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GEOELECTRICAL LABORATORY AND FIELD STUDIES OF MATERIALS FROM THE TUCSON MINE DUMP NEAR LEADVILLE, COLORADO

by David L. Campbell[1] and Robert J. Horton[1]

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[1] Denver, Colorado

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INTRODUCTION

As part of a project to investigate formation of acid mine drainage, our USGS group has been doing integrated geological, geochemical, and geophysical studies of mine dumps in Colorado and New Mexico. One of these is the Tucson Mine dump, near Leadville, Colorado (site map, Fig. 1). The Tucson mine dump consists of 8 distinct lobes of mine waste that radiate out from a central dump like fingers on a hand (Fig.2). Different lobes are different colors, so probably contain different kinds of mine waste. In the course of our work, we collected separate grab samples from each of the lobes, as well as a composite sample that included material from the central dump and all of the lobes. We measured electrical properties of several of the grab samples and of the composite sample in the USGS Petrophysical Laboratory, Denver, Colorado (PetLab). We also performed field spectral induced polarization (SIP) measurements on Lobes 1,2,3,5,6, and 8 (Fig. 2). This report gives detailed graphs and tables of all the SIP properties of Tucson Mine dump materials that we measured in field and laboratory.

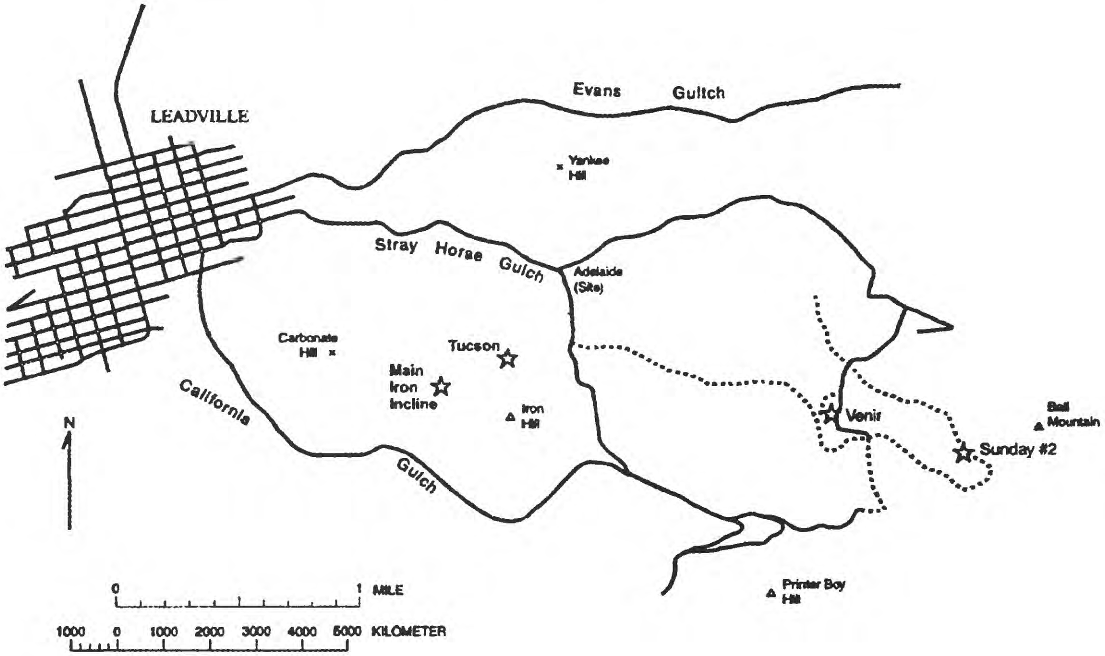

Figure 1. Outline map of mining areas east of Leadville, Colorado. Large stars indicate mine dumps our USGS team has studied. The Tucson mine dump is in the left-center of this map.

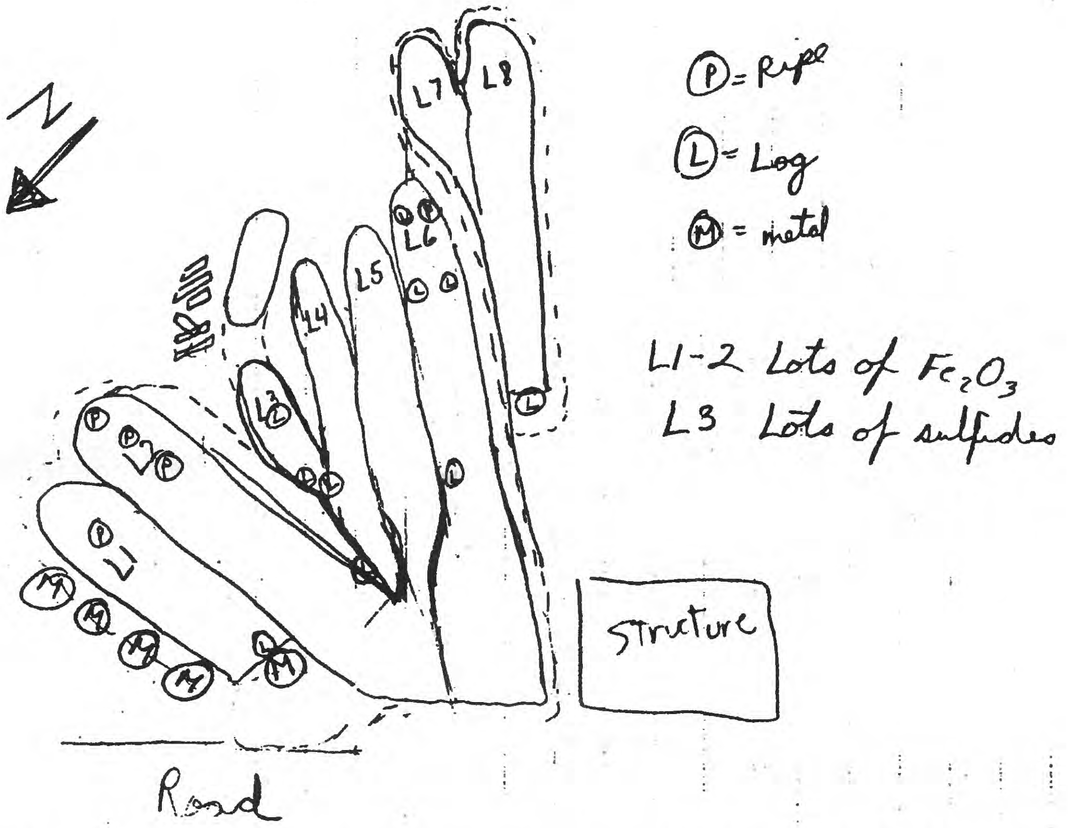

Figure 2. Sketch of lobes (L1, … , L8) at Tucson mine dump, edited from a USGS field notebook. The notation "Log" (for the circled L symbol) merely refers to wooden debris; it does not imply that data was recorded at that place.

PETROPHYSICAL LABORATORY PROCEDURE

Local grab samples from the Tucson dump were collected using a trowel. A composite sample for the entire Tucson mine dump was also collected via the protocol of Smith and others (2000). The samples were kept in plastic bags to maintain their natural pore waters insofar as possible. Nevertheless, they had become quite dry by the time they got measured in PetLab, and were too resistive to make "as received" measurements. Consequently, they were rehydrated using de-ionized water and measured wet. PetLab procedures and apparatus are described by Olhoeft (1979), Jones (1997), and Campbell and Horton (2000).

Measurements were made of the composite sample, and of grab samples from Lobe 1 (chocolate brown to black color, many magnetite grains), Lobe 3 (silver-gray color, many sulfide grains), Lobe 4 (reddish-brown color, unknown composition), and Lobe 5 (medium gray color, unknown composition). There were 2 samples from Lobe 3; an ordinary sample and a high-sulfide sample. The ordinary sample was measured both dry and wet (about 10% water). The wet sample was measured driving its currents at 5 different voltage levels, so as to check for possible nonlinearity effects due to current density. No significant differences were seen using 0.1, 0.2, 0.3, 0.4, and 0.5 volts. Therefore, we use only the 0.3 volt measurement in the following graphs as the "wet lobe 3" sample.

Our standard graph of the resulting measurements (e.g., Fig. 3) consists of three panels, all of which plot various quantities versus a common frequency abcissa. The upper panel shows the variation with frequency of resistivity (left legend, triangular symbols) and of phase (right legend, circle or diamond symbols). If the phase is negative (the usual situation), its sign is reversed and the value is plotted as a circle. If the phase is positive—much less usual, but possible—the sign is not changed and the value is plotted as a diamond. A vertical whisker through each symbol indicates error bars. The solid, often quite jagged, lines through the data are predicted values of resistivity and phase based on Hilbert transforms. The lower two panels give other indicators of possible errors in the measurements. These are percent Hilbert distortion in the resistivity measurement, %RHD, Hilbert distortion in the phase measurement, PHD, percent total harmonic distortion %THD, and spontaneous potential in millivolts, SP/mV. These quantities are described more fully by Campbell and Horton (2000).

Figures 3-9 are standard PetLab data graphs for measured samples from Lobe 1 (Fig.3), Lobe 3 (the "sulfide" lobe, Figs. 4-6), Lobe 4 (Fig. 7), Lobe 5 (Fig. 8), and the Tucson composite sample (Fig. 9). All samples had some bad data points that threw off the Hilbert calculations. The RHD and PHD (Hilbert) scales for most samples are dominated by one or two extreme, and probably meaningless, values, which swamp out possibly significant variations in other frequency ranges where the data was fairly good. An exception is the Lobe 3 data, where we see some Hilbert distortions for frequencies below about 10 Hz. Cation-exchange reactions can give rise to Hilbert distortions, and cannot be ruled out for any of these samples. All samples except for Lobe 5 had some (<1%) harmonic distortion at low frequencies, and all but Lobe 3 had some harmonic distortion (<1%) between 10 and 1000 Hz, with the maximum harmonic distortion at 100-300 Hz. This may indicate oxidation-reduction processes taking place at those frequencies.

COMPARISONS BETWEEN LOBE AND COMPOSITE SAMPLES

Figures 10-13 plot properties of the grab samples (open symbols) against those of the common composite sample (solid symbols). All these samples were wet, containing about 6-10% water. All grab sample resistivity curves fell below that of the composite. Lobes 1 and 3 had high (negative) phase values throughout the measured frequency range, whereas the Lobe 4 and 5 phase curves become positive for frequencies less than 0.02 Hz. The composite sample has a positive phase value at the lowest measured frequency (0.002 Hz), suggesting it may also have positive phase values below that frequency.

Figure 14 plots properties of the Lobe 3 sample when it was dry (open symbols) versus when it was wet (solid symbols). We see that wetting this sample decreases its resistivity, but has little effect on phase.

Figure 15 plots properties of the Lobe 3 high-sulfide sample (open symbols) versus those of the ordinary sample (solid symbols). We see that the high-sulfide sample has a generally lower resistivity than the ordinary sample, and that both samples have similar phase curves for frequencies above about 1 Hz. The high-sulfide sample's phase values drop successively below those of the ordinary sample for frequencies below 1 Hz.

PETROPHYSICAL CHARACTERISTICS

Simple indices

Some of the parameters that have historically been used to characterize induced polarization response, as measured in the field, can be directly read or calculated from petrophysical curves. Denoting resistivity as R, and phase as P, these include:

LowRes (low resistivity)= R(0.1 Hz).

PRE (percent resistivity effect)= 100 x [R(0.1 Hz) – R(1.0 Hz)] / R(1.0 Hz).

LowPhz (low phase)= -P(0.1Hz).

PPE (percent phase effect) = -100 x { P(0.1 Hz) – P(1.0 Hz) } / P(1.0 Hz).

These simple indices, and the formatting of our standard tables describing them (such as table 1, below) are described in more detail by Campbell and Horton (in prep.).

Table 1 lists these indices for the Tucson Mine dump samples. There is little difference in any of the indices for the series of measurements of the wet ordinary sample from Lobe 3 that tested the effect of varying the driving voltages used in the measurement. Similarly, we see little difference in the indices between measurements on the ordinary Lobe 3 sample when it was wet or dry, except that LowRes is higher in the dry condition. The (wet) sulfide-rich sample from Lobe 3 had much lower LowRes than the wet ordinary sample from Lobe 3, and its values of PRE, LowPhz, and PPE were also lower. All PPE values for Lobe 3 were negative, whereas those for the other lobes were all positive. Similarly, all the LowPhz and PRE values for Lobe 3 were higher than those for the other lobes and all LowRes values were lower. All these conditions probably reflect higher amounts of sulfides in Lobe 3. As might be expected, the composite sample had values of PRE, LowPhz, and PPE that were intermediate between those of the separate lobe samples. However, its LowRes value was higher than those of any of the individual lobe samples, and we cannot explain why that should be.

Table 1.--Simple IP Indexes for samples from the Tucson mine dump. PRE and PPE are calculated between 0.1 and 1.0 Hz.

	LowRes	PRE	LowPhz	PPE
tucson1.txt tucson lobe 1 with about 10% water	100.24	7.31	38.49	49.54
tucson2.txt tucson sulfide sample from lobe 3 as rec'd	0.94	18.99	102.25	6.99
Tucson3.txt Tucson lobe 3 no water added	4.15	26.52	156.00	-9.30
Tucson10.txt Tucson lobe 3, current test .1	3.29	25.57	147.62	-6.37
Tucson9.txt Tucson lobe 3, current test .2	3.12	25.81	149.73	-7.09
Tucson8.txt Tucson lobe 3, current test .3 volts	3.12	25.81	149.63	-7.03
Tucson7.txt Tucson lobe 3, current test .4 volts	3.13	25.70	149.73	-7.33
Tucson6.txt Tucson Lobe 3, current test .5 volts	3.15	26.00	147.19	-5.56
Tucson4.txt Tucson lobe 4 with 10% water	73.80	2.34	8.56	75.08
Tucson5.txt Tucson lobe 5 with 10% water	90.28	6.10	18.96	73.97
Compst5.txt Composite Sample, Tucson with 6% water	167.40	4.21	31.36	3.00

Cole-Cole fits

The simple indices defined above are useful for making gross comparisons between petrophysical curves, and for correlating such curves with field data. However, they gloss over details of the curves, particularly the phase curves, that can reflect grain size and textural properties, mineralogical compositions, and geochemical reactions that may be taking place. The latter may reflect interactions between grains and pore waters, and so can be of particular interest in acid mine drainage studies.

In order to more fully describe the details of the resistivity and phase curves measured in Pet Lab, we fit them numerically using the Cole-Cole formula (Cole and Cole, 1941):

Complex conductivity $\sigma(\omega) = \{1 + m\,[\,(i\,\omega\tau)^c / (1 + (1-m)\,(i\,\omega\tau)^c]\,\} / R_o + i\,\omega\varepsilon_o K_{00}$.

The above equation follows the form of Major and Silic (1981), except that term including the dielectric constant K_{00} has been added (Jones, 1997). See Campbell and Horton (in prep.) for a fuller description of Cole-Cole fits.

Most spectra display more than one relaxation, so that the sum of several Cole-Cole terms is used to describe the shape of the complete spectrum. Figures 16-22 show two-term Cole-Cole fits to the data plotted in Figs. 3-9.

Table 2 gives Cole-Cole parameters that have been fit to the petrophysical curves for some of the Tucson Mine dump samples.

Table 2. Cole-Cole parameters for Tucson mine dump samples.

	R_o	K_{oo}	m_1	τ_1	c_1	m_2	τ_2	c_2
Lobe 1	114	2500	0.075	4.30e+1	0.830	0.440	3.20e-2	0.500
Lobe 3 dry	6.7	5130	0.656	3.88e+0	0.375	0.454	2.30e-6	0.903
Lobe 3 wet	4.8	4834	0.630	2.70e+0	0.390	0.470	2.60e-6	0.910
Lobe 3 sulf	1.13	5500	0.450	6.20e-1	0.480	0.580	2.80e-6	0.780
Lobe 4	70	3000	-0.057	8.00e+1	0.760	0.280	6.30e-3	0.500
Lobe 5	89	3000	-0.069	6.00e+0	0.570	0.390	2.90e-2	0.530
Composite	183	2800	0.100	5.00e+0	0.580	0.270	4.40e-3	0.440

FIELD SIP MEASUREMENTS

In August, 1998, we made field SIP measurements on Lobes 1, 2, 3, 5, 6, and 8 of the Tucson Mine dump. We used a Zonge NT20 transmitter and GDP32 receiver, in dipole-dipole configuration with 5 ft dipoles. Data series were taken using the fundamental frequencies of 0.125, 0.5, 2, 8, 32., and 128 Hz. The equipment finds responses at each fundamental frequency and at its 3rd, 5th, 7th, and 9th harmonics, so that a total of 30 overlapping frequencies were measured. Figures 23-57 show the resulting spectra, plotted in both Argand (i.e., phasor) and spectral formats. There are 5 figures for each instrumental set-up, labeled N=1 through 5, which can be roughly considered as measuring successively deeper into the lobe. The data is typically poorer at higher N values (for example, Fig. 42, consisting of meaningless noise). Lobe 1 was measured twice, first with the transmitter at one end of the potential electrode array (Spread 1, Figs. 23-27), and then with it moved to the other end (Spread 2, Figs. 28-32). On almost all of these plots the 128 Hz series has obvious problems with electromagnetic coupling, and should be disregarded. The trustworthy parts of the spectra from all lobes but Lobe 3 are generally flat. Lobe 3, the "sulfide" lobe, has phase spectra that are concave upward and resistivity spectra that slope sinuously downward (Figs. 38-41).

COMPARISON OF LABORATORY AND FIELD SPECTRA

Figures 58-60 compare laboratory and field spectra for Lobes 1, 3, and 5. There is a serious lack of agreement between them. We note that the laboratory measurements were made on small samples that had been disturbed, dried out and re-watered with de-ionized water, whereas the field measurements were made on blocks of ground with a size of the order of the dipole spacing (5 feet), containing undisturbed material, in situ, with natural porewaters in place. A further complication may arise from the use of de-ionized water to rehydrate the dried samples. We hoped that salts left behind when the original sample was dried would go back into solution, so that the rehydration water would resemble the original porewater. Very possibly this did not happen. In particular, we note that the in situ resistivity values for all but Lobe 3 are much higher than the PetLab resistivity values. This argues that the PetLab samples may have had either too much water or too few salts (not all the original salts had re-equilibrated into the rehydration waters, in other words). Some differences must be expected due to all these factors. In our opinion, however, they do not account for such major lack of agreement between the two kinds of measurements. Some other factors that we haven't yet considered may be operating here.

ACKNOWLEGEMENTS

We thank summer students J. Christopher Eckhart for helping make the field SIP measurements and Alyssa Kohlman and Shay Beanland for making the laboratory measurements.

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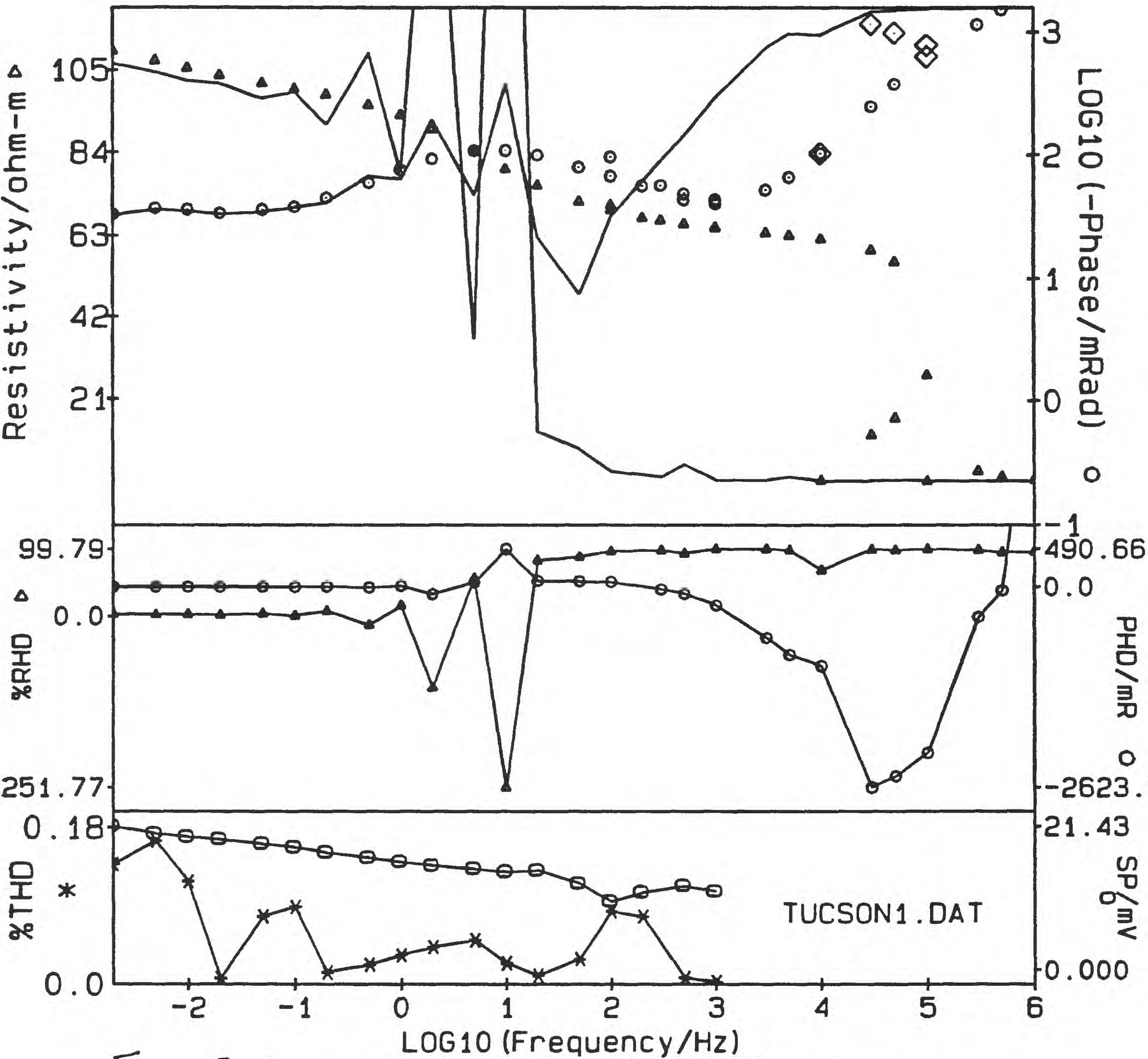


