



U. S. DEPARTMENT OF THE INTERIOR

U. S. GEOLOGICAL SURVEY

***Schlumberger DC Resistivity Soundings in the Boulder Watershed, Jefferson and
Lewis and Clark Counties, Montana***

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U. S. Geological Survey Open-File Report 00-110
version 2.00

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INTRODUCTION

During July, 1997, twenty four Schlumberger dc resistivity soundings were made in the Boulder watershed and adjacent areas (fig. 1). The objective of geophysical studies in the watershed is to map subsurface lithologic, structural and hydrologic features important in controlling possible ground water contamination from mining activities and for design of remediation efforts. These studies are part of an abandoned mine land study (<http://amli.usgs.gov/amli/>) of the Boulder Basin mining district (<http://www.deq.state.mt.us/mtmines2/1inkdocs/techdocs/73tech.html>).

The Boulder Basin mining district is located in the Northeast part of the Cretaceous Boulder Batholith. Geologic mapping in the area has been done by Becraft and others, 1963, and Ruppel, 1963. A more recent summary of the geologic setting is given by O'Neill and others (2000) The majority of the batholith is a multi-textured granitoid which include different plutons. In the Boulder watershed the batholith is overlain by cogenetic Elkhorn Mountains Volcanics which are predominately quartz latite to andesite in composition

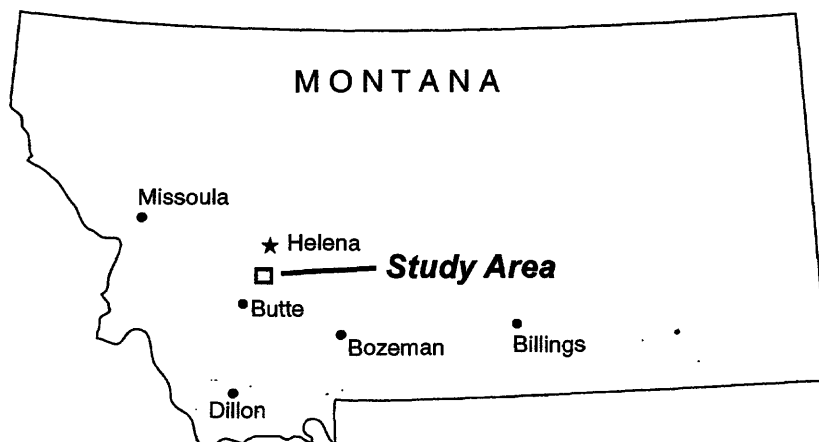


Figure 1 Index map for the study area

The Boulder Batholith is extensively jointed particularly in this study area which is in the upper part of the Batholith. The batholithic rocks are cut by numerous faults which trend northeast or east. The mineralization follows the east-trending faults or shear zones.

Pleistocene glacial till is present on some of the upland surfaces. Till is present in many of the flat areas in the valleys. Till is present in many of the flat areas in the valleys and lateral moraines are present along some of the larger valleys. Tertiary unconsolidated gravels mantle the uplands. Holocene fluvial-alluvial and minor pond and bog deposits have accumulated along some parts of the drainages.

The first geophysical work in the area by the USGS was a helicopter airborne geophysical survey carried out in 1996 using electromagnetic (EM) and magnetic survey systems (Smith et al., 2000). EM survey

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measurements are used to map variations in subsurface resistivity or its reciprocal conductivity. The dc resistivity survey was done as a follow-up of the airborne survey and to address smaller scale subsurface mapping issues.

An electronic version of this open-file report can be found in the abandoned mine lands web site given above and in <http://greenwood.cr.usgs.gov/>. The digital version includes plot files and digital data files for the dc resistivity soundings.

METHOD

The dc resistivity method involves the observation of electrical fields caused by current introduced into the ground (Sheriff, 1988). In dc soundings, the electrical fields are observed as a function of expanding current electrodes. By expanding the current electrodes, the apparent resistivity of the subsurface can be calculated as a function of vertical depth. Detailed description of various dc sounding methods can be found in standard geophysical texts such as Telford, and others (1990). A very good general reference is Zhody and others (1974). There are a number of world wide web sites that have information about dc sounding methods. The University of British Columbia maintains a web site (<http://www.geop.ubc.ca/ubcgif/tutorials/resip/resip.html>) which has an introductory geophysical section on resistivity methods. Another good introductory site is maintained by the Colorado School of mines (http://magma.Mines.EDU/fs_home/tboyd/GP311/). The Environmental Engineering Geophysical Society (EEGS) also has an excellent web site (<http://www.eegs.org>) that has numerous links to geophysical topics including dc resistivity methods.

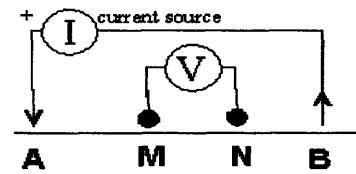


Figure 2 DC resistivity array where AB are current electrodes and MN are voltage electrodes.

SURVEY

In this survey an ABEM SAS⁽¹⁾ (<http://www.abem.se/>) dc resistivity system was used in a Schlumberger electrode array (fig. 2). Current electrode spacing began with .91m and ended with 61 m (3ft to 200ft). The maximum electrode spacing was determined by instrumental and operational considerations which were primarily power and portability. The voltage (potential) electrode spacing was maintained at less the 1/3 the current electrode spacing and increased once per decade spacing. When the voltage electrode spacing was changed, two repeat measurements were made at the previous and new MN spacings. In general the maximum depth of investigation for the survey is about 30 meters. A total of twenty soundings were made in the Boulder Basin watershed (fig. 3) which are designated MTAMLxx where xx is the sounding number. Four additional soundings were made in the Ten Mile drainage to the north of the Boulder Basin (MTAML 20-24). Location information for all soundings is given in Table 1.

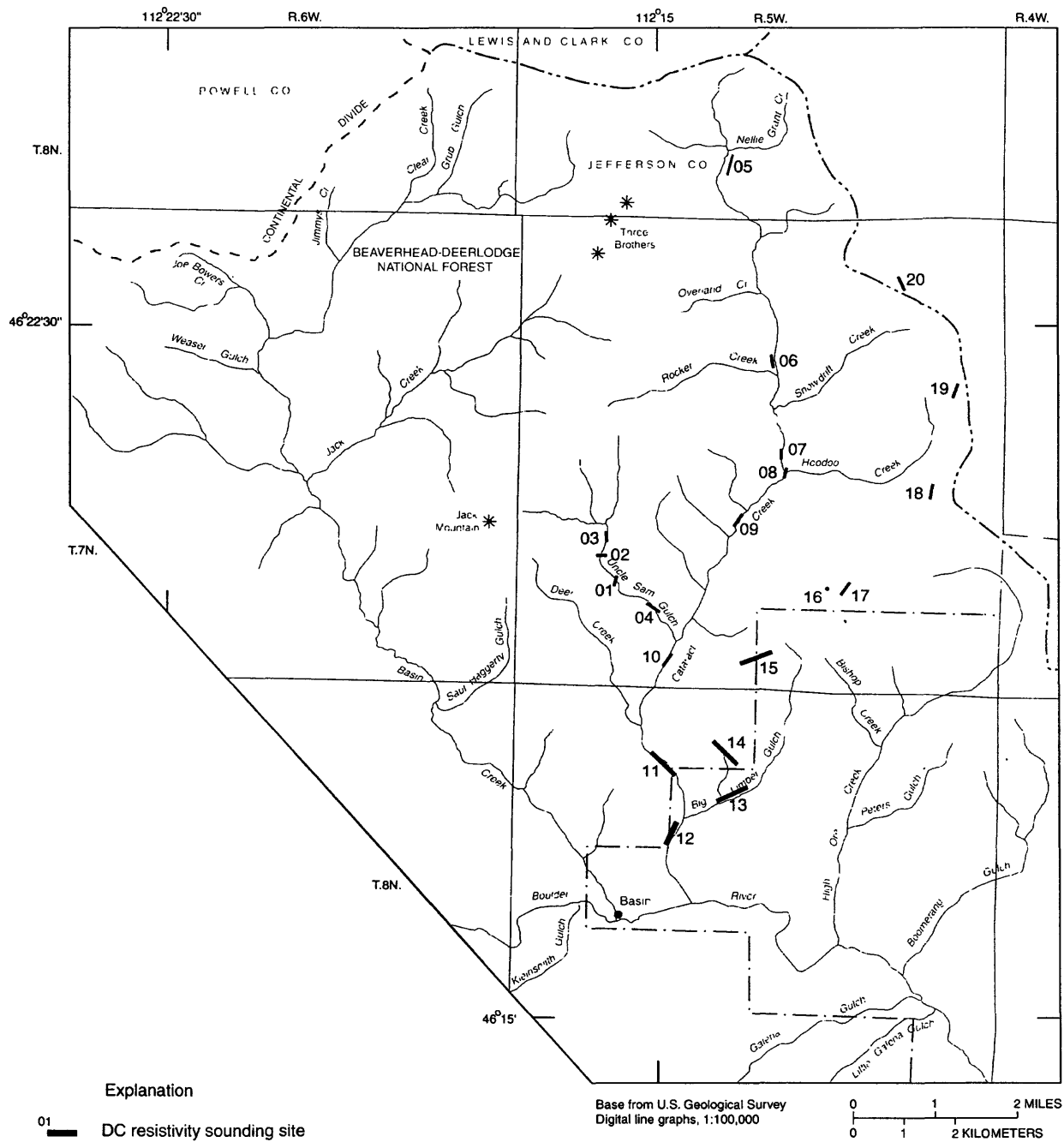


Figure 3. DC resistivity sounding locations in the Boulder Basin watershed

Table 1. DC sounding locations in geographic coordinates. The latitude and longitude are referenced to WGS84. UTM coordinates are referenced to NAD27, zone 12 (-111 degrees west).

BOULDER BASIN 1997 SCHLUMBERGER SOUNDING LOCATIONS					
SOUNDING NUMBER	LATITUDE	LONGITUDE	UTM EASTING (Kilometers)	UTM NORTHING (Kilometers)	ELEVATION (feet)
MTAML01	46° 20.63'	112° 15.65'	402.977606	5133.023297	7160
MTAML02	46° 21.045'	112° 15.977'	402.570517	5133.798517	8000
MTAML03	46° 21.177'	112° 15.974'	402.578274	5134.042903	8000
MTAML04	46° 19.471'	112° 15.034'	403.733737	5130.864451	6680
MTAML05	46° 24.19'	112° 13.70'	405.580819	5139.576690	7160
MTAML06	46° 22.00'	112° 13.0'	406.415242	5135.507198	6800
MTAML07	46° 21.00'	112° 12.90'	406.515017	5133.653351	6690
MTAML08	46° 20.70'	112° 13.2'	406.121747	5133.103704	6480
MTAML09	46° 19.90'	112° 14.0'	405.046736	5129.971421	6440
MTAML10	46° 18.9'	112° 14.8'	404.017307	5129.802303	6200
MTAML11	46° 15.0'	112° 17.8'	400.049610	5122.641875	5920
MTAML12	46° 17.0'	112° 13.9'	405.117481	5126.265705	5440
MTAML13	46° 17.3'	112° 17.3'	400.761177	5126.890657	5600
MTAML14	46° 17.9'	112° 14.1'	404.886669	5127.936372	6120
MTAML15	46° 19'	112° 13.4'	405.816622	5129.959483	7160
MTAML16	46° 19.8'	112° 12.4'	407.122335	5131.421297	7560
MTAML17	46° 18.9'	112° 14.8'	404.017307	5129.802303	7640
MTAML18	46° 20.7'	112° 10.8'	409.199702	5133.057057	7240
MTAML19	46° 22.0'	112° 10.3'	409.876574	5135.454977	7480
MTAML20	46° 23.0'	112° 11.7'	408.109772	5137.333693	7480
MTAML21	46° 28.7'	112° 14.6'	404.559172	5147.946786	6150
MTAML22	46° 27.7'	112° 14.9'	404.146107	5146.100926	6350
MTAML23	46° 26.3'	112° 14.2'	405.001366	5143.494173	6740
MTAML24	46° 25.5'	112° 15.0'	403.953707	5142.028761	6780

DISCUSSION

Data collected in the field were entered into the INTERPEX⁽¹⁾ program RESIX-IP™ (version 2.0). Using this program, a “smooth” layered earth model was computed for each sounding. The smooth model is an inversion process which produces a layer and resistivity for each observation point. Details of the program are given in the manual (Interpex, 1993) and additional information can be found on their web site (www.interpex.com). Field data, interpreted smooth model, and plot is given for each sounding in Appendix A.

The apparent resistivities estimated in the airborne electromagnetic survey (Smith and others, 2000) average on the order of low hundreds of ohm-meters through much of the depth range of the measurements. In some areas, deeper estimated resistivities are a few tens of ohm-meters. This is rather surprising considering that the resistivity of fresh volcanic and batholithic rocks such as characteristic of the Boulder Batholith are commonly in the 1,000's of ohm-meters (Telford and others, 1990).

