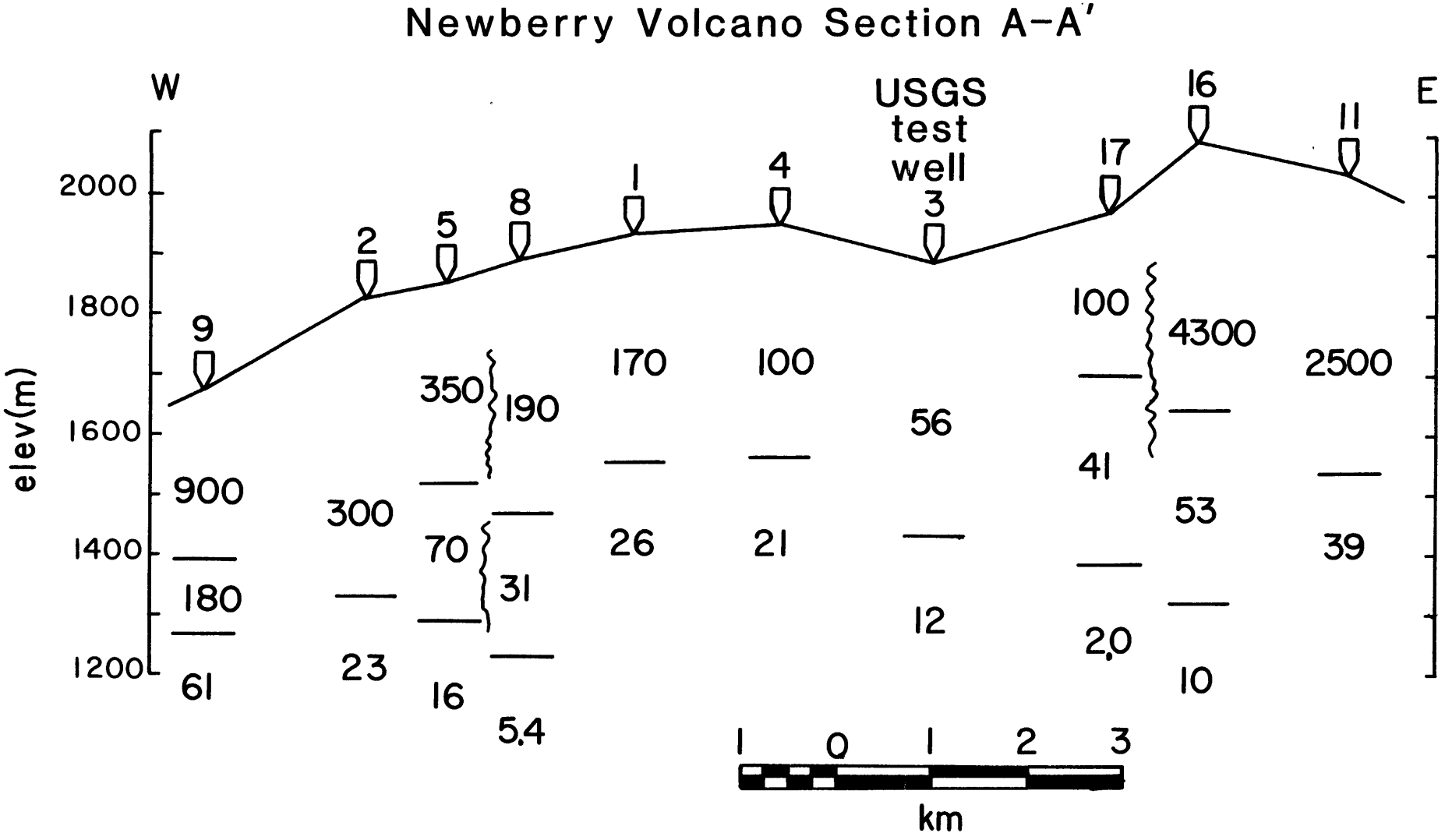

Newberry Crater NB-17 3 layer
LAYER RESISTIVITY (OHM-M.)
10 3
10 2
10 1
10 0
100.
200.
300.
400.
500.
600.
700.
800.
900.
1000.
1100.
LAYER DEPTH (M.)