Figure 3. tucson lobe 1 with about 10% water

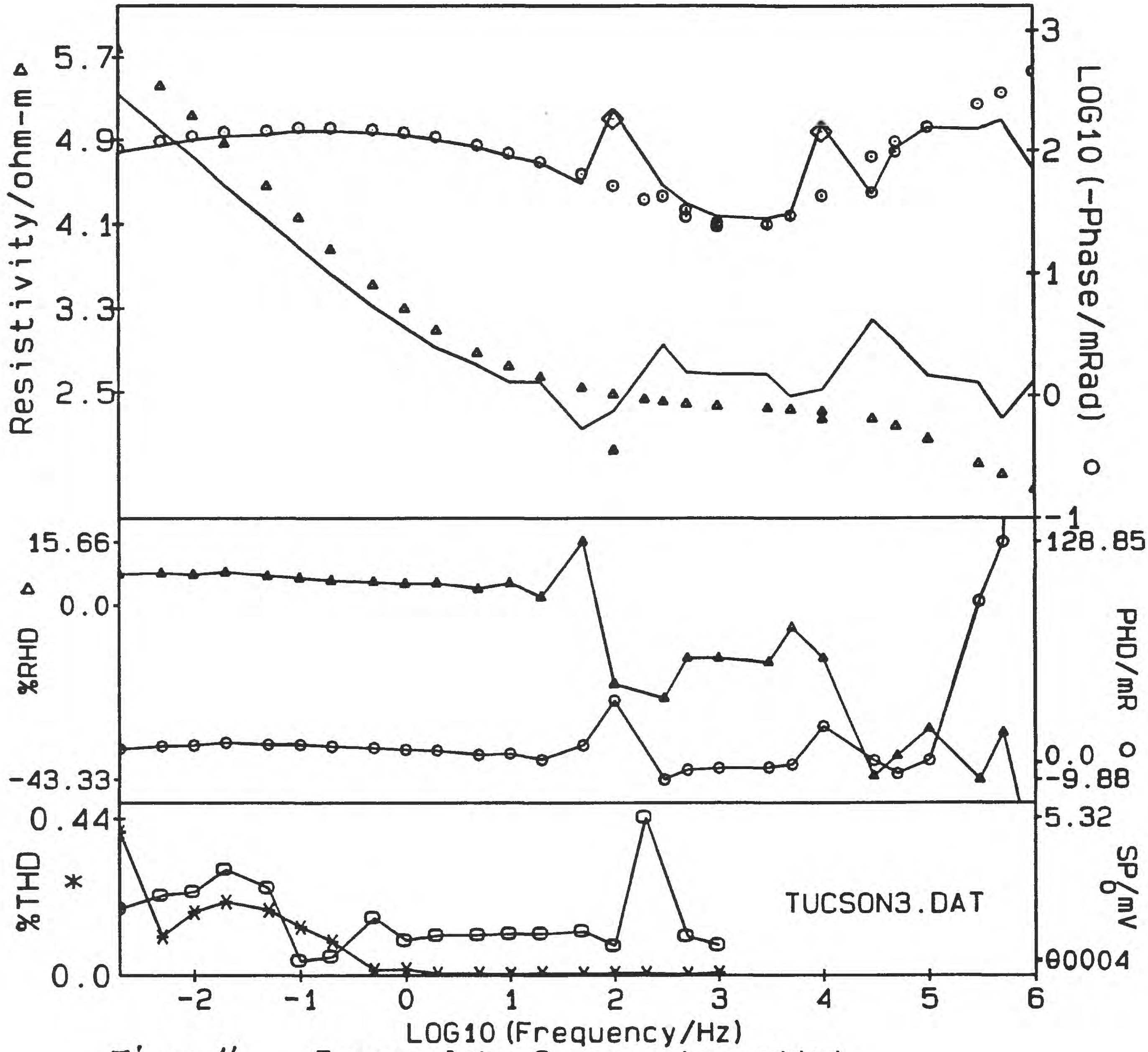


Figure 4. Tucson lobe 3, no water added

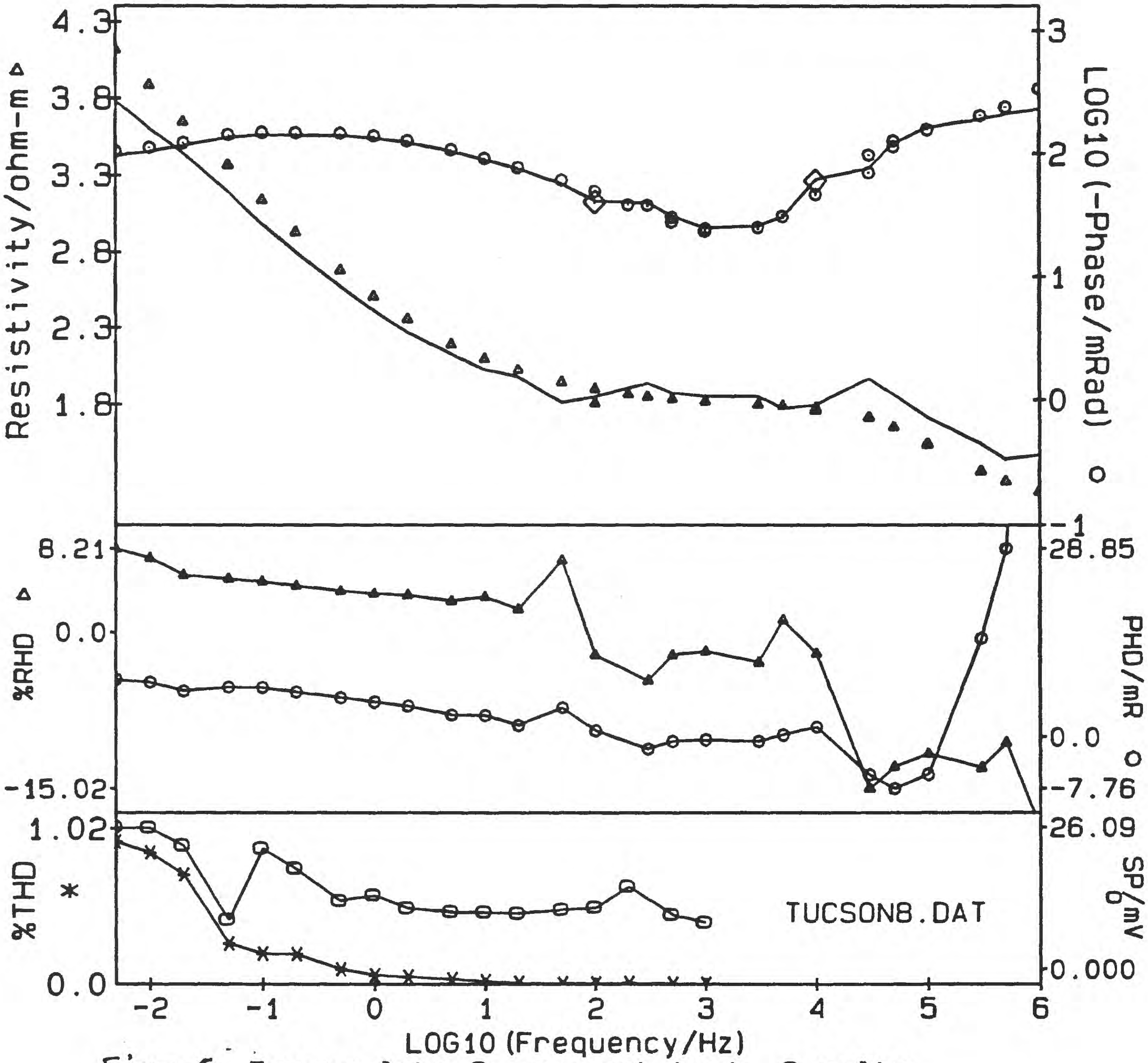


Figure 5. Tucson lobe 3, current test .3 volts

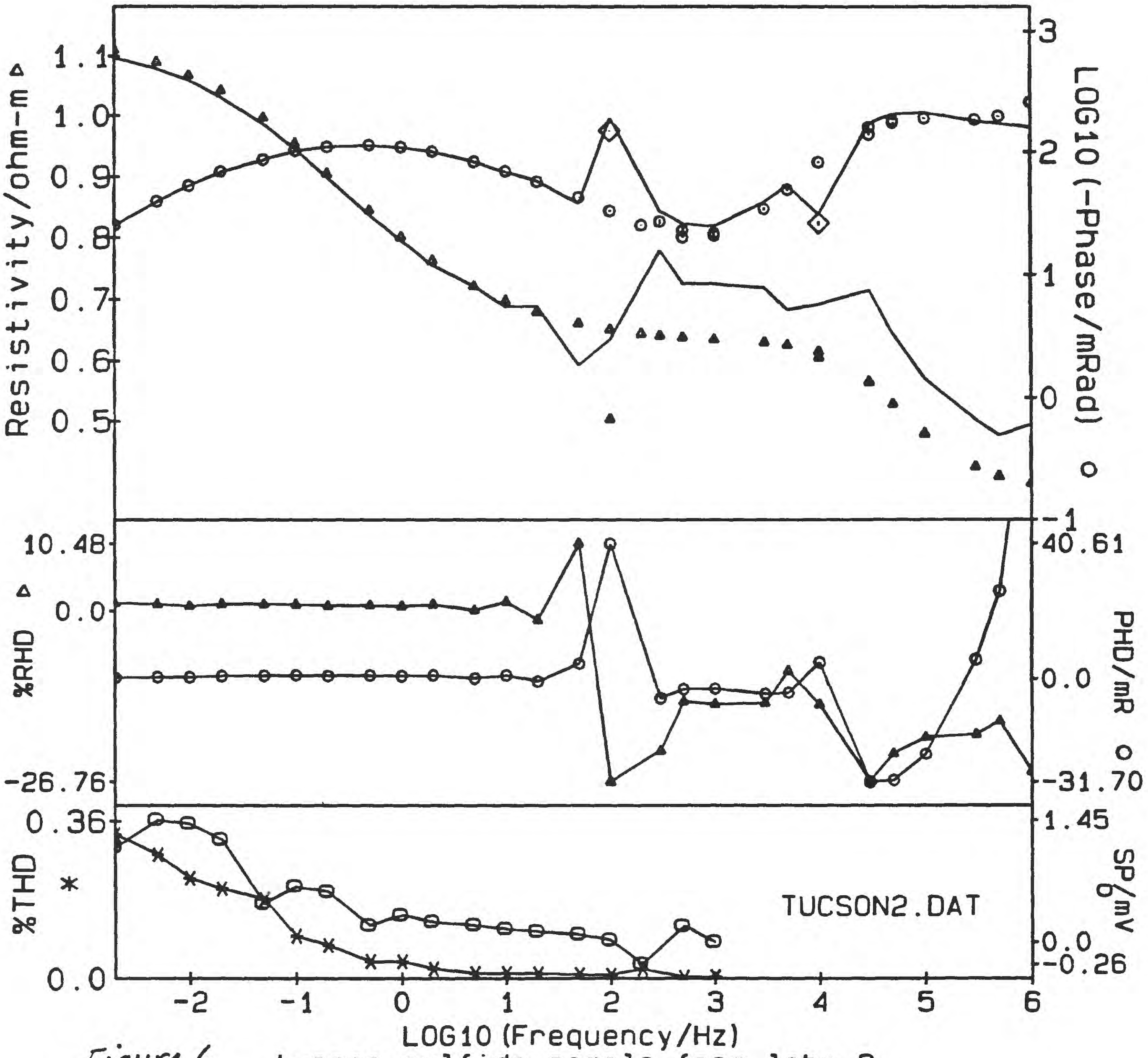


Figure 6. tucson sulfide sample from lobe 3

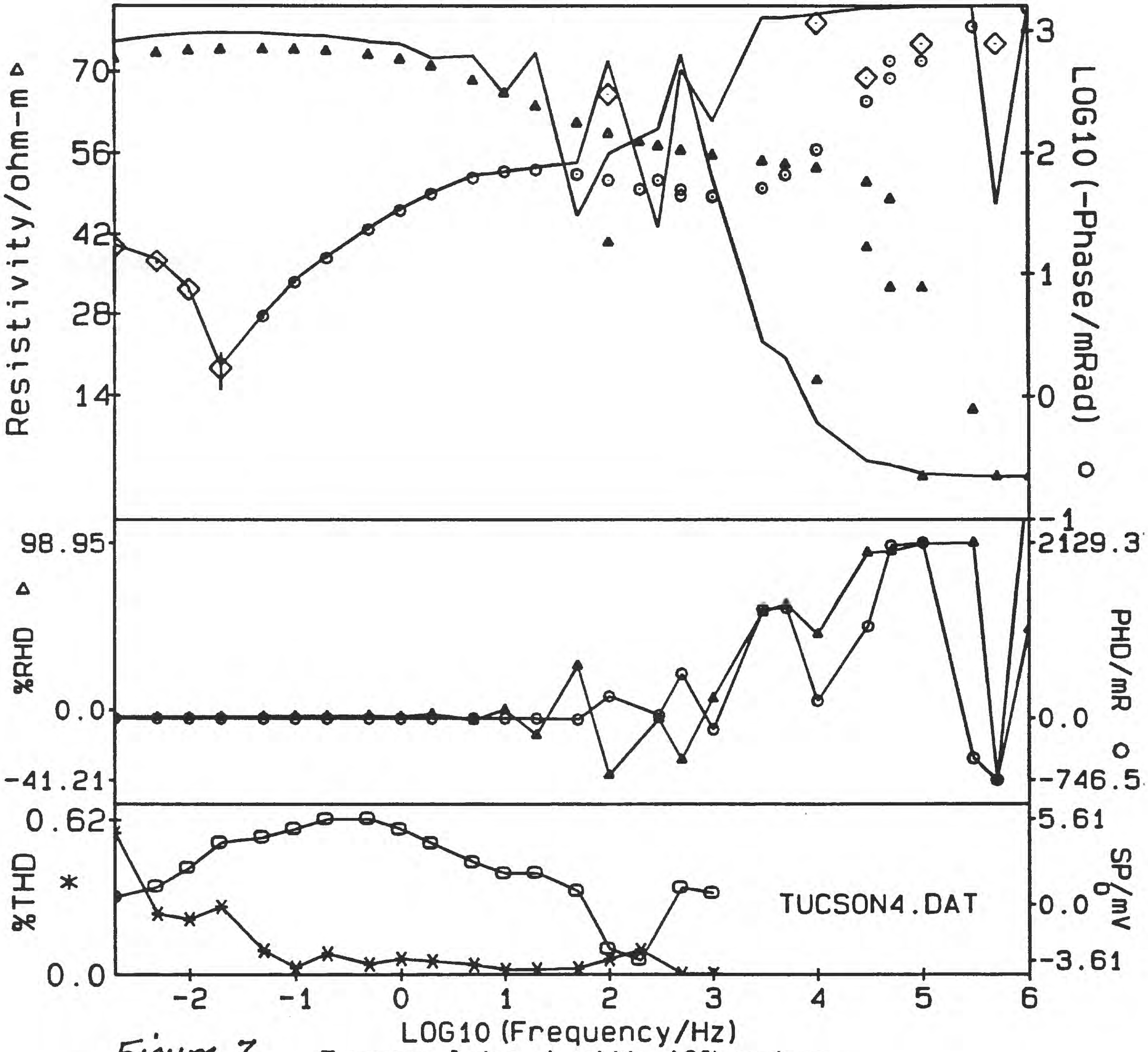


Figure 7. Tucson lobe 4 with 10% water

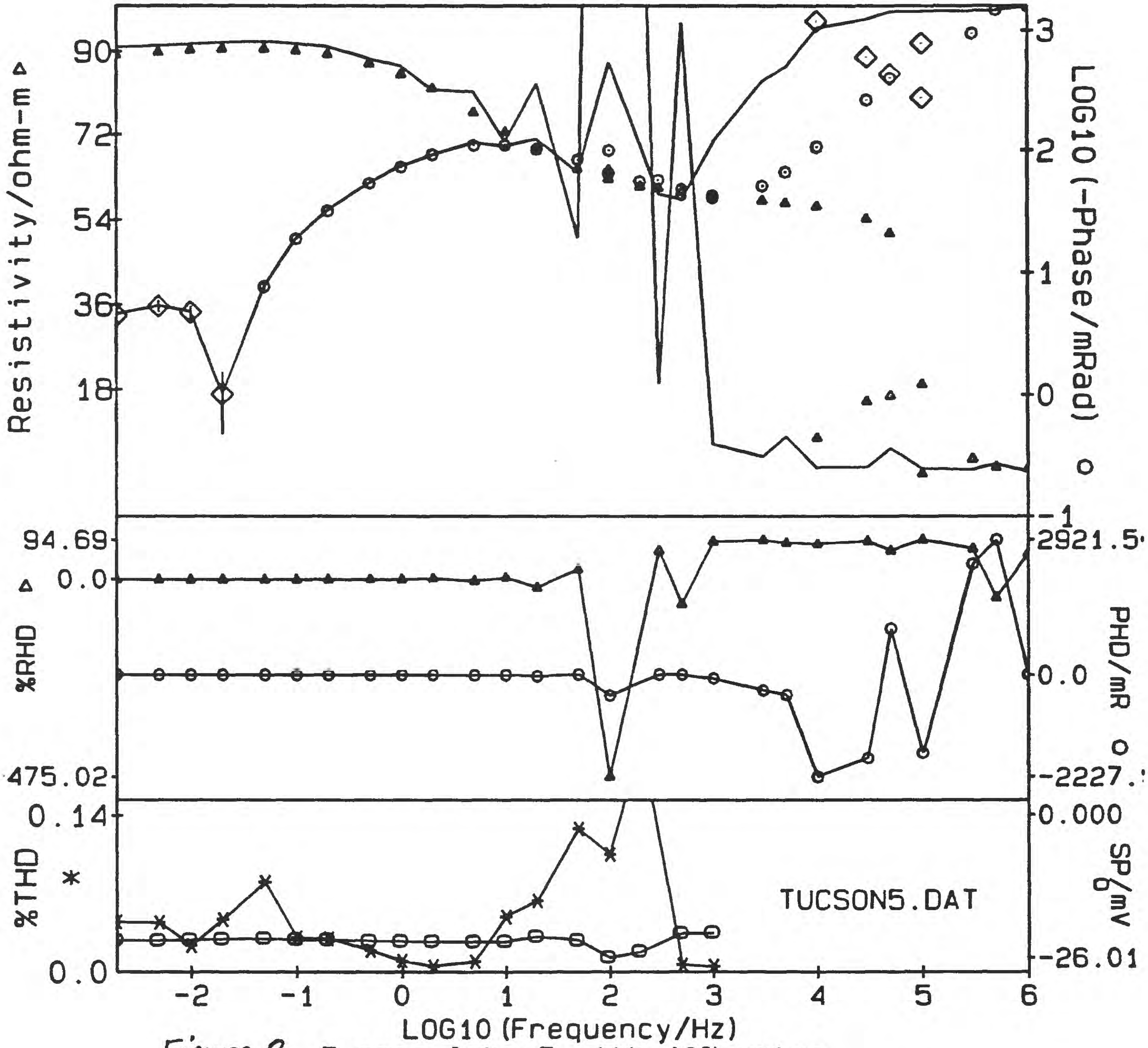


Figure 8. Tucson lobe 5 with 10% water

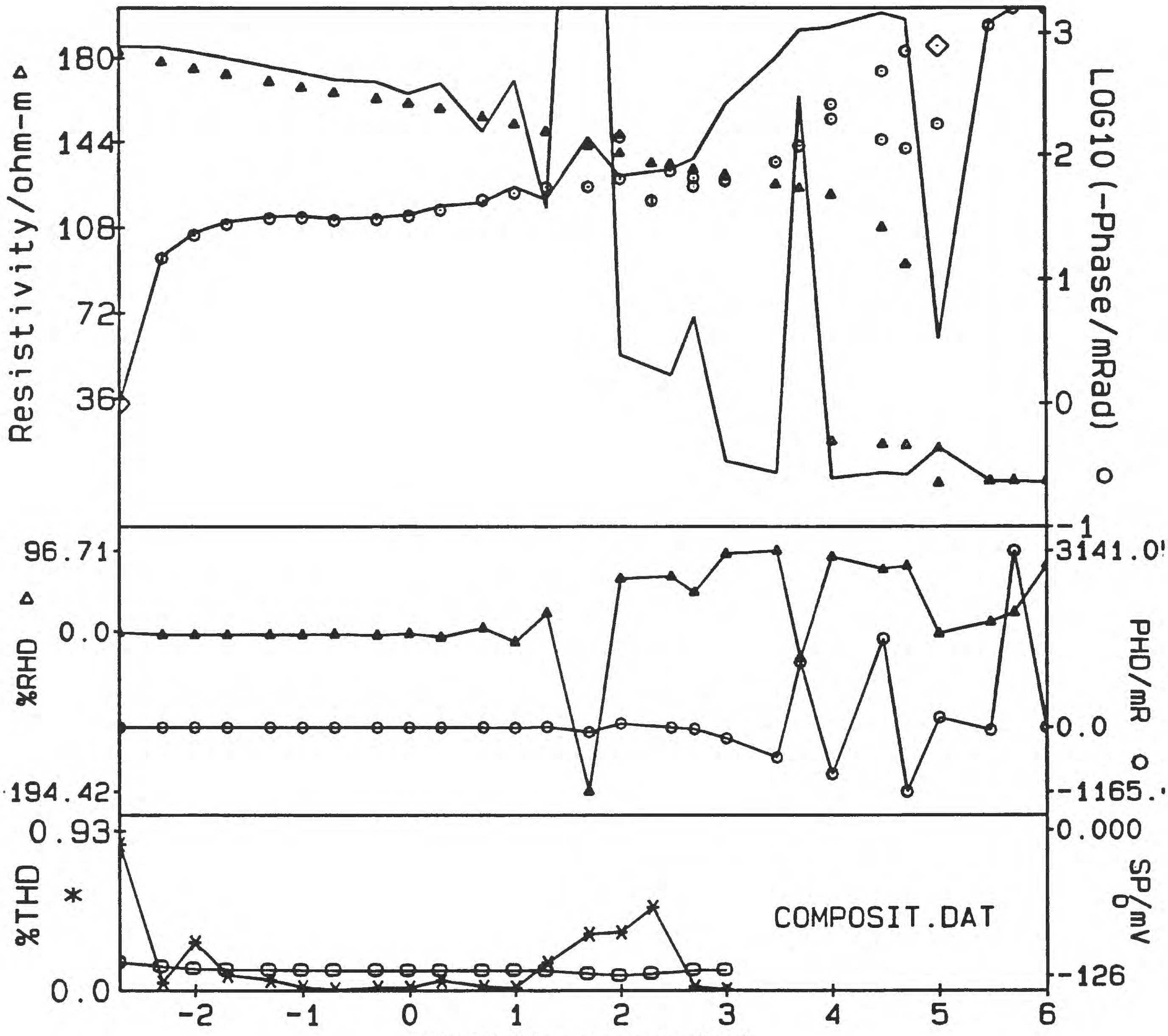


Figure 9. Composite Sample, Tucson with 6% water

Figure 10.

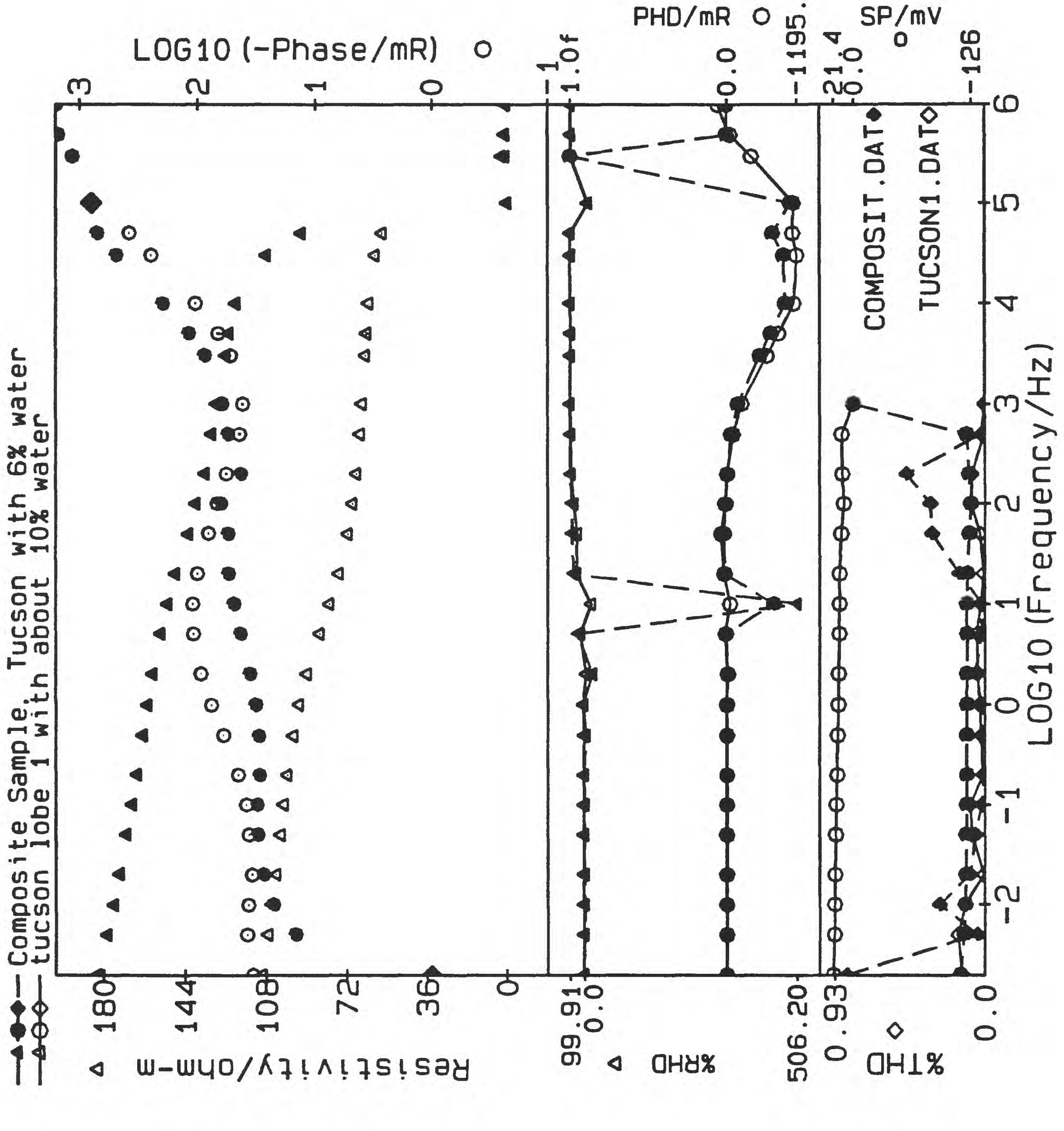

Composite Sample, Tucson with 6% water
tucson lobe 1 with about 10% water
LOG10 (-Phase/mR)
3
2
1
0
-1
1.0f
PHD/mR
0.0
1195.
SP/mV
21.4
0.0
126
Resistivity/ohm-m
180
144
108
72
36
0
99.91
0.0
%RHD
506.20
0.93
0.0
%THD
0.0
-2
-1
0
1
2
3
4
5
6
LOG10 (Frequency/Hz)
COMPOSIT.DAT
TUCSON1.DAT

Figure 11.

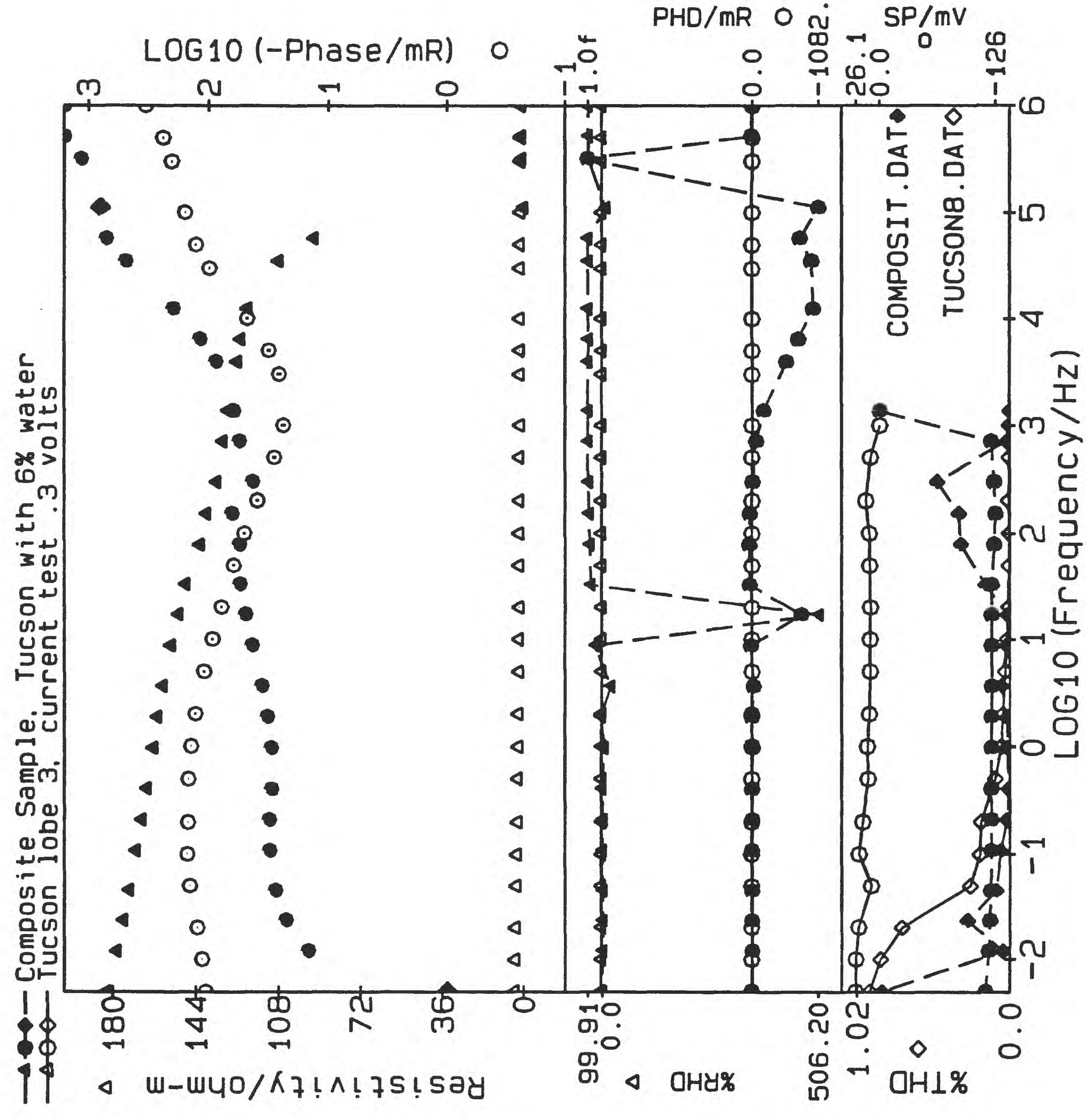

Composite Sample, Tucson with 6% water
Tucson lobe 3, current test .3 volts
LOG10 (-Phase/mR)
3
2
1
0
-1
Resistivity/ohm-m
180
144
108
72
36
0
%RHD
99.91
0.0
1.0f
506.20
PHD/mR
0.0
-1082.!
SP/mV
26.1
0.0
-126
%THD
1.02
0.0
COMPOSIT.DAT
TUCSONB.DAT
LOG10 (Frequency/Hz)
-2
-1
0
1
2
3
4
5
6

Figure 12.

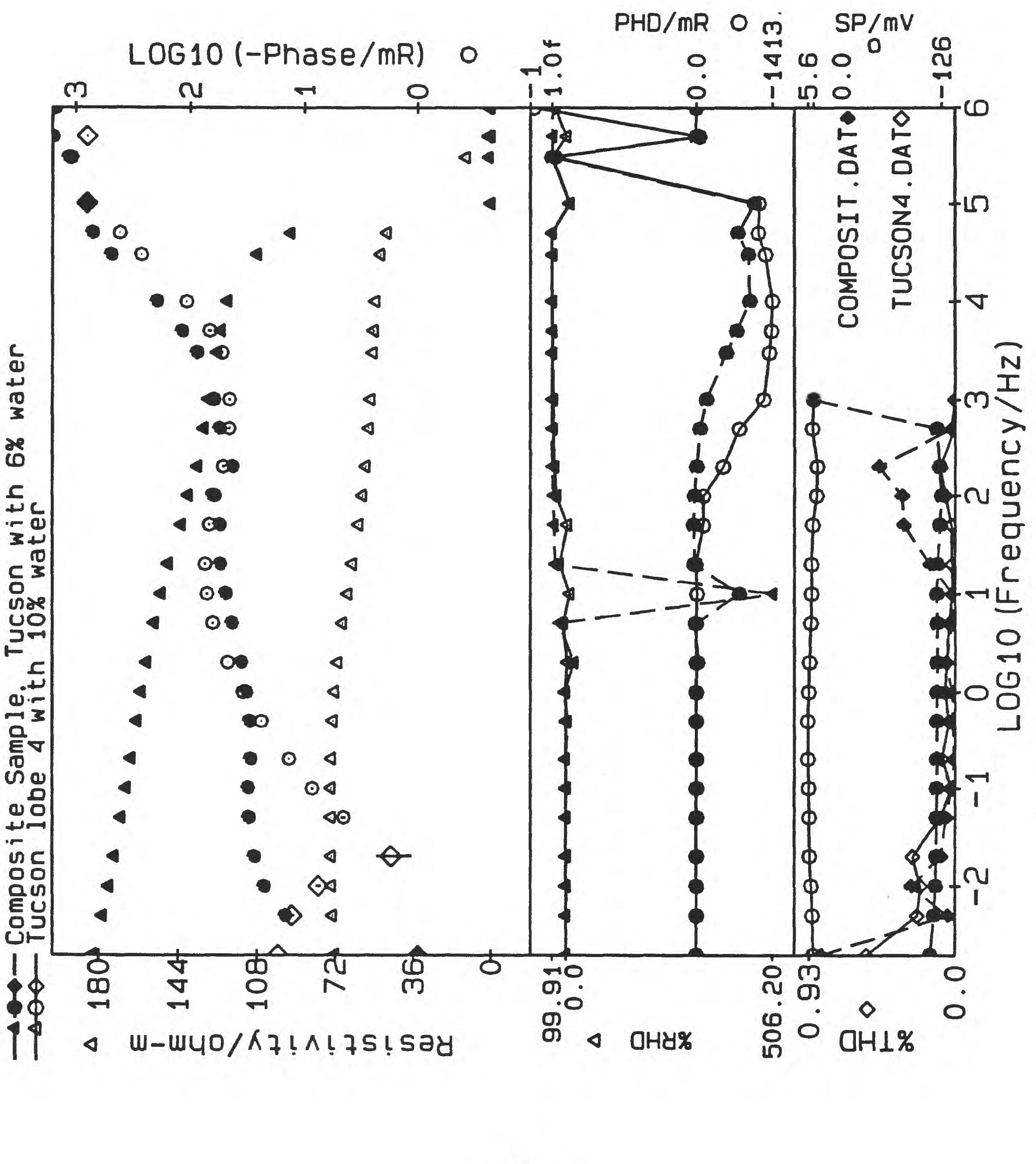
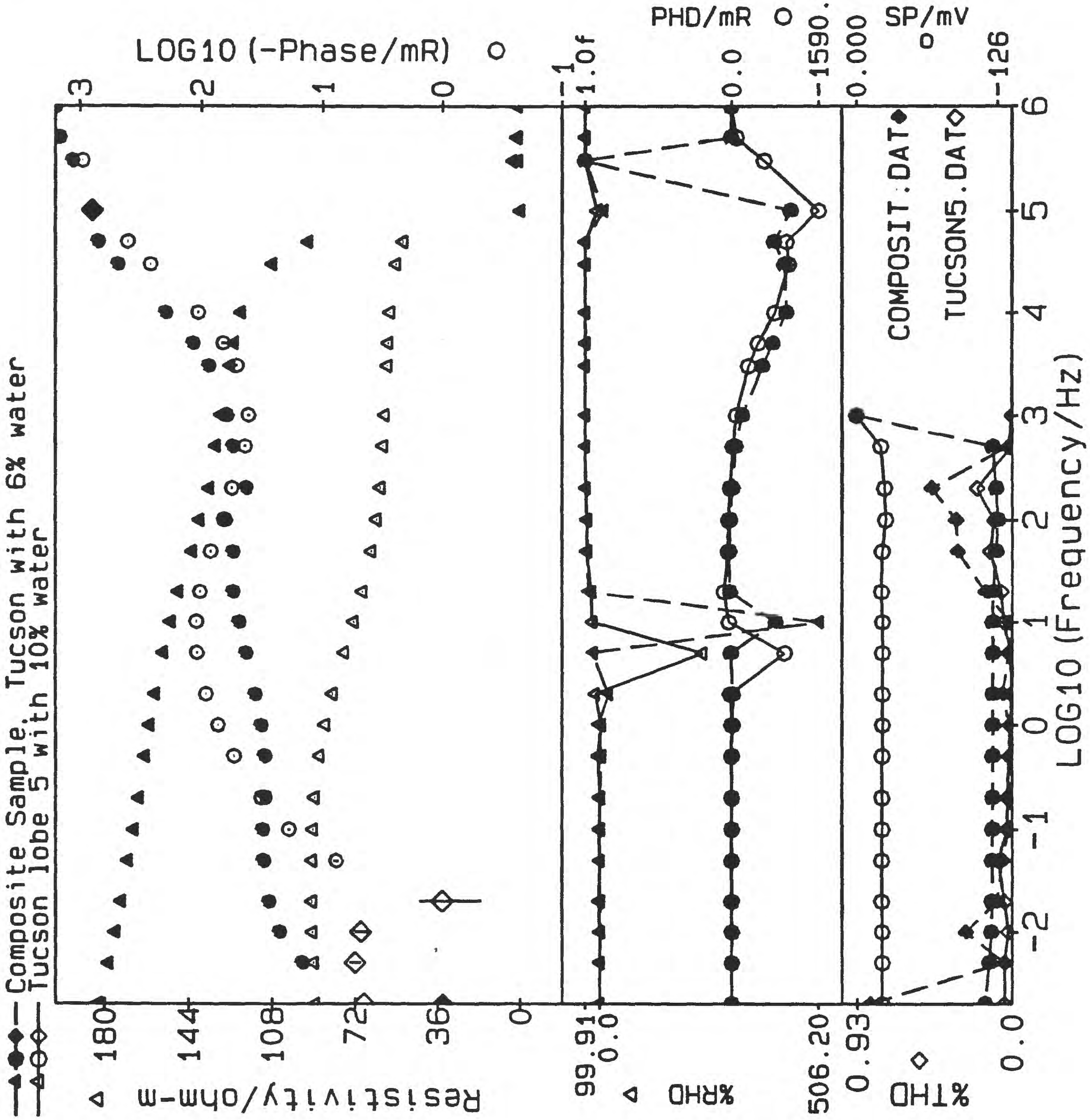

Composite Sample, Tucson with 6% water
Tucson lobe 4 with 10% water
Resistivity/ohm-m
180
144
108
72
36
0
LOG10 (-Phase/mR)
3
2
1
0
-1
99.91
%RHD
506.20
0.0
1.0f
PHD/mR
0.0
-1413.
0.93
%THD
0.0
SP/mV
5.6
0.0
-126
COMPOSIT.DAT
TUCSON4.DAT
-2
-1
0
1
2
3
4
5
6
LOG10 (Frequency/Hz)

Figure 13.



Composite Sample, Tucson with 6% water
Tucson lobe 5 with 10% water
LOG10 (-Phase/mR) ○
3
2
1
0
-1
Resistivity/ohm-m △
180
144
108
72
36
0
99.91
0.0
%RHD △
506.20
-1.0f
PHD/mR ○
0.0
-1590.
0.93
%THD ◇
0.0
0.000
SP/mV ○
-126
COMPOSIT.DAT◆
TUCSON5.DAT◇
6
5
4
3
2
1
0
-1
-2
LOG10 (Frequency/Hz)

Figure 14.

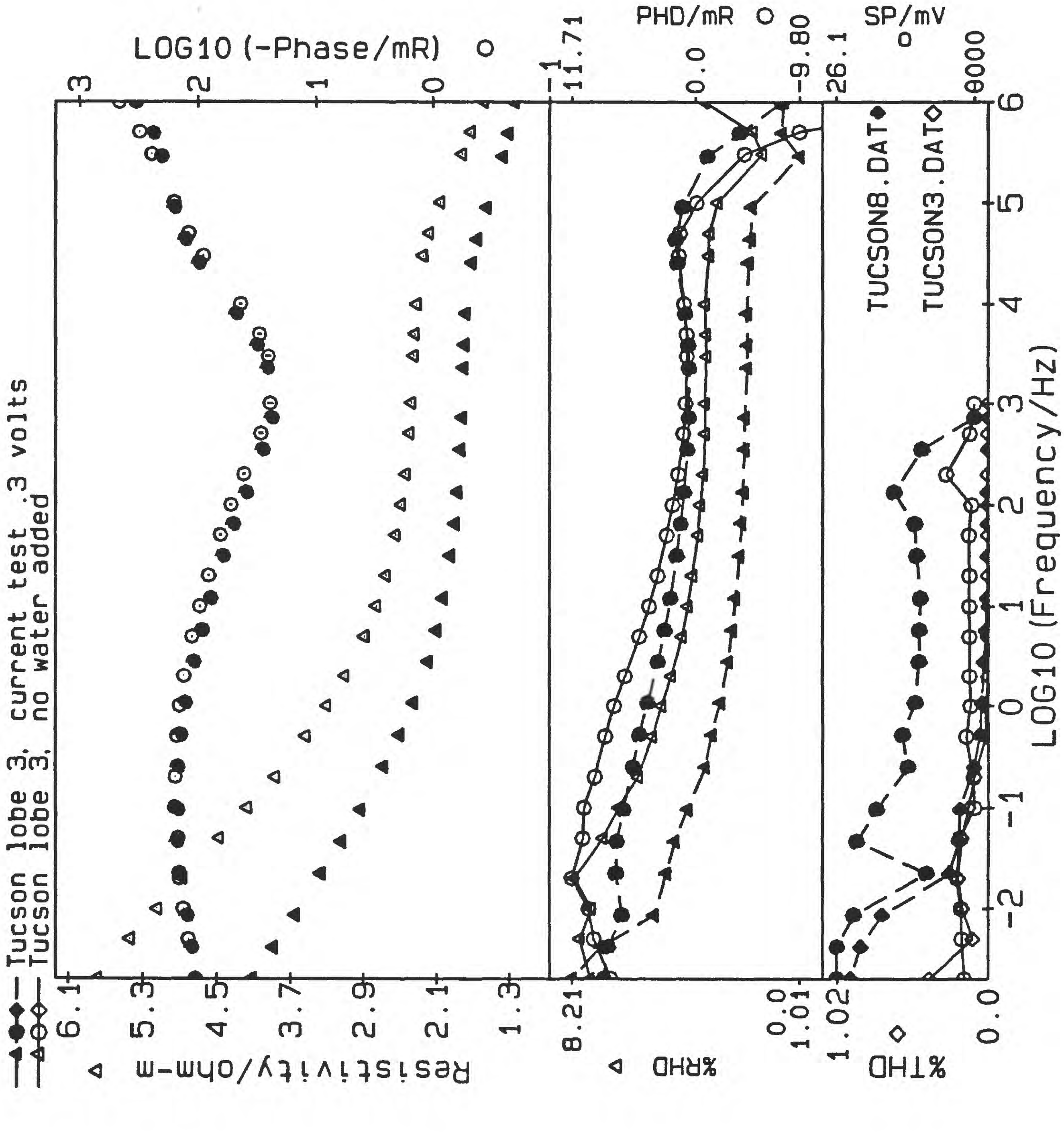
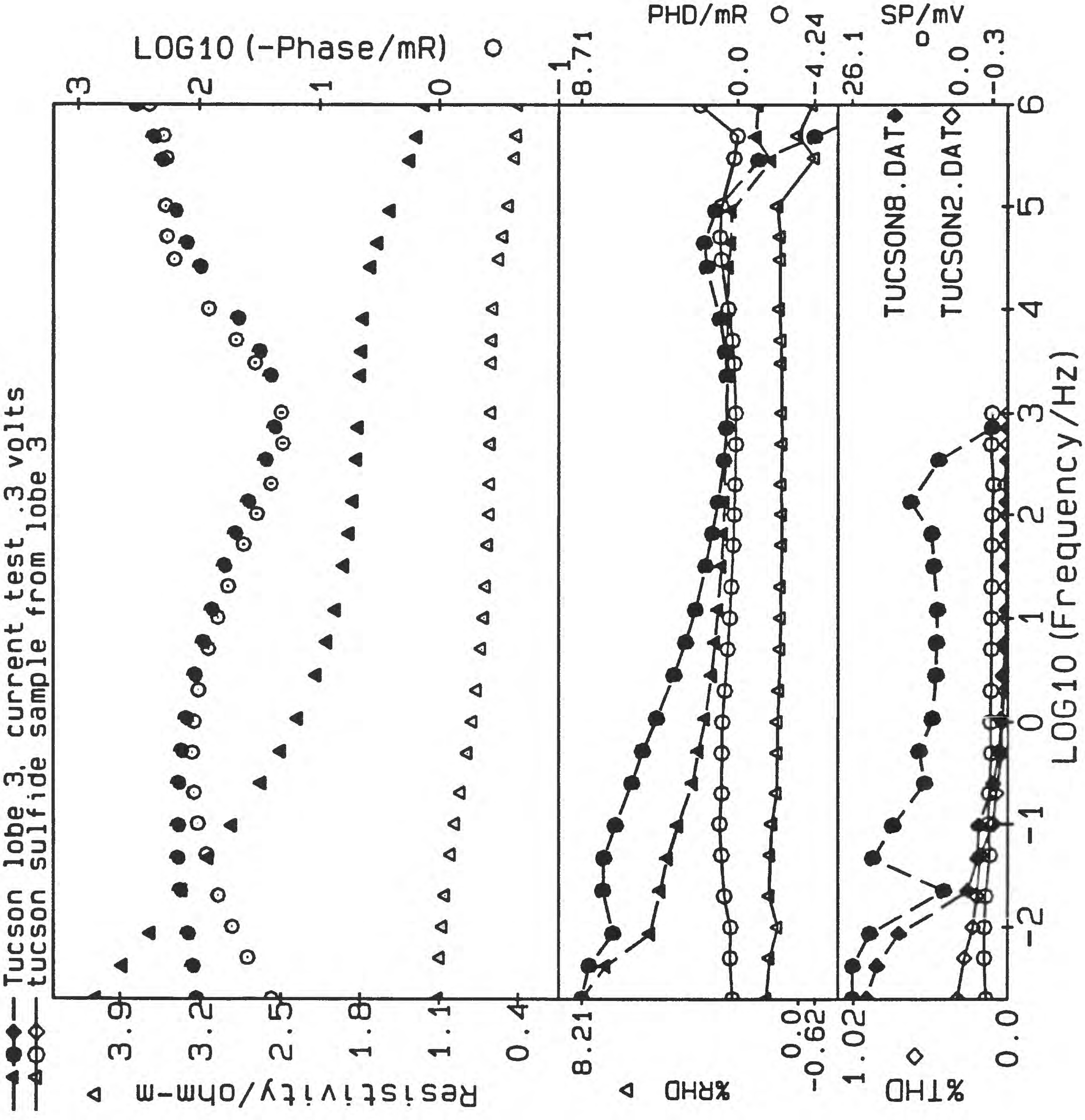

Tucson lobe 3. current test .3 volts
Tucson lobe 3. no water added
Resistivity/ohm-m
6.1
5.3
4.5
3.7
2.9
2.1
1.3
LOG10 (-Phase/mR)
3
2
1
0
-1
11.71
8.21
%RHD
0.0
1.01
PHD/mR
0.0
-9.80
1.02
%THD
0.0
-26.1
SP/mV
0000
TUCSON8.DAT
TUCSON3.DAT
-2
-1
0
1
2
3
4
5
6
LOG10 (Frequency/Hz)

Figure 15.