DC resistivity sounding, MTAML01F, was made near the head of the Uncle Sam Gulch drainage (fig. 3) and is shown in Figure 4 as well as in Appendix A. This part of Uncle Sam Gulch has a north - south trending zone of low estimated subsurface resistivity and magnetization from the airborne survey. A drill hole 1 km to the south of this sounding reached a depth of 16.5m (50 feet). McDougal (written communication) describes the upper half of the drill hole as altered with the fresher rocks at the bottom of the hole. However the fresher intrusive rock is

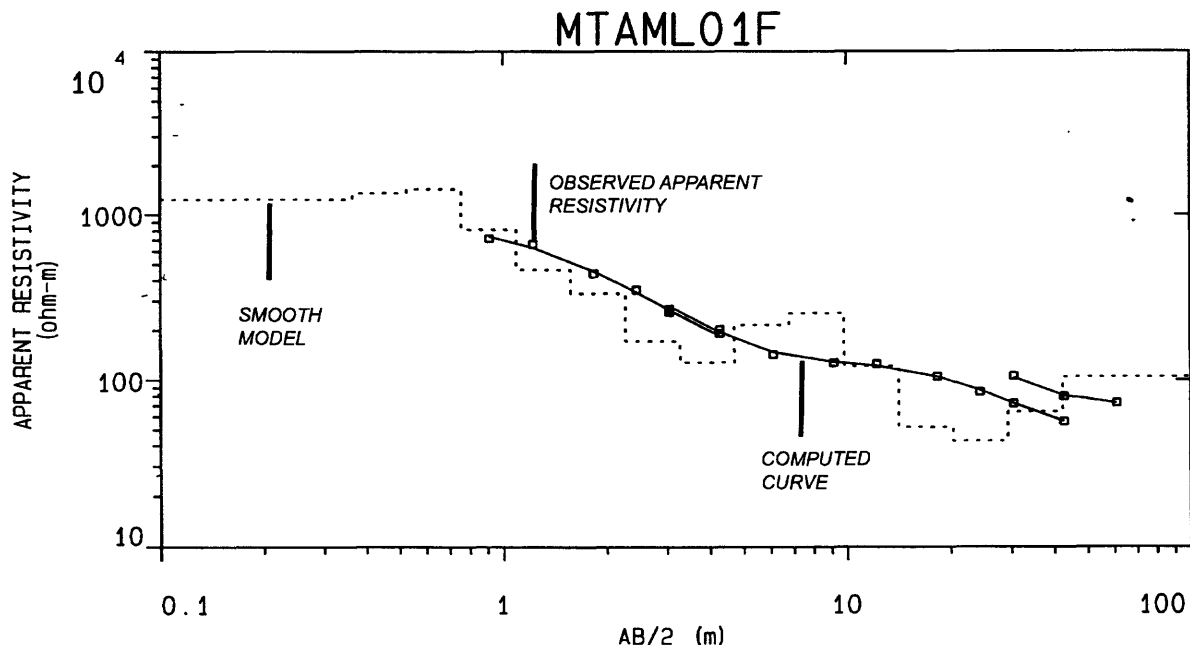


Figure 4 DC resistivity sounding at the head of Uncle Sam Gulch. The x-axis is electrode spacing (AB/2) and depth of smooth model. The y-axis is the measured apparent resistivity and the interpreted smooth layer model resistivity.

fractured with probable low temperature hydrothermal alteration along the fractures. It is not possible to tell with the present data whether the more surficial alteration is weathering or low temperature hydrothermal alteration. At least in this general area ground truth suggests that batholith rocks are not as resistive as was expected.

In general the lower than expected estimated resistivities from the airborne survey are on the same order of magnitude as ground survey. The implication of this observation is that the volcanic and batholithic rocks, within 60m of the surface, are fractured and altered. A consequence of this hypothesis is that while a large portion of the groundwater flow is in the near surface there is probably also a vertical flow component.

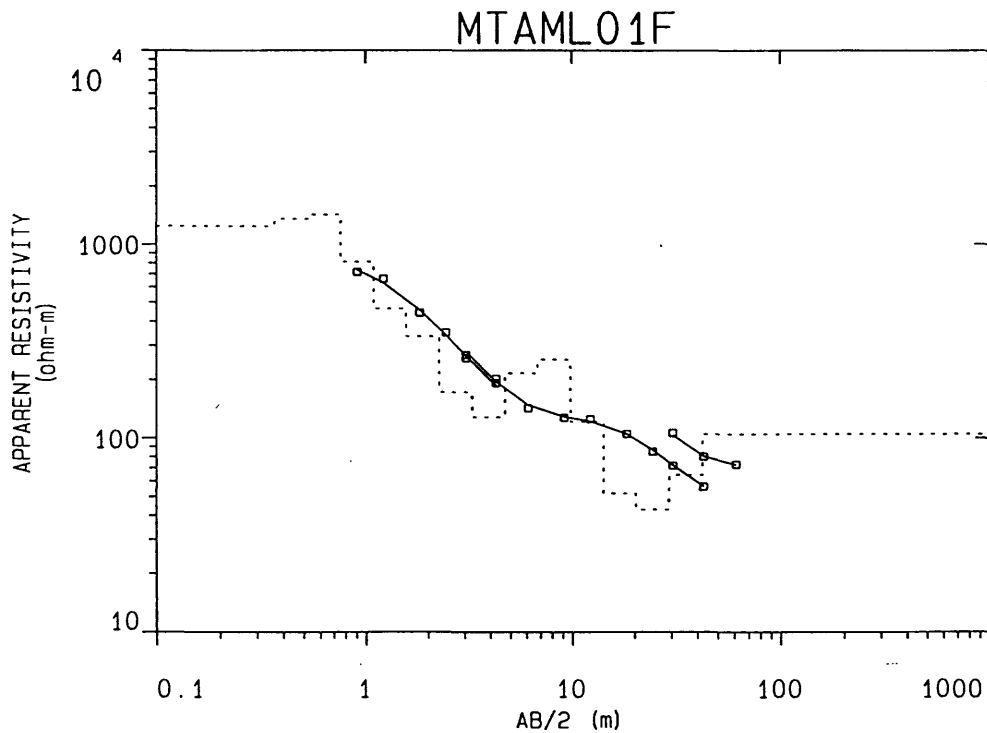
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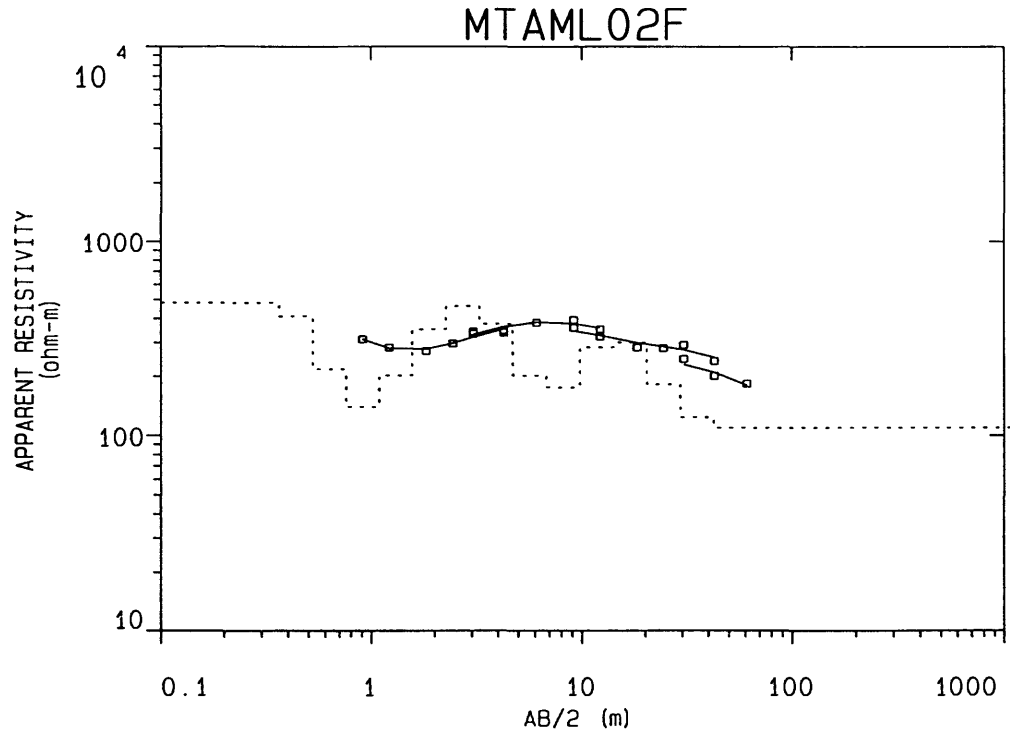
APPENDIX A

DC SOUNDING PLOTS, FIELD DATA, AND INTERPRETED MODELS

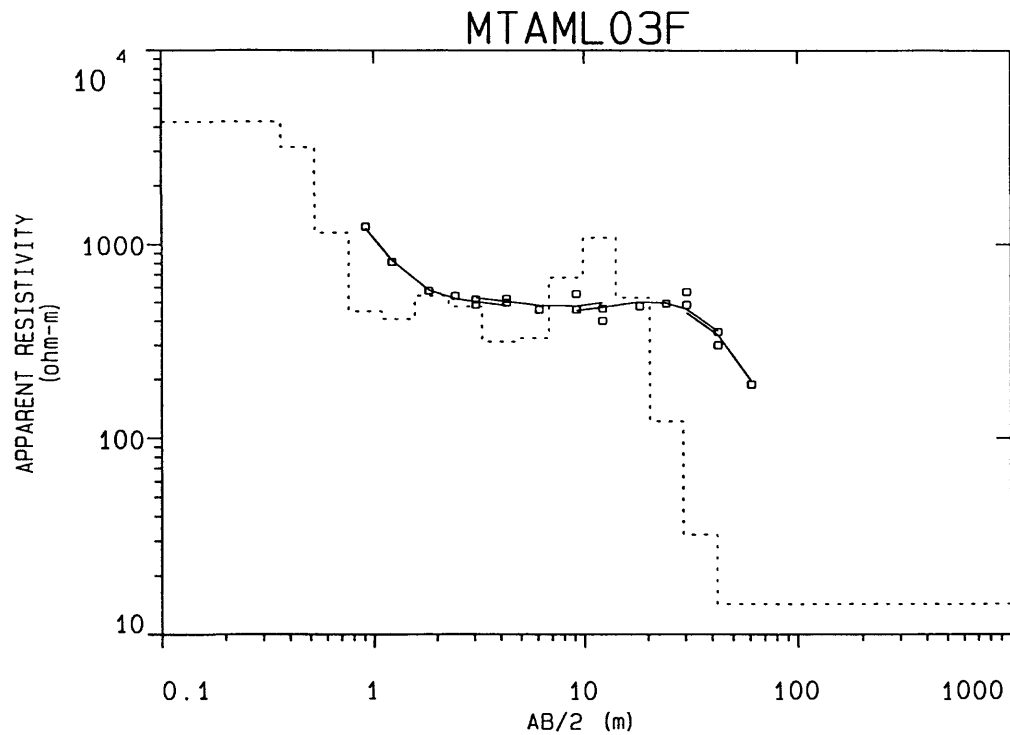
(see Figure 4 in main text for plotting conventions)



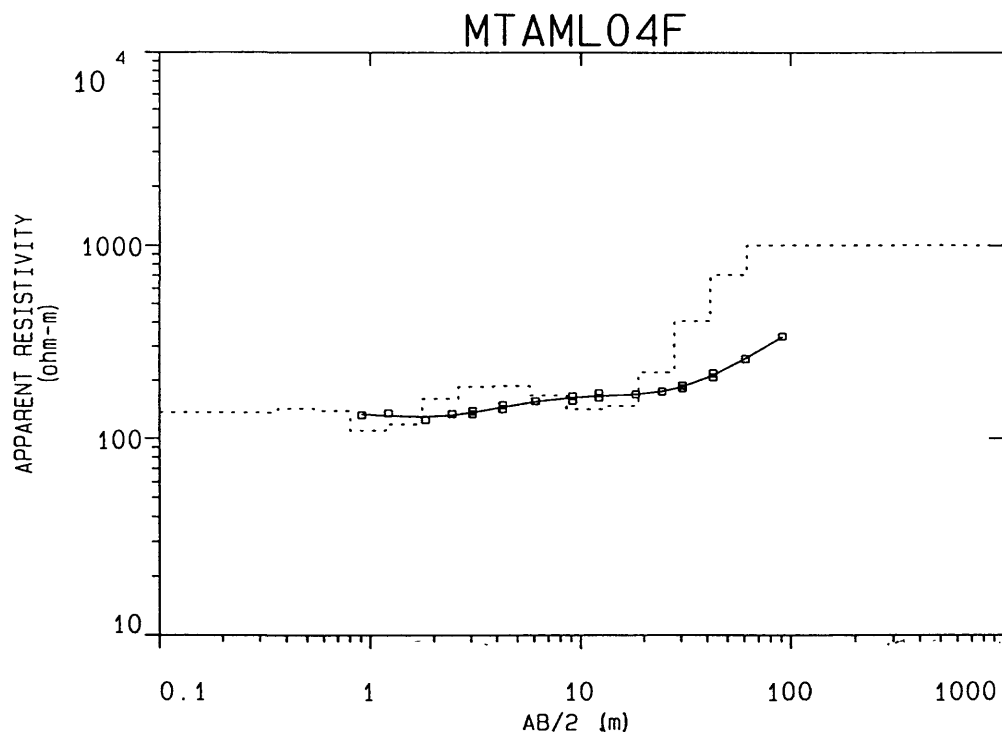
MTAML01F 7/16/97			MODEL		
No.	SPACING	RESISTIVITY	LAYER	RESISTIVITY	THICKNESS
			1	1.24088E+03	3.64000E-01
1	0.9100	717.0000	2	1.35492E+03	1.60752E-01
2	1.2200	661.0000	3	1.43008E+03	2.31745E-01
3	1.8300	442.0000	4	8.12320E+02	3.34090E-01
4	2.4400	350.0000	5	4.63855E+02	4.81634E-01
5	3.0500	258.0000	6	3.34890E+02	6.94337E-01
6	4.2700	192.0000	7	1.72008E+02	1.00097E+00
7	3.0500	268.0000	8	1.27921E+02	1.44303E+00
8	4.2700	202.0000	9	2.15767E+02	2.08032E+00
9	6.1000	142.0000	10	2.53782E+02	2.99904E+00
10	9.1400	127.0000	11	1.21339E+02	4.32350E+00
11	12.1900	125.0000	12	5.19987E+01	6.23288E+00
12	18.2900	105.0000	13	4.28554E+01	8.98549E+00
13	24.3800	85.0000	14	6.44841E+01	1.29537E+01
14	30.4800	72.0000	15	1.04769E+02	
15	42.6700	56.0000			
16	30.4800	106.0000			
17	42.6700	80.0000			
18	60.9600	73.0000			