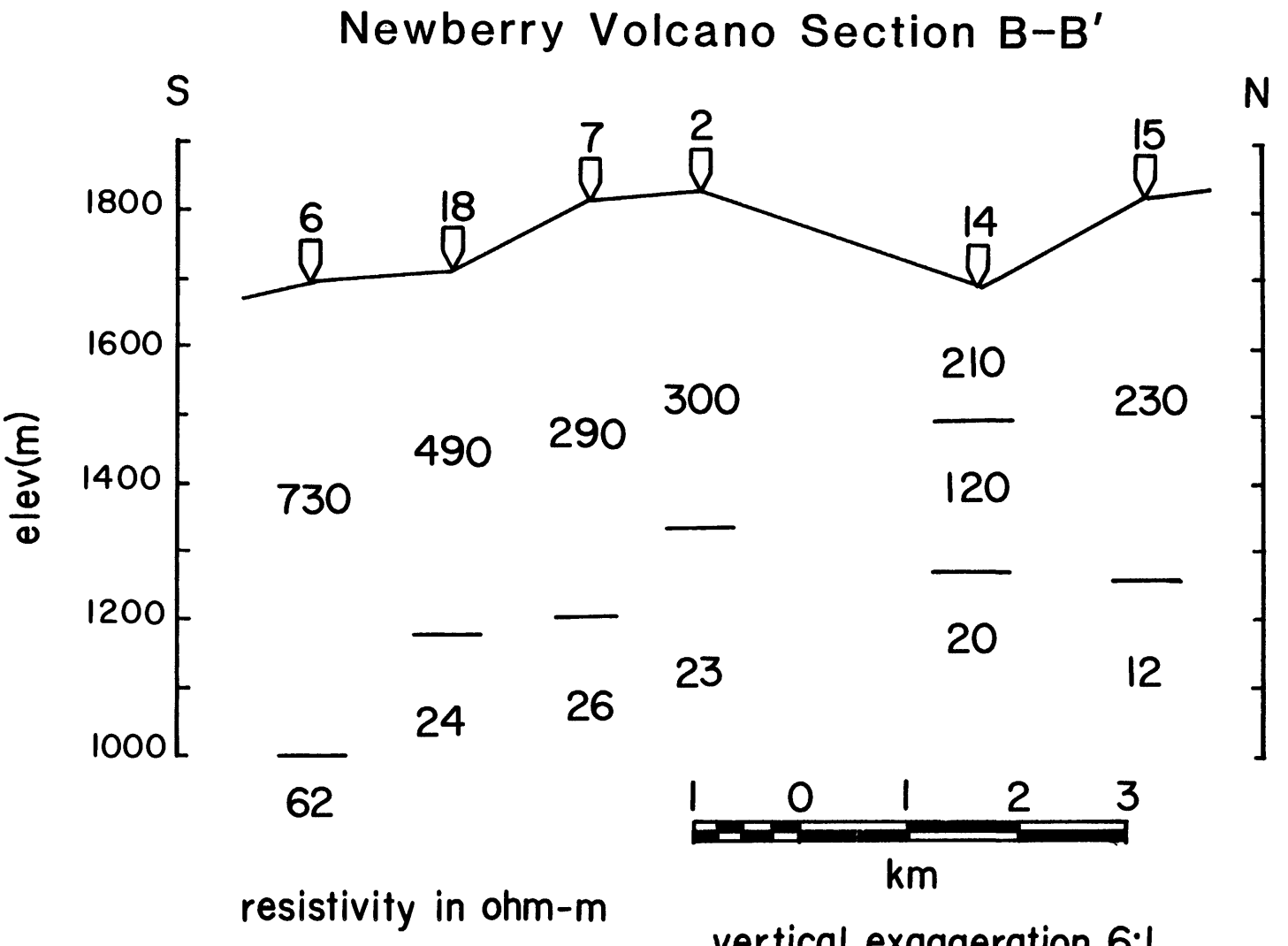
```
<NLSTCI2>:    Newoerry Crater  NB-18  2 layer
A= 0.860000E+02
PARAMETERS HELD FIXED: IB=  4
***** X-CONVERGENCE *****

  I     OBS.Y(I)        CAL             RES          %RES.ERR       X(I,1)
  1  0.408000E+03  0.438315E+03 -0.303E+02 -0.691621E+01  0.120000E-02
  2  0.335000E+03  0.353527E+03 -0.185E+02 -0.524060E+01  0.160000E-02
  3  0.290000E+03  0.296412E+03 -0.641E+01 -0.216309E+01  0.200000E-02
  4  0.239000E+03  0.245090E+03 -0.609E+01 -0.248474E+01  0.260000E-02
  5  0.206000E+03  0.199036E+03  0.696E+01  0.349862E+01  0.340000E-02
  6  0.180000E+03  0.169992E+03  0.100E+02  0.588740E+01  0.420000E-02
  7  0.159000E+03  0.150416E+03  0.858E+01  0.570653E+01  0.500000E-02
  8  0.144000E+03  0.135808E+03  0.819E+01  0.603215E+01  0.580000E-02
  9  0.125000E+03  0.120438E+03  0.456E+01  0.378774E+01  0.700000E-02