Tucson lobe 3. current test .3 volts
tucson sulfide sample from lobe 3
LOG10 (-Phase/mR)
-3
-2
-1
-0
1
Resistivity/ohm-m
3.9
3.2
2.5
1.8
1.1
0.4
%RHD
8.21
0.0
-0.62
8.71
-0.0
-4.24
PHD/mR
SP/mV
26.1
0.0
-0.3
%THD
1.02
0.0
TUCSON8.DAT
TUCSON2.DAT
LOG10 (Frequency/Hz)
-2
-1
0
1
2
3
4
5
6

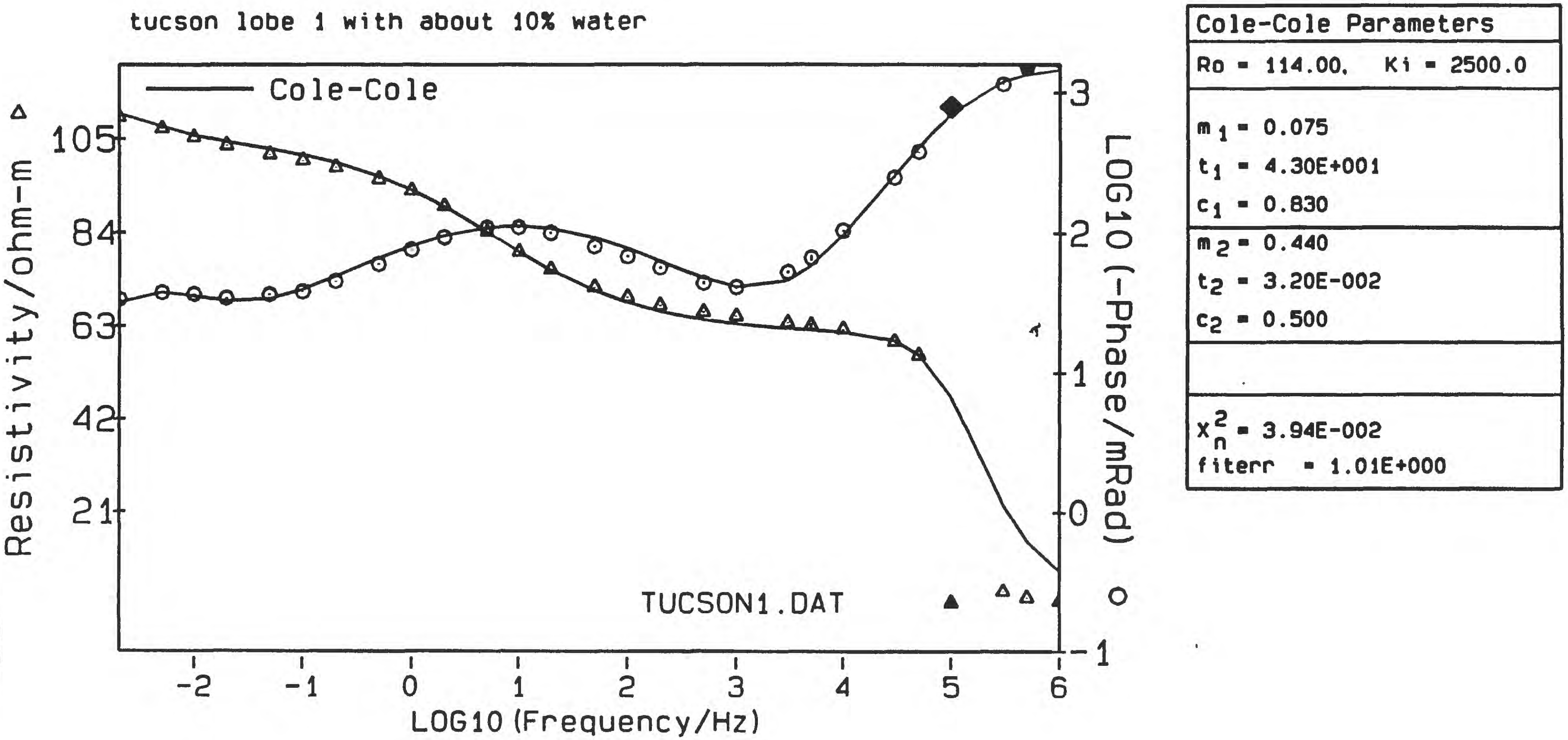
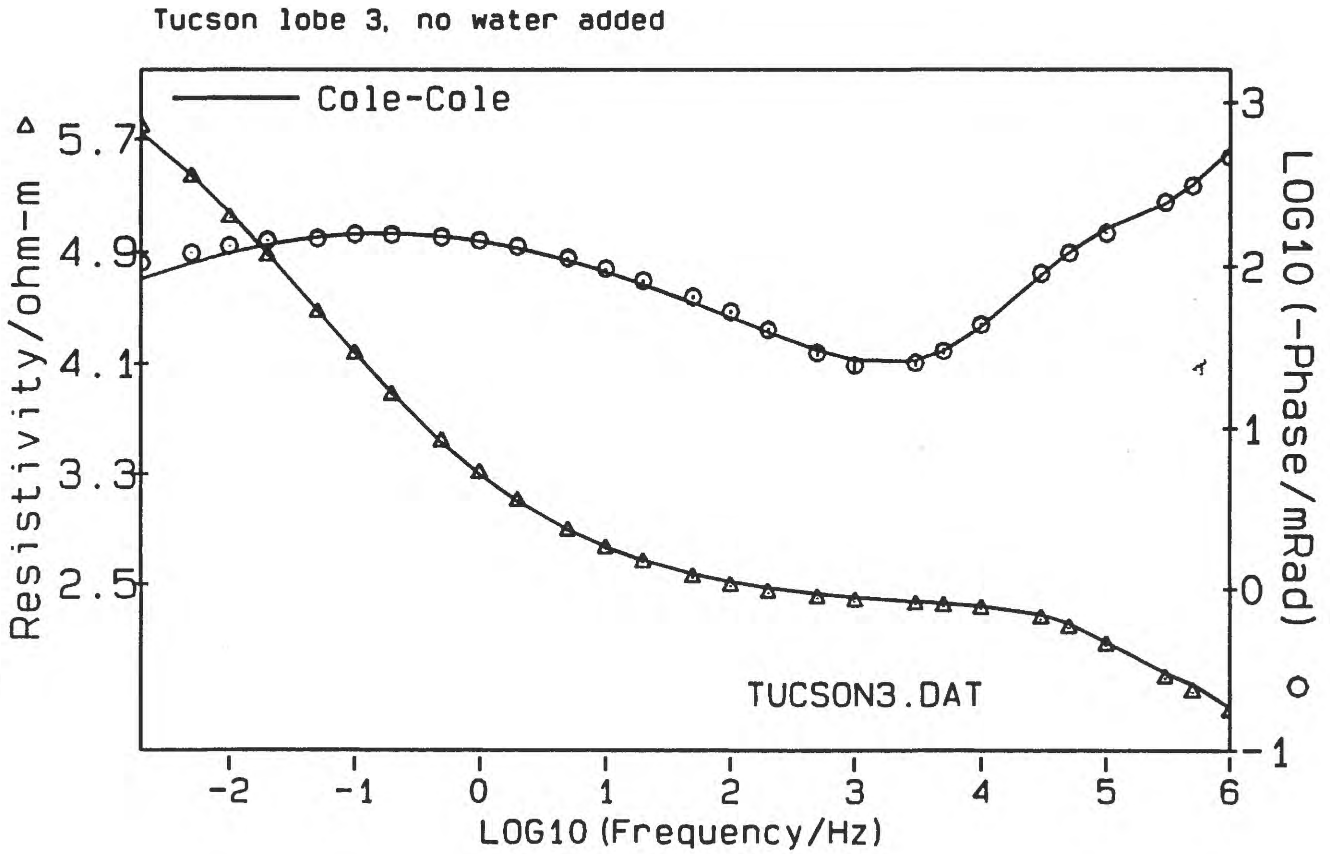

tucson lobe 1 with about 10% water
Cole-Cole
Resistivity/ohm-m
105
84
63
42
21
LOG10 (-Phase/mRad)
3
2
1
0
-1
TUCSON1.DAT
-2
-1
0
1
2
3
4
5
6
LOG10 (Frequency/Hz)
Cole-Cole Parameters
Ro = 114.00, Ki = 2500.0
m1 = 0.075
t1 = 4.30E+001
c1 = 0.830
m2 = 0.440
t2 = 3.20E-002
c2 = 0.500
xn2 = 3.94E-002
fiterr = 1.01E+000

Figure 16.



Cole-Cole Parameters

Ro = 6.70, Ki = 5130.0

m_1 = 0.656
t_1 = 3.88E+000
c_1 = 0.375

m_2 = 0.454
t_2 = 2.30E-006
c_2 = 0.903

x_n^2 = 5.22E-004

Figure 17.

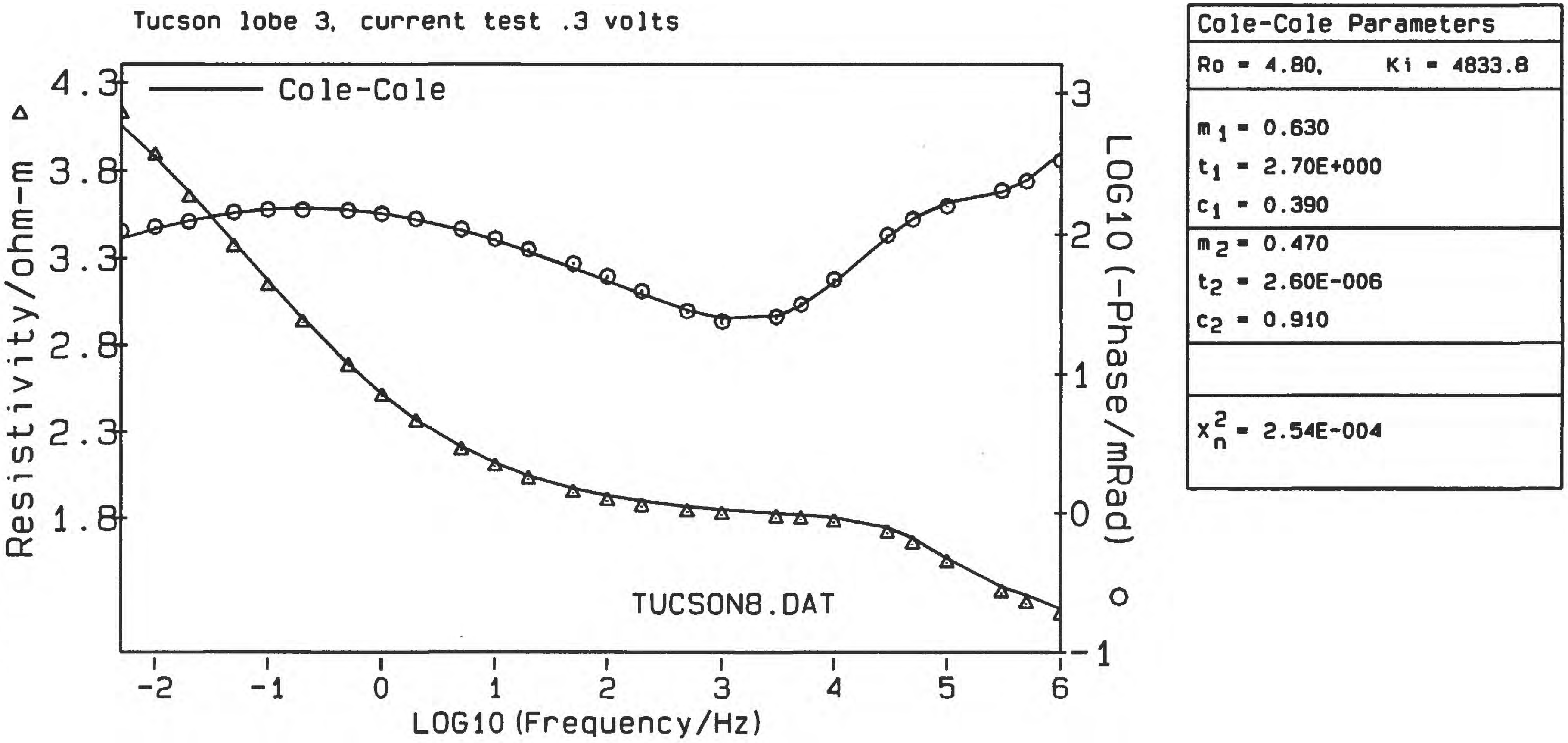
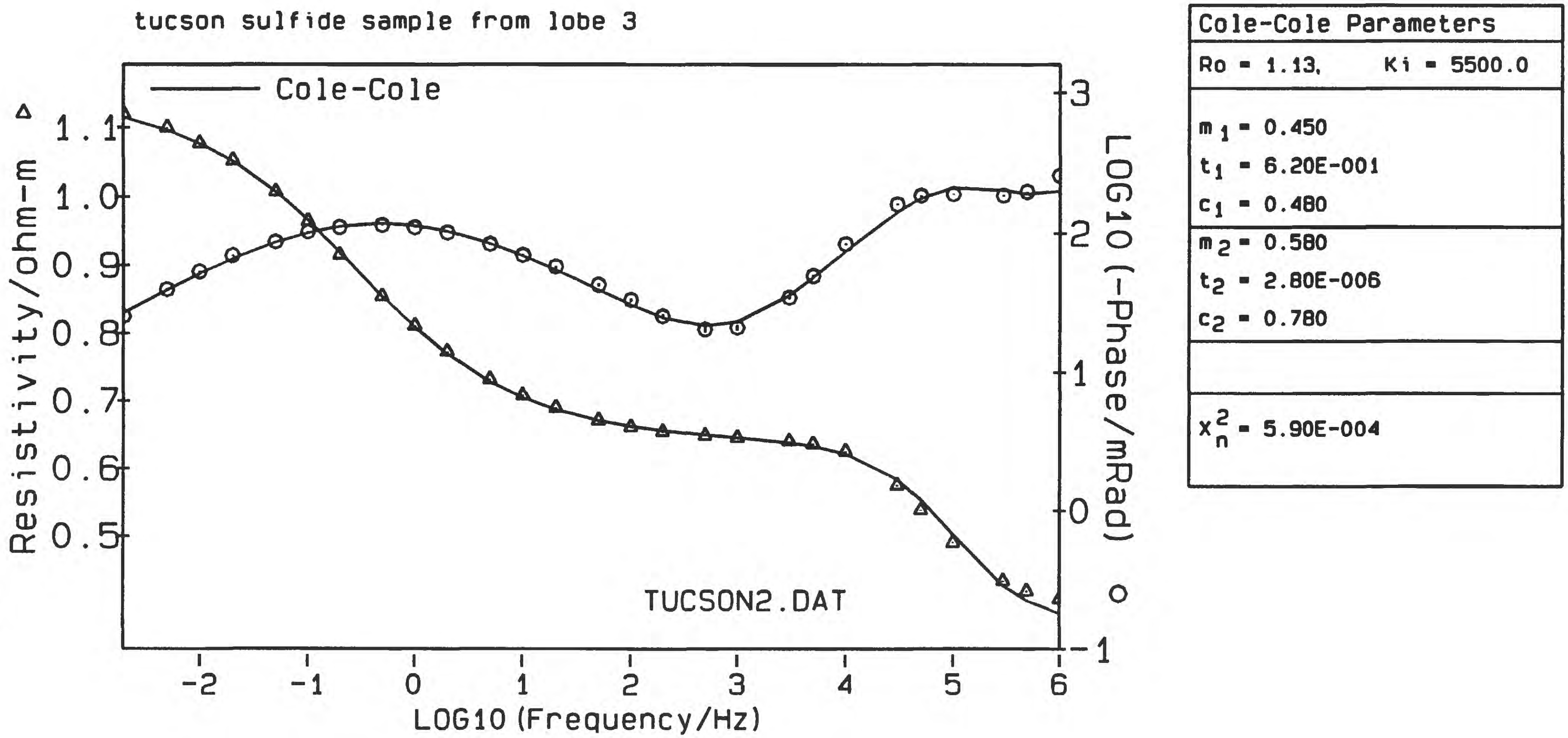

Tucson lobe 3, current test .3 volts
Cole-Cole
Resistivity/ohm-m △
4.3
3.8
3.3
2.8
2.3
1.8
LOG10 (-Phase/mRad) ○
3
2
1
0
-1
-2
-1
0
1
2
3
4
5
6
LOG10 (Frequency/Hz)
TUCSON8.DAT
Cole-Cole Parameters
Ro = 4.80,
Ki = 4833.8
m1 = 0.630
t1 = 2.70E+000
c1 = 0.390
m2 = 0.470
t2 = 2.60E-006
c2 = 0.910
x2n = 2.54E-004

Figure 18.



Cole-Cole Parameters

R_o = 1.13, K_i = 5500.0

m_1 = 0.450
t_1 = 6.20E-001
c_1 = 0.480

m_2 = 0.580
t_2 = 2.80E-006
c_2 = 0.780

x_n^2 = 5.90E-004

Figure 19.

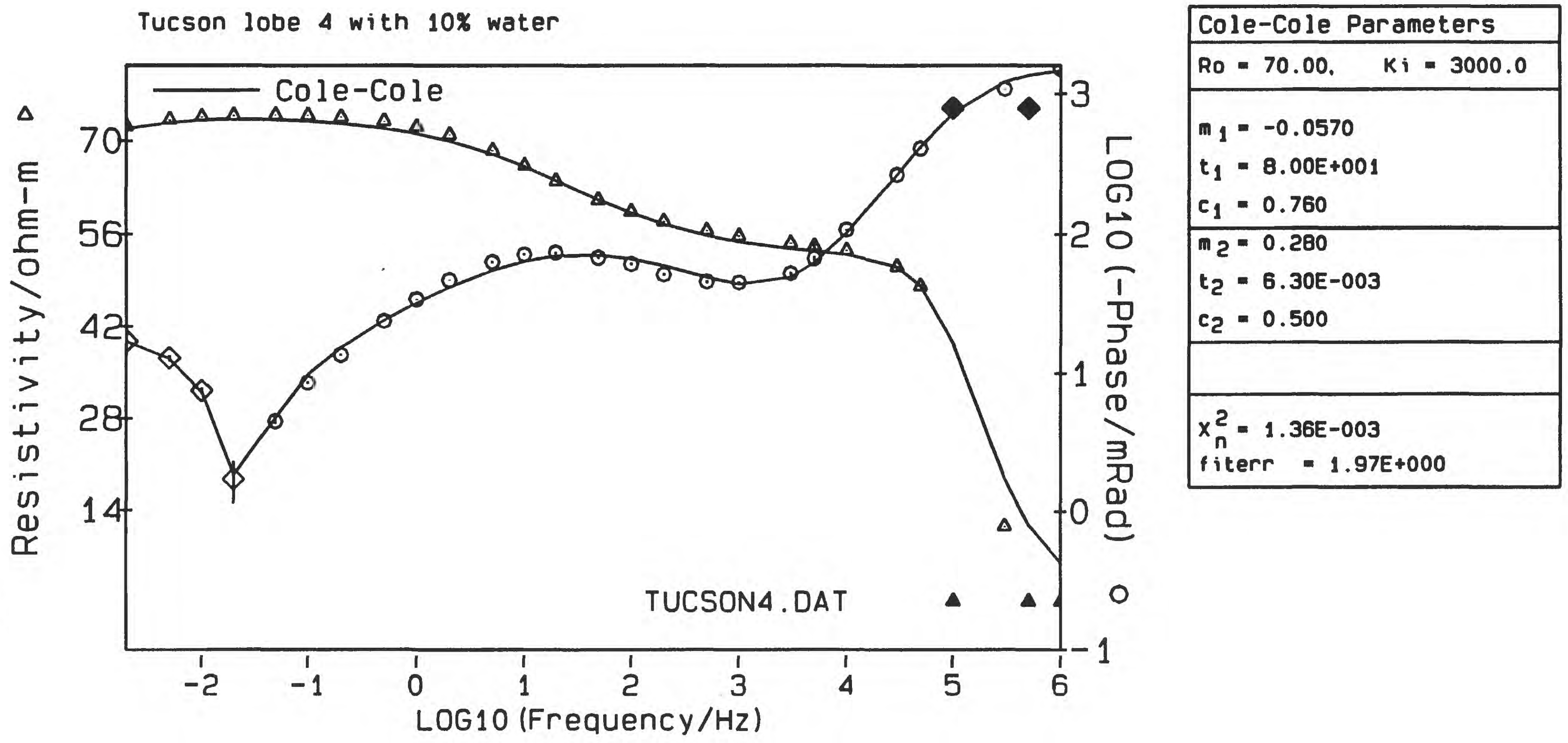

Tucson lobe 4 with 10% water
Cole-Cole
Resistivity/ohm-m △
70
56
42
28
14
LOG10 (-Phase/mRad) ○
3
2
1
0
-1
-2
-1
0
1
2
3
4
5
6
LOG10 (Frequency/Hz)
TUCSON4.DAT
Cole-Cole Parameters
Ro = 70.00, Ki = 3000.0
m1 = -0.0570
t1 = 8.00E+001
c1 = 0.760
m2 = 0.280
t2 = 6.30E-003
c2 = 0.500
x2n = 1.36E-003
fiterr = 1.97E+000

Figure 20.

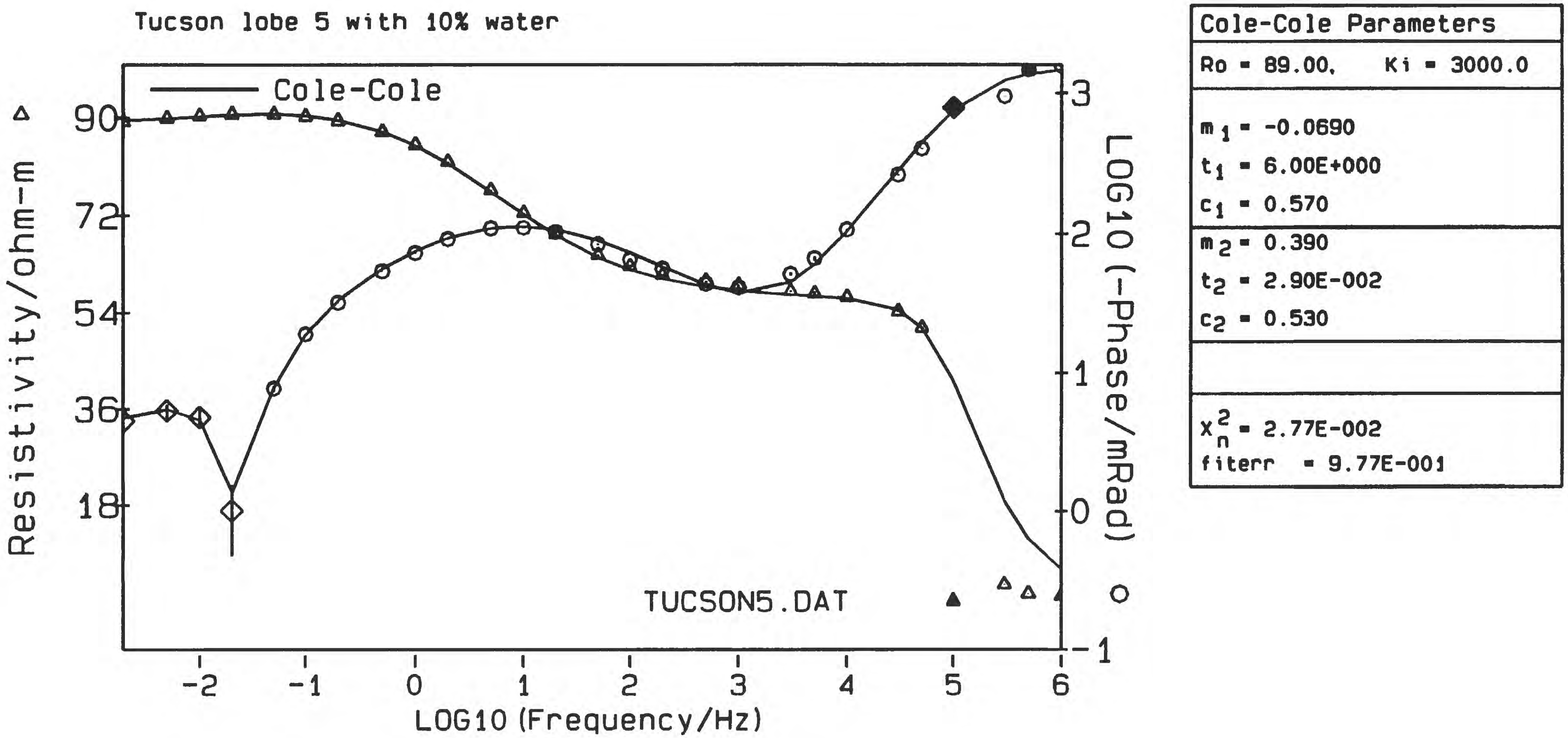

Tucson lobe 5 with 10% water
Cole-Cole
Resistivity/ohm-m △
90
72
54
36
18
LOG10 (-Phase/mRad) ○
3
2
1
0
-1
TUCSON5.DAT
-2
-1
0
1
2
3
4
5
6
LOG10 (Frequency/Hz)
Cole-Cole Parameters
Ro = 89.00, Ki = 3000.0
m1 = -0.0690
t1 = 6.00E+000
c1 = 0.570
m2 = 0.390
t2 = 2.90E-002
c2 = 0.530
x2n = 2.77E-002
fiterr = 9.77E-001

Figure 21.

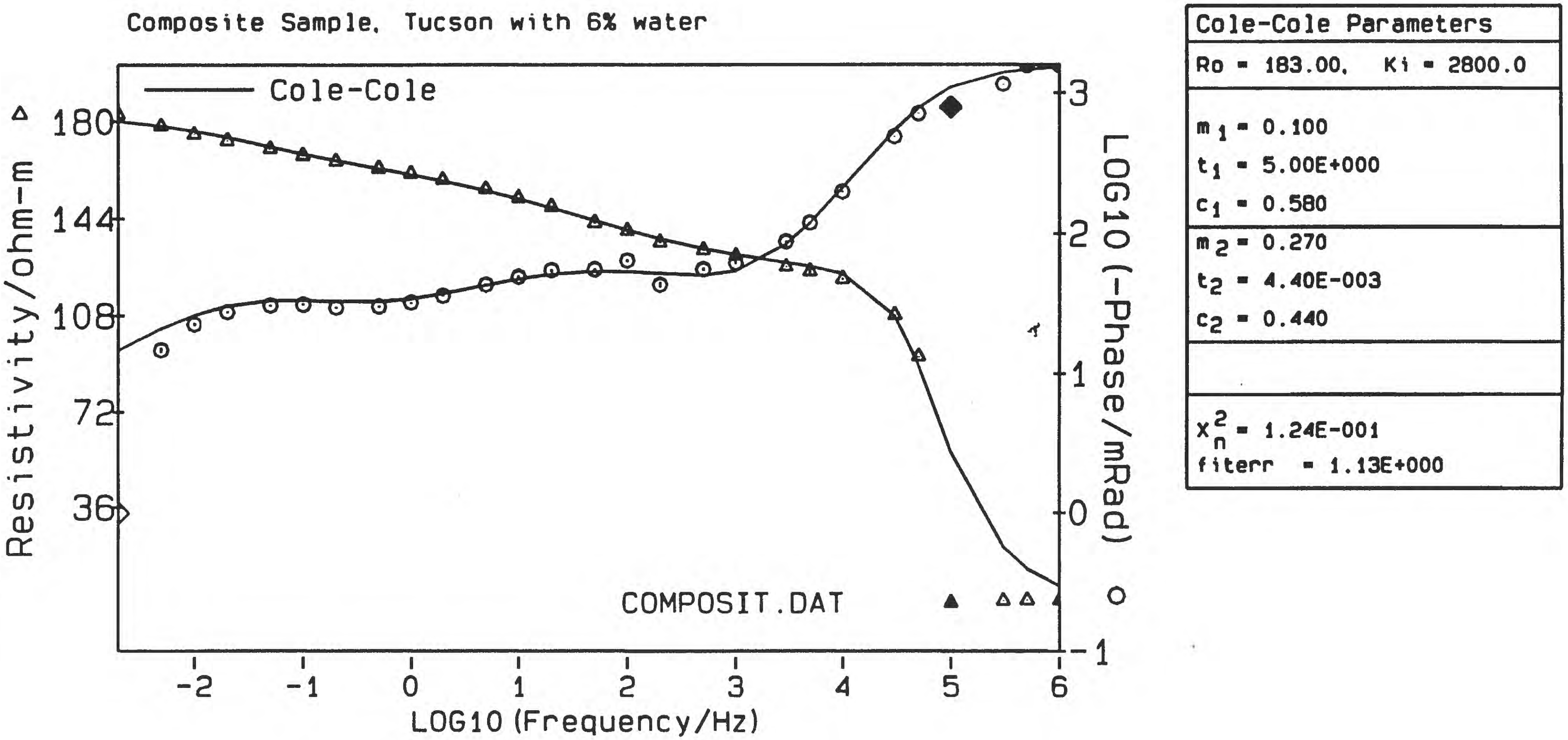

Composite Sample, Tucson with 6% water
Cole-Cole
△ Resistivity/ohm-m
180
144
108
72
36
LOG10 (-Phase/mRad) ○
3
2
1
0
-1
-2
-1
0
1
2
3
4
5
6
LOG10 (Frequency/Hz)
COMPOSIT.DAT
Cole-Cole Parameters
Ro = 183.00, Ki = 2800.0
m 1 = 0.100
t1 = 5.00E+000
c1 = 0.580
m 2 = 0.270
t2 = 4.40E-003
c2 = 0.440
x2n = 1.24E-001
fiterr = 1.13E+000

Figure 22.