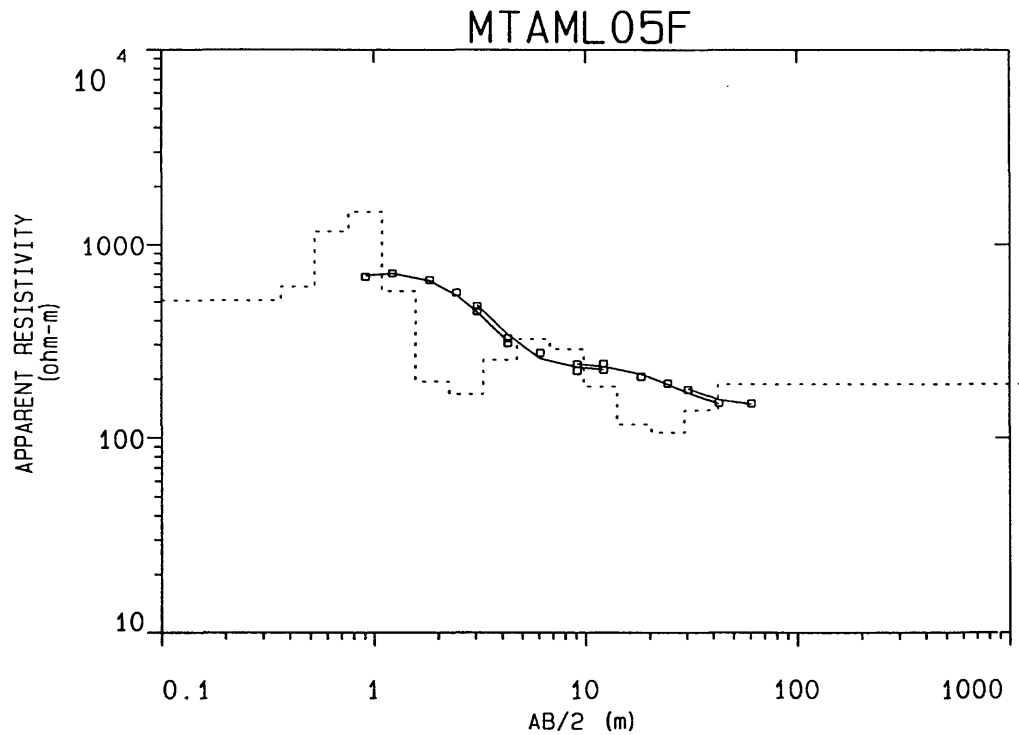
MTAML02F			MODEL		
No.	SPACING	RESISTIVITY	LAYER	RESISTIVITY	THICKNESS
			1	6.18836E+02	3.64000E-01
1	0.9100	312.0000	2	5.31692E+02	1.60752E-01
2	1.2200	283.0000	3	2.77934E+02	2.31745E-01
3	1.8300	271.0000	4	1.70258E+02	3.34090E-01
4	2.4400	296.0000	5	2.54555E+02	4.81634E-01
5	3.0500	333.0000	6	4.85399E+02	6.94337E-01
6	4.2700	338.0000	7	6.31567E+02	1.00097E+00
7	3.0500	341.0000	8	4.66404E+02	1.44303E+00
8	4.2700	348.0000	9	2.44284E+02	2.08032E+00
9	6.1000	381.0000	10	2.09956E+02	2.99904E+00
10	9.1400	394.0000	11	3.16497E+02	4.32350E+00
11	12.1900	353.0000	12	3.26856E+02	6.23288E+00
12	9.1400	359.0000	13	1.94202E+02	8.98549E+00
13	12.1900	323.0000	14	1.18326E+02	1.29537E+01
14	18.2900	283.0000	15	9.09654E+01	
15	24.3800	281.0000			
16	30.4800	292.0000			
17	42.6700	240.0000			
18	30.4800	246.0000			
19	42.6700	201.0000			
20	60.9600	184.0000			



Field Data			Model		
MTAML03F 7/16/97			LAYER	RESISTIVITY	THICKNESS
No.	SPACING	RESISTIVITY			
1	0.9100	1234.0000	1	4.24666E+03	3.64000E-01
2	1.2200	811.0000	2	3.13880E+03	1.60752E-01
3	1.8300	576.0000	3	1.14907E+03	2.31745E-01
4	2.4400	542.0000	4	4.51024E+02	3.34090E-01
5	3.0500	488.0000	5	4.10562E+02	4.81634E-01
6	4.2700	499.0000	6	5.41689E+02	6.94337E-01
7	3.0500	519.0000	7	4.78274E+02	1.00097E+00
8	4.2700	523.0000	8	3.13475E+02	1.44303E+00
9	6.1000	460.0000	9	3.26427E+02	2.08032E+00
10	9.1400	460.0000	10	6.75057E+02	2.99904E+00
11	12.1900	402.0000	11	1.08238E+03	4.32350E+00
12	9.1400	555.0000	12	5.31537E+02	6.23288E+00
13	12.1900	466.0000	13	1.22075E+02	8.98549E+00
14	18.2900	480.0000	14	3.23298E+01	1.29537E+01
15	24.3800	495.0000	15	1.43128E+01	
16	30.4800	488.0000			
17	42.6700	301.0000			
18	30.4800	570.0000			
19	42.6700	353.0000			
20	60.9600	189.0000			



Field Data			Model		
MTAML04F					
No.	SPACING	RESISTIVITY	LAYER	RESISTIVITY	THICKNESS
1	0.9100	132.0000	1	1.36092E+02	3.64000E-01
2	1.2200	135.0000	2	1.42719E+02	1.76172E-01
3	1.8300	125.0000	3	1.39027E+02	2.61438E-01
4	2.4400	134.0000	4	1.09900E+02	3.87972E-01
5	3.0500	134.0000	5	1.18637E+02	5.75746E-01
6	4.2700	142.0000	6	1.60442E+02	8.54402E-01
7	3.0500	139.0000	7	1.86126E+02	1.26792E+00
8	4.2700	149.0000	8	1.87172E+02	1.88159E+00
9	6.1000	156.0000	9	1.67785E+02	2.79226E+00
10	9.1400	166.0000	10	1.41925E+02	4.14368E+00
11	12.1900	172.0000	11	1.47654E+02	6.14919E+00
12	9.1400	157.0000	12	2.21504E+02	9.12533E+00
13	12.1900	163.0000	13	4.08854E+02	1.35419E+01
14	18.2900	170.0000	14	7.09434E+02	2.00961E+01
15	24.3800	176.0000	15	1.00088E+03	
16	30.4800	189.0000			
17	42.6700	219.0000			
18	30.4800	183.0000			
19	42.6700	209.0000			
20	60.9600	260.0000			
21	91.4400	340.0000			



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MTAML05F 7/17/97

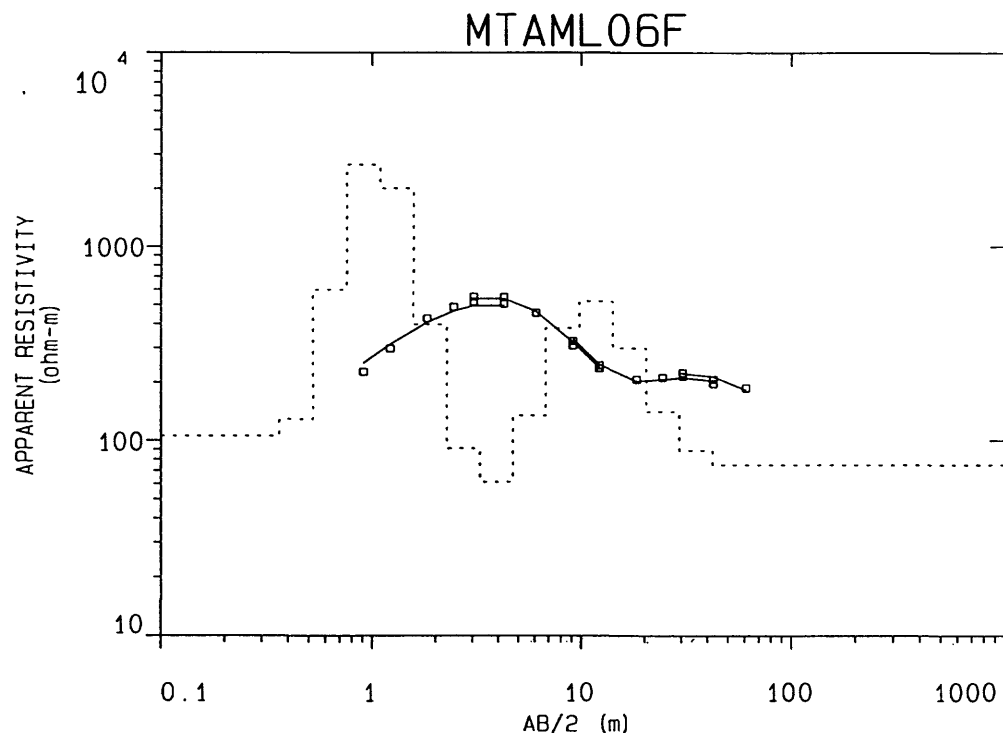
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5	3.0500	446.0000
6	4.2700	305.0000
7	3.0500	476.0000
8	4.2700	323.0000
9	6.1000	272.0000
10	9.1400	238.0000
11	12.1900	240.0000
12	9.1400	220.0000
13	12.1900	223.0000
14	18.2900	206.0000
15	24.3800	190.0000
16	30.4800	177.0000
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20	60.9600	150.0000