 10  0.114000E+03  0.106171E+03  0.783E+01  0.737443E+01  0.860000E-02
 11  0.954000E+02  0.959114E+02 -0.511E+00 -0.533230E+00  0.102000E-01
 12  0.879000E+02  0.882818E+02 -0.382E+00 -0.432450E+00  0.118000E-01
** RMSERR=  0.13793665E+02

CORRELATION MATRIX
 1  0.1000E+01
 2  0.9710E-02  0.1000E+01
 3 -0.4974E+00  0.3889E+00  0.1000E+01

  **PARM_SOL.    STD_ERROR    REL_ERROR     % ERROR **
 1  0.2060E-02  0.1934E-04  0.9391E-02  0.9391E+00
 2  0.4233E-01  0.9932E-03  0.2346E-01  0.2346E+01
 3  0.5350E+03  0.1765E-02  0.3300E-05  0.3300E-03

PARAMETER NAME      FINAL SOLUTION        RESISTIVITY   LAYER DEPTH
   1   SIGMA( 1) =  0.20598779E-02   1  0.48546567E+03
   2   SIGMA( 2) =  0.42326998E-01   2  0.23625584E+02
   3   THICK( 1) =  0.53501312E+03                      1  0.53501312E+03
   4   SHIFT     =  0.10000000E+01
```