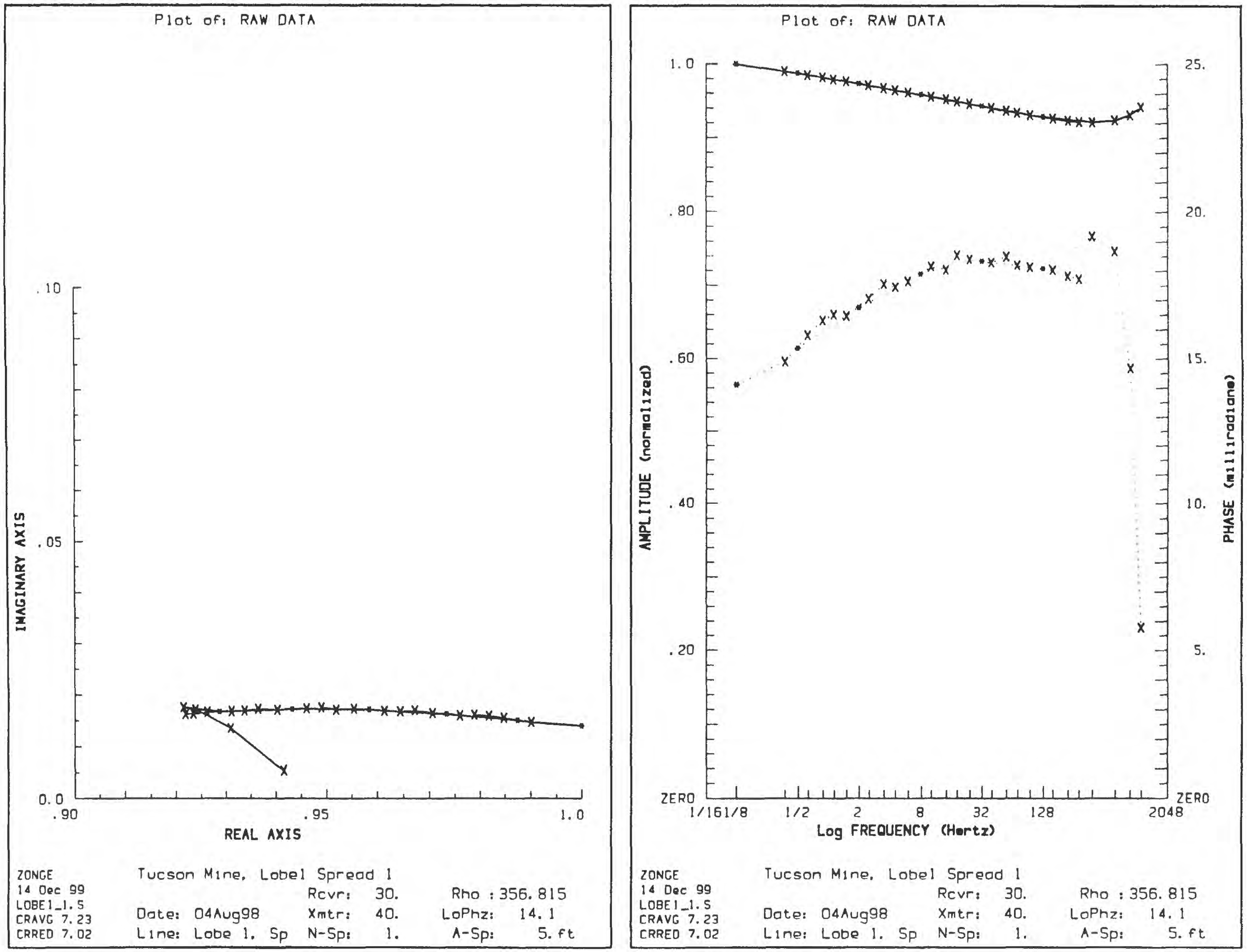

Plot of: RAW DATA
IMAGINARY AXIS
.10
.05
0.0
.90
.95
1.0
REAL AXIS
ZONGE
14 Dec 99
LOBE1_1.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobel Spread 1
Date: 04Aug98
Line: Lobe 1. Sp
Rcvr: 30.
Xmtr: 40.
N-Sp: 1.
Rho : 356.815
LoPhz: 14.1
A-Sp: 5. ft
Plot of: RAW DATA
AMPLITUDE (normalized)
1.0
.80
.60
.40
.20
ZERO
PHASE (milliradians)
25.
20.
15.
10.
5.
ZERO
1/161/8
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
14 Dec 99
LOBE1_1.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobel Spread 1
Date: 04Aug98
Line: Lobe 1. Sp
Rcvr: 30.
Xmtr: 40.
N-Sp: 1.
Rho : 356.815
LoPhz: 14.1
A-Sp: 5. ft

Figure 23.

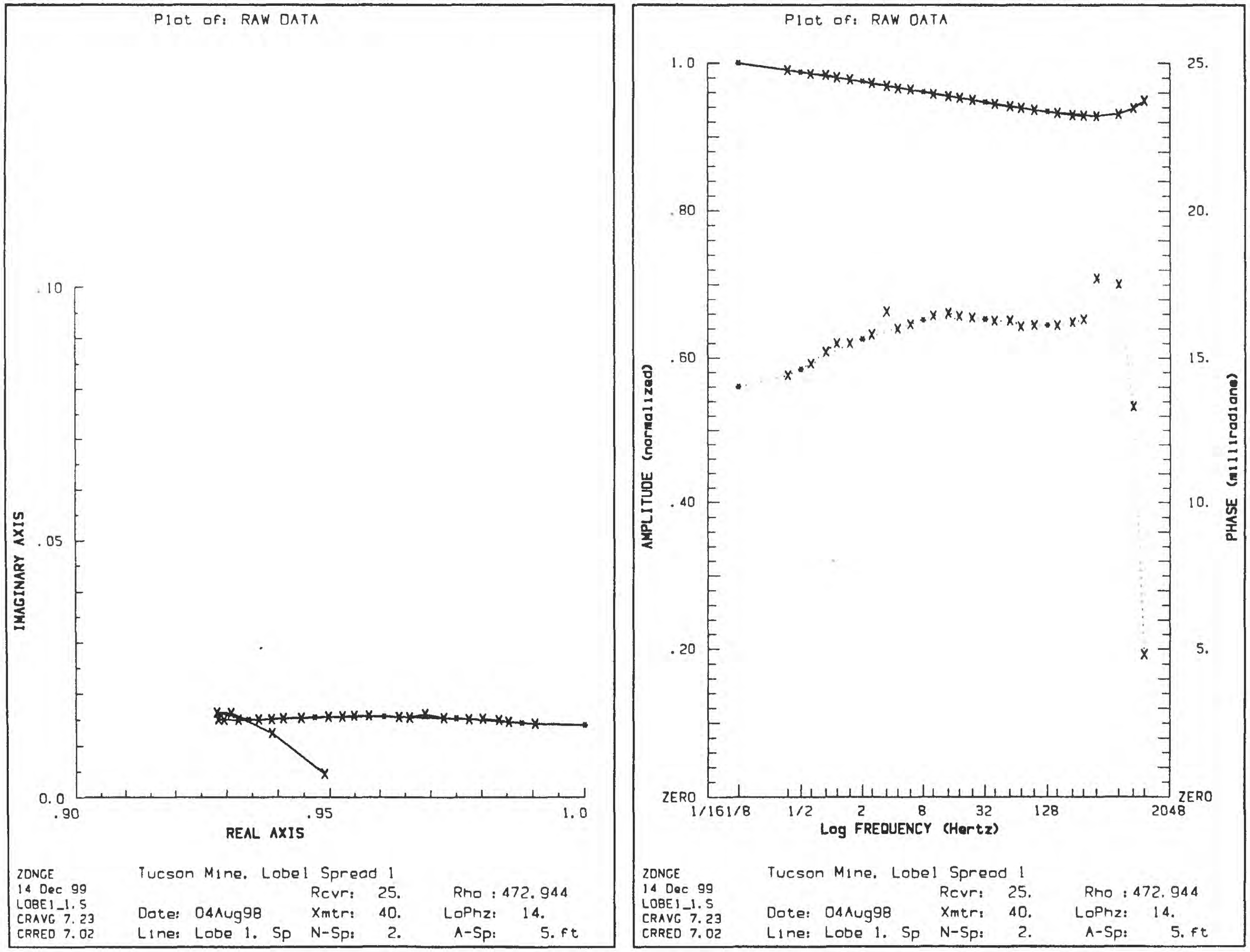

Plot of: RAW DATA
IMAGINARY AXIS
.10
.05
0.0
.90
.95
1.0
REAL AXIS
ZONGE
14 Dec 99
LOBE1_1.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobel Spread 1
Rcvr: 25.
Rho : 472.944
Date: 04Aug98
Xmtr: 40.
LoPhz: 14.
Line: Lobe 1. Sp
N-Sp: 2.
A-Sp: 5. ft
Plot of: RAW DATA
AMPLITUDE (normalized)
1.0
.80
.60
.40
.20
ZERO
PHASE (milliradians)
25.
20.
15.
10.
5.
ZERO
1/161/8
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
14 Dec 99
LOBE1_1.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobel Spread 1
Rcvr: 25.
Rho : 472.944
Date: 04Aug98
Xmtr: 40.
LoPhz: 14.
Line: Lobe 1. Sp
N-Sp: 2.
A-Sp: 5. ft

Figure 24.

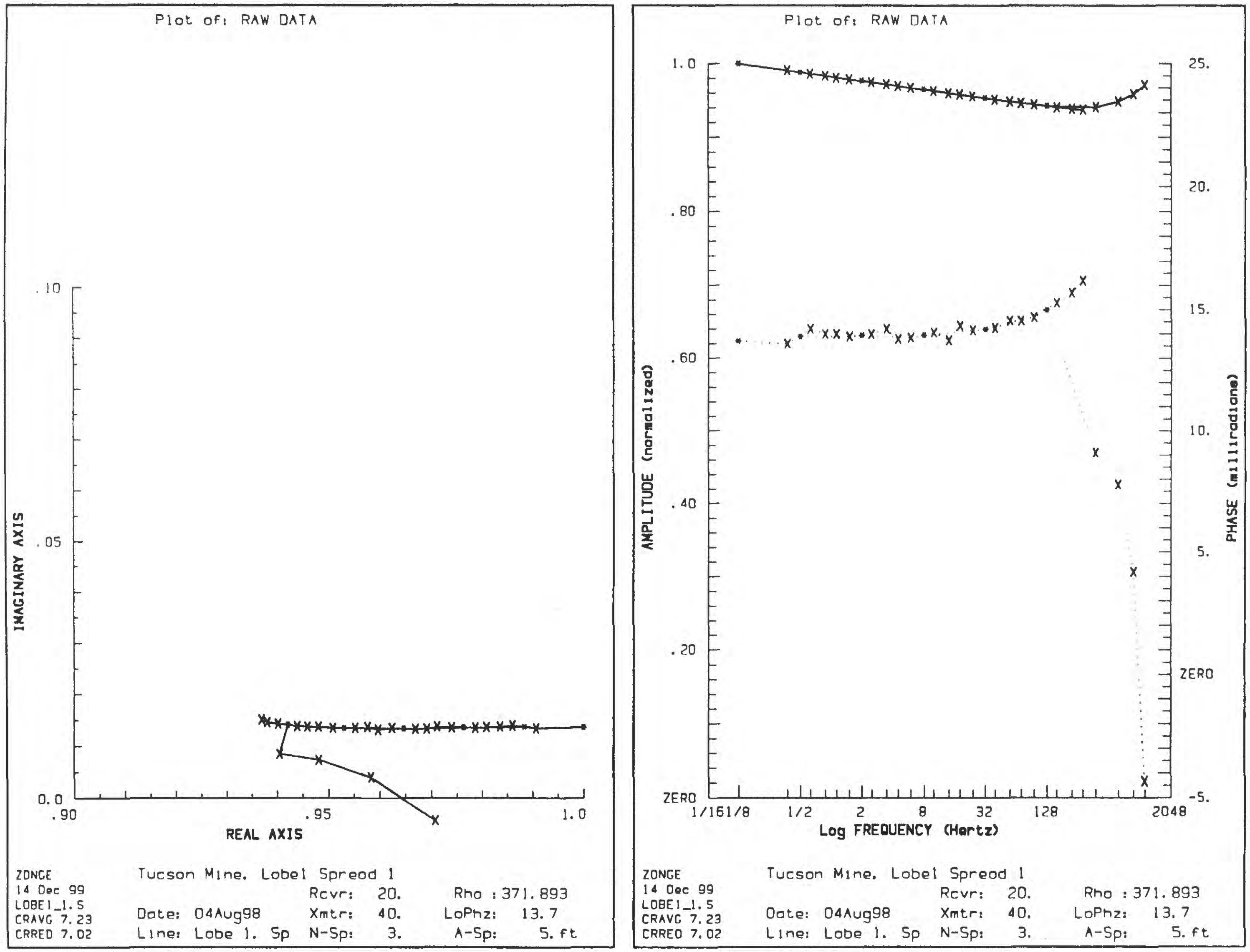

Plot of: RAW DATA
IMAGINARY AXIS
.10
.05
0.0
.90
.95
1.0
REAL AXIS
ZONGE
14 Dec 99
LOBE1_1.S
CRAVG 7.23
CRRED 7.02
Tucson Mine. Lobel Spread 1
Date: 04Aug98
Line: Lobe 1. Sp
Rcvr: 20.
Xmtr: 40.
N-Sp: 3.
Rho : 371.893
LoPhz: 13.7
A-Sp: 5. ft
Plot of: RAW DATA
AMPLITUDE (normalized)
1.0
.80
.60
.40
.20
ZERO
1/161/8
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
PHASE (milliradians)
25.
20.
15.
10.
5.
ZERO
-5.
ZONGE
14 Dec 99
LOBE1_1.S
CRAVG 7.23
CRRED 7.02
Tucson Mine. Lobel Spread 1
Date: 04Aug98
Line: Lobe 1. Sp
Rcvr: 20.
Xmtr: 40.
N-Sp: 3.
Rho : 371.893
LoPhz: 13.7
A-Sp: 5. ft

Figure 25.

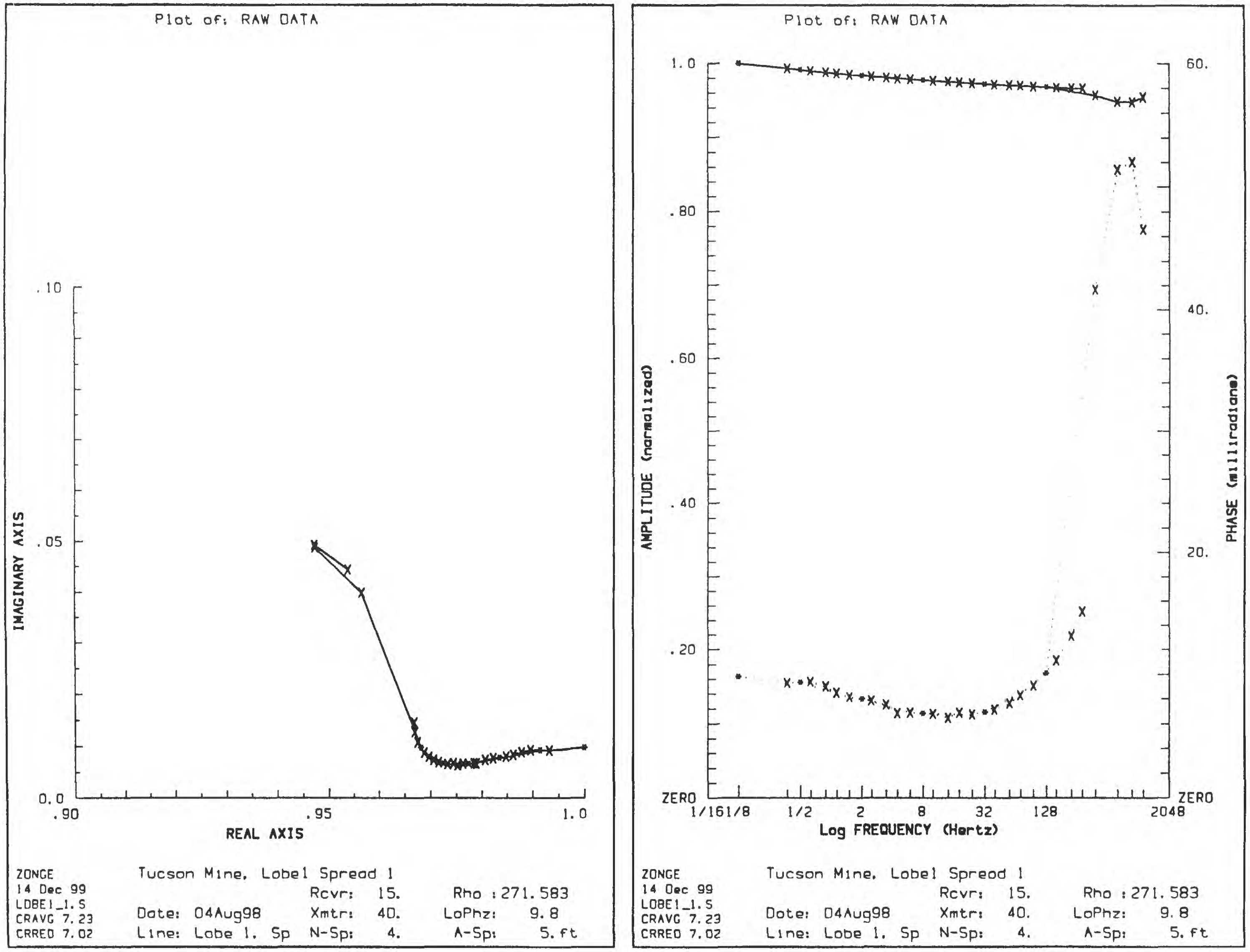

Plot of: RAW DATA
IMAGINARY AXIS
.10
.05
0.0
.90
.95
1.0
REAL AXIS
ZONGE
14 Dec 99
LOBE1_1.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe1 Spread 1
Date: 04Aug98
Line: Lobe 1. Sp
Rcvr: 15.
Xmtr: 40.
N-Sp: 4.
Rho : 271.583
LoPhz: 9.8
A-Sp: 5. ft
Plot of: RAW DATA
AMPLITUDE (normalized)
1.0
.80
.60
.40
.20
ZERO
PHASE (milliradians)
60.
40.
20.
ZERO
1/16
1/8
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
14 Dec 99
LOBE1_1.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe1 Spread 1
Date: 04Aug98
Line: Lobe 1. Sp
Rcvr: 15.
Xmtr: 40.
N-Sp: 4.
Rho : 271.583
LoPhz: 9.8
A-Sp: 5. ft

Figure 26.

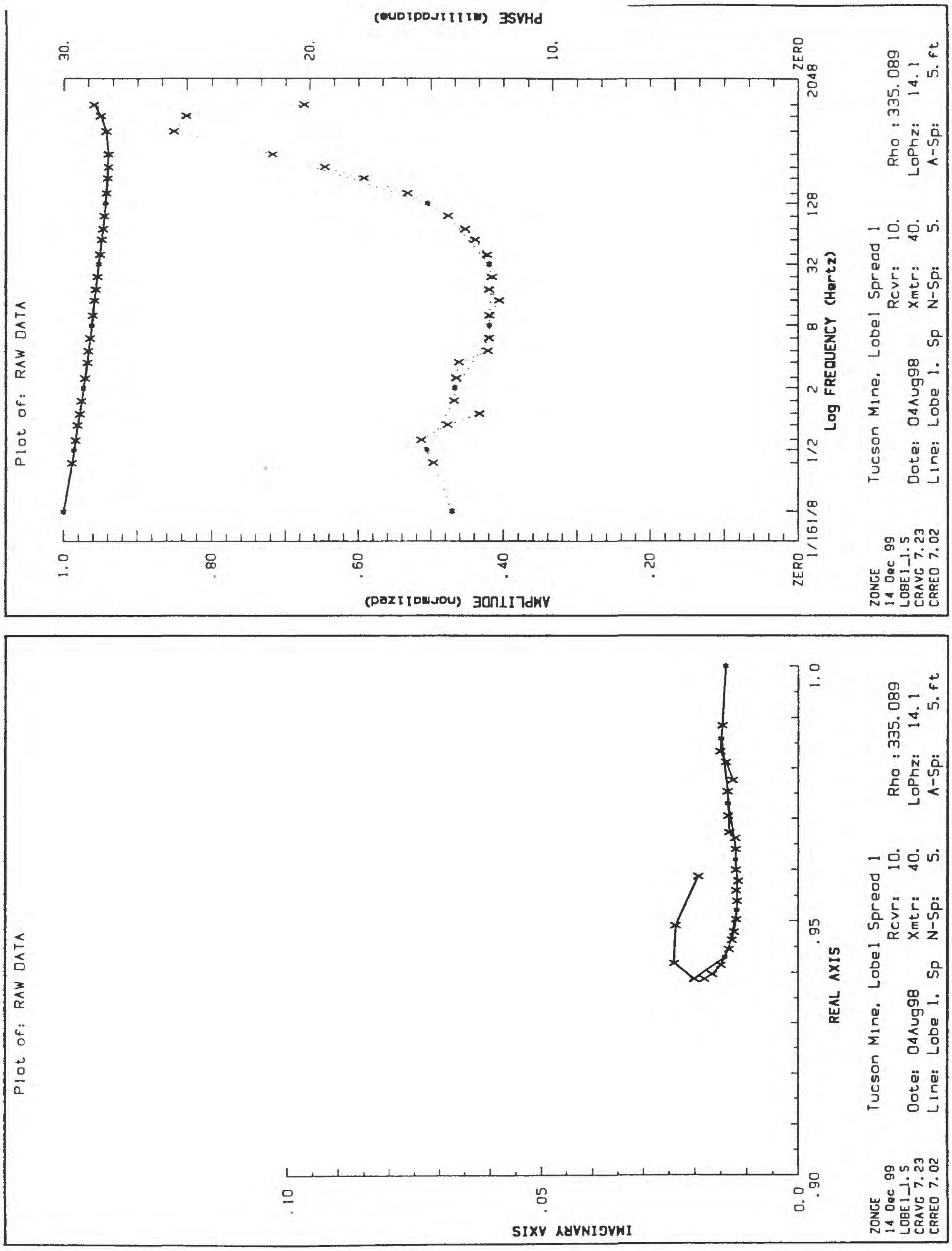

Plot of: RAW DATA
PHASE (milliradians)
30.
20.
10.
AMPLITUDE (normalized)
1.0
.80
.60
.40
.20
ZERO
1/16
1/8
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
14 Dec 99
LOBE1_1.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobel Spread 1
Date: 04Aug98
Line: Lobe 1. Sp
Rcvr: 10.
Xmtr: 40.
N-Sp: 5.
Rho : 335.089
LoPhz: 14.1
A-Sp: 5. ft
Plot of: RAW DATA
IMAGINARY AXIS
.10
.05
0.0
.90
.95
1.0
REAL AXIS
ZONGE
14 Dec 99
LOBE1_1.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobel Spread 1
Date: 04Aug98
Line: Lobe 1. Sp
Rcvr: 10.
Xmtr: 40.
N-Sp: 5.
Rho : 335.089
LoPhz: 14.1
A-Sp: 5. ft

Figure 27.

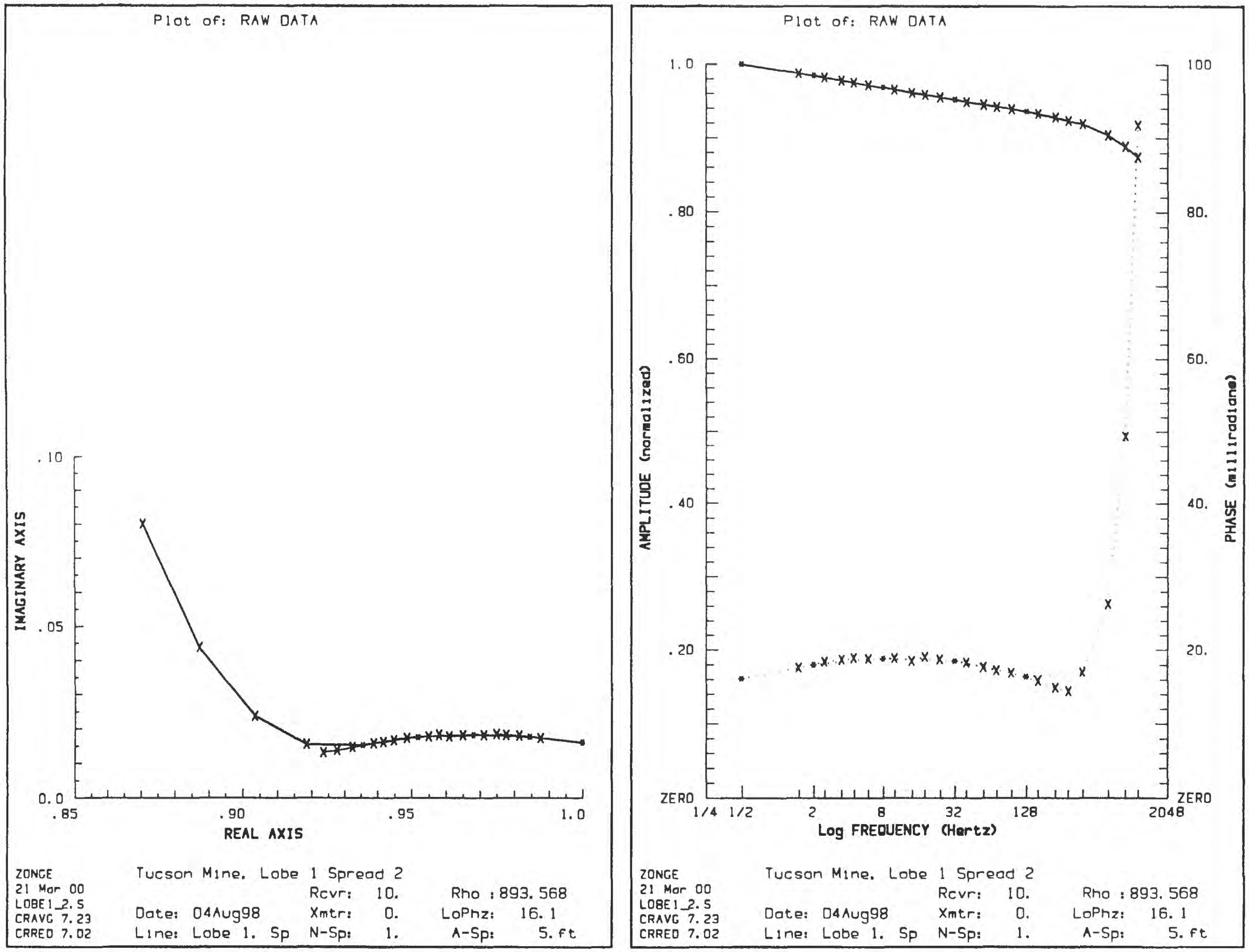

Plot of: RAW DATA
IMAGINARY AXIS
.10
.05
0.0
.85
.90
.95
1.0
REAL AXIS
ZONGE
21 Mar 00
LOBE1_2.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 1 Spread 2
Rcvr: 10.
Rho : 893.568
Date: 04Aug98
Xmtr: 0.
LoPhz: 16.1
Line: Lobe 1. Sp
N-Sp: 1.
A-Sp: 5.ft
Plot of: RAW DATA
AMPLITUDE (normalized)
1.0
.80
.60
.40
.20
ZERO
PHASE (milliradians)
100
80.
60.
40.
20.
ZERO
1/4
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
21 Mar 00
LOBE1_2.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 1 Spread 2
Rcvr: 10.
Rho : 893.568
Date: 04Aug98
Xmtr: 0.
LoPhz: 16.1
Line: Lobe 1. Sp
N-Sp: 1.
A-Sp: 5.ft

Figure 28.

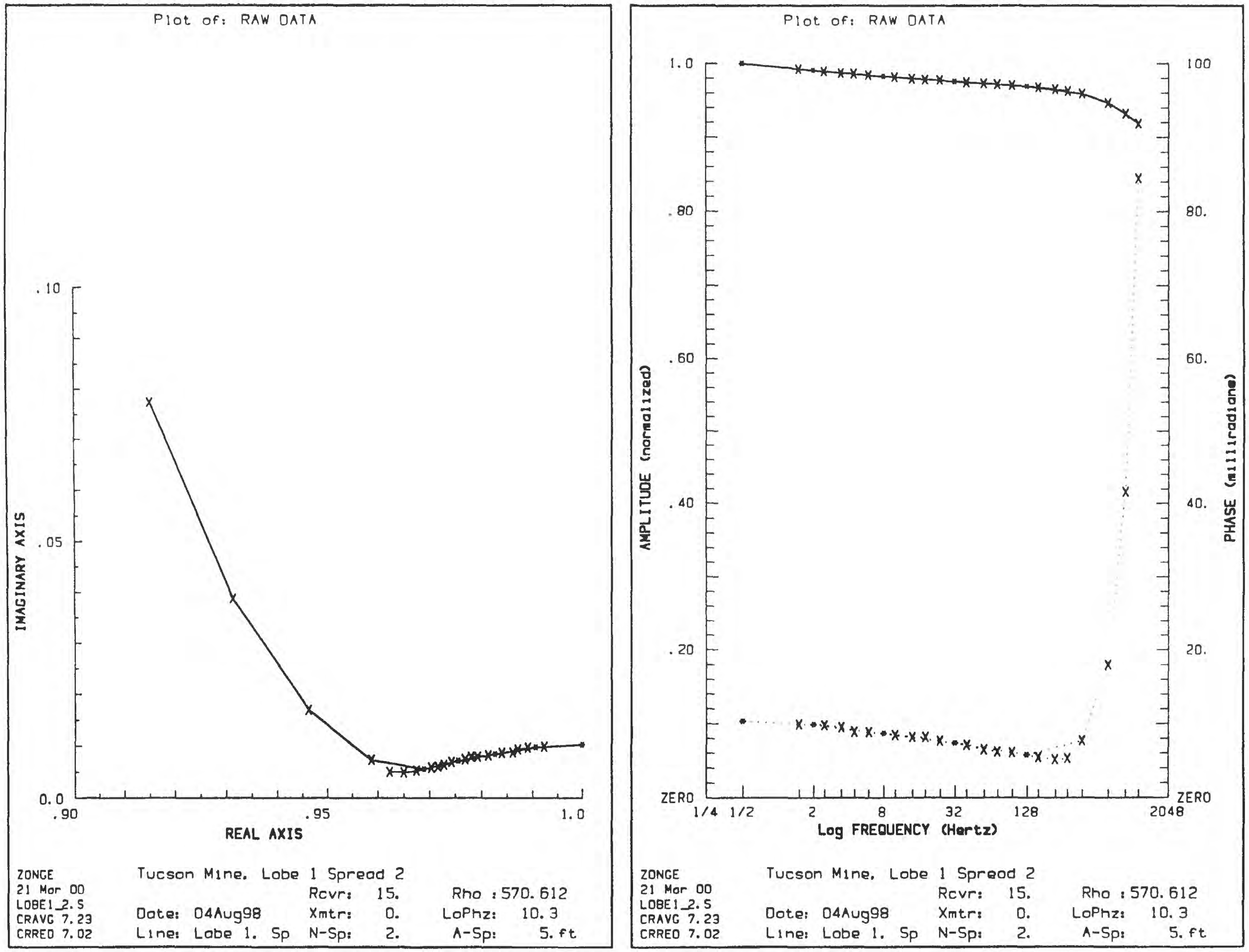

Plot of: RAW DATA
IMAGINARY AXIS
.10
.05
0.0
.90
.95
1.0
REAL AXIS
ZONGE
21 Mar 00
LOBE1_2.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 1 Spread 2
Date: 04Aug98
Line: Lobe 1. Sp
Rcvr: 15.
Xmtr: 0.
N-Sp: 2.
Rho : 570.612
LoPhz: 10.3
A-Sp: 5. ft
Plot of: RAW DATA
AMPLITUDE (normalized)
1.0
.80
.60
.40
.20
ZERO
PHASE (milliradians)
100
80.
60.
40.
20.
ZERO
1/4
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
21 Mar 00
LOBE1_2.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 1 Spread 2
Date: 04Aug98
Line: Lobe 1. Sp
Rcvr: 15.
Xmtr: 0.
N-Sp: 2.
Rho : 570.612
LoPhz: 10.3
A-Sp: 5. ft

Figure 29.

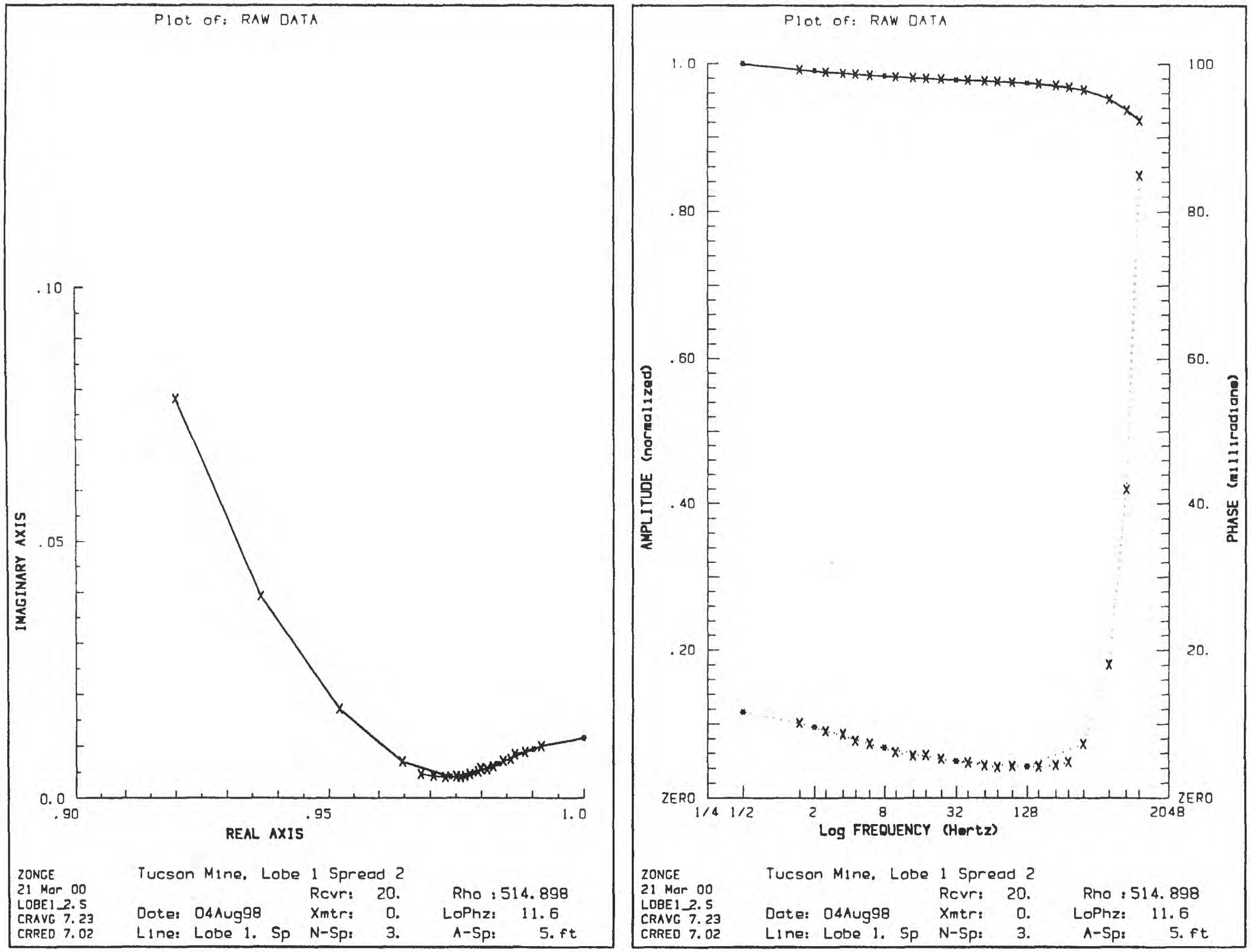

Plot of: RAW DATA
IMAGINARY AXIS
.10
.05
0.0
.90
.95
1.0
REAL AXIS
ZONGE
21 Mar 00
LOBE1_2.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 1 Spread 2
Date: 04Aug98
Line: Lobe 1. Sp
Rcvr: 20.
Xmtr: 0.
N-Sp: 3.
Rho : 514.898
LoPhz: 11.6
A-Sp: 5. ft
Plot of: RAW DATA
AMPLITUDE (normalized)
1.0
.80
.60
.40
.20
ZERO
PHASE (milliradians)
100
80.
60.
40.
20.
ZERO
1/4
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
21 Mar 00
LOBE1_2.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 1 Spread 2
Date: 04Aug98
Line: Lobe 1. Sp
Rcvr: 20.
Xmtr: 0.
N-Sp: 3.
Rho : 514.898
LoPhz: 11.6
A-Sp: 5. ft

Figure 30.