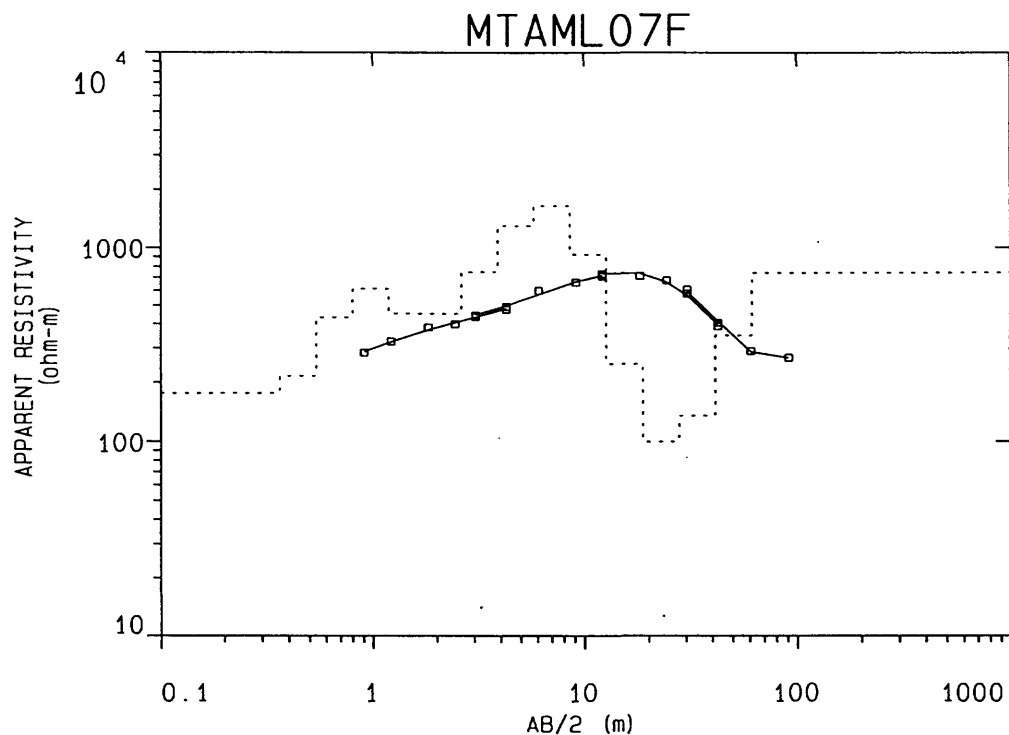
Model

LAYER	RESISTIVITY	THICKNESS
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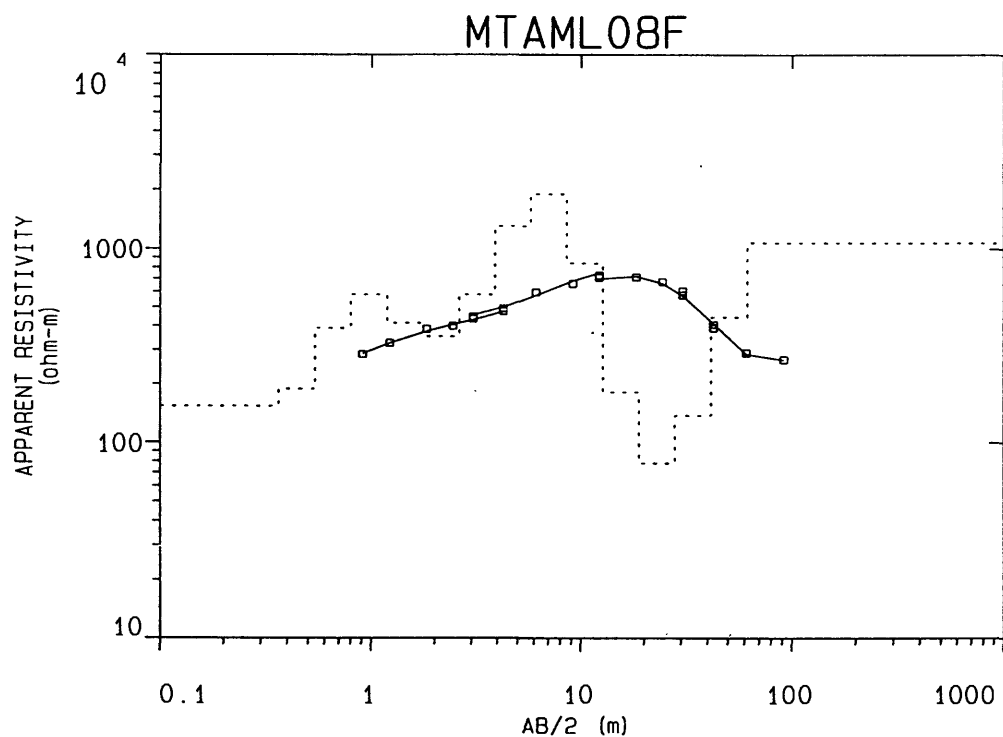
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3	9.32547E+02	2.31745E-01
4	1.19405E+03	3.34090E-01
5	4.61964E+02	4.81634E-01
6	1.53763E+02	6.94337E-01
7	1.35328E+02	1.00097E+00
8	2.16536E+02	1.44303E+00
9	2.85328E+02	2.08032E+00
10	2.61154E+02	2.99904E+00
11	1.74167E+02	4.32350E+00
12	1.08141E+02	6.23288E+00
13	9.79040E+01	8.98549E+00
14	1.41144E+02	1.29537E+01
15	2.18094E+02	



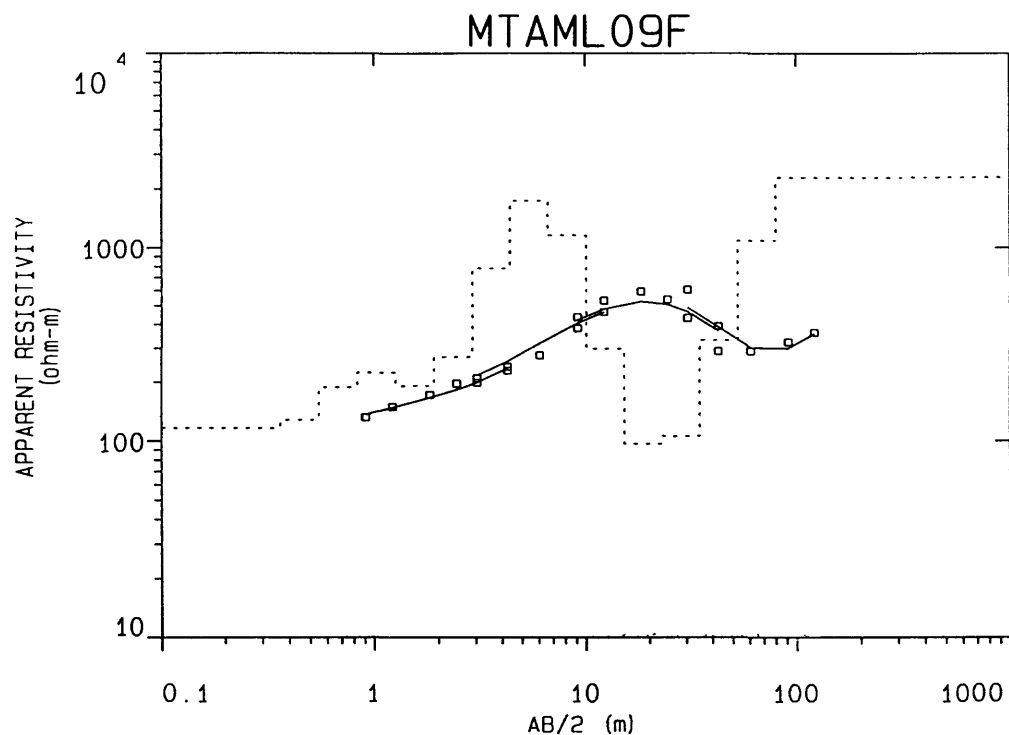
Field Data			Model		
MTAML06F 7/17/97					
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1	0.9100	227.0000	1	4.05882E+02	3.64000E-01
2	1.2200	298.0000	2	4.80886E+02	1.60752E-01
3	1.8300	428.0000	3	9.32547E+02	2.31745E-01
4	2.4400	490.0000	4	1.19405E+03	3.34090E-01
5	3.0500	521.0000	5	4.61964E+02	4.81634E-01
6	4.2700	507.0000	6	1.53763E+02	6.94337E-01
7	3.0500	554.0000	7	1.35328E+02	1.00097E+00
8	4.2700	551.0000	8	2.16536E+02	1.44303E+00
9	6.1000	457.0000	9	2.85328E+02	2.08032E+00
10	9.1400	310.0000	10	2.61154E+02	2.99904E+00
11	12.1900	236.0000	11	1.74167E+02	4.32350E+00
12	9.1400	326.0000	12	1.08141E+02	6.23288E+00
13	12.1900	245.0000	13	9.79040E+01	8.98549E+00
14	18.2900	207.0000	14	1.41144E+02	1.29537E+01
15	24.3800	212.0000	15	2.18094E+02	
16	30.4800	215.0000			
17	42.6700	197.0000			
18	30.4800	224.0000			
19	42.6700	207.0000			
20	60.9600	187.0000			



Field Data			Model		
MTAML07F 7/17/97					
No.	SPACING	RESISTIVITY	LAYER	RESISTIVITY	THICKNESS
1	0.9100	285.0000	1	1.76144E+02	3.64000E-01
2	1.2200	325.0000	2	2.16096E+02	1.76172E-01
3	1.8300	385.0000	3	4.33279E+02	2.61438E-01
4	2.4400	399.0000	4	6.12386E+02	3.87972E-01
5	3.0500	435.0000	5	4.54253E+02	5.75746E-01
6	4.2700	477.0000	6	4.52992E+02	8.54402E-01
7	3.0500	445.0000	7	7.48909E+02	1.26792E+00
8	4.2700	493.0000	8	1.29574E+03	1.88159E+00
9	6.1000	597.0000	9	1.64527E+03	2.79226E+00
10	9.1400	661.0000	10	9.23208E+02	4.14368E+00
11	12.1900	712.0000	11	2.48936E+02	6.14919E+00
12	12.1900	731.0000	12	9.99219E+01	9.12533E+00
13	18.2900	715.0000	13	1.35477E+02	1.35419E+01
14	24.3800	677.0000	14	3.49313E+02	2.00961E+01
15	30.4800	578.0000	15	7.41689E+02	
16	42.6700	390.0000			
17	30.4800	606.0000			
18	42.6700	407.0000			
19	60.9600	290.0000			
20	91.4400	268.0000			

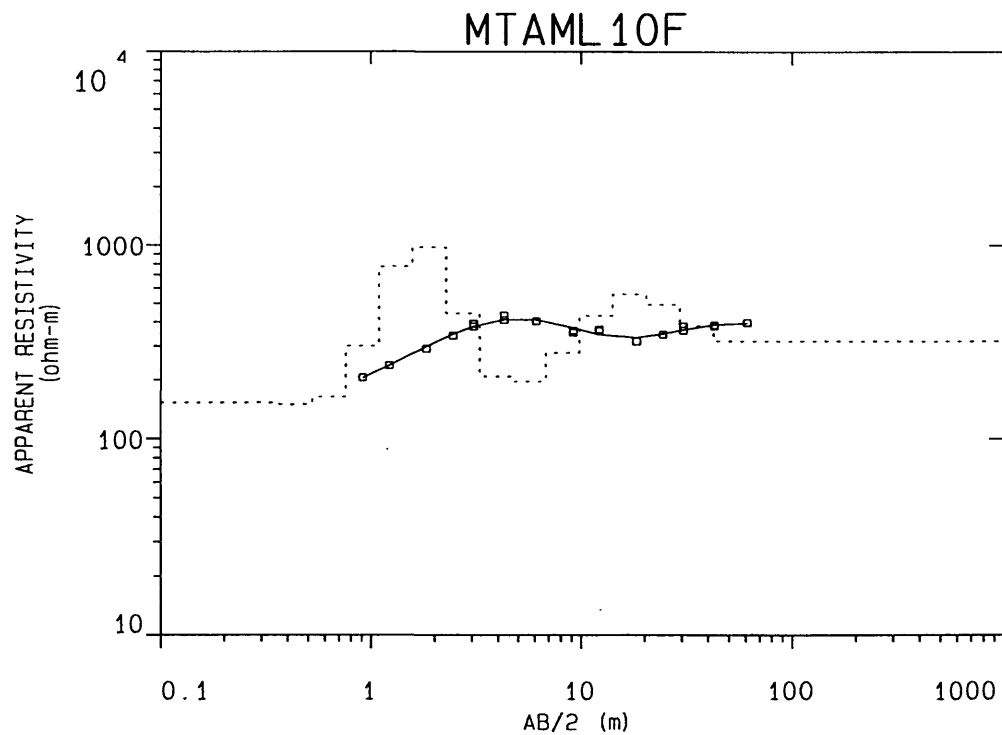


Field Data			Model		
MTAML08F			LAYER	RESISTIVITY	THICKNESS
No.	SPACING	RESISTIVITY			
1	0.9100	285.0000	1	1.53773E+02	3.64000E-01
2	1.2200	325.0000	2	1.88627E+02	1.76172E-01
3	1.8300	385.0000	3	3.88849E+02	2.61438E-01
4	2.4400	399.0000	4	5.80315E+02	3.87972E-01
5	3.0500	435.0000	5	4.12875E+02	5.75746E-01
6	4.2700	477.0000	6	3.52151E+02	8.54402E-01
7	3.0500	445.0000	7	5.80421E+02	1.26792E+00
8	4.2700	493.0000	8	1.30445E+03	1.88159E+00
9	6.1000	597.0000	9	1.90177E+03	2.79226E+00
10	9.1400	661.0000	10	8.42244E+02	4.14368E+00
11	12.1900	712.0000	11	1.82132E+02	6.14919E+00
12	12.1900	731.0000	12	7.80182E+01	9.12533E+00
13	18.2900	715.0000	13	1.37630E+02	1.35419E+01
14	24.3800	677.0000	14	4.43974E+02	2.00961E+01
15	30.4800	578.0000	15	1.07295E+03	
16	42.6700	390.0000			
17	30.4800	606.0000			
18	42.6700	407.0000			
19	60.9600	290.0000			
20	91.4400	268.0000			

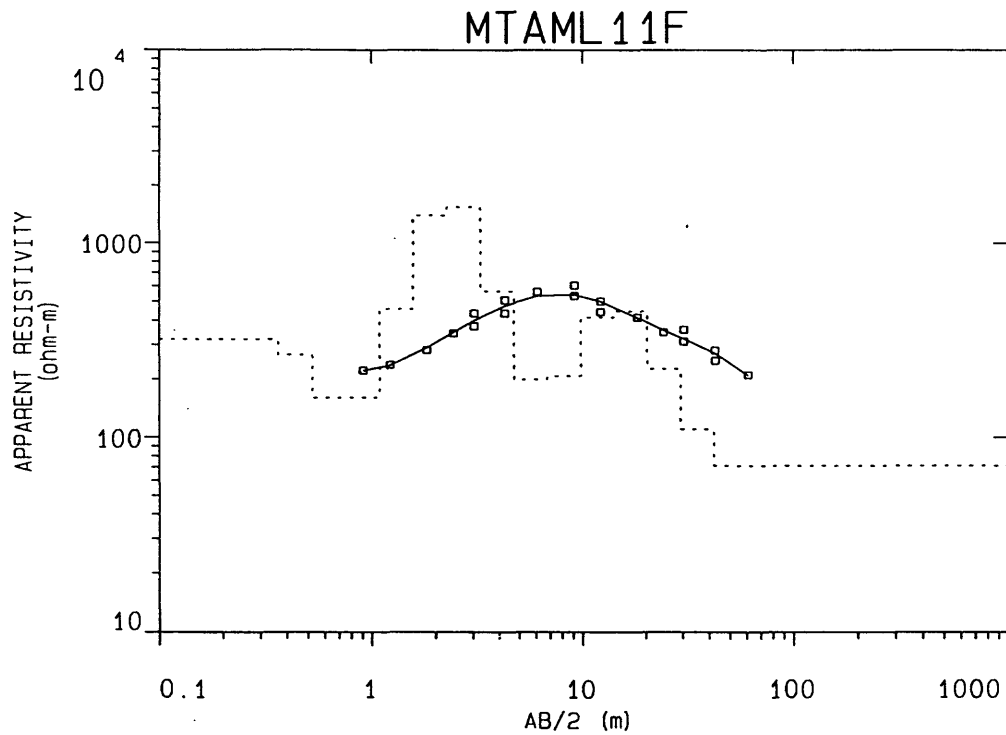


Field Data		
MTAML09F 7/17/97		
No.	SPACING	RESISTIVITY
1	0.9100	132.0000
2	1.2200	149.0000
3	1.8300	172.0000
4	2.4400	197.0000
5	3.0500	210.0000
6	4.2700	241.0000
7	3.0500	199.0000
8	4.2700	230.0000
9	6.1000	276.0000
10	9.1400	382.0000
11	12.1900	464.0000
12	9.1400	436.0000
13	12.1900	531.0000
14	18.2900	594.0000
15	24.3800	540.0000
16	30.4800	432.0000
17	42.6700	290.0000
18	30.4800	608.0000
19	42.6700	392.0000
20	60.9600	291.0000
21	91.4400	324.0000
22	121.2200	363.0000