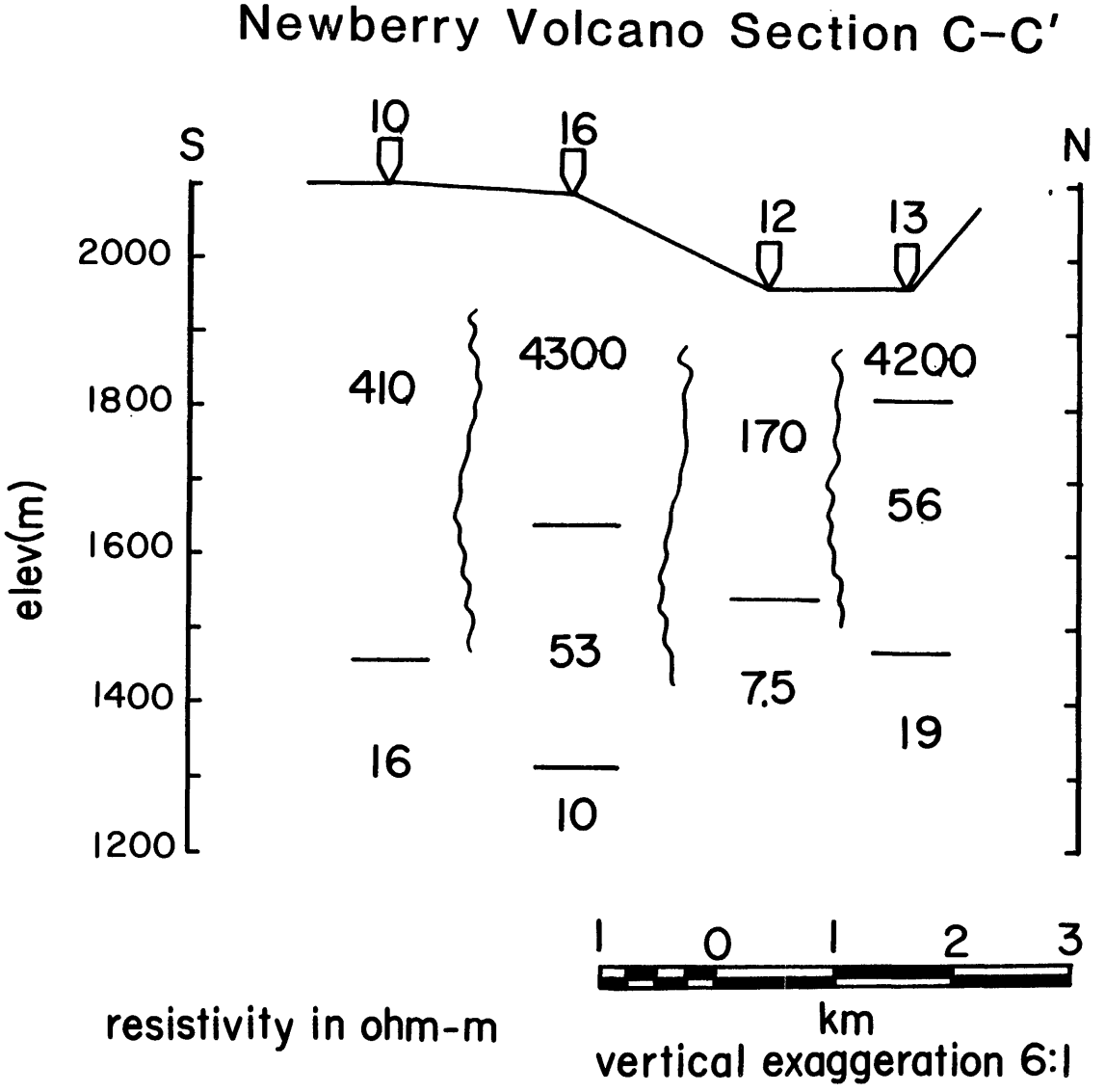
19a


Newberry Crater NB-18 2 layer
APPARENT RESISTIVITY (OHM-M.)
10 3
10 2
10 1
10 -3
10 -2
10 -1
TIME (SEC.)


Newberry Crater NB-18 2 layer
LAYER RESISTIVITY (OHM-M.)
10 3
10 2
10 1
100.
200.
300.
400.
500.
600.
700.
800.
900.
1000.
1100.
LAYER DEPTH (M.)


Newberry Volcano Section A–A'
W
E
USGS test well 3
elev(m)
2000
1800
1600
1400
1200
9
2
5
8
1
4
3
17
16
11
900
180
61
300
23
350
190
70
31
16
5.4
170
26
100
21
56
12
100
41
4300
53
20
10
2500
39
1 0 1 2 3
km
vertical exaggeration 6:1
resistivity in ohm-m


Newberry Volcano Section B-B'
S
N
1800
1600
1400
1200
1000
elev(m)
6
18
7
2
14
15
730
490
290
300
210
230
120
62
24
26
23
20
12
1 0 1 2 3
km
resistivity in ohm-m
vertical exaggeration 6:1


Newberry Volcano Section C-C'
S
N
10
16
12
13
2000
1800
1600
1400
1200
elev(m)
410
4300
170
4200
56
53
7.5
19
16
10
1 0 1 2 3
km
resistivity in ohm-m
vertical exaggeration 6:1