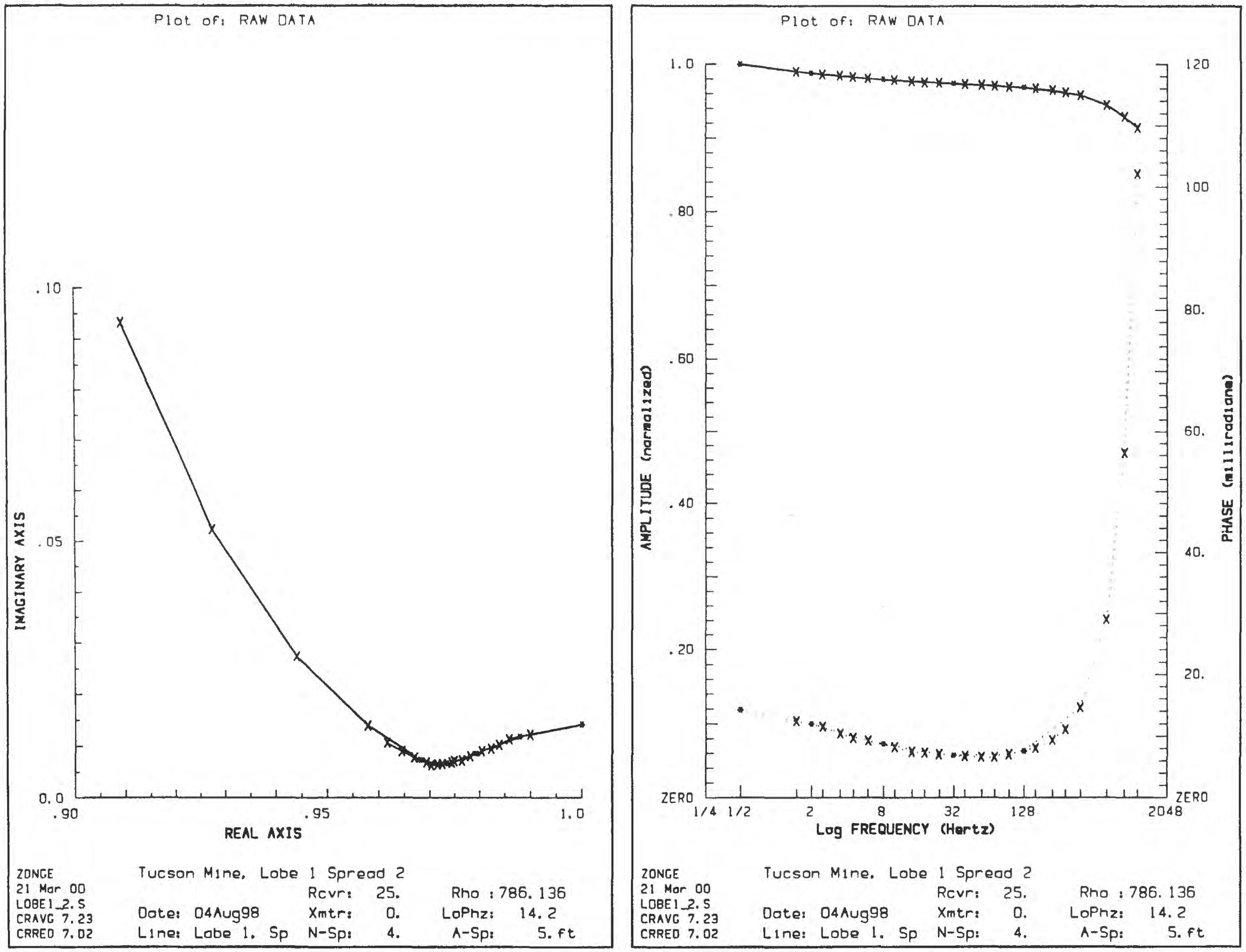
Plot of: RAW DATA
IMAGINARY AXIS
.10
.05
0.0
.90
.95
1.0
REAL AXIS
ZONGE
21 Mar 00
LOBE1_2.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 1 Spread 2
Date: 04Aug98
Line: Lobe 1. Sp
Rcvr: 25.
Xmtr: 0.
N-Sp: 4.
Rho : 786.136
LoPhz: 14.2
A-Sp: 5. ft
Plot of: RAW DATA
AMPLITUDE (normalized)
1.0
.80
.60
.40
.20
ZERO
PHASE (milliradians)
120
100
80.
60.
40.
20.
ZERO
1/4
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
21 Mar 00
LOBE1_2.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 1 Spread 2
Date: 04Aug98
Line: Lobe 1. Sp
Rcvr: 25.
Xmtr: 0.
N-Sp: 4.
Rho : 786.136
LoPhz: 14.2
A-Sp: 5. ft

Figure 31.

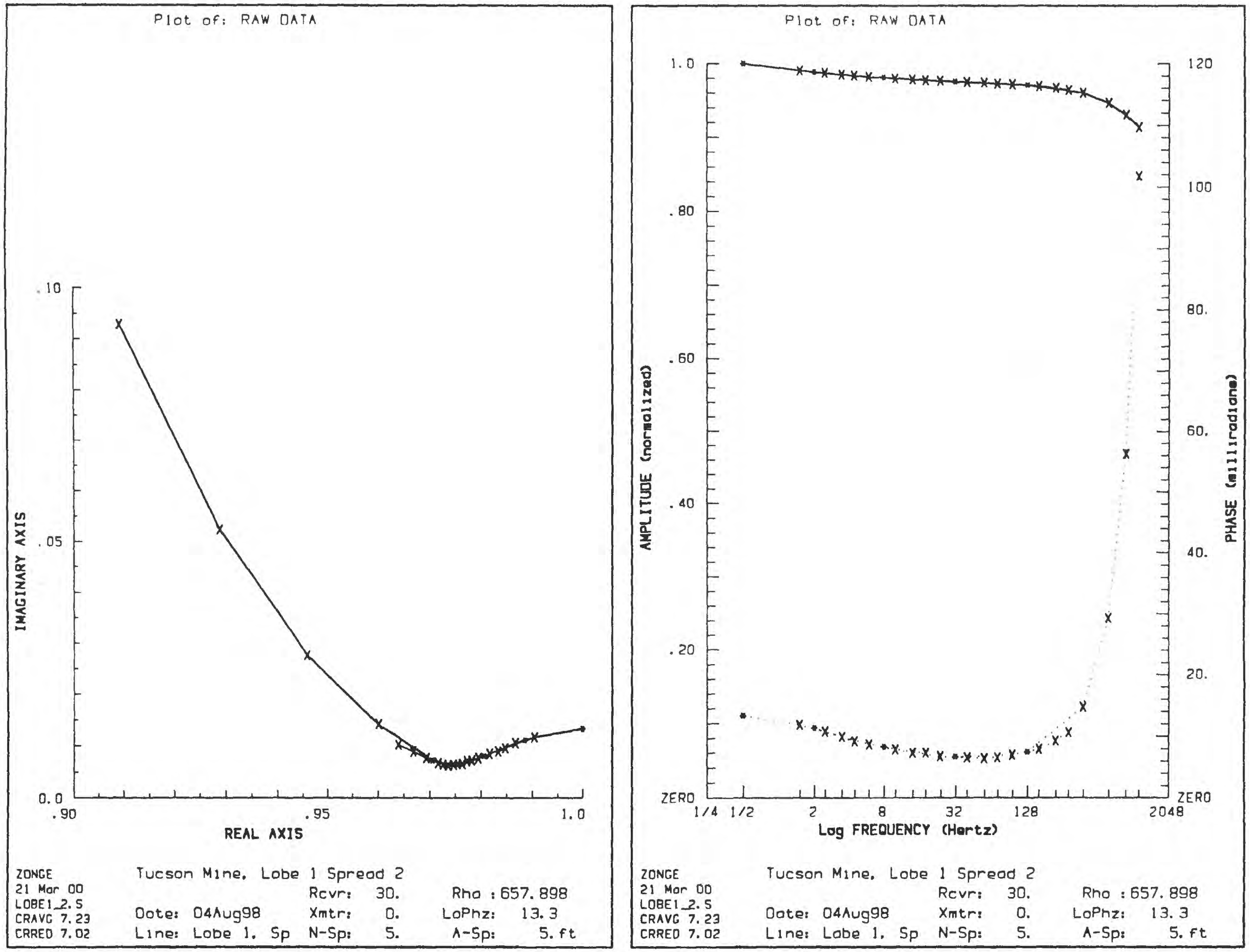

Plot of: RAW DATA
IMAGINARY AXIS
.10
.05
0.0
.90
.95
1.0
REAL AXIS
ZONGE
21 Mar 00
LOBE1_2.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 1 Spread 2
Date: 04Aug98
Line: Lobe 1, Sp
Rcvr: 30.
Xmtr: 0.
N-Sp: 5.
Rho : 657.898
LoPhz: 13.3
A-Sp: 5.ft
Plot of: RAW DATA
AMPLITUDE (normalized)
1.0
.80
.60
.40
.20
ZERO
PHASE (milliradians)
120
100
80.
60.
40.
20.
ZERO
1/4
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
21 Mar 00
LOBE1_2.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 1 Spread 2
Date: 04Aug98
Line: Lobe 1, Sp
Rcvr: 30.
Xmtr: 0.
N-Sp: 5.
Rho : 657.898
LoPhz: 13.3
A-Sp: 5.ft

Figure 32.

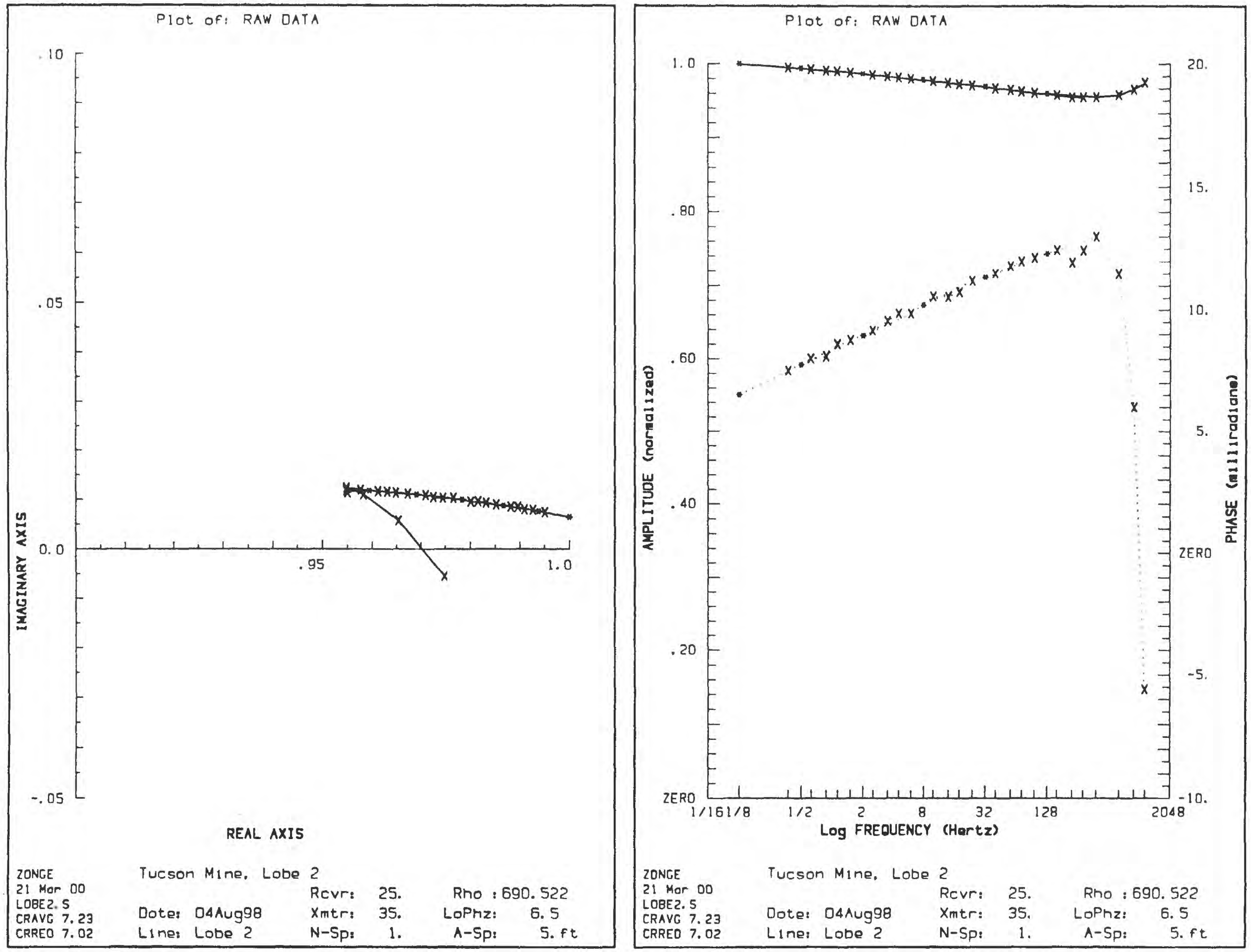

Plot of: RAW DATA
IMAGINARY AXIS
.10
.05
0.0
-.05
.95
1.0
REAL AXIS
ZONGE
21 Mar 00
LOBE2.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 2
Date: 04Aug98
Line: Lobe 2
Rcvr: 25.
Xmtr: 35.
N-Sp: 1.
Rho : 690.522
LoPhz: 6.5
A-Sp: 5.ft
Plot of: RAW DATA
AMPLITUDE (normalized)
1.0
.80
.60
.40
.20
ZERO
PHASE (milliradians)
20.
15.
10.
5.
ZERO
-5.
-10.
1/16
1/8
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
21 Mar 00
LOBE2.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 2
Date: 04Aug98
Line: Lobe 2
Rcvr: 25.
Xmtr: 35.
N-Sp: 1.
Rho : 690.522
LoPhz: 6.5
A-Sp: 5.ft

Figure 33.

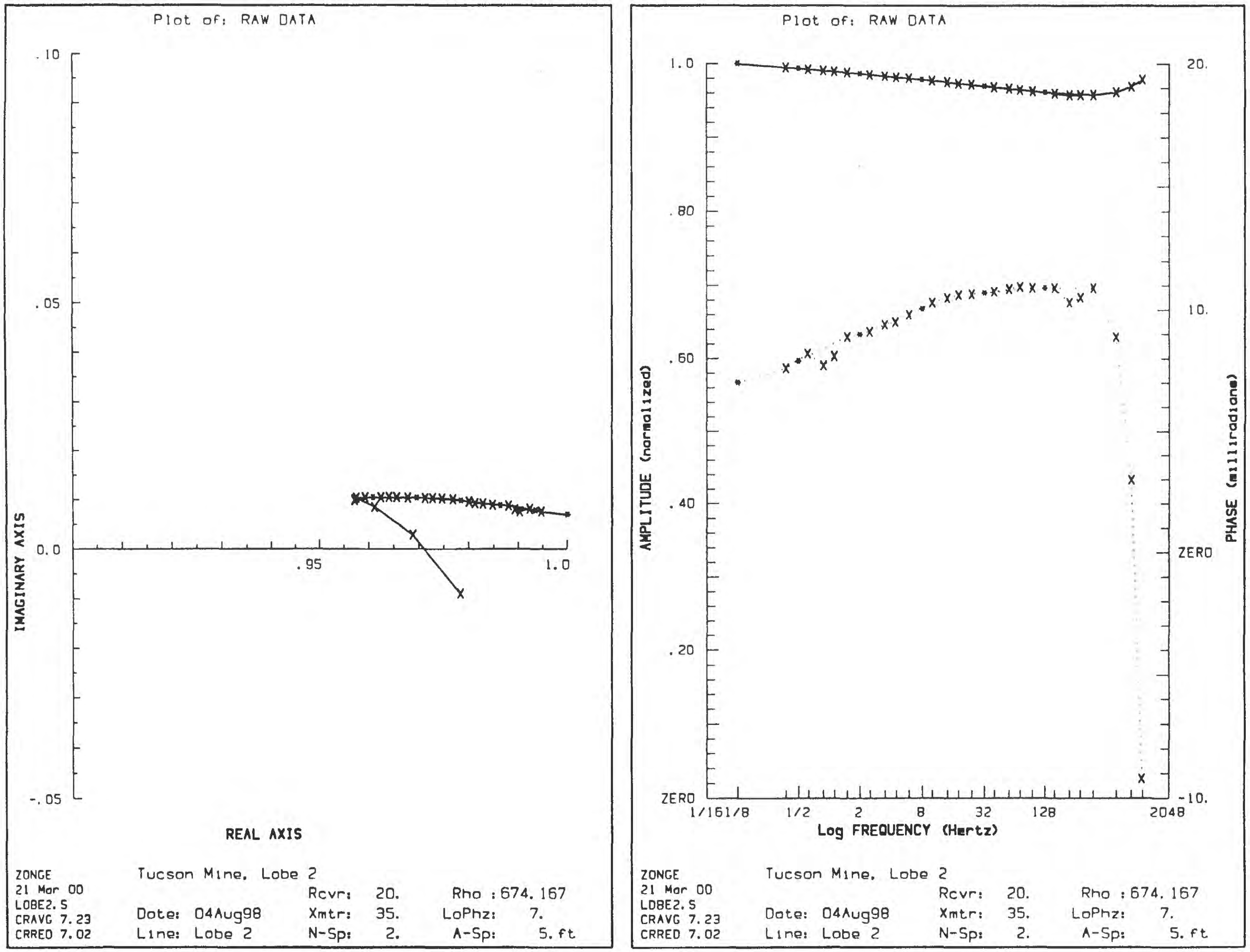

Plot of: RAW DATA
.10
.05
0.0
-.05
IMAGINARY AXIS
.95
1.0
REAL AXIS
ZONGE
21 Mar 00
LOBE2.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 2
Date: 04Aug98
Line: Lobe 2
Rcvr: 20.
Xmtr: 35.
N-Sp: 2.
Rho : 674.167
LoPhz: 7.
A-Sp: 5. ft
Plot of: RAW DATA
1.0
.80
.60
.40
.20
ZERO
AMPLITUDE (normalized)
20.
10.
ZERO
-10.
PHASE (milliradians)
1/16
1/8
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
21 Mar 00
LOBE2.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 2
Date: 04Aug98
Line: Lobe 2
Rcvr: 20.
Xmtr: 35.
N-Sp: 2.
Rho : 674.167
LoPhz: 7.
A-Sp: 5. ft

Figure 34.

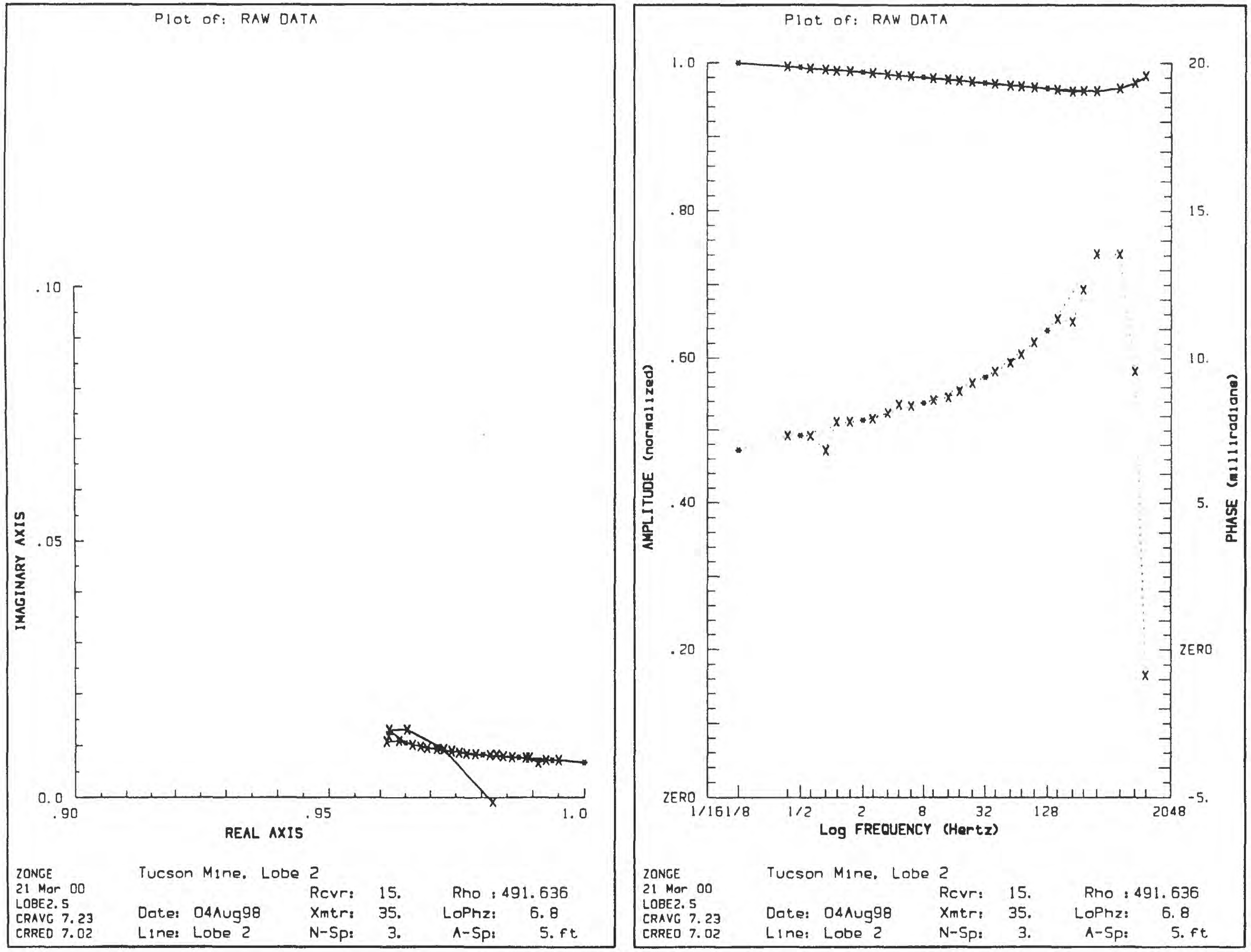

Plot of: RAW DATA
IMAGINARY AXIS
.10
.05
0.0
.90
.95
1.0
REAL AXIS
ZONGE
21 Mar 00
LOBE2.5
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 2
Date: 04Aug98
Line: Lobe 2
Rcvr: 15.
Xmtr: 35.
N-Sp: 3.
Rho : 491.636
LoPhz: 6.8
A-Sp: 5.ft
Plot of: RAW DATA
AMPLITUDE (normalized)
1.0
.80
.60
.40
.20
ZERO
PHASE (milliradians)
20.
15.
10.
5.
ZERO
-5.
1/161/8
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
21 Mar 00
LOBE2.5
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 2
Date: 04Aug98
Line: Lobe 2
Rcvr: 15.
Xmtr: 35.
N-Sp: 3.
Rho : 491.636
LoPhz: 6.8
A-Sp: 5.ft

Figure 35.

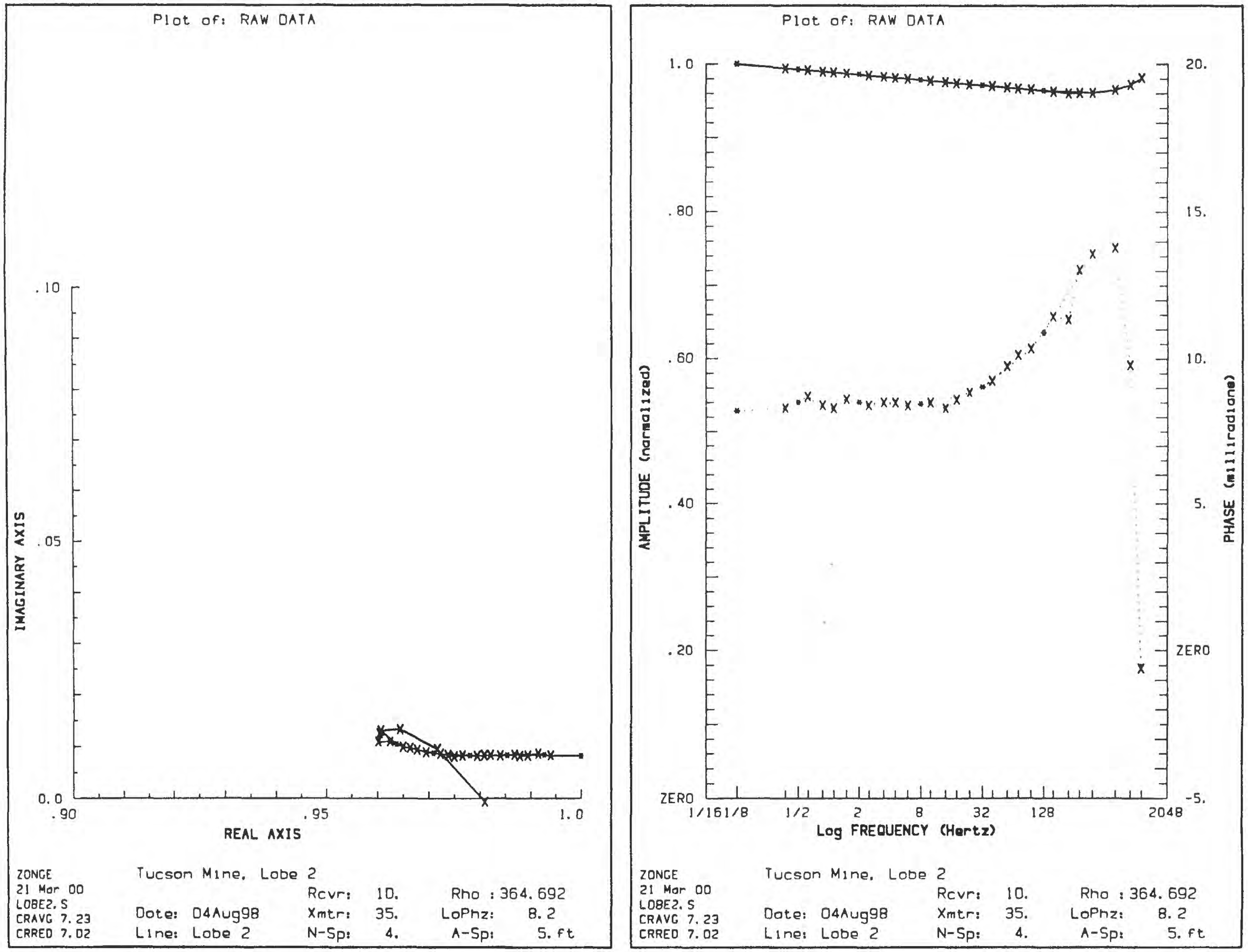

Plot of: RAW DATA
IMAGINARY AXIS
.10
.05
0.0
.90
.95
1.0
REAL AXIS
ZONGE
21 Mar 00
LOBE2.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 2
Date: 04Aug98
Line: Lobe 2
Rcvr: 10.
Xmtr: 35.
N-Sp: 4.
Rho : 364.692
LoPhz: 8.2
A-Sp: 5.ft
Plot of: RAW DATA
AMPLITUDE (normalized)
1.0
.80
.60
.40
.20
ZERO
PHASE (milliradians)
20.
15.
10.
5.
ZERO
-5.
1/16
1/8
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
21 Mar 00
LOBE2.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 2
Date: 04Aug98
Line: Lobe 2
Rcvr: 10.
Xmtr: 35.
N-Sp: 4.
Rho : 364.692
LoPhz: 8.2
A-Sp: 5.ft

Figure 36.

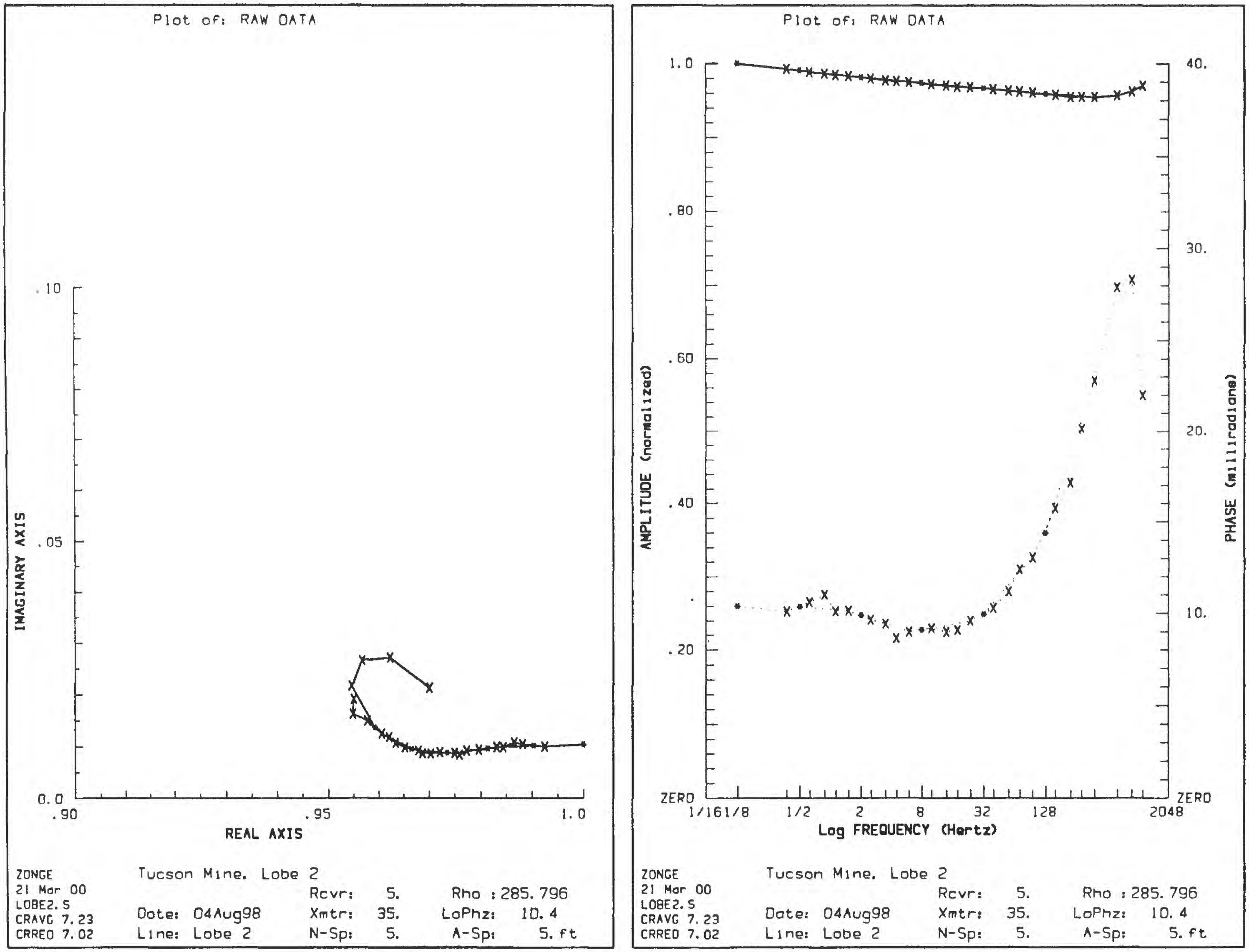

Plot of: RAW DATA
IMAGINARY AXIS
.10
.05
0.0
.90
.95
1.0
REAL AXIS
ZONGE
21 Mar 00
LOBE2.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 2
Date: 04Aug98
Line: Lobe 2
Rcvr: 5.
Xmtr: 35.
N-Sp: 5.
Rho : 285.796
LoPhz: 10.4
A-Sp: 5. ft
Plot of: RAW DATA
AMPLITUDE (normalized)
1.0
.80
.60
.40
.20
ZERO
PHASE (milliradians)
40.
30.
20.
10.
ZERO
1/16
1/8
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
21 Mar 00
LOBE2.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 2
Date: 04Aug98
Line: Lobe 2
Rcvr: 5.
Xmtr: 35.
N-Sp: 5.
Rho : 285.796
LoPhz: 10.4
A-Sp: 5. ft

Figure 37.