Model		
LAYER	RESISTIVITY	THICKNESS
1	1.16299E+02	3.64000E-01
2	1.28174E+02	1.87160E-01
3	1.88328E+02	2.83394E-01
4	2.25221E+02	4.29109E-01
5	1.91438E+02	6.49746E-01
6	2.69986E+02	9.83831E-01
7	7.80270E+02	1.48969E+00
8	1.73600E+03	2.25566E+00
9	1.15781E+03	3.41547E+00
10	2.99384E+02	5.17163E+00
11	9.63374E+01	7.83076E+00
12	1.05713E+02	1.18572E+01
13	3.31439E+02	1.79538E+01
14	1.09175E+03	2.71853E+01
15	2.28174E+03	

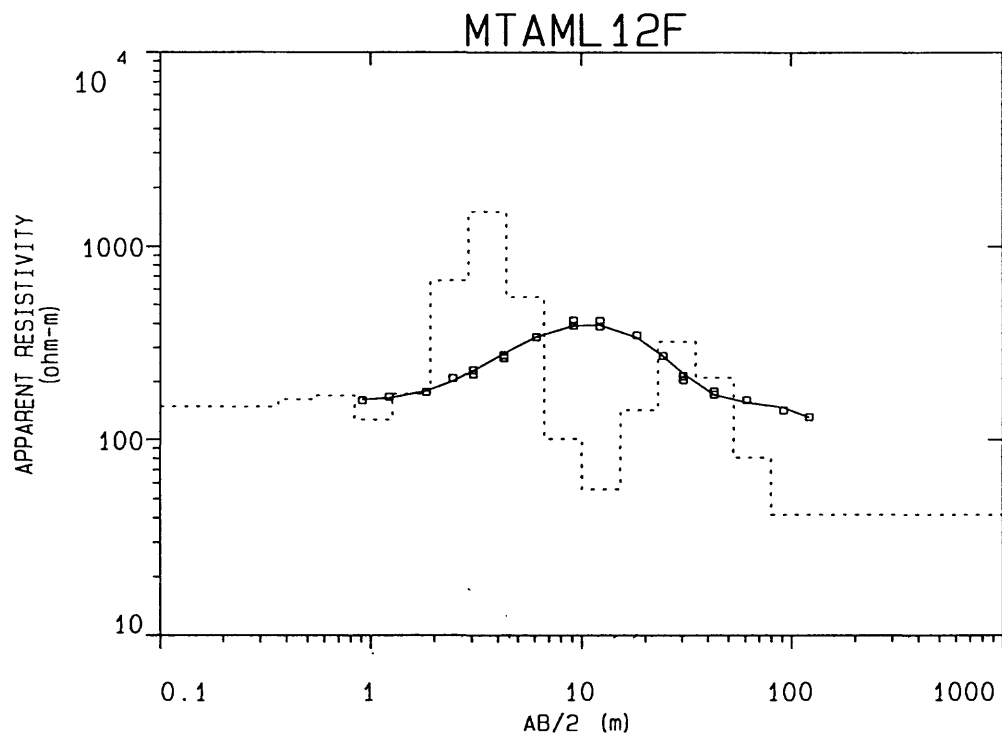


Field Data			Model		
MTAML10F 7/18/97					
No.	SPACING	RESISTIVITY	LAYER	RESISTIVITY	THICKNESS
IP			1	1.53600E+02	3.64000E-01
1	0.9100	206.0000	2	1.49670E+02	1.60752E-01
2	1.2200	239.0000	3	1.64097E+02	2.31745E-01
3	1.8300	292.0000	4	3.01211E+02	3.34090E-01
4	2.4400	341.0000	5	7.76222E+02	4.81634E-01
5	3.0500	380.0000	6	9.78207E+02	6.94337E-01
6	4.2700	411.0000	7	4.44290E+02	1.00097E+00
7	3.0500	394.0000	8	2.09300E+02	1.44303E+00
8	4.2700	434.0000	9	1.97288E+02	2.08032E+00
9	6.1000	406.0000	10	2.78426E+02	2.99904E+00
10	9.1400	363.0000	11	4.33726E+02	4.32350E+00
11	12.1900	368.0000	12	5.59702E+02	6.23288E+00
12	9.1400	354.0000	13	4.95811E+02	8.98549E+00
13	12.1900	361.0000	14	3.83329E+02	1.29537E+01
14	18.2900	319.0000	15	3.20018E+02	
15	24.3800	346.0000			
16	30.4800	363.0000			
17	42.6700	383.0000			
18	30.4800	382.0000			
19	42.6700	387.0000			
20	60.9600	398.0000			



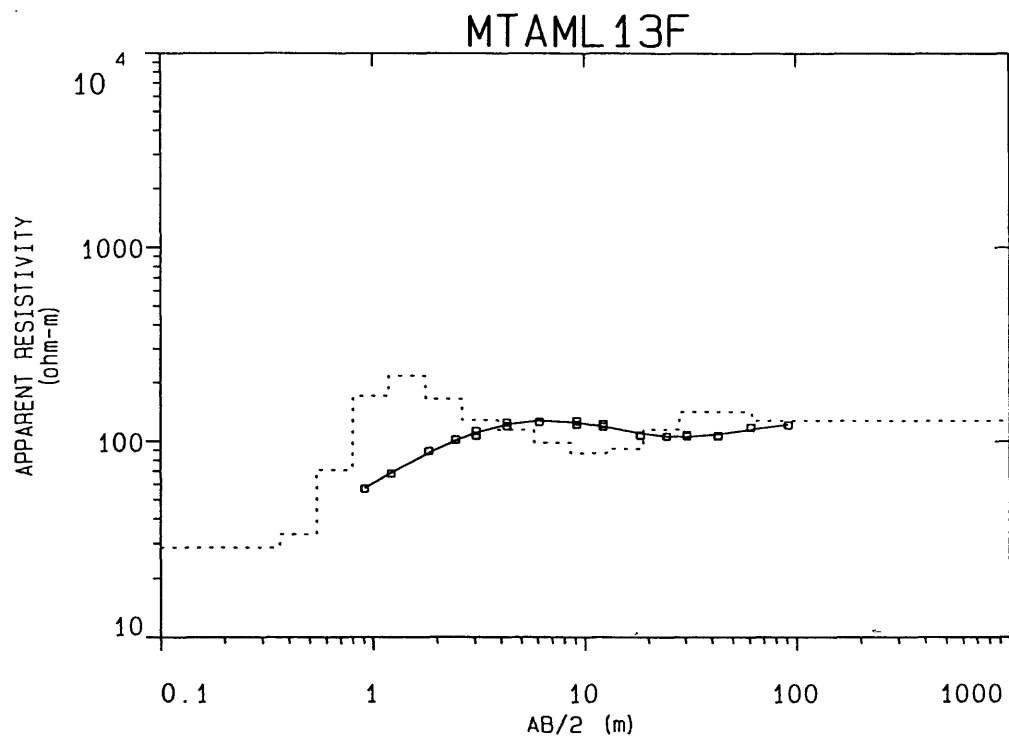
Field Data		
MTAML11F 7/18/97		
No.	SPACING	RESISTIVITY
1	0.9100	222.0000
2	1.2200	237.0000
3	1.8300	282.0000
4	2.4400	344.0000
5	3.0500	374.0000
6	4.2700	435.0000
7	3.0500	436.0000
8	4.2700	510.0000
9	6.1000	560.0000
10	9.1400	535.0000
11	12.1900	444.0000
12	9.1400	605.0000
13	12.1900	504.0000
14	18.2900	415.0000
15	24.3800	350.0000
16	30.4800	313.0000
17	42.6700	250.0000
18	30.4800	360.0000
19	42.6700	282.0000
20	60.9600	211.0000

Model		
LAYER	RESISTIVITY	THICKNESS
1	3.09878E+02	3.64000E-01
2	2.66535E+02	1.60752E-01
3	1.71944E+02	2.31745E-01
4	1.76759E+02	3.34090E-01
5	4.55392E+02	4.81634E-01
6	1.25485E+03	6.94337E-01
7	1.44167E+03	1.00097E+00
8	5.87740E+02	1.44303E+00
9	2.22228E+02	2.08032E+00
10	2.26143E+02	2.99904E+00
11	4.19200E+02	4.32350E+00
12	4.27776E+02	6.23288E+00
13	2.22581E+02	8.98549E+00
14	1.15446E+02	1.29537E+01
15	7.85129E+01	

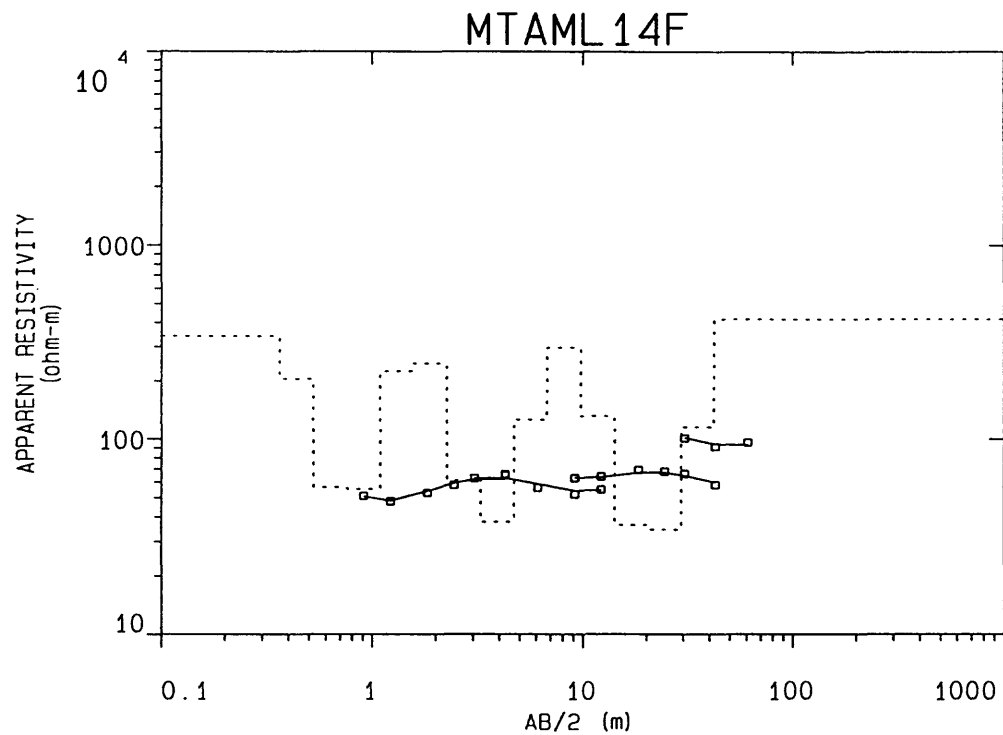


Field Data		
MTAML12F 7/18/97		
No.	SPACING	RESISTIVITY
1	0.9100	160.0000
2	1.2200	167.0000
3	1.8300	177.0000
4	2.4400	209.0000
5	3.0500	230.0000
6	4.2700	276.0000
7	3.0500	219.0000
8	4.2700	266.0000
9	6.1000	341.0000
10	9.1400	392.0000
11	12.1900	389.0000
12	9.1400	417.0000
13	12.1900	415.0000
14	18.2900	350.0000
15	24.3800	273.0000
16	30.4800	215.0000
17	42.6700	179.0000
18	30.4800	205.0000
19	42.6700	172.0000
20	60.9600	161.0000
21	91.4400	142.0000
22	121.2200	131.0000