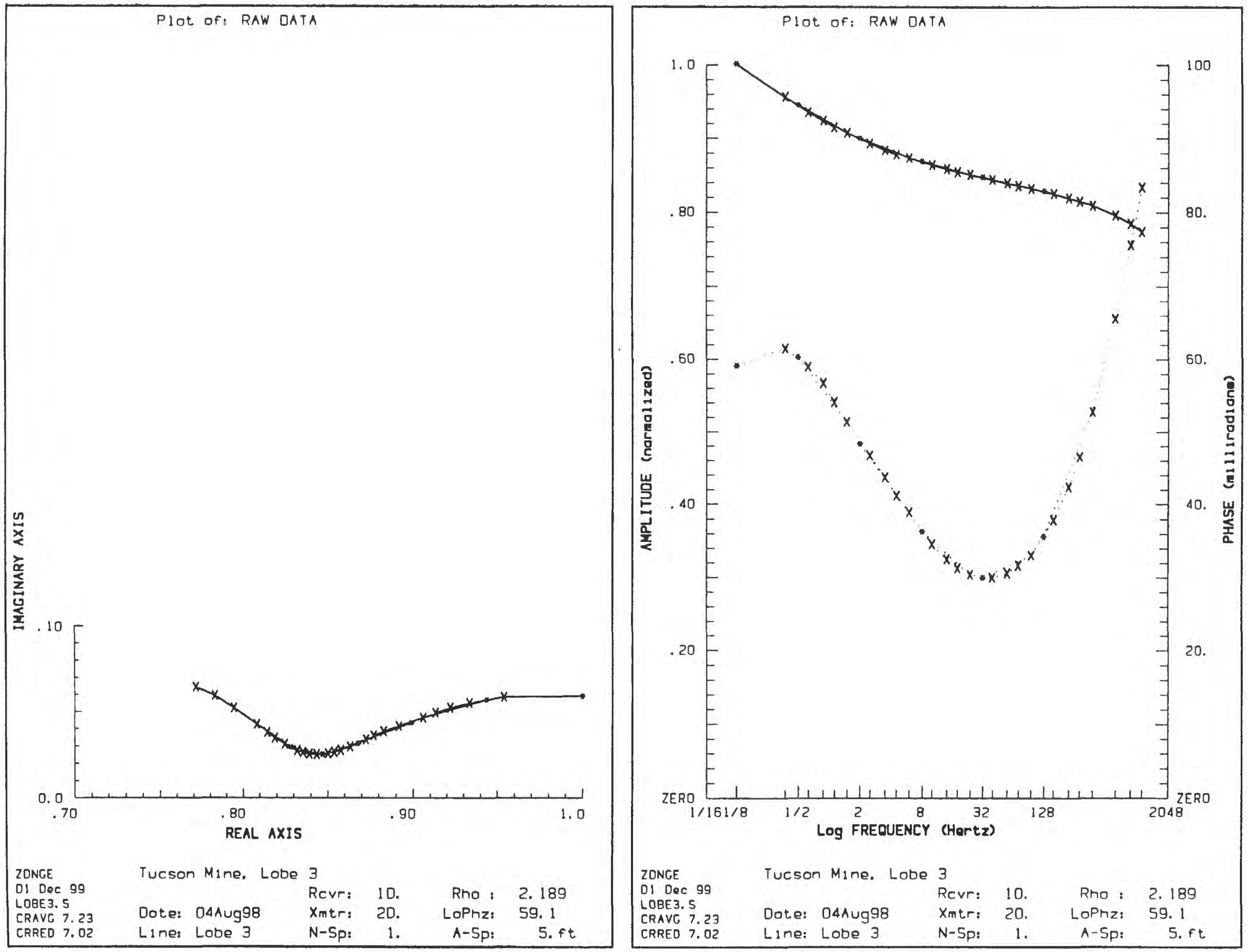

Plot of: RAW DATA
IMAGINARY AXIS
.10
0.0
.70
.80
.90
1.0
REAL AXIS
ZONGE
01 Dec 99
LOBE3.5
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 3
Date: 04Aug98
Line: Lobe 3
Rcvr: 10.
Xmtr: 20.
N-Sp: 1.
Rho : 2.189
LoPhz: 59.1
A-Sp: 5.ft
Plot of: RAW DATA
AMPLITUDE (normalized)
1.0
.80
.60
.40
.20
ZERO
PHASE (milliradians)
100
80.
60.
40.
20.
ZERO
1/16
1/8
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
01 Dec 99
LOBE3.5
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 3
Date: 04Aug98
Line: Lobe 3
Rcvr: 10.
Xmtr: 20.
N-Sp: 1.
Rho : 2.189
LoPhz: 59.1
A-Sp: 5.ft

Figure 38.

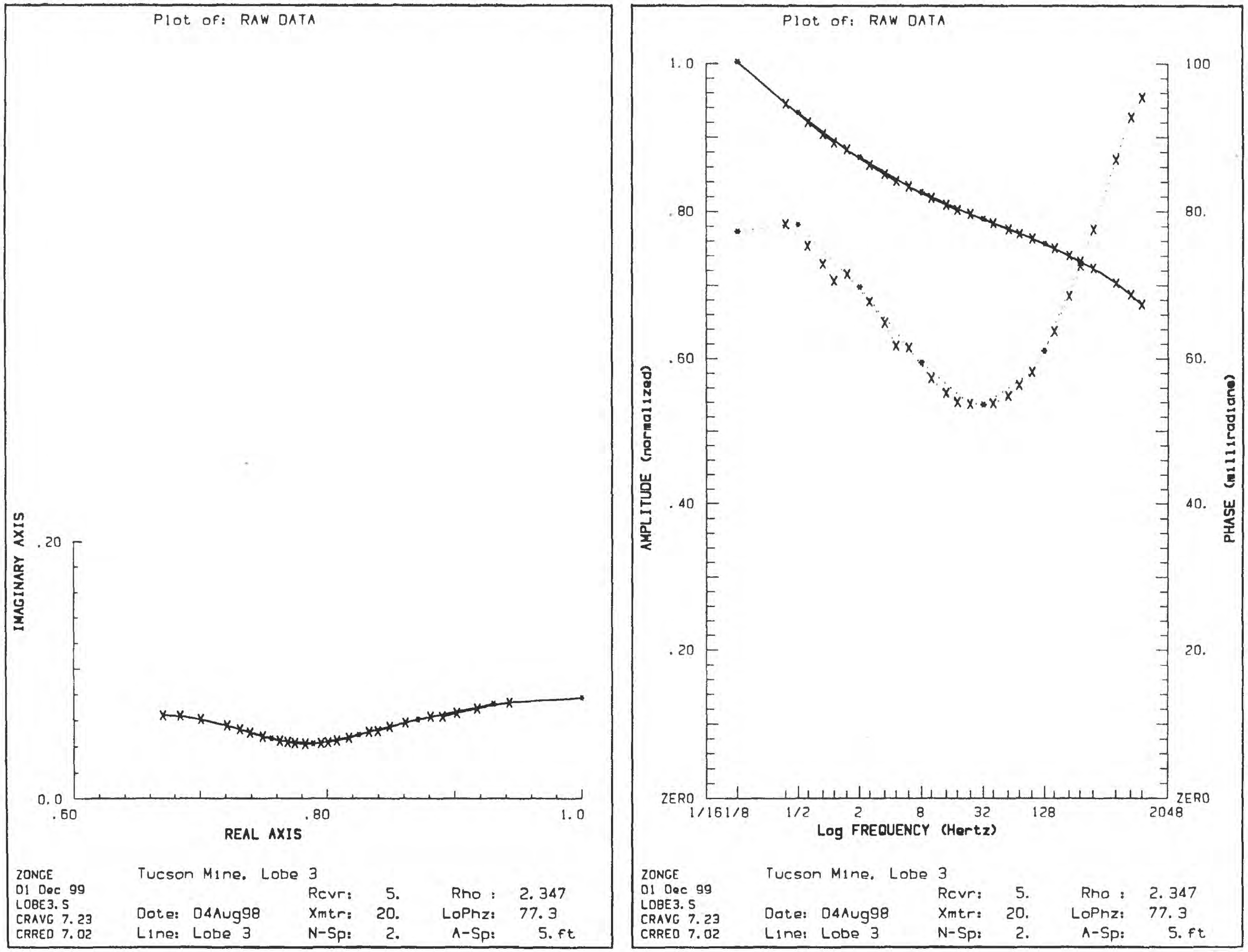

Plot of: RAW DATA
IMAGINARY AXIS
.20
0.0
.60
.80
1.0
REAL AXIS
ZONGE
01 Dec 99
LOBE3.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 3
Date: 04Aug98
Line: Lobe 3
Rcvr: 5.
Xmtr: 20.
N-Sp: 2.
Rho : 2.347
LoPhz: 77.3
A-Sp: 5. ft
Plot of: RAW DATA
AMPLITUDE (normalized)
1.0
.80
.60
.40
.20
ZERO
PHASE (milliradians)
100
80.
60.
40.
20.
ZERO
1/16
1/8
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
01 Dec 99
LOBE3.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 3
Date: 04Aug98
Line: Lobe 3
Rcvr: 5.
Xmtr: 20.
N-Sp: 2.
Rho : 2.347
LoPhz: 77.3
A-Sp: 5. ft

Figure 39.

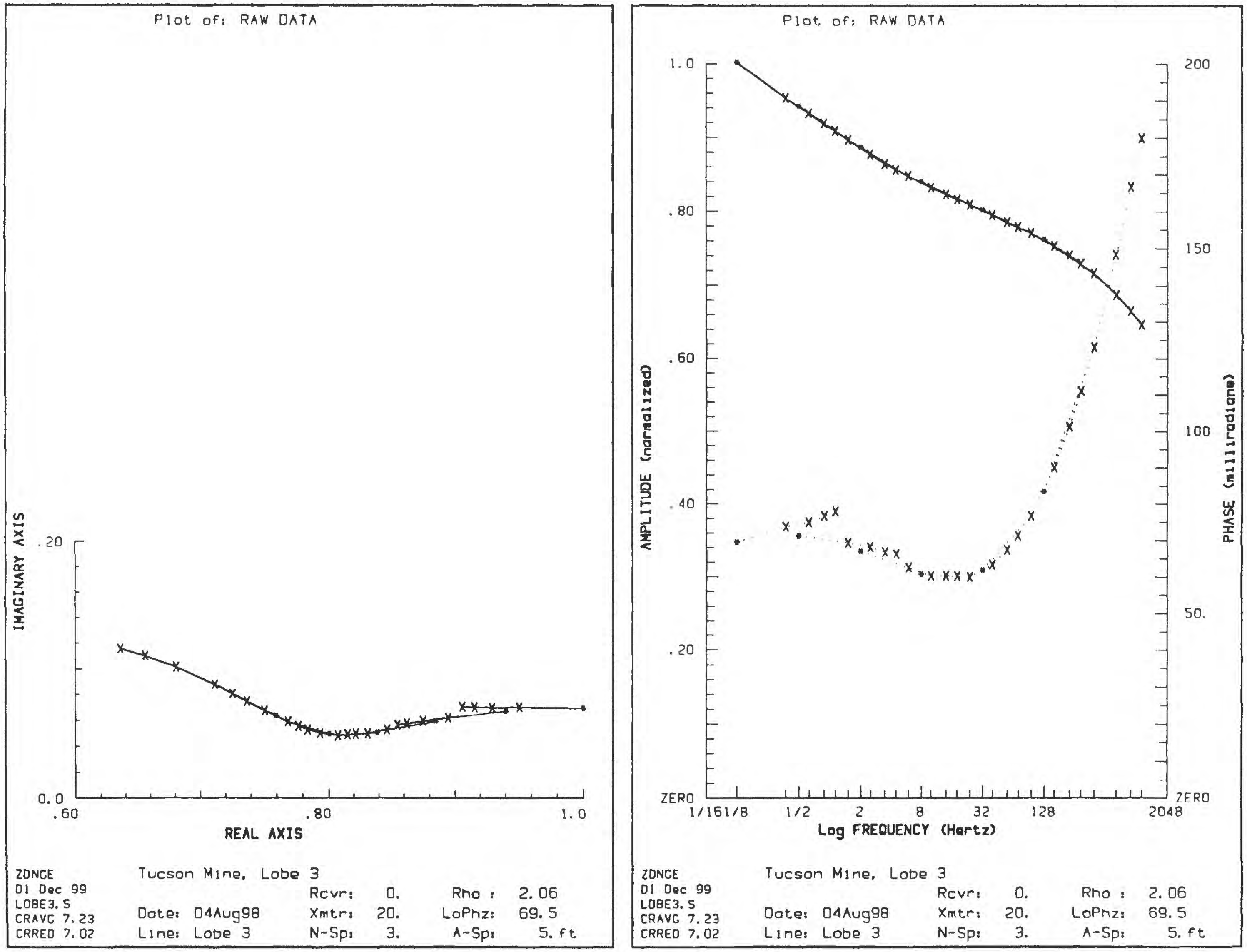

Plot of: RAW DATA
IMAGINARY AXIS
.20
0.0
.60
.80
1.0
REAL AXIS
ZDNGE
D1 Dec 99
LOBE3.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 3
Date: 04Aug98
Line: Lobe 3
Rcvr: 0.
Xmtr: 20.
N-Sp: 3.
Rho : 2.06
LoPhz: 69.5
A-Sp: 5. ft
Plot of: RAW DATA
AMPLITUDE (normalized)
1.0
.80
.60
.40
.20
ZERO
PHASE (milliradians)
200
150
100
50.
ZERO
1/16
1/8
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZDNGE
D1 Dec 99
LOBE3.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 3
Date: 04Aug98
Line: Lobe 3
Rcvr: 0.
Xmtr: 20.
N-Sp: 3.
Rho : 2.06
LoPhz: 69.5
A-Sp: 5. ft

Figure 40.

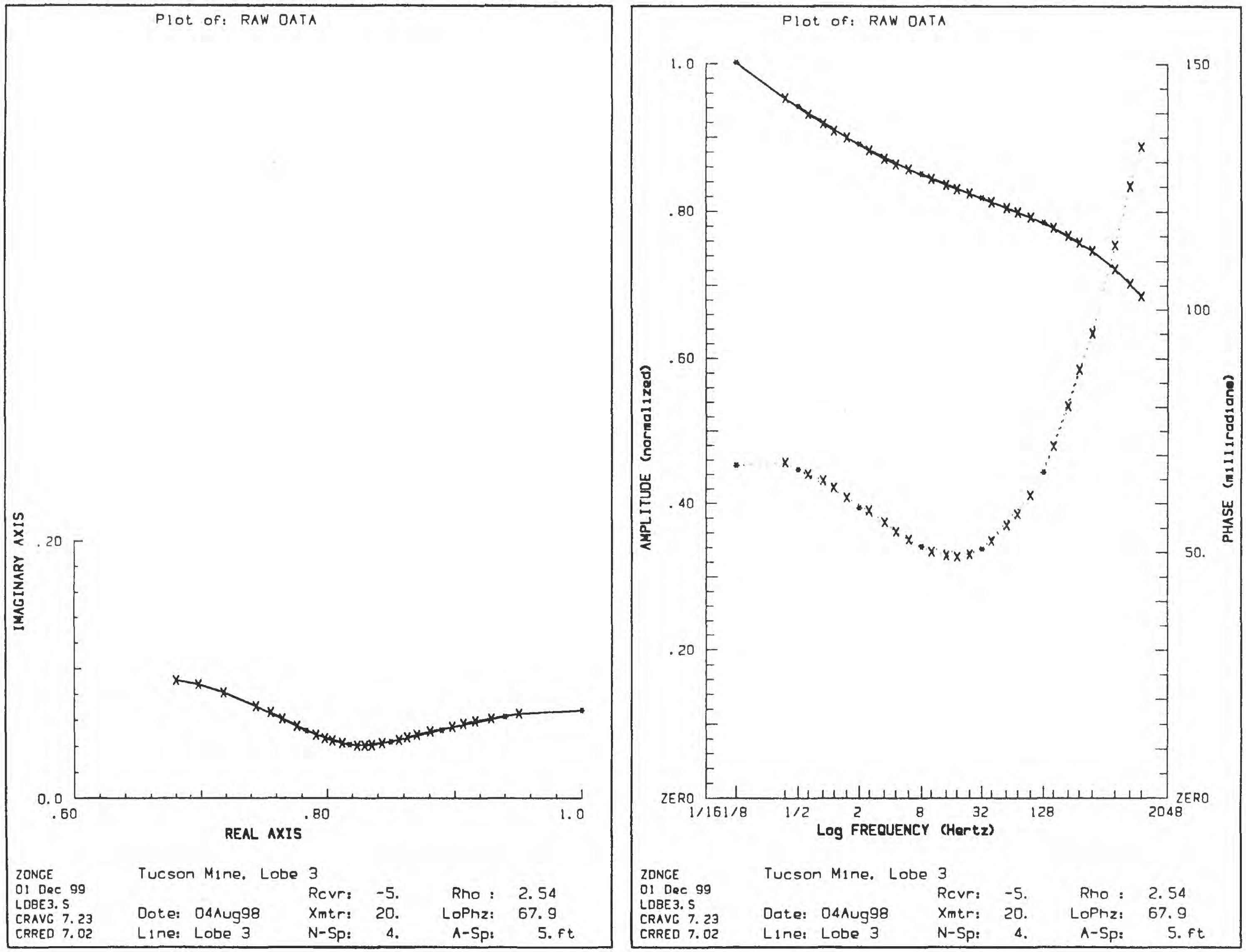

Plot of: RAW DATA
IMAGINARY AXIS
.20
0.0
.60
.80
1.0
REAL AXIS
ZONGE
01 Dec 99
LOBE3.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 3
Date: 04Aug98
Line: Lobe 3
Rcvr: -5.
Xmtr: 20.
N-Sp: 4.
Rho : 2.54
LoPhz: 67.9
A-Sp: 5.ft
Plot of: RAW DATA
AMPLITUDE (normalized)
1.0
.80
.60
.40
.20
ZERO
PHASE (milliradians)
150
100
50.
ZERO
1/16
1/8
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
01 Dec 99
LOBE3.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 3
Date: 04Aug98
Line: Lobe 3
Rcvr: -5.
Xmtr: 20.
N-Sp: 4.
Rho : 2.54
LoPhz: 67.9
A-Sp: 5.ft

Figure 41.

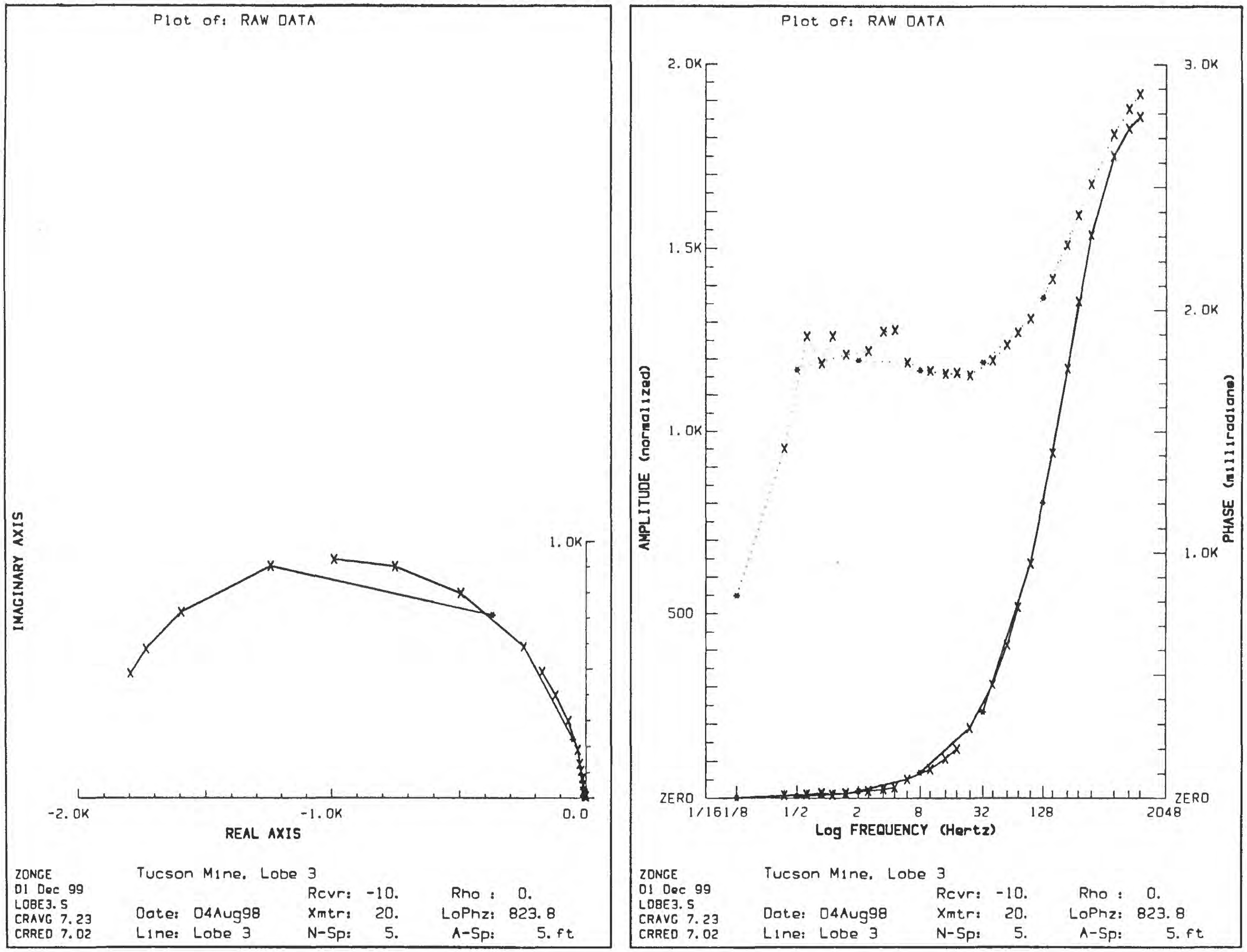

Plot of: RAW DATA
IMAGINARY AXIS
REAL AXIS
-2.0K
-1.0K
0.0
1.0K
ZONGE
01 Dec 99
LOBE3.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 3
Date: 04Aug98
Line: Lobe 3
Rcvr: -10.
Xmtr: 20.
N-Sp: 5.
Rho : 0.
LoPhz: 823.8
A-Sp: 5. ft
Plot of: RAW DATA
AMPLITUDE (normalized)
PHASE (milliradians)
2.0K
1.5K
1.0K
500
ZERO
3.0K
2.0K
1.0K
ZERO
1/16
1/8
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
01 Dec 99
LOBE3.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 3
Date: 04Aug98
Line: Lobe 3
Rcvr: -10.
Xmtr: 20.
N-Sp: 5.
Rho : 0.
LoPhz: 823.8
A-Sp: 5. ft

Figure 42.

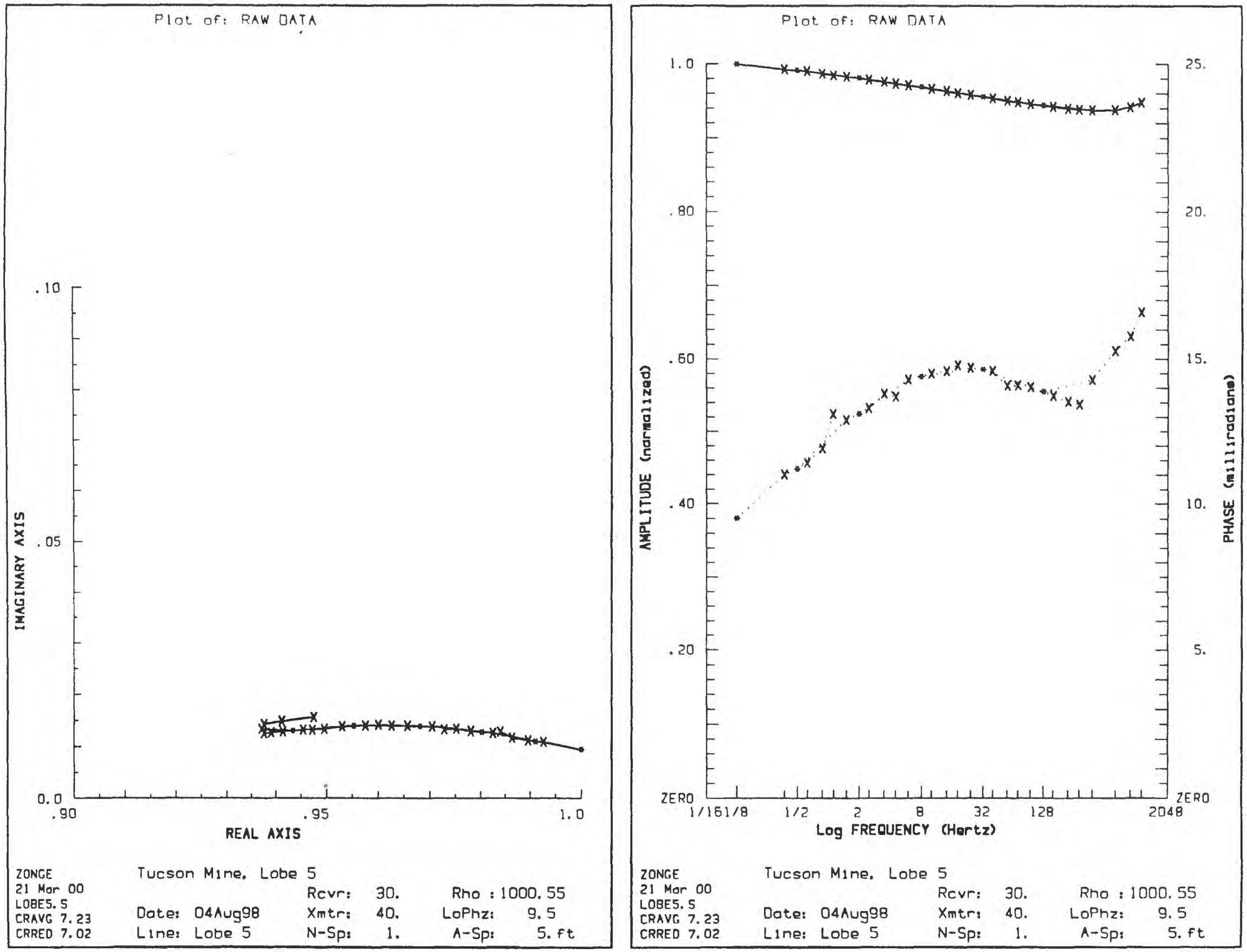

Plot of: RAW DATA
IMAGINARY AXIS
.10
.05
0.0
.90
.95
1.0
REAL AXIS
ZONGE
21 Mar 00
LOBES.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 5
Date: 04Aug98
Line: Lobe 5
Rcvr: 30.
Xmtr: 40.
N-Sp: 1.
Rho : 1000.55
LoPhz: 9.5
A-Sp: 5. ft
Plot of: RAW DATA
AMPLITUDE (normalized)
1.0
.80
.60
.40
.20
ZERO
PHASE (milliradians)
25.
20.
15.
10.
5.
ZERO
1/16 1/8
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
21 Mar 00
LOBES.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 5
Date: 04Aug98
Line: Lobe 5
Rcvr: 30.
Xmtr: 40.
N-Sp: 1.
Rho : 1000.55
LoPhz: 9.5
A-Sp: 5. ft

Figure 43.

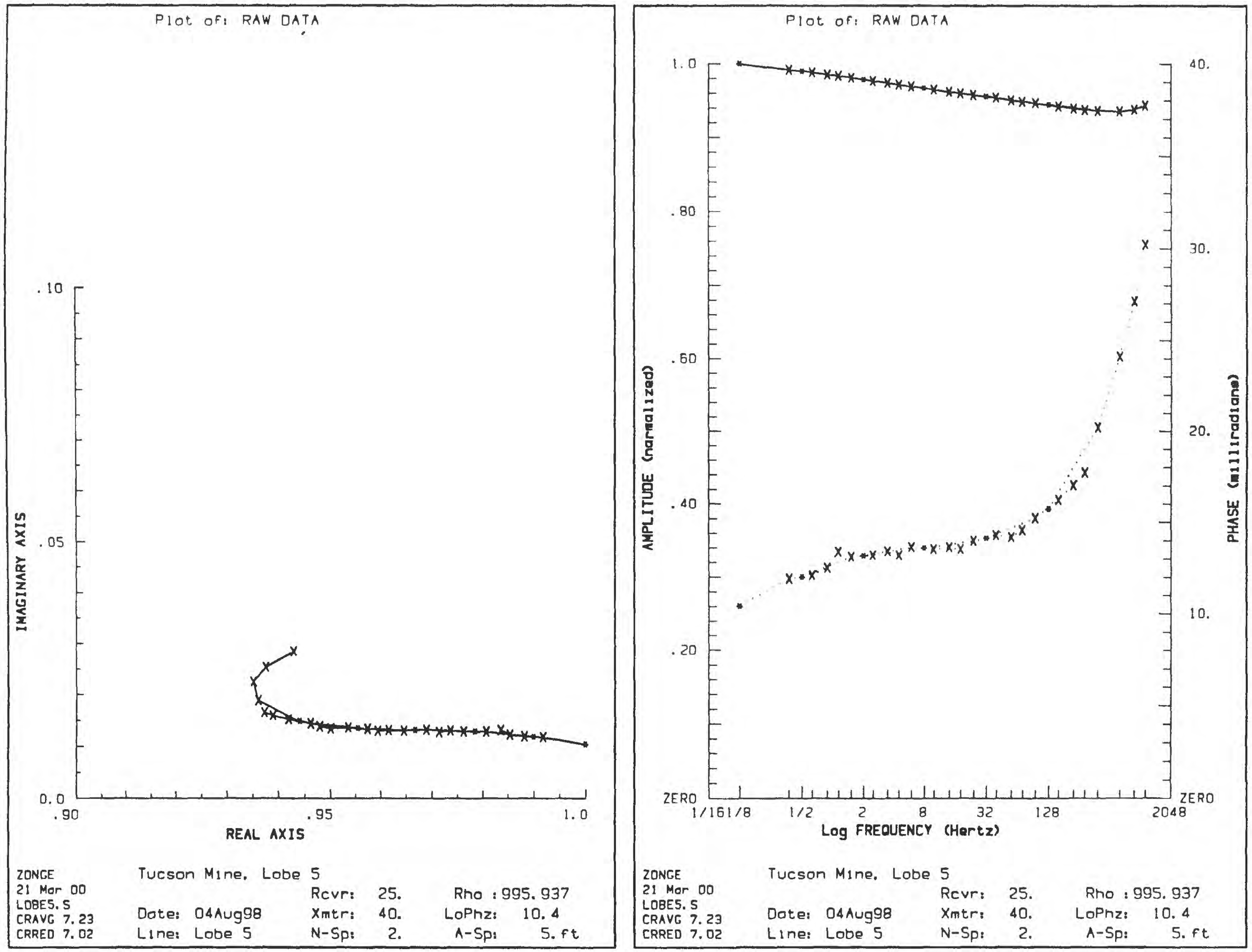

Plot of: RAW DATA
IMAGINARY AXIS
.10
.05
0.0
.90
.95
1.0
REAL AXIS
ZONGE
21 Mar 00
LOBES.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 5
Date: 04Aug98
Line: Lobe 5
Rcvr: 25.
Xmtr: 40.
N-Sp: 2.
Rho : 995.937
LoPhz: 10.4
A-Sp: 5.ft
Plot of: RAW DATA
AMPLITUDE (normalized)
1.0
.80
.60
.40
.20
ZERO
PHASE (milliradians)
40.
30.
20.
10.
ZERO
1/16
1/8
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
21 Mar 00
LOBES.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 5
Date: 04Aug98
Line: Lobe 5
Rcvr: 25.
Xmtr: 40.
N-Sp: 2.
Rho : 995.937
LoPhz: 10.4
A-Sp: 5.ft

Figure 44.

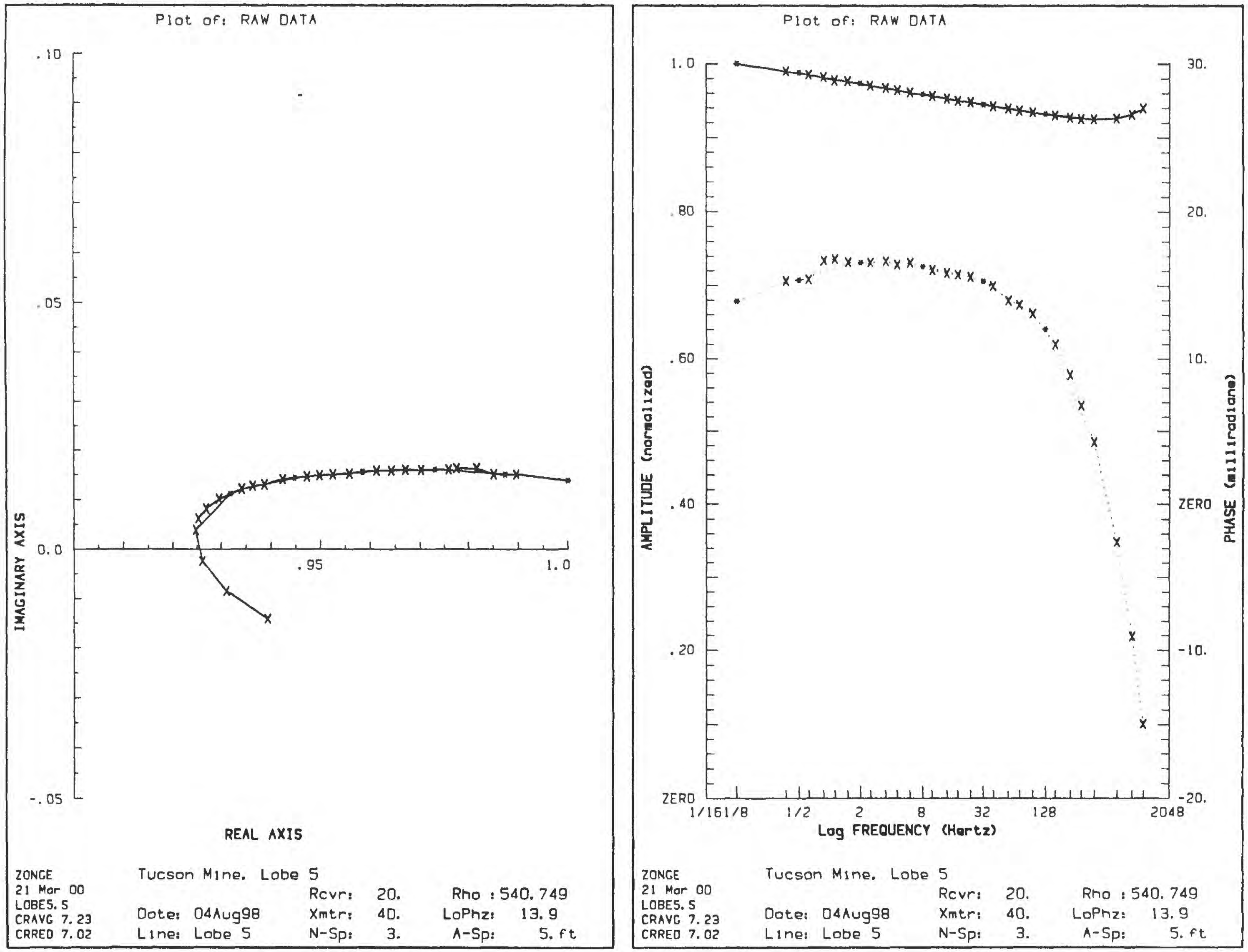

Plot of: RAW DATA
.10
.05
0.0
-.05
IMAGINARY AXIS
.95
1.0
REAL AXIS
ZONGE
21 Mar 00
LOBE5.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 5
Date: 04Aug98
Line: Lobe 5
Rcvr: 20.
Xmtr: 40.
N-Sp: 3.
Rho : 540.749
LoPhz: 13.9
A-Sp: 5. ft
Plot of: RAW DATA
1.0
.80
.60
.40
.20
ZERO
AMPLITUDE (normalized)
30.
20.
10.
ZERO
-10.
-20.
PHASE (milliradians)
1/16
1/8
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
21 Mar 00
LOBE5.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 5
Date: 04Aug98
Line: Lobe 5
Rcvr: 20.
Xmtr: 40.
N-Sp: 3.
Rho : 540.749
LoPhz: 13.9
A-Sp: 5. ft

Figure 45.

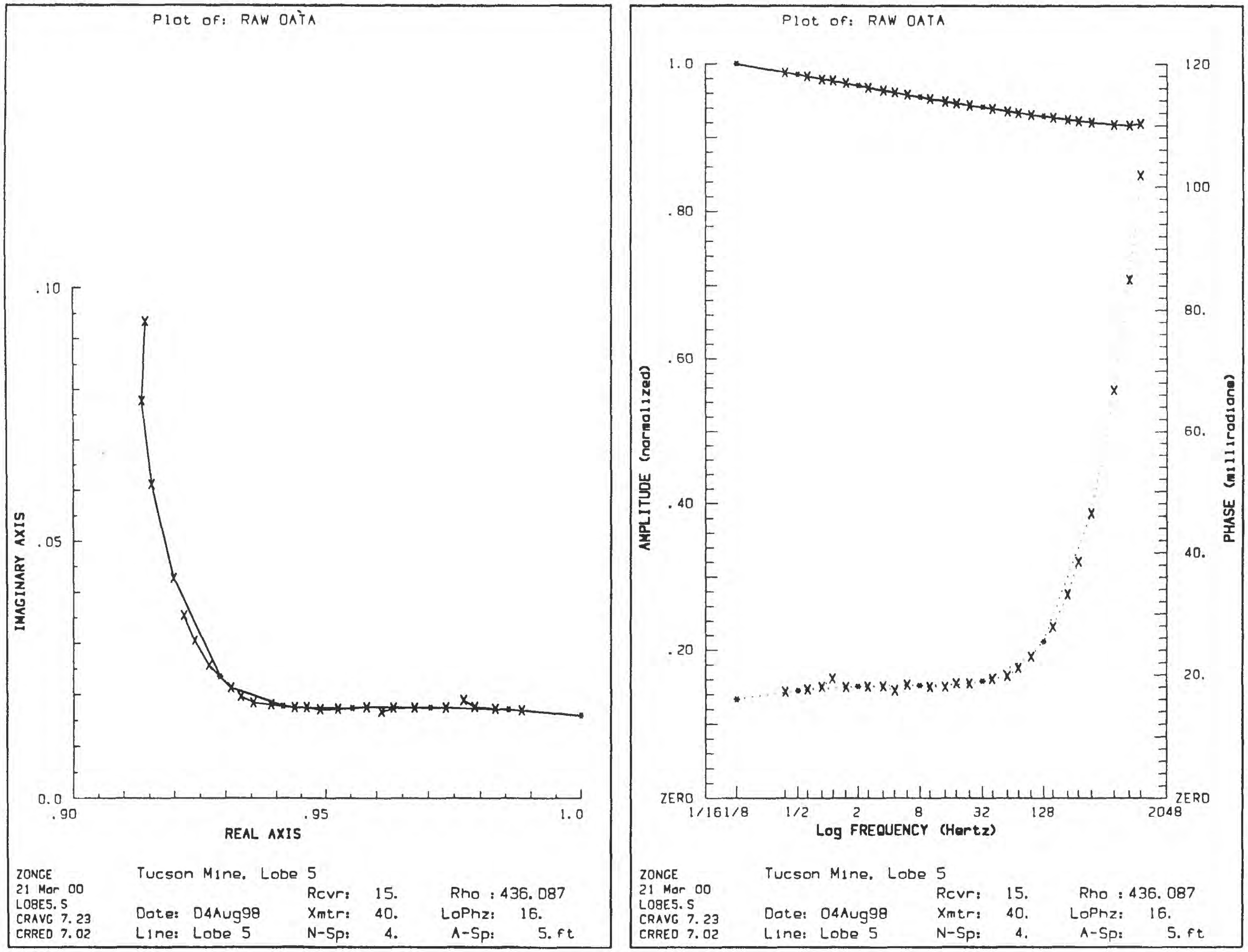

Plot of: RAW OATA
.10
.05
0.0
IMAGINARY AXIS
.90
.95
1.0
REAL AXIS
ZONGE
21 Mar 00
LOBE5.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 5
Date: 04Aug98
Line: Lobe 5
Rcvr: 15.
Xmtr: 40.
N-Sp: 4.
Rho : 436.087
LoPhz: 16.
A-Sp: 5.ft
Plot of: RAW OATA
1.0
.80
.60
.40
.20
ZERO
AMPLITUDE (normalized)
120
100
80.
60.
40.
20.
ZERO
PHASE (milliradians)
1/16
1/8
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
21 Mar 00
LOBE5.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 5
Date: 04Aug98
Line: Lobe 5
Rcvr: 15.
Xmtr: 40.
N-Sp: 4.
Rho : 436.087
LoPhz: 16.
A-Sp: 5.ft

Figure 46.

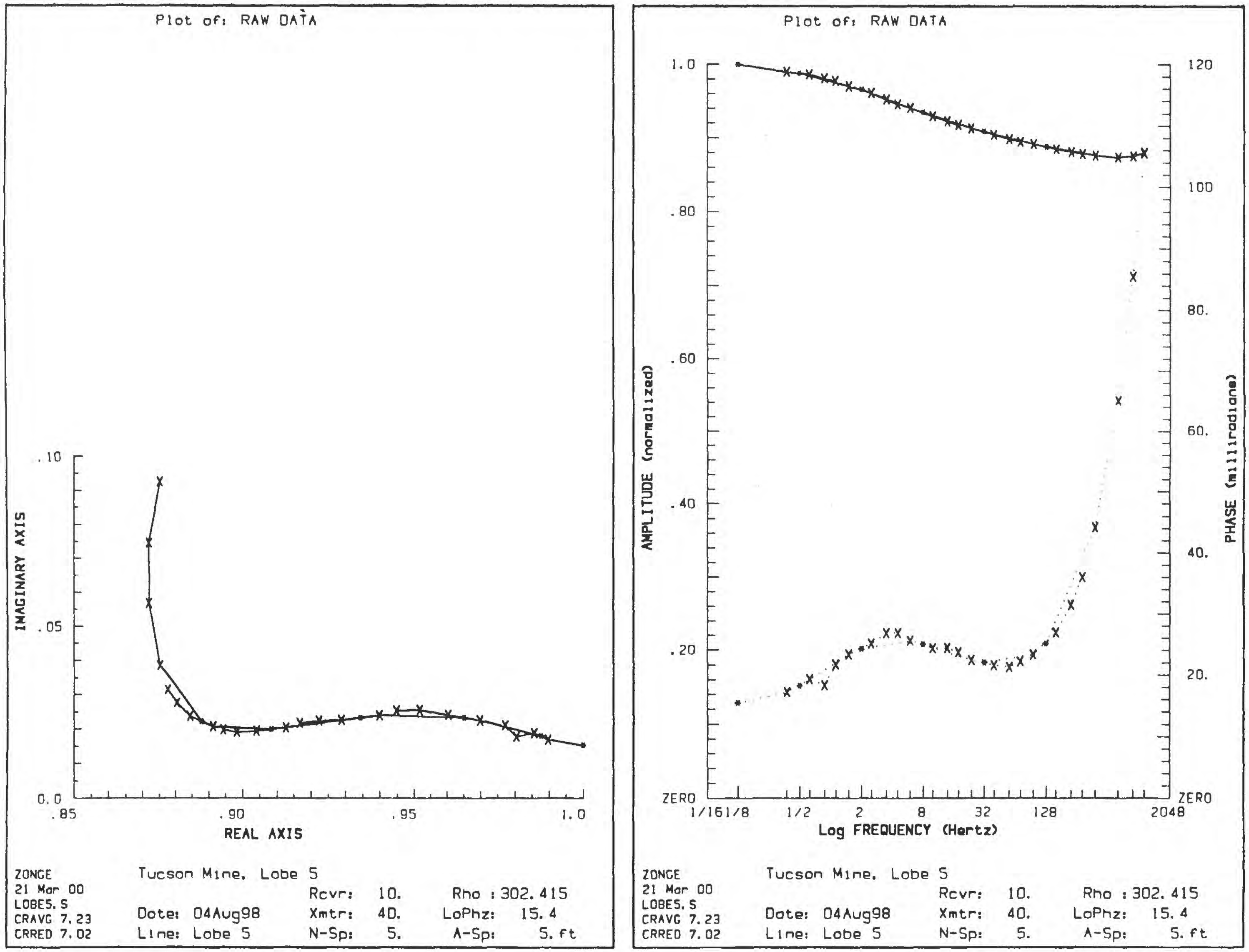

Plot of: RAW DATA
IMAGINARY AXIS
.10
.05
0.0
.85
.90
.95
1.0
REAL AXIS
ZONGE
21 Mar 00
LOBES.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 5
Date: 04Aug98
Line: Lobe 5
Rcvr: 10.
Xmtr: 40.
N-Sp: 5.
Rho : 302.415
LoPhz: 15.4
A-Sp: 5. ft
Plot of: RAW DATA
AMPLITUDE (normalized)
1.0
.80
.60
.40
.20
ZERO
PHASE (milliradians)
120
100
80.
60.
40.
20.
ZERO
1/16
1/8
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
21 Mar 00
LOBES.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 5
Date: 04Aug98
Line: Lobe 5
Rcvr: 10.
Xmtr: 40.
N-Sp: 5.
Rho : 302.415
LoPhz: 15.4
A-Sp: 5. ft

Figure 47.

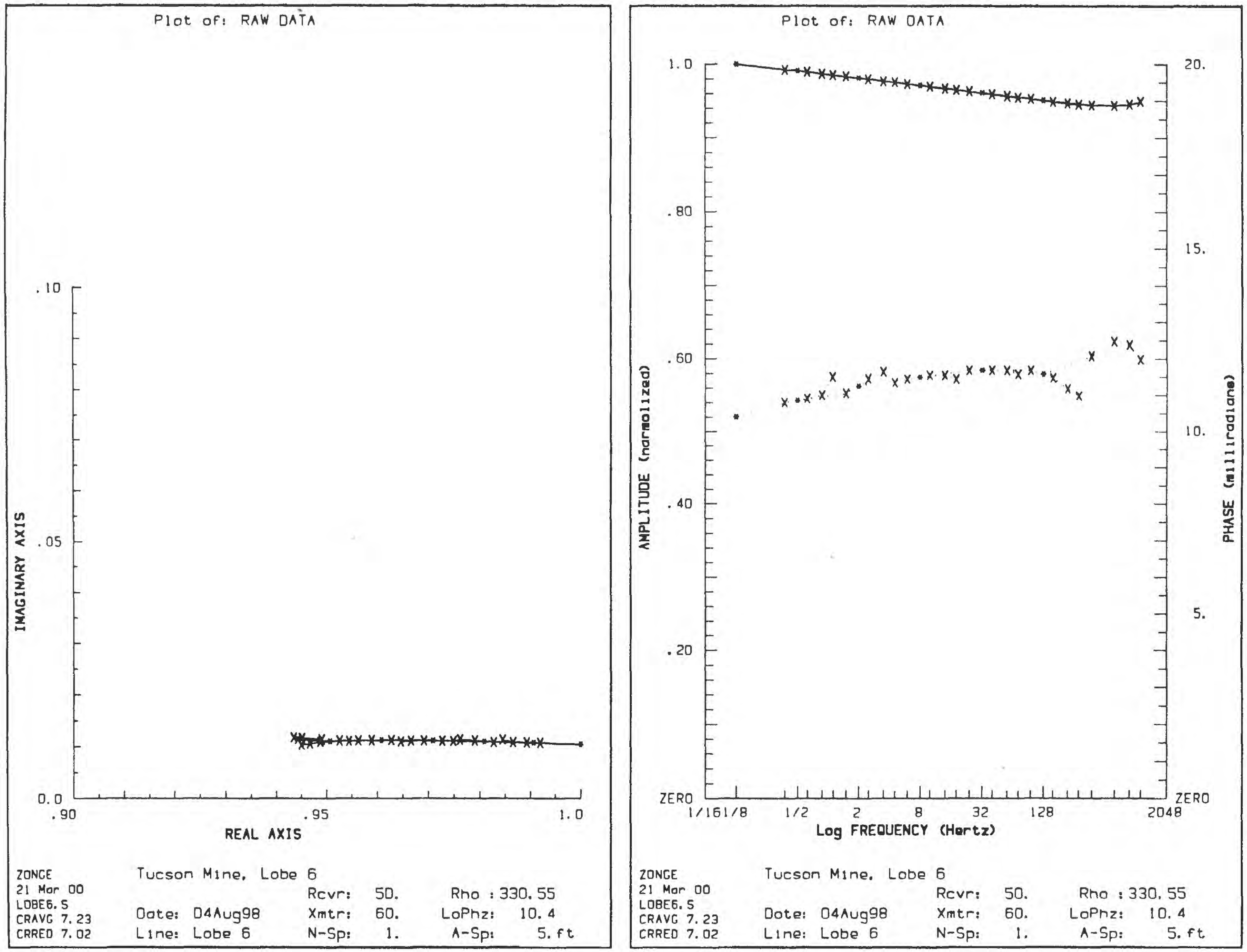

Plot of: RAW DATA
IMAGINARY AXIS
.10
.05
0.0
.90
.95
1.0
REAL AXIS
ZONCE
21 Mar 00
LOBE6.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 6
Date: 04Aug98
Line: Lobe 6
Rcvr: 50.
Xmtr: 60.
N-Sp: 1.
Rho : 330.55
LoPhz: 10.4
A-Sp: 5.ft
Plot of: RAW DATA
AMPLITUDE (normalized)
1.0
.80
.60
.40
.20
ZERO
PHASE (milliradians)
20.
15.
10.
5.
ZERO
1/161/8
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONCE
21 Mar 00
LOBE6.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 6
Date: 04Aug98
Line: Lobe 6
Rcvr: 50.
Xmtr: 60.
N-Sp: 1.
Rho : 330.55
LoPhz: 10.4
A-Sp: 5.ft

Figure 48.

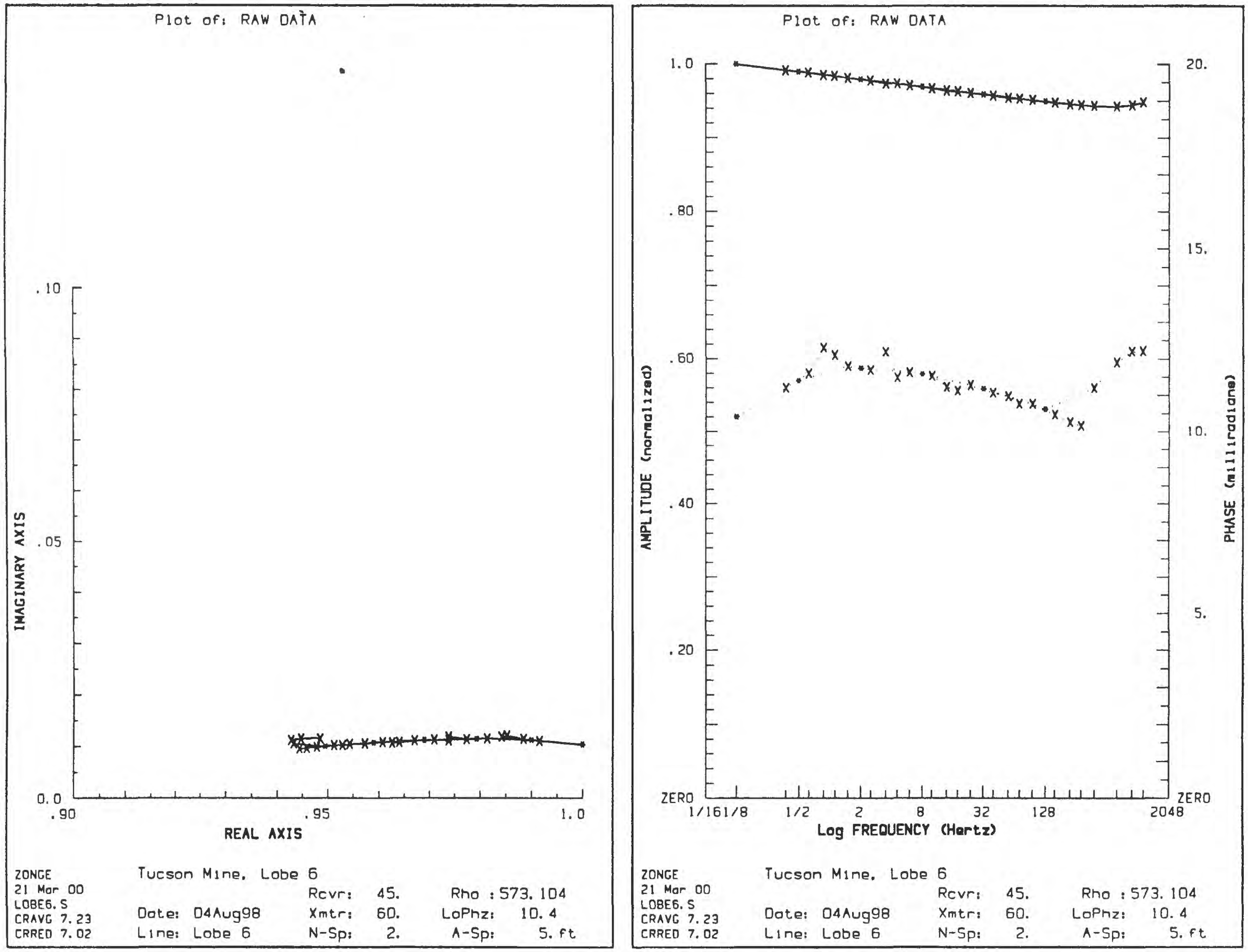

Plot of: RAW DATA
IMAGINARY AXIS
.10
.05
0.0
.90
.95
1.0
REAL AXIS
ZONGE
21 Mar 00
LOBE6.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 6
Date: 04Aug98
Line: Lobe 6
Rcvr: 45.
Xmtr: 60.
N-Sp: 2.
Rho : 573.104
LoPhz: 10.4
A-Sp: 5. ft
Plot of: RAW DATA
AMPLITUDE (normalized)
1.0
.80
.60
.40
.20
ZERO
PHASE (milliradians)
20.
15.
10.
5.
ZERO
1/16
1/8
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
21 Mar 00
LOBE6.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 6
Date: 04Aug98
Line: Lobe 6
Rcvr: 45.
Xmtr: 60.
N-Sp: 2.
Rho : 573.104
LoPhz: 10.4
A-Sp: 5. ft

Figure 49.

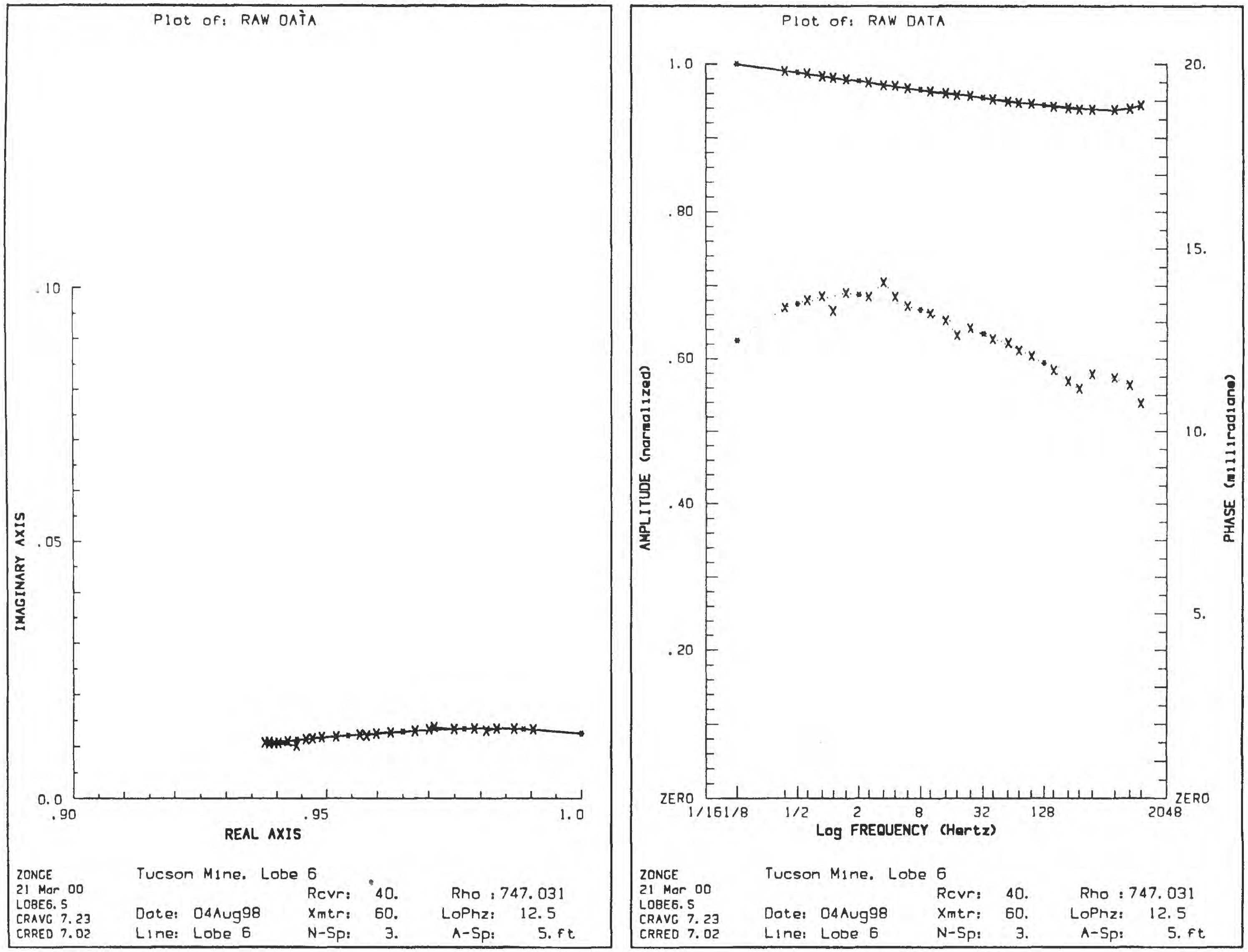
Plot of: RAW DATA
IMAGINARY AXIS
.10
.05
0.0
.90
.95
1.0
REAL AXIS
ZONGE
21 Mar 00
LOBE6.S
CRAVG 7.23
CRRED 7.02
Tucson Mine. Lobe 6
Date: 04Aug98
Line: Lobe 6
Rcvr: 40.
Xmtr: 60.
N-Sp: 3.
Rho : 747.031
LoPhz: 12.5
A-Sp: 5.ft
Plot of: RAW DATA
AMPLITUDE (normalized)
1.0
.80
.60
.40
.20
ZERO
PHASE (milliradians)
20.
15.
10.
5.
ZERO
1/16
1/8
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
21 Mar 00
LOBE6.S
CRAVG 7.23
CRRED 7.02
Tucson Mine. Lobe 6
Date: 04Aug98
Line: Lobe 6
Rcvr: 40.
Xmtr: 60.
N-Sp: 3.
Rho : 747.031
LoPhz: 12.5
A-Sp: 5.ft

Figure 50.

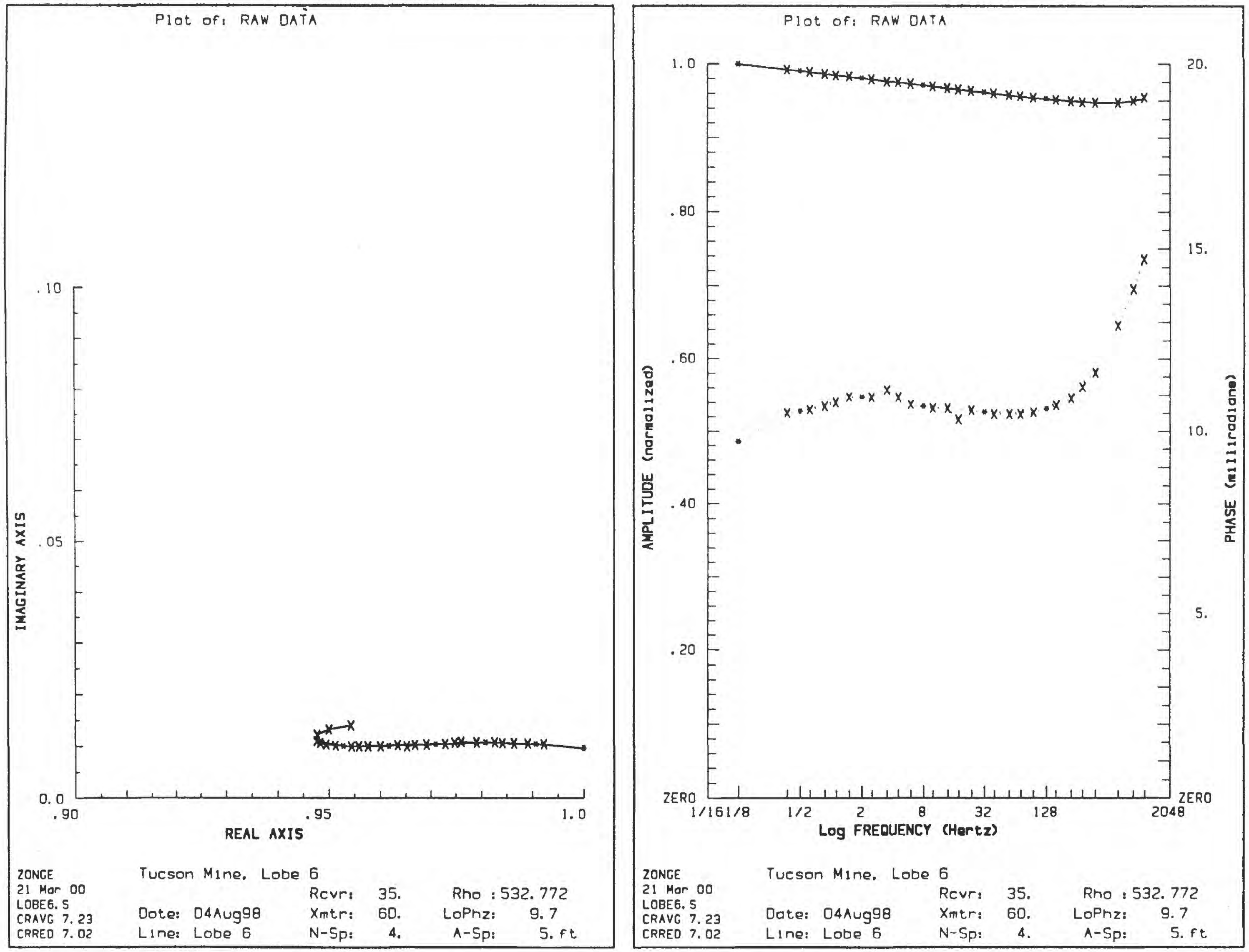

Plot of: RAW DATA
IMAGINARY AXIS
.10
.05
0.0
.90
.95
1.0
REAL AXIS
ZONGE
21 Mar 00
LOBE6.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 6
Date: 04Aug98
Line: Lobe 6
Rcvr: 35.
Xmtr: 60.
N-Sp: 4.
Rho : 532.772
LoPhz: 9.7
A-Sp: 5.ft
Plot of: RAW DATA
AMPLITUDE (normalized)
1.0
.80
.60
.40
.20
ZERO
PHASE (milliradians)
20.
15.
10.
5.
ZERO
1/16
1/8
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
21 Mar 00
LOBE6.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 6
Date: 04Aug98
Line: Lobe 6
Rcvr: 35.
Xmtr: 60.
N-Sp: 4.
Rho : 532.772
LoPhz: 9.7
A-Sp: 5.ft

Figure 51.

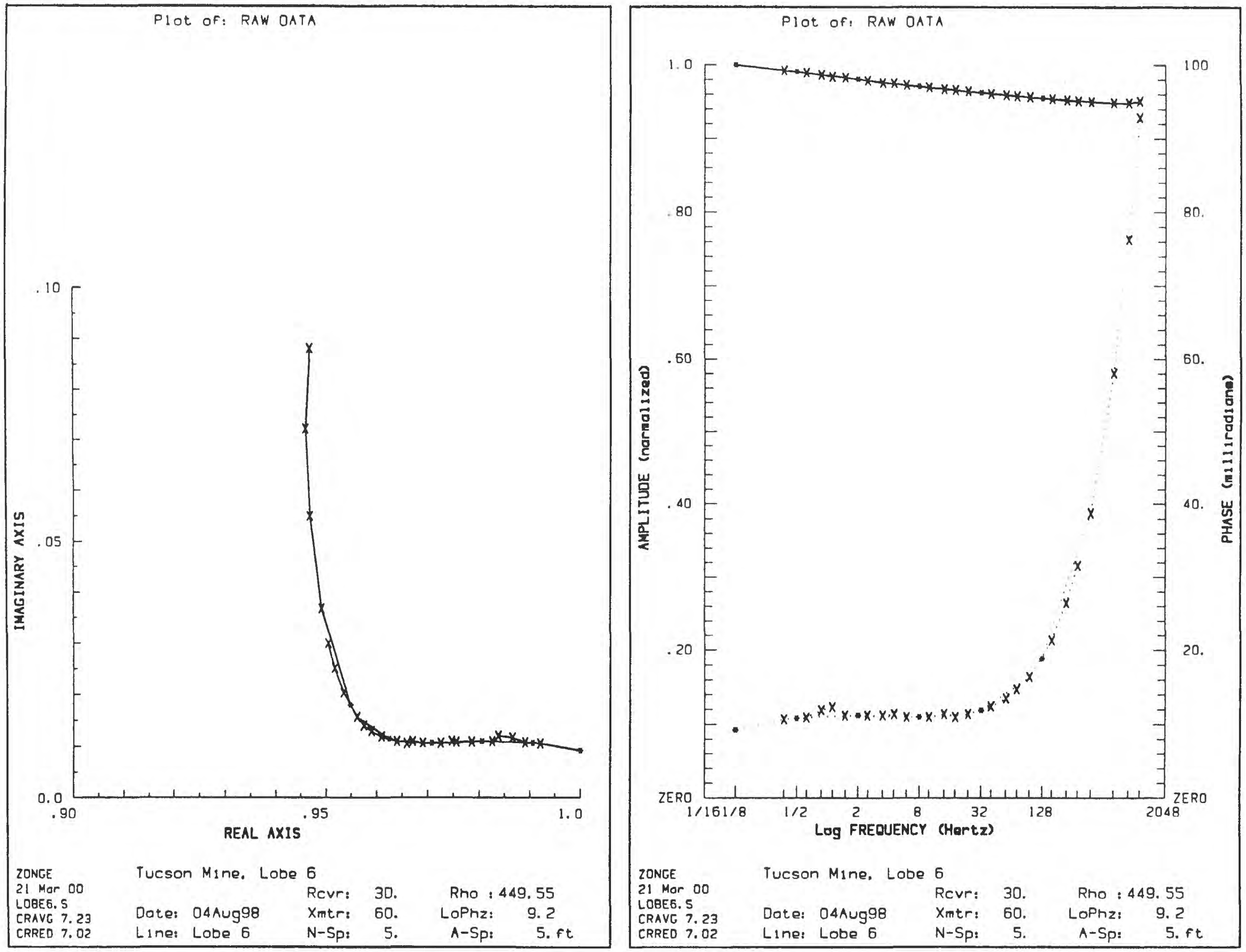

Plot of: RAW DATA
.10
.05
0.0
.90
.95
1.0
IMAGINARY AXIS
REAL AXIS
ZONGE
21 Mar 00
LOBE6.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 6
Date: 04Aug98
Line: Lobe 6
Rcvr: 30.
Xmtr: 60.
N-Sp: 5.
Rho : 449.55
LoPhz: 9.2
A-Sp: 5. ft
Plot of: RAW DATA
1.0
.80
.60
.40
.20
ZERO
100
80.
60.
40.
20.
ZERO
AMPLITUDE (normalized)
PHASE (milliradians)
1/161/8
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
21 Mar 00
LOBE6.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 6
Date: 04Aug98
Line: Lobe 6
Rcvr: 30.
Xmtr: 60.
N-Sp: 5.
Rho : 449.55
LoPhz: 9.2
A-Sp: 5. ft

Figure 52.