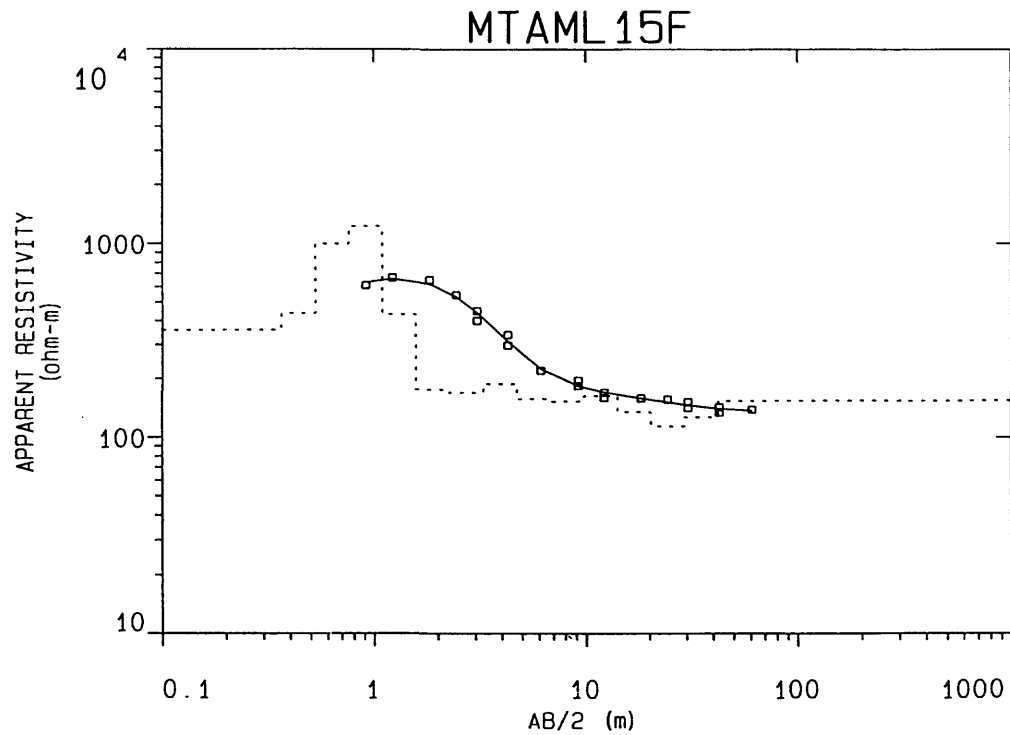
Model		
MTAML12F		
LAYER	RESISTIVITY	THICKNESS
1	1.48130E+02	3.64000E-01
2	1.61710E+02	1.87160E-01
3	1.70087E+02	2.83394E-01
4	1.26569E+02	4.29109E-01
5	1.72622E+02	6.49746E-01
6	6.69227E+02	9.83831E-01
7	1.51229E+03	1.48969E+00
8	5.49258E+02	2.25566E+00
9	1.01016E+02	3.41547E+00
10	5.59496E+01	5.17163E+00
11	1.42764E+02	7.83076E+00
12	3.24040E+02	1.18572E+01
13	2.10453E+02	1.79538E+01
14	8.10702E+01	2.71853E+01
15	4.14056E+01	



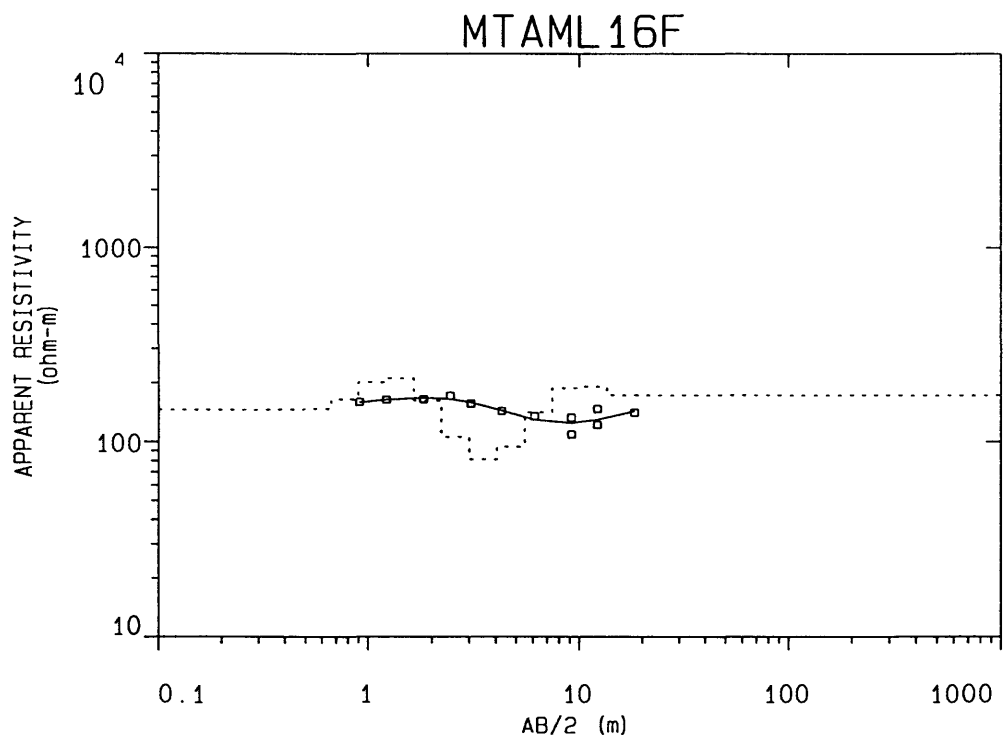
Field Data			Model		
MTAML13F 7/18/97			MTAML13F		
No.	SPACING	RESISTIVITY	LAYER	RESISTIVITY	THICKNESS
IP			1	2.86089E+01	3.64000E-01
1	0.9100	57.0000	2	3.34422E+01	1.76172E-01
2	1.2200	68.0000	3	7.12468E+01	2.61438E-01
3	1.8300	89.0000	4	1.71398E+02	3.87972E-01
4	2.4400	102.0000	5	2.16903E+02	5.75746E-01
5	3.0500	113.0000	6	1.65122E+02	8.54402E-01
6	4.2700	125.0000	7	1.28737E+02	1.26792E+00
7	3.0500	107.0000	8	1.14508E+02	1.88159E+00
8	4.2700	120.0000	9	9.86297E+01	2.79226E+00
9	6.1000	126.0000	10	8.68170E+01	4.14368E+00
10	9.1400	127.0000	11	9.15966E+01	6.14919E+00
11	12.1900	123.0000	12	1.14995E+02	9.12533E+00
12	9.1400	122.0000	13	1.41397E+02	1.35419E+01
13	12.1900	119.0000	14	1.41608E+02	2.00961E+01
14	18.2900	107.0000	15	1.27383E+02	
15	24.3800	106.0000			
16	30.4800	106.0000			
17	42.6700	106.0000			
18	30.4800	108.0000			
19	42.6700	107.0000			
20	60.9600	118.0000			
21	91.4400	121.0000			



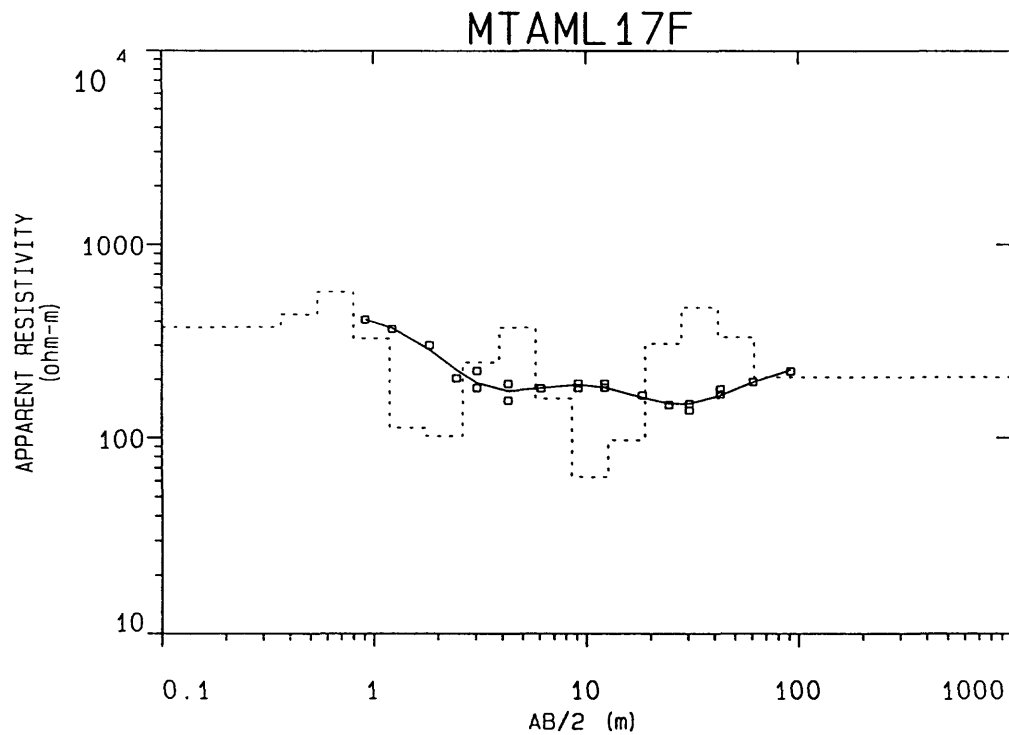
Field Data			Model		
MTAML14F 7/18/97			MTAML14F		
No.	SPACING	RESISTIVITY	LAYER	RESISTIVITY	THICKNESS
1	0.9100	51.0000	1	3.40394E+02	3.64000E-01
2	1.2200	48.0000	2	2.04997E+02	1.60752E-01
3	1.8300	53.0000	3	5.66520E+01	2.31745E-01
4	2.4400	58.0000	4	5.54597E+01	3.34090E-01
5	3.0500	63.0000	5	2.25378E+02	4.81634E-01
6	4.2700	65.0000	6	2.46276E+02	6.94337E-01
7	3.0500	63.0000	7	6.14633E+01	1.00097E+00
8	4.2700	66.0000	8	3.78329E+01	1.44303E+00
9	6.1000	56.0000	9	1.25977E+02	2.08032E+00
10	9.1400	52.0000	10	2.97188E+02	2.99904E+00
11	12.1900	55.0000	11	1.31336E+02	4.32350E+00
12	9.1400	63.0000	12	3.62666E+01	6.23288E+00
13	12.1900	64.0000	13	3.43172E+01	8.98549E+00
14	18.2900	69.0000	14	1.15233E+02	1.29537E+01
15	24.3800	68.0000	15	4.17884E+02	
16	30.4800	66.0000			
17	42.6700	58.0000			
18	30.4800	101.0000			
19	42.6700	91.0000			
20	60.9600	96.0000			



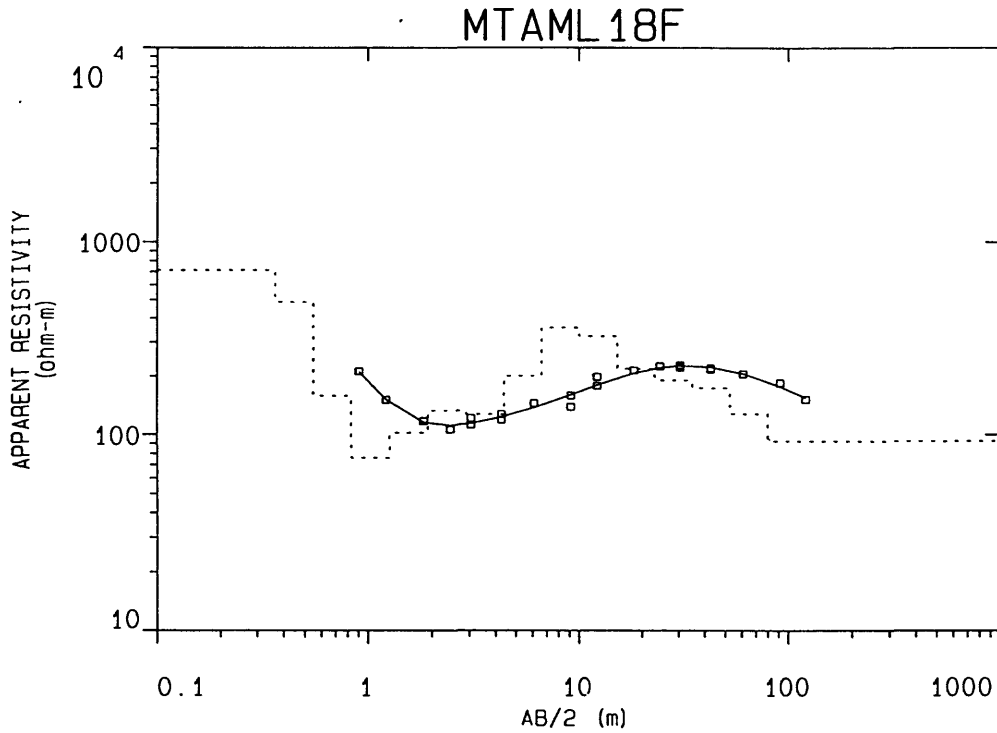
Field Data			Model		
MTAML15F 7/18/97			MTAML15F		
No.	SPACING	RESISTIVITY	LAYER	RESISTIVITY	THICKNESS
1	0.9100	610.0000	1	3.58325E+02	3.64000E-01
2	1.2200	668.0000	2	4.37357E+02	1.60752E-01
3	1.8300	650.0000	3	9.95202E+02	2.31745E-01
4	2.4400	543.0000	4	1.22608E+03	3.34090E-01
5	3.0500	451.0000	5	4.32250E+02	4.81634E-01
6	4.2700	339.0000	6	1.75361E+02	6.94337E-01
7	3.0500	401.0000	7	1.69119E+02	1.00097E+00
8	4.2700	299.0000	8	1.88482E+02	1.44303E+00
9	6.1000	221.0000	9	1.57947E+02	2.08032E+00
10	9.1400	184.0000	10	1.53138E+02	2.99904E+00
11	12.1900	160.0000	11	1.63642E+02	4.32350E+00
12	9.1400	196.0000	12	1.34964E+02	6.23288E+00
13	12.1900	170.0000	13	1.14094E+02	8.98549E+00
14	18.2900	159.0000	14	1.27078E+02	1.29537E+01
15	24.3800	157.0000	15	1.54599E+02	
16	30.4800	152.0000			
17	42.6700	143.0000			
18	30.4800	142.0000			
19	42.6700	134.0000			
20	60.9600	139.0000			