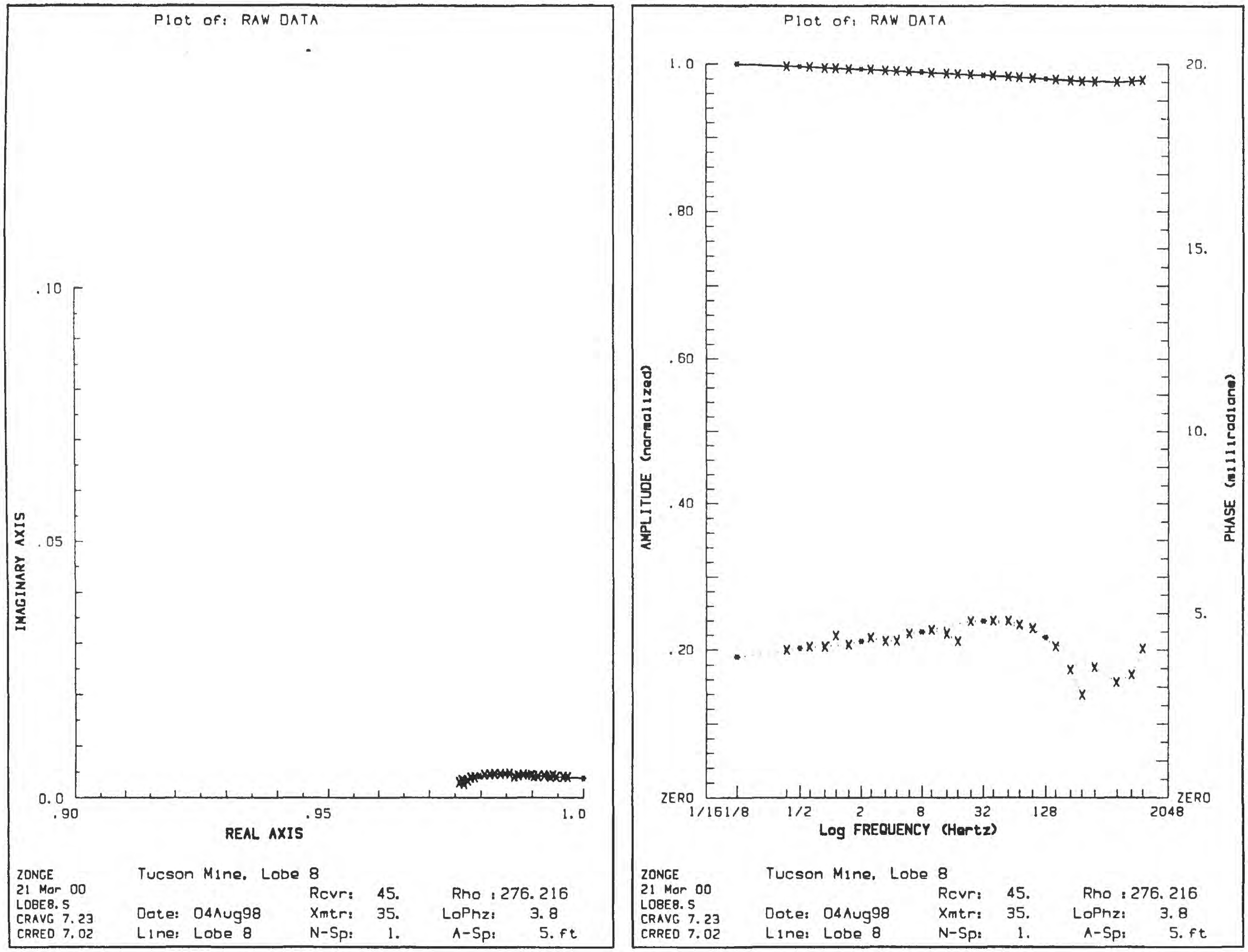

Plot of: RAW DATA
IMAGINARY AXIS
.10
.05
0.0
.90
.95
1.0
REAL AXIS
ZONGE
21 Mar 00
LOBE8.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 8
Date: 04Aug98
Line: Lobe 8
Rcvr: 45.
Xmtr: 35.
N-Sp: 1.
Rho : 276.216
LoPhz: 3.8
A-Sp: 5.ft
Plot of: RAW DATA
AMPLITUDE (normalized)
1.0
.80
.60
.40
.20
ZERO
PHASE (milliradians)
20.
15.
10.
5.
ZERO
1/16
1/8
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
21 Mar 00
LOBE8.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 8
Date: 04Aug98
Line: Lobe 8
Rcvr: 45.
Xmtr: 35.
N-Sp: 1.
Rho : 276.216
LoPhz: 3.8
A-Sp: 5.ft

Figure 53.

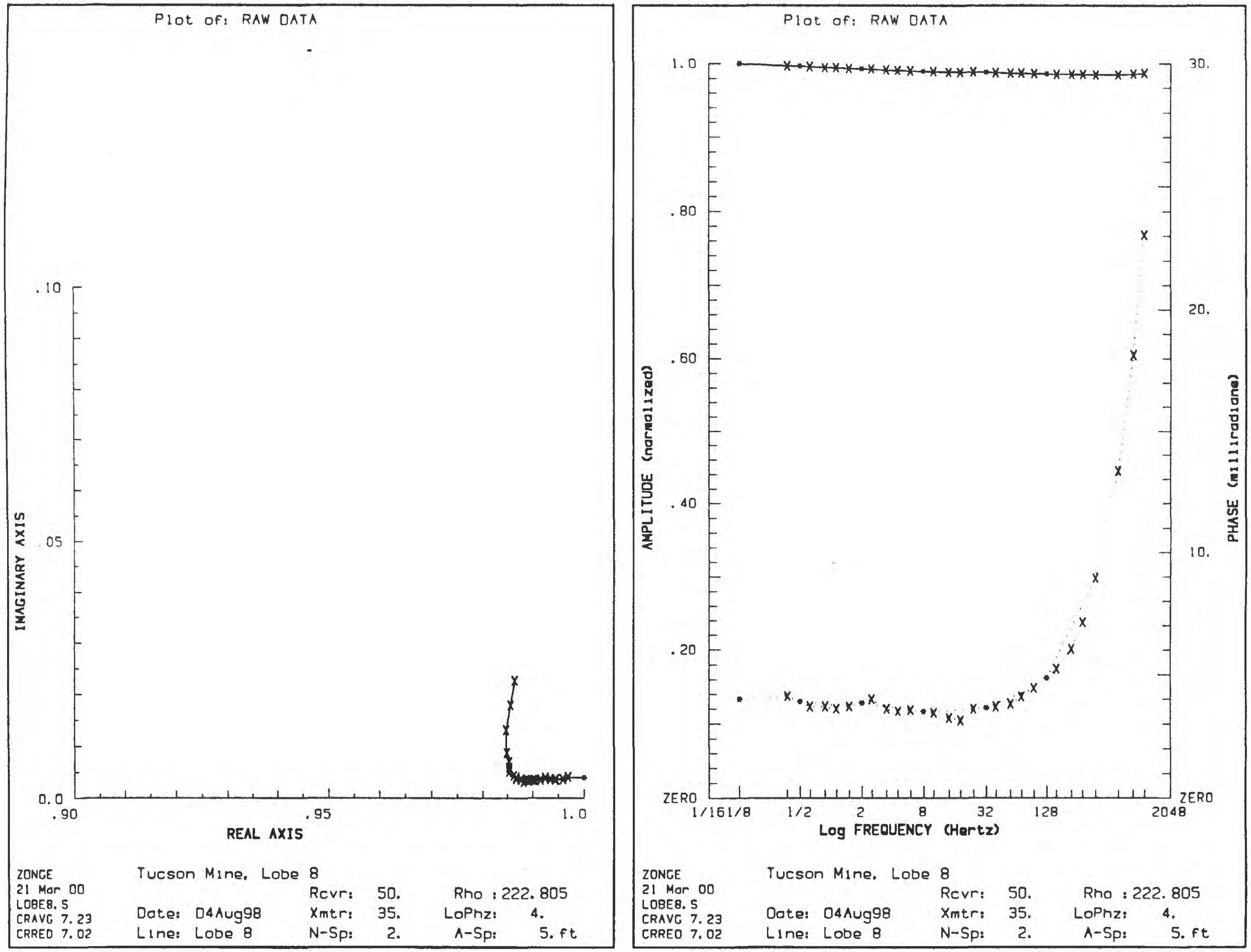

Plot of: RAW DATA
IMAGINARY AXIS
.10
.05
0.0
.90
.95
1.0
REAL AXIS
ZONGE
21 Mar 00
LOBE8.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 8
Date: 04Aug98
Line: Lobe 8
Rcvr: 50.
Xmtr: 35.
N-Sp: 2.
Rho : 222.805
LoPhz: 4.
A-Sp: 5.ft
Plot of: RAW DATA
AMPLITUDE (normalized)
1.0
.80
.60
.40
.20
ZERO
PHASE (milliradians)
30.
20.
10.
ZERO
1/16
1/8
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
21 Mar 00
LOBE8.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 8
Date: 04Aug98
Line: Lobe 8
Rcvr: 50.
Xmtr: 35.
N-Sp: 2.
Rho : 222.805
LoPhz: 4.
A-Sp: 5.ft

Figure 54.

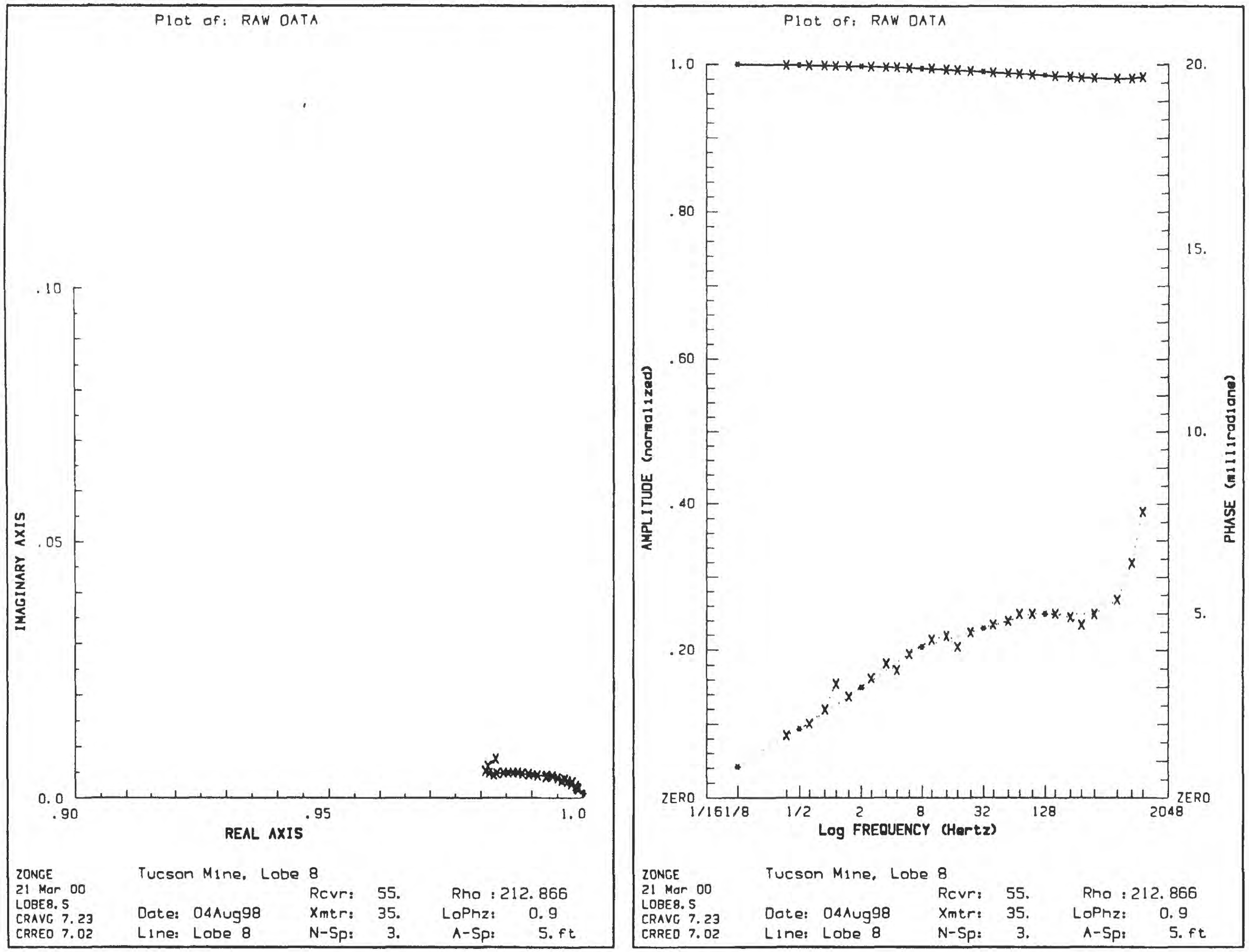

Plot of: RAW DATA
IMAGINARY AXIS
.10
.05
0.0
.90
.95
1.0
REAL AXIS
ZONGE
21 Mar 00
LOBE8.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 8
Date: 04Aug98
Line: Lobe 8
Rcvr: 55.
Xmtr: 35.
N-Sp: 3.
Rho : 212.866
LoPhz: 0.9
A-Sp: 5.ft
Plot of: RAW DATA
AMPLITUDE (normalized)
1.0
.80
.60
.40
.20
ZERO
PHASE (milliradians)
20.
15.
10.
5.
ZERO
1/16
1/8
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
21 Mar 00
LOBE8.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 8
Date: 04Aug98
Line: Lobe 8
Rcvr: 55.
Xmtr: 35.
N-Sp: 3.
Rho : 212.866
LoPhz: 0.9
A-Sp: 5.ft

Figure 55.

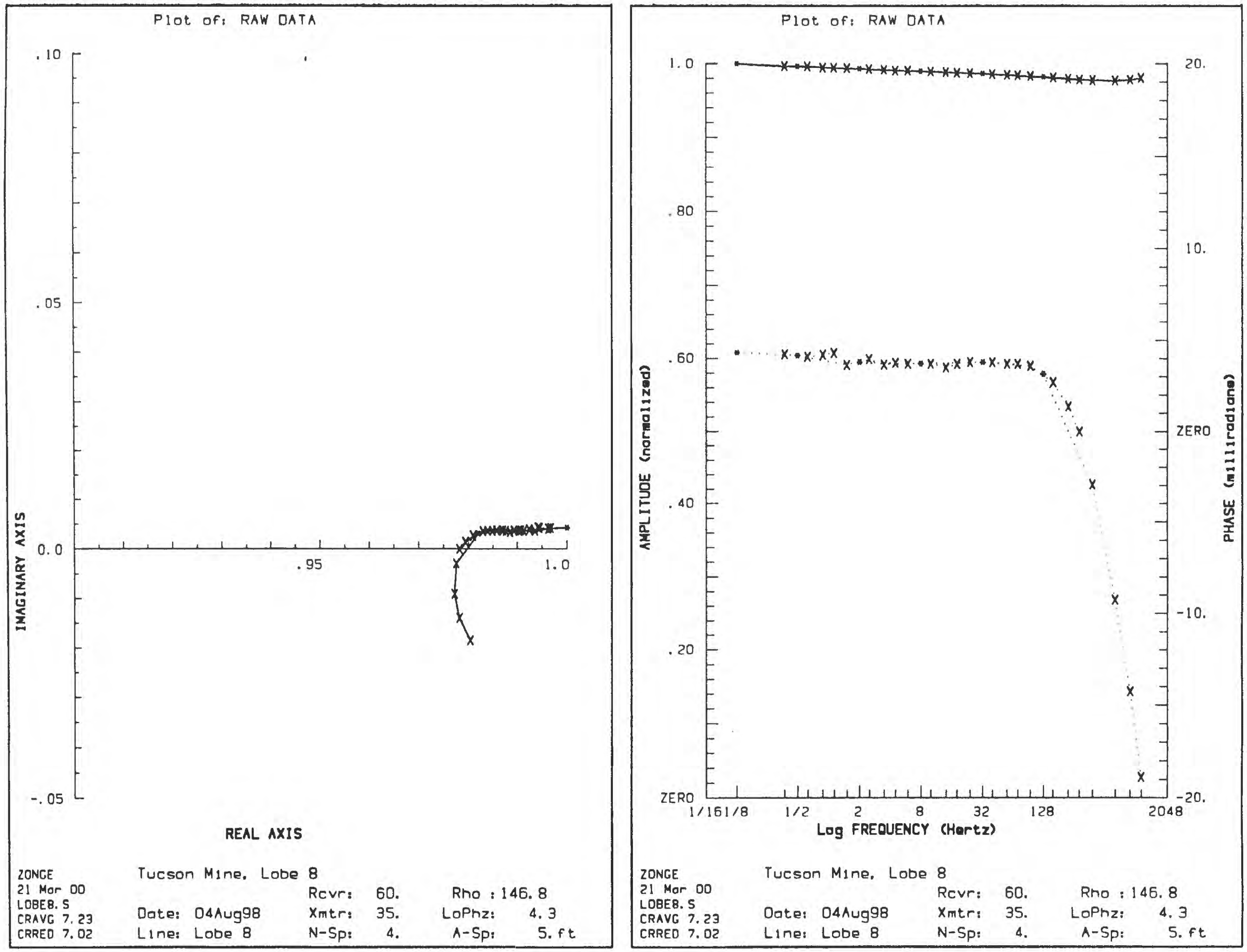

Plot of: RAW DATA
.10
.05
0.0
-.05
IMAGINARY AXIS
.95
1.0
REAL AXIS
ZONGE
21 Mar 00
LOBE8.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 8
Date: 04Aug98
Line: Lobe 8
Rcvr: 60.
Xmtr: 35.
N-Sp: 4.
Rho : 146.8
LoPhz: 4.3
A-Sp: 5.ft
Plot of: RAW DATA
1.0
.80
.60
.40
.20
ZERO
AMPLITUDE (normalized)
20.
10.
ZERO
-10.
-20.
PHASE (milliradians)
1/16
1/8
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
21 Mar 00
LOBE8.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 8
Date: 04Aug98
Line: Lobe 8
Rcvr: 60.
Xmtr: 35.
N-Sp: 4.
Rho : 146.8
LoPhz: 4.3
A-Sp: 5.ft

Figure 56.

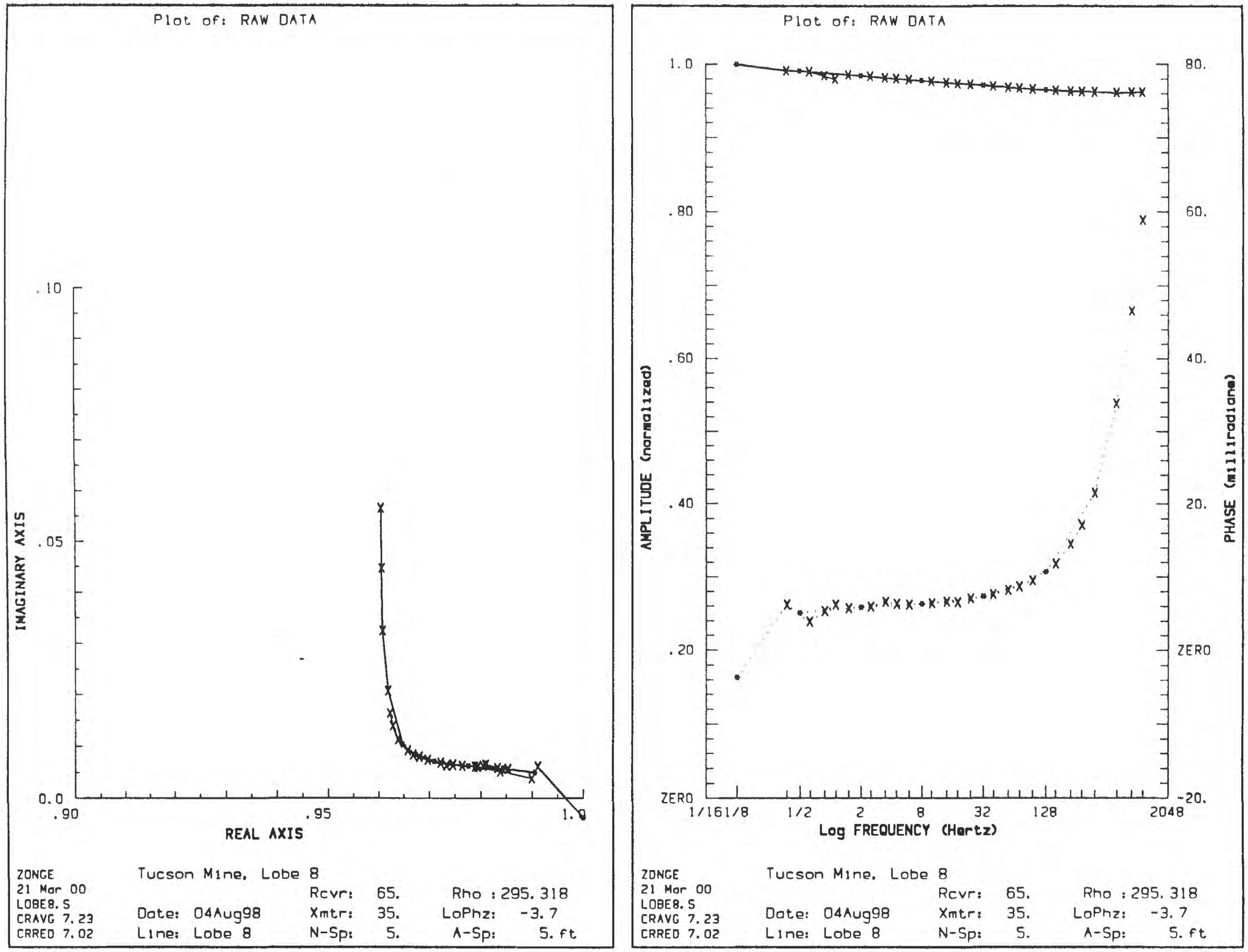

Plot of: RAW DATA
IMAGINARY AXIS
.10
.05
0.0
.90
.95
1.0
REAL AXIS
ZONGE
21 Mar 00
LOBE8.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 8
Date: 04Aug98
Line: Lobe 8
Rcvr: 65.
Xmtr: 35.
N-Sp: 5.
Rho : 295.318
LoPhz: -3.7
A-Sp: 5. ft
Plot of: RAW DATA
AMPLITUDE (normalized)
1.0
.80
.60
.40
.20
ZERO
PHASE (milliradians)
80.
60.
40.
20.
ZERO
-20.
1/16
1/8
1/2
2
8
32
128
2048
Log FREQUENCY (Hertz)
ZONGE
21 Mar 00
LOBE8.S
CRAVG 7.23
CRRED 7.02
Tucson Mine, Lobe 8
Date: 04Aug98
Line: Lobe 8
Rcvr: 65.
Xmtr: 35.
N-Sp: 5.
Rho : 295.318
LoPhz: -3.7
A-Sp: 5. ft

Figure 57.

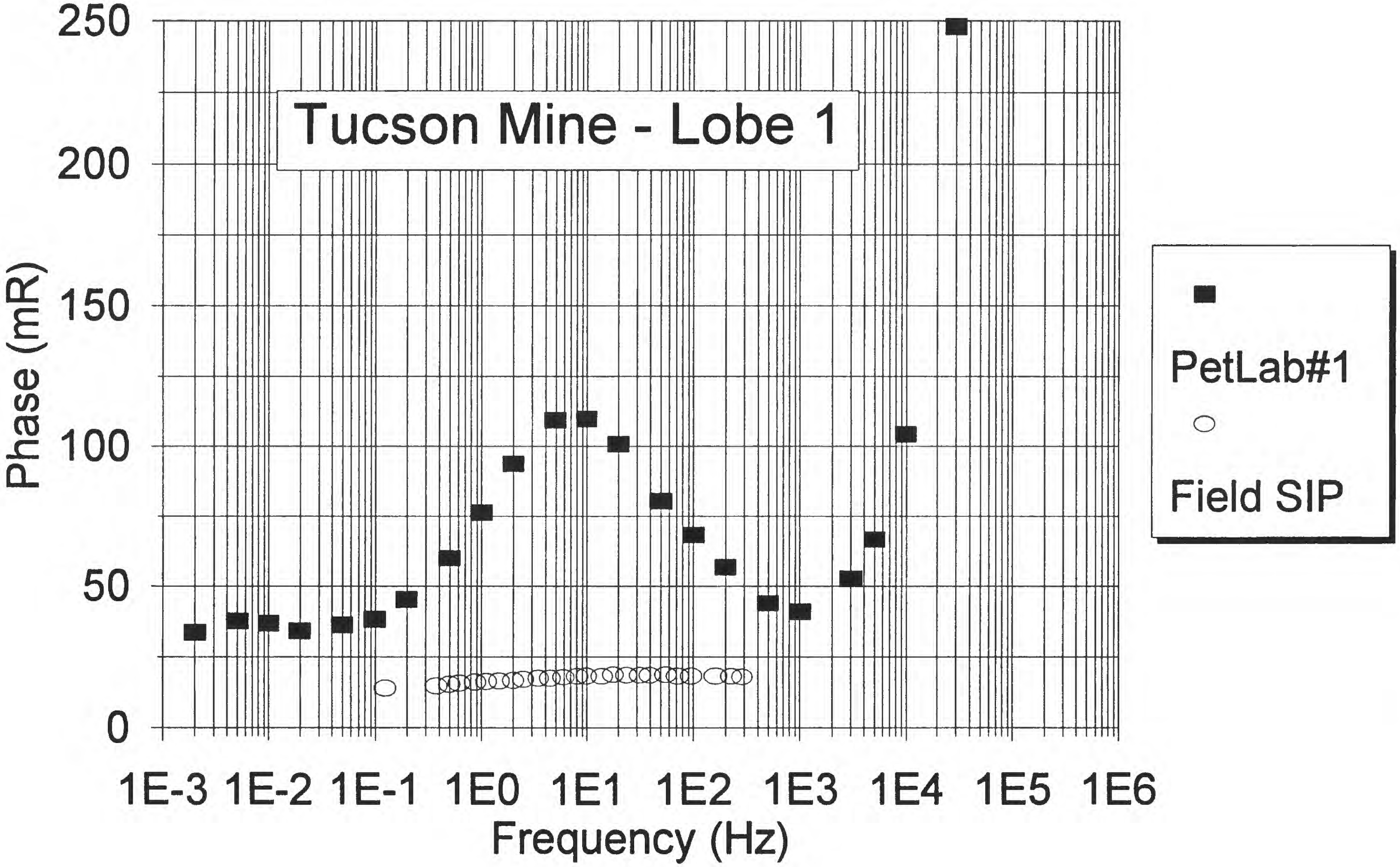

Tucson Mine - Lobe 1
Phase (mR)
250
200
150
100
50
0
1E-3
1E-2
1E-1
1E0
1E1
1E2
1E3
1E4
1E5
1E6
Frequency (Hz)
PetLab#1
Field SIP

Figure 58.

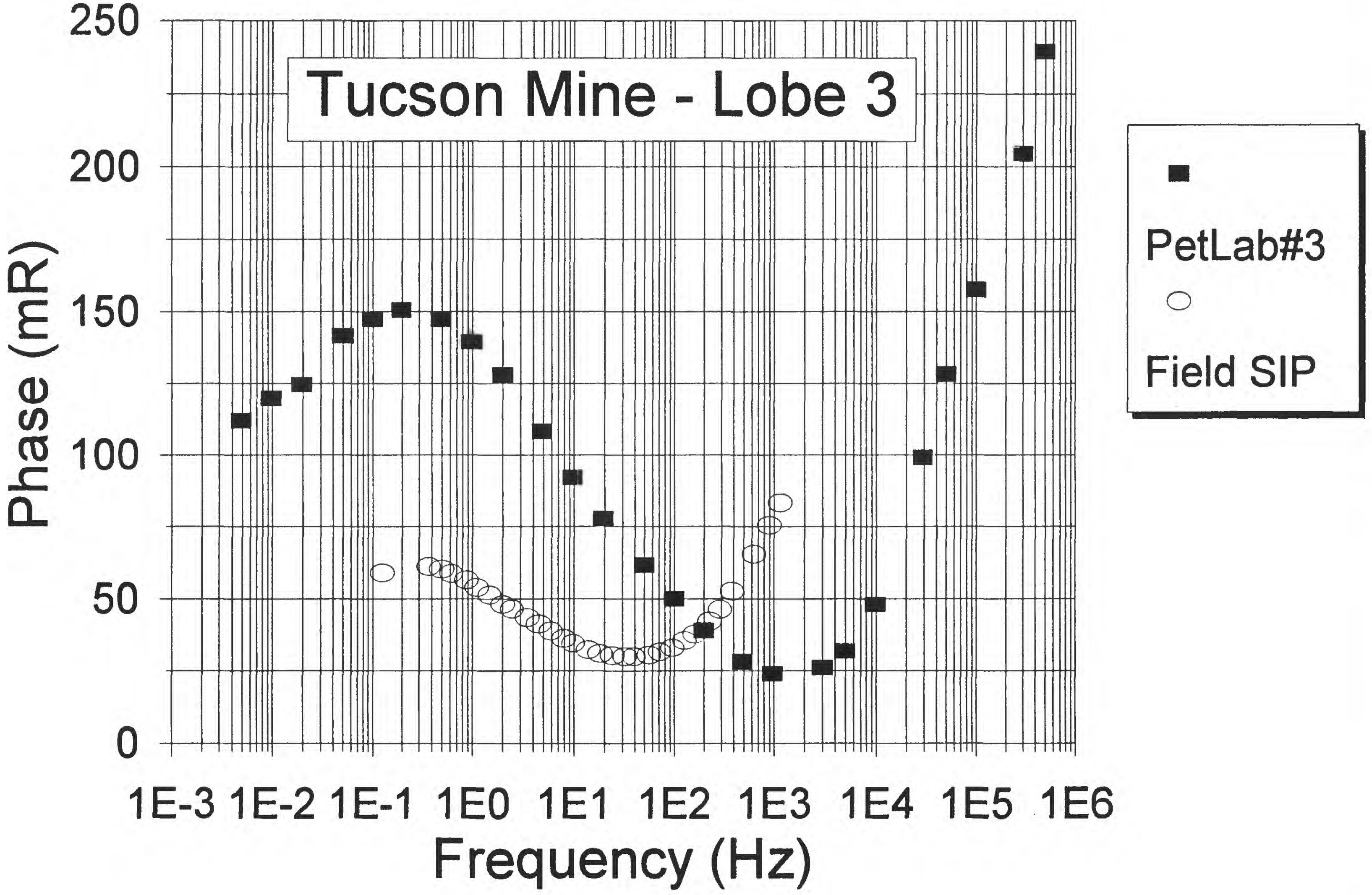

Tucson Mine - Lobe 3
Phase (mR)
250
200
150
100
50
0
1E-3
1E-2
1E-1
1E0
1E1
1E2
1E3
1E4
1E5
1E6
Frequency (Hz)
■ PetLab#3
○ Field SIP

Figure 59.

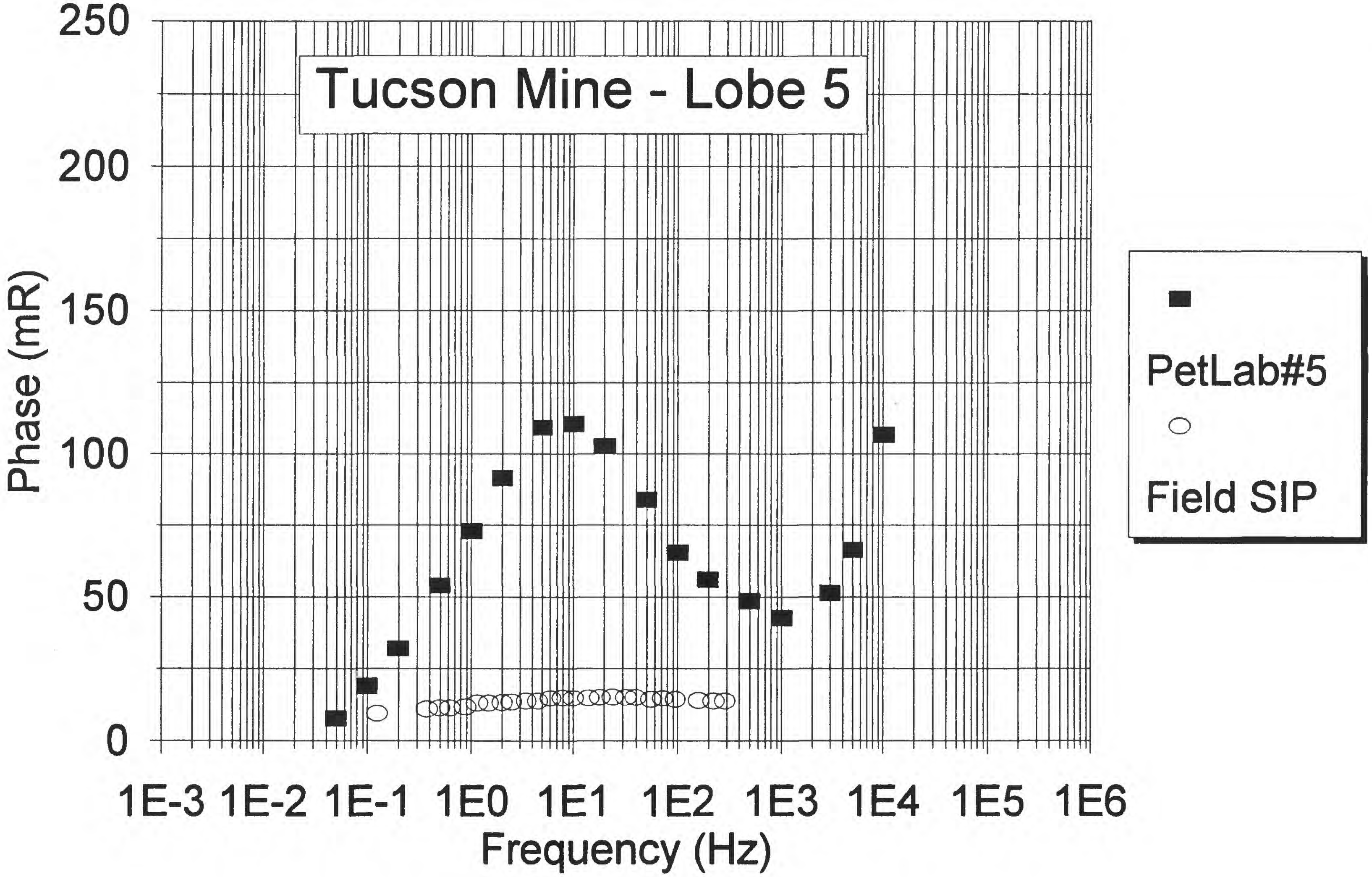

Tucson Mine - Lobe 5
Phase (mR)
250
200
150
100
50
0
1E-3
1E-2
1E-1
1E0
1E1
1E2
1E3
1E4
1E5
1E6
Frequency (Hz)
■ PetLab#5
○ Field SIP

Figure 60.