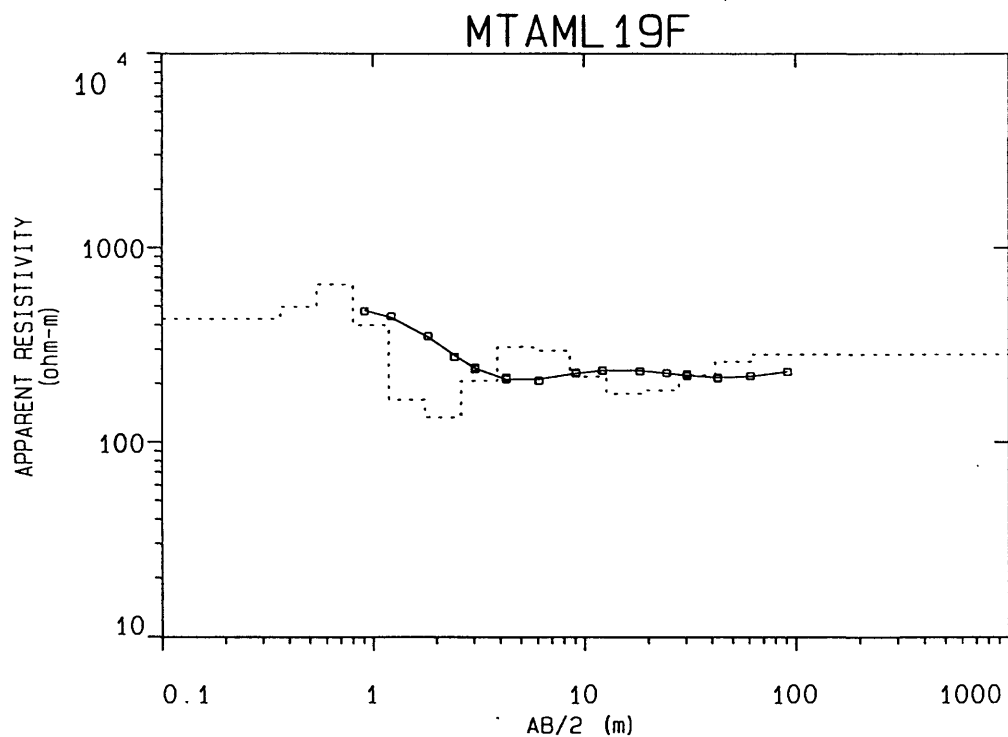
Field Data			Model		
MTAML16	7/18/97	MTAML16			
No.	SPACING	RESISTIVITY	LAYER	RESISTIVITY	THICKNESS
1	0.9100	159.0000	1	1.46009E+02	3.64000E-01
2	1.2200	164.0000	2	1.45739E+02	1.27990E-01
3	1.8300	165.0000	3	1.47327E+02	1.72994E-01
4	2.4400	172.0000	4	1.64926E+02	2.33822E-01
5	3.0500	157.0000	5	2.01537E+02	3.16039E-01
6	4.2700	144.0000	6	2.11117E+02	4.27164E-01
7	3.0500	156.0000	7	1.62114E+02	5.77364E-01
8	4.2700	144.0000	8	1.05657E+02	7.80377E-01
9	6.1000	135.0000	9	8.12522E+01	1.05477E+00
10	9.1400	133.0000	10	9.41355E+01	1.42565E+00
11	12.1900	147.0000	11	1.41801E+02	1.92694E+00
12	9.1400	109.0000	12	1.88181E+02	2.60450E+00
13	12.1900	122.0000	13	1.91647E+02	3.52029E+00
14	18.2900	141.0000	14	1.72858E+02	



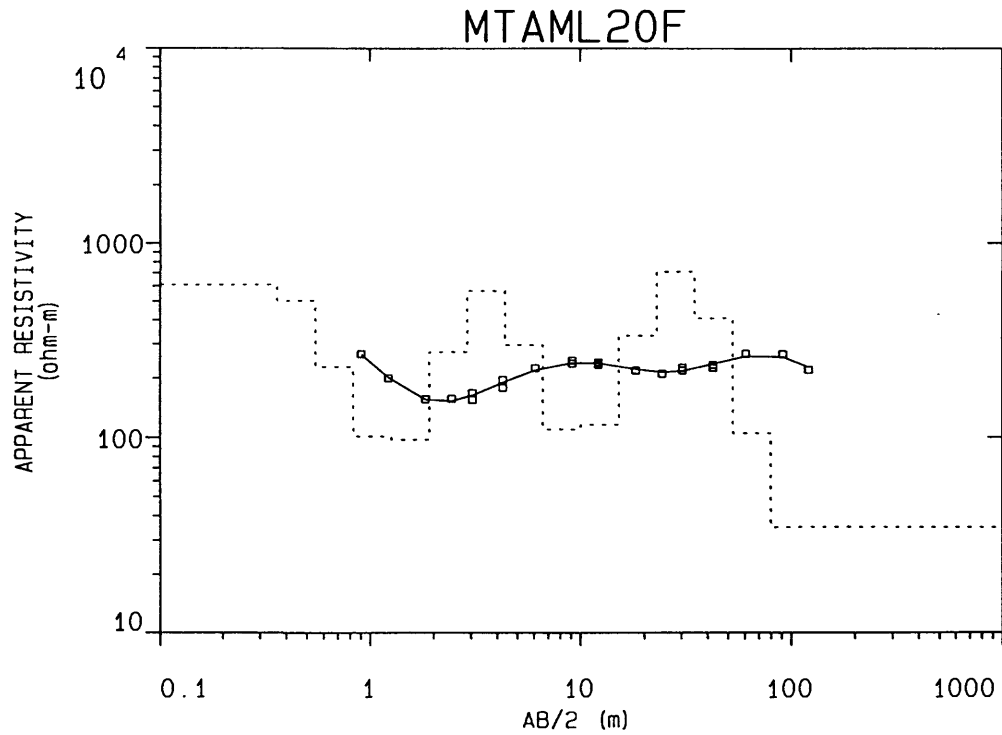
Field Data			Model		
MTAML17 7/18/97			MTAML17		
No.	SPACING	RESISTIVITY	LAYER	RESISTIVITY	THICKNESS
1	0.9100	409.0000	1	3.73381E+02	3.64000E-01
2	1.2200	366.0000	2	4.34783E+02	1.76172E-01
3	1.8300	301.0000	3	5.70197E+02	2.61438E-01
4	2.4400	203.0000	4	3.25329E+02	3.87972E-01
5	3.0500	181.0000	5	1.12531E+02	5.75746E-01
6	4.2700	156.0000	6	1.02247E+02	8.54402E-01
7	3.0500	222.0000	7	2.45128E+02	1.26792E+00
8	4.2700	190.0000	8	3.71460E+02	1.88159E+00
9	6.1000	180.0000	9	1.59473E+02	2.79226E+00
10	9.1400	191.0000	10	6.28795E+01	4.14368E+00
11	12.1900	191.0000	11	9.72504E+01	6.14919E+00
12	9.1400	181.0000	12	3.07245E+02	9.12533E+00
13	12.1900	182.0000	13	4.75109E+02	1.35419E+01
14	18.2900	166.0000	14	3.32374E+02	2.00961E+01
15	24.3800	148.0000	15	2.06043E+02	
16	30.4800	150.0000			
17	42.6700	179.0000			
18	30.4800	139.0000			
19	42.6700	168.0000			
20	60.9600	195.0000			
21	91.4400	221.0000			



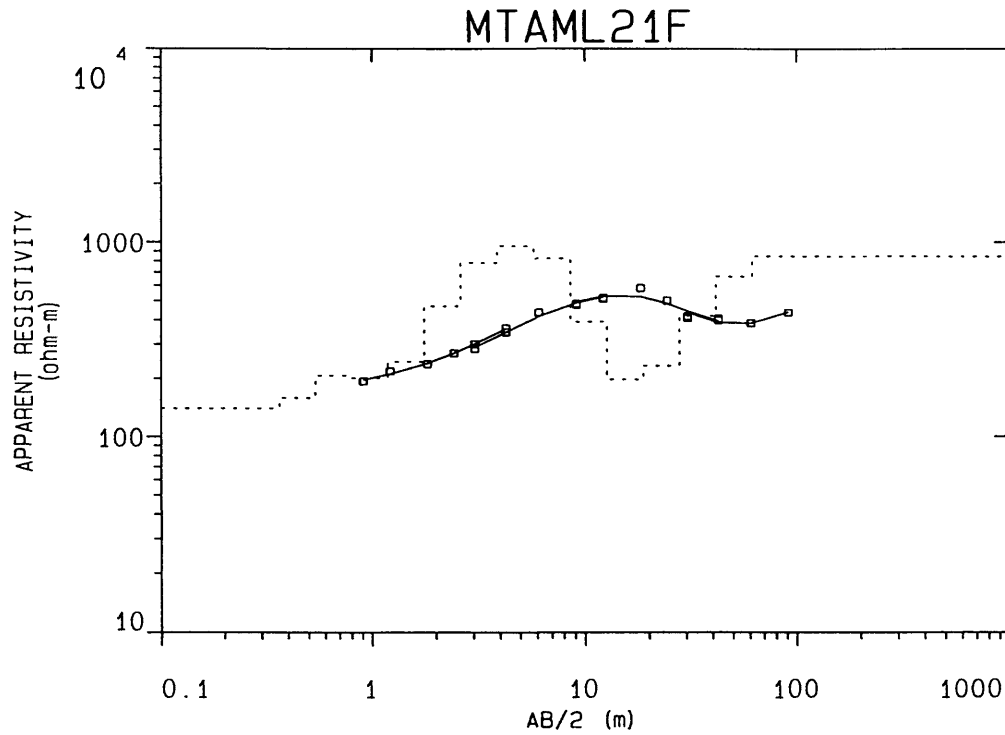
Field Data			Model		
MTAML18 07/19/97			MTAML18		
No.	SPACING	RESISTIVITY	LAYER	RESISTIVITY	THICKNESS
1	0.9100	212.0000	1	7.14870E+02	3.64000E-01
2	1.2200	151.0000	2	4.87992E+02	1.87160E-01
3	1.8300	117.0000	3	1.58349E+02	2.83394E-01
4	2.4400	106.0000	4	7.60553E+01	4.29109E-01
5	3.0500	112.0000	5	1.01784E+02	6.49746E-01
6	4.2700	119.0000	6	1.32364E+02	9.83831E-01
7	3.0500	121.0000	7	1.27096E+02	1.48969E+00
8	4.2700	127.0000	8	2.00590E+02	2.25566E+00
9	6.1000	145.0000	9	3.57981E+02	3.41547E+00
10	9.1400	159.0000	10	3.23929E+02	5.17163E+00
11	12.1900	199.0000	11	2.19173E+02	7.83076E+00
12	9.1400	139.0000	12	1.91665E+02	1.18572E+01
13	12.1900	179.0000	13	1.74044E+02	1.79538E+01
14	18.2900	215.0000	14	1.27816E+02	2.71853E+01
15	24.3800	226.0000	15	9.25100E+01	
16	30.4800	229.0000			
17	42.6700	221.0000			
18	30.4800	223.0000			
19	42.6700	218.0000			
20	60.9600	206.0000			
21	91.4400	185.0000			
22	121.2200	152.0000			



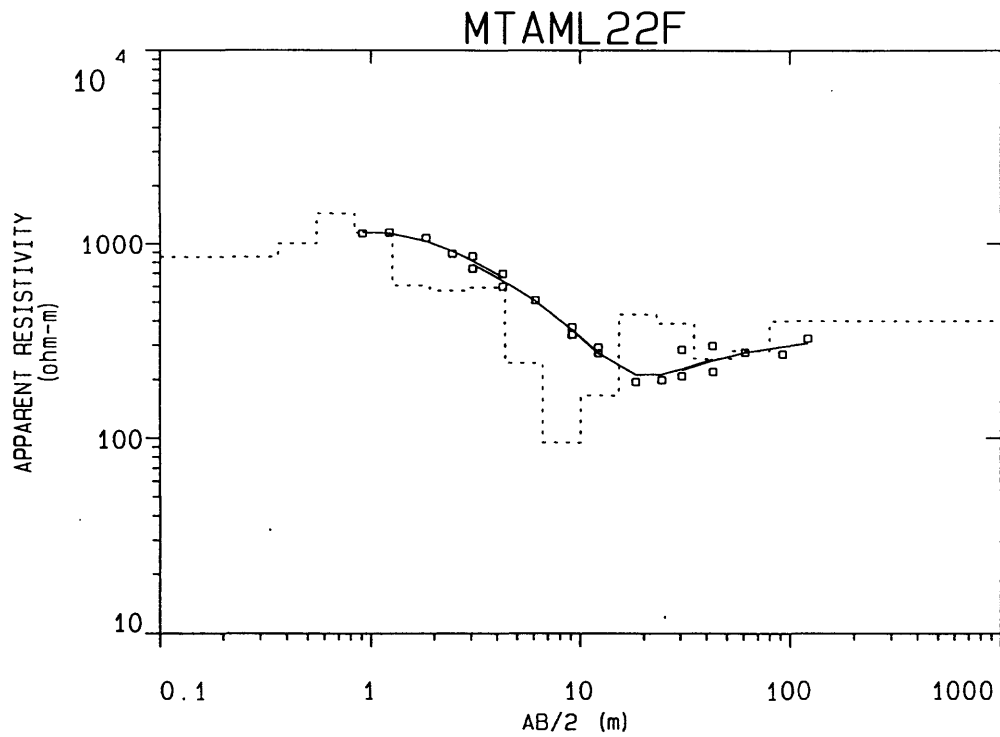
Field Data			Model		
MTAML19F 07/19/97			MTAML19		
No.	SPACING	RESISTIVITY	LAYER	RESISTIVITY	THICKNESS
1	0.9100	472.0000	1	4.30743E+02	3.64000E-01
2	1.2200	445.0000	2	4.96719E+02	1.76172E-01
3	1.8300	351.0000	3	6.46899E+02	2.61438E-01
4	2.4400	275.0000	4	4.00117E+02	3.87972E-01
5	3.0500	242.0000	5	1.65002E+02	5.75746E-01
6	4.2700	215.0000	6	1.34182E+02	8.54402E-01
7	3.0500	237.0000	7	2.06164E+02	1.26792E+00
8	4.2700	211.0000	8	3.08732E+02	1.88159E+00
9	6.1000	207.0000	9	2.96205E+02	2.79226E+00
10	9.1400	226.0000	10	2.17554E+02	4.14368E+00
11	12.1900	233.0000	11	1.77680E+02	6.14919E+00
12	9.1400	228.0000	12	1.84780E+02	9.12533E+00
13	12.1900	235.0000	13	2.21832E+02	1.35419E+01
14	18.2900	232.0000	14	2.60476E+02	2.00961E+01
15	24.3800	227.0000	15	2.82942E+02	
16	30.4800	219.0000			
17	42.6700	213.0000			
18	30.4800	224.0000			
19	42.6700	215.0000			
20	60.9600	219.0000			
21	91.4400	230.0000			



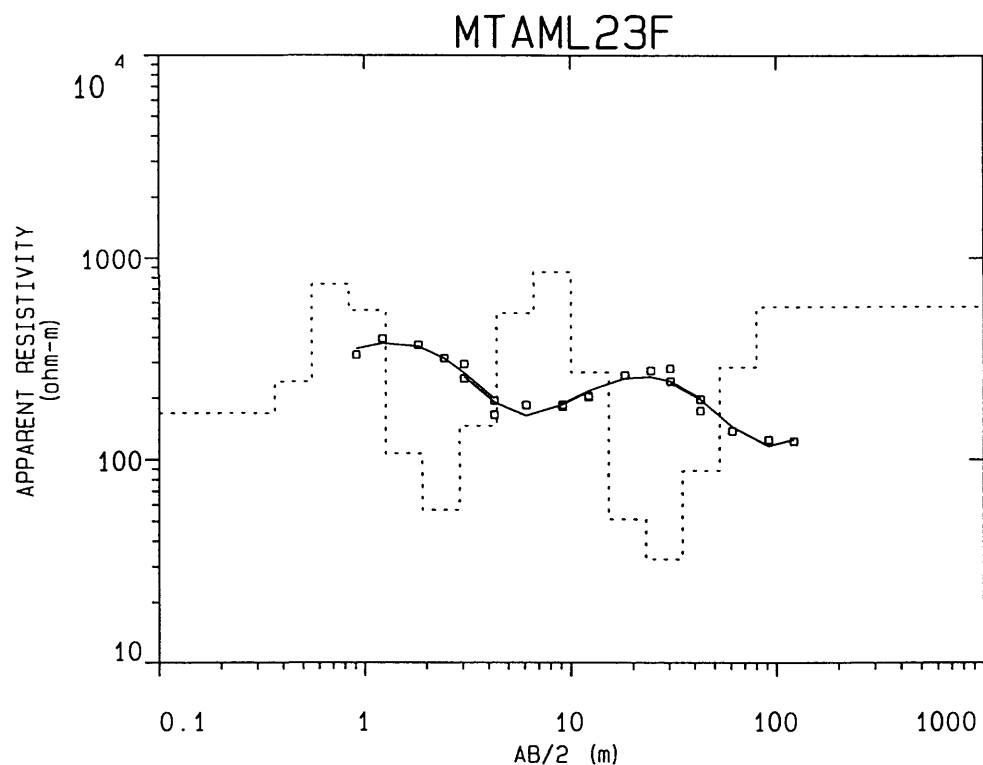
Field Data			Model		
MTAML20 07/19/97			MTAML20		
No.	SPACING	RESISTIVITY	LAYER	RESISTIVITY	THICKNESS
1	0.9100	266.0000	1	6.08710E+02	3.64000E-01
2	1.2200	200.0000	2	5.04214E+02	1.87160E-01
3	1.8300	156.0000	3	2.28498E+02	2.83394E-01
4	2.4400	157.0000	4	1.01319E+02	4.29109E-01
5	3.0500	155.0000	5	9.74619E+01	6.49746E-01
6	4.2700	179.0000	6	2.72444E+02	9.83831E-01
7	3.0500	168.0000	7	5.65895E+02	1.48969E+00
8	4.2700	196.0000	8	2.96630E+02	2.25566E+00
9	6.1000	225.0000	9	1.09684E+02	3.41547E+00
10	9.1400	246.0000	10	1.15726E+02	5.17163E+00
11	12.1900	241.0000	11	3.31858E+02	7.83076E+00
12	9.1400	238.0000	12	7.11029E+02	1.18572E+01
13	12.1900	235.0000	13	4.08123E+02	1.79538E+01
14	18.2900	219.0000	14	1.05115E+02	2.71853E+01
15	24.3800	211.0000	15	3.49186E+01	
16	30.4800	219.0000			
17	42.6700	226.0000			
18	30.4800	227.0000			
19	42.6700	234.0000			
20	60.9600	267.0000			
21	91.4400	266.0000			
22	121.2200	221.0000			



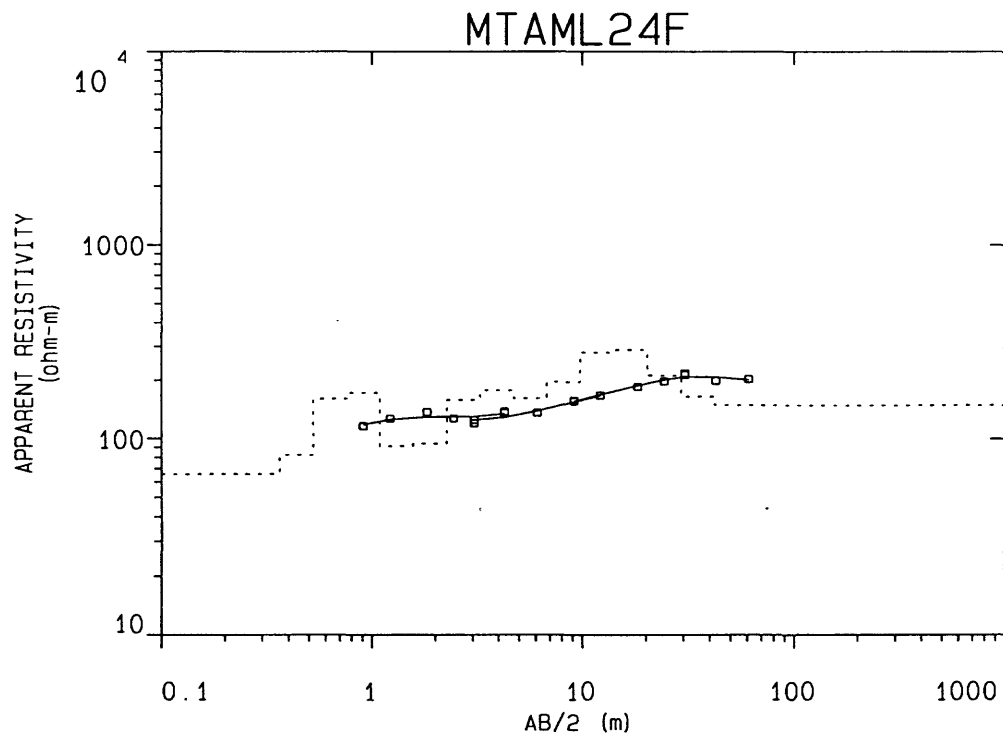
Field Data			Model		
MTAML21	07/20/97	MTAML21			
No.	SPACING	RESISTIVITY	LAYER	RESISTIVITY	THICKNESS
1	0.9100	193.0000	1	1.39795E+02	3.64000E-01
2	1.2200	218.0000	2	1.58416E+02	1.76172E-01
3	1.8300	237.0000	3	2.06691E+02	2.61438E-01
4	2.4400	270.0000	4	2.01616E+02	3.87972E-01
5	3.0500	300.0000	5	2.43284E+02	5.75746E-01
6	4.2700	361.0000	6	4.71695E+02	8.54402E-01
7	3.0500	284.0000	7	7.82412E+02	1.26792E+00
8	4.2700	346.0000	8	9.52058E+02	1.88159E+00
9	6.1000	436.0000	9	8.22371E+02	2.79226E+00
10	9.1400	477.0000	10	3.90032E+02	4.14368E+00
11	12.1900	512.0000	11	1.97309E+02	6.14919E+00
12	9.1400	482.0000	12	2.32639E+02	9.12533E+00
13	12.1900	517.0000	13	4.19008E+02	1.35419E+01
14	18.2900	579.0000	14	6.65439E+02	2.00961E+01
15	24.3800	500.0000	15	8.45382E+02	
16	30.4800	416.0000			
17	42.6700	405.0000			
18	30.4800	408.0000			
19	42.6700	398.0000			
20	60.9600	385.0000			
21	91.4400	436.0000			



Field Data			Model		
MTAML22	07/20/97		MTAML22		
No.	SPACING	RESISTIVITY	LAYER	RESISTIVITY	THICKNESS
1	0.9100	1128.0000	1	8.53018E+02	3.64000E-01
2	1.2200	1142.0000	2	9.99862E+02	1.87160E-01
3	1.8300	1071.0000	3	1.43535E+03	2.83394E-01
4	2.4400	887.0000	4	1.13513E+03	4.29109E-01
5	3.0500	740.0000	5	6.06024E+02	6.49746E-01
6	4.2700	599.0000	6	5.71225E+02	9.83831E-01
7	3.0500	858.0000	7	5.92023E+02	1.48969E+00
8	4.2700	698.0000	8	2.43449E+02	2.25566E+00
9	6.1000	510.0000	9	9.46088E+01	3.41547E+00
10	9.1400	340.0000	10	1.65553E+02	5.17163E+00
11	12.1900	274.0000	11	4.31058E+02	7.83076E+00
12	9.1400	371.0000	12	3.89209E+02	1.18572E+01
13	12.1900	292.0000	13	2.57136E+02	1.79538E+01
14	18.2900	195.0000	14	2.82090E+02	2.71853E+01
15	24.3800	199.0000	15	3.98472E+02	
16	30.4800	209.0000			
17	42.6700	220.0000			
18	30.4800	286.0000			
19	42.6700	300.0000			
20	60.9600	277.0000			
21	91.4400	271.0000			
22	121.2200	325.0000			



Field Data			Model		
MTAML23	07/20/97		MTAML23		
No.	SPACING	RESISTIVITY	LAYER	RESISTIVITY	THICKNESS
1	0.9100	328.0000	1	1.68854E+02	3.64000E-01
2	1.2200	395.0000	2	2.41135E+02	1.87160E-01
3	1.8300	367.0000	3	7.41857E+02	2.83394E-01
4	2.4400	315.0000	4	5.48808E+02	4.29109E-01
5	3.0500	250.0000	5	1.07175E+02	6.49746E-01
6	4.2700	166.0000	6	5.67944E+01	9.83831E-01
7	3.0500	295.0000	7	1.46348E+02	1.48969E+00
8	4.2700	195.0000	8	5.30008E+02	2.25566E+00
9	6.1000	185.0000	9	8.50472E+02	3.41547E+00
10	9.1400	182.0000	10	2.68590E+02	5.17163E+00
11	12.1900	203.0000	11	5.12708E+01	7.83076E+00
12	9.1400	186.0000	12	3.28168E+01	1.18572E+01
13	12.1900	206.0000	13	8.82809E+01	1.79538E+01
14	18.2900	260.0000	14	2.84541E+02	2.71853E+01
15	24.3800	274.0000	15	5.71323E+02	
16	30.4800	242.0000			
17	42.6700	174.0000			
18	30.4800	281.0000			
19	42.6700	198.0000			
20	60.9600	138.0000			
21	91.4400	125.0000			
22	121.2200	123.0000			



Field Data			Model		
MTAML24 07/20/97			MTAML24		
No.	SPACING	RESISTIVITY	LAYER	RESISTIVITY	THICKNESS
1	0.9100	116.0000	1	6.56772E+01	3.64000E-01
2	1.2200	127.0000	2	8.22652E+01	1.60752E-01
3	1.8300	137.0000	3	1.61093E+02	2.31745E-01
4	2.4400	127.0000	4	1.72325E+02	3.34090E-01
5	3.0500	120.0000	5	9.17063E+01	4.81634E-01
6	4.2700	136.0000	6	9.44392E+01	6.94337E-01
7	3.0500	125.0000	7	1.58672E+02	1.00097E+00
8	4.2700	138.0000	8	1.77541E+02	1.44303E+00
9	6.1000	136.0000	9	1.61651E+02	2.08032E+00
10	9.1400	156.0000	10	1.96120E+02	2.99904E+00
11	12.1900	167.0000	11	2.79336E+02	4.32350E+00
12	9.1400	157.0000	12	2.86921E+02	6.23288E+00
13	12.1900	167.0000	13	2.12262E+02	8.98549E+00
14	18.2900	185.0000	14	1.64609E+02	1.29537E+01
15	24.3800	198.0000	15	1.48746E+02	
16	30.4800	213.0000			
17	30.4800	218.0000			
18	42.6700	199.0000			
19	60.9600	203.0000			