Magnetotelluric Survey to Characterize the Sunnyside Porphyry Copper System in the Patagonia Mountains, Arizona

By Brian D. Rodriguez and Jay A. Sampson

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
mile, nautical (nmi)	1.852	kilometer (km)
yard (yd)	0.9144	meter (m)

SI to Inch/Pound

Multiply	By	To obtain
	Length	
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
kilometer (km)	0.5400	mile, nautical (nmi)
meter (m)	1.094	yard (yd)

Vertical coordinate information is referenced to the 1866 Clarke Spheroid.
Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).
Elevation, as used in this report, refers to distance above the vertical datum.

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Abstract

The Sunnyside porphyry copper system is part of the concealed San Rafael Valley porphyry system located in the Patagonia Mountains of Arizona. To help characterize the size and resistivity of the mineralized area beneath overburden, a regional east-west magnetotelluric sounding profile was acquired. This is a data release report of the magnetotelluric sounding data collected along the east-west profile; no interpretation of the data is included.

Introduction

The Great Basin province of the western United States potentially contains concealed mineral deposits. This study uses the magnetotelluric method to determine if a polarizable mineral deposit (indicative of metallic content) buried beneath thick overburden can be detected. Conventional geophysical exploration methods using induced polarization surveys have limited signal penetration depth and require large, cumbersome transmitters. The magnetotelluric method measures and records the Earth's natural time-varying electromagnetic signals as they pass through the subsurface. A relatively new technique known as the Natural Field Induced Polarization method (Gasperikova and Morrison, 2001) extracts induced polarization parameters from magnetotelluric data. In order to accomplish this, the skin depth of the target must be known in order to distinguish the electromagnetic response of the mineral deposit from the surrounding host medium. One must know the general size and electrical resistivity of the target to calculate the skin depth.

The Sunnyside porphyry copper system is part of the concealed San Rafael Valley porphyry system located in the Patagonia Mountains of Arizona. To help characterize the size and resistivity of the mineralized area beneath overburden, a regional east-west magnetotelluric sounding profile was acquired (fig. 1). Resistivity modeling of the magnetotelluric data can be used to help determine the size and resistivity of the target. The purpose of this report is to release the magnetotelluric sounding data collected along the east-west profile; no interpretation of the data is included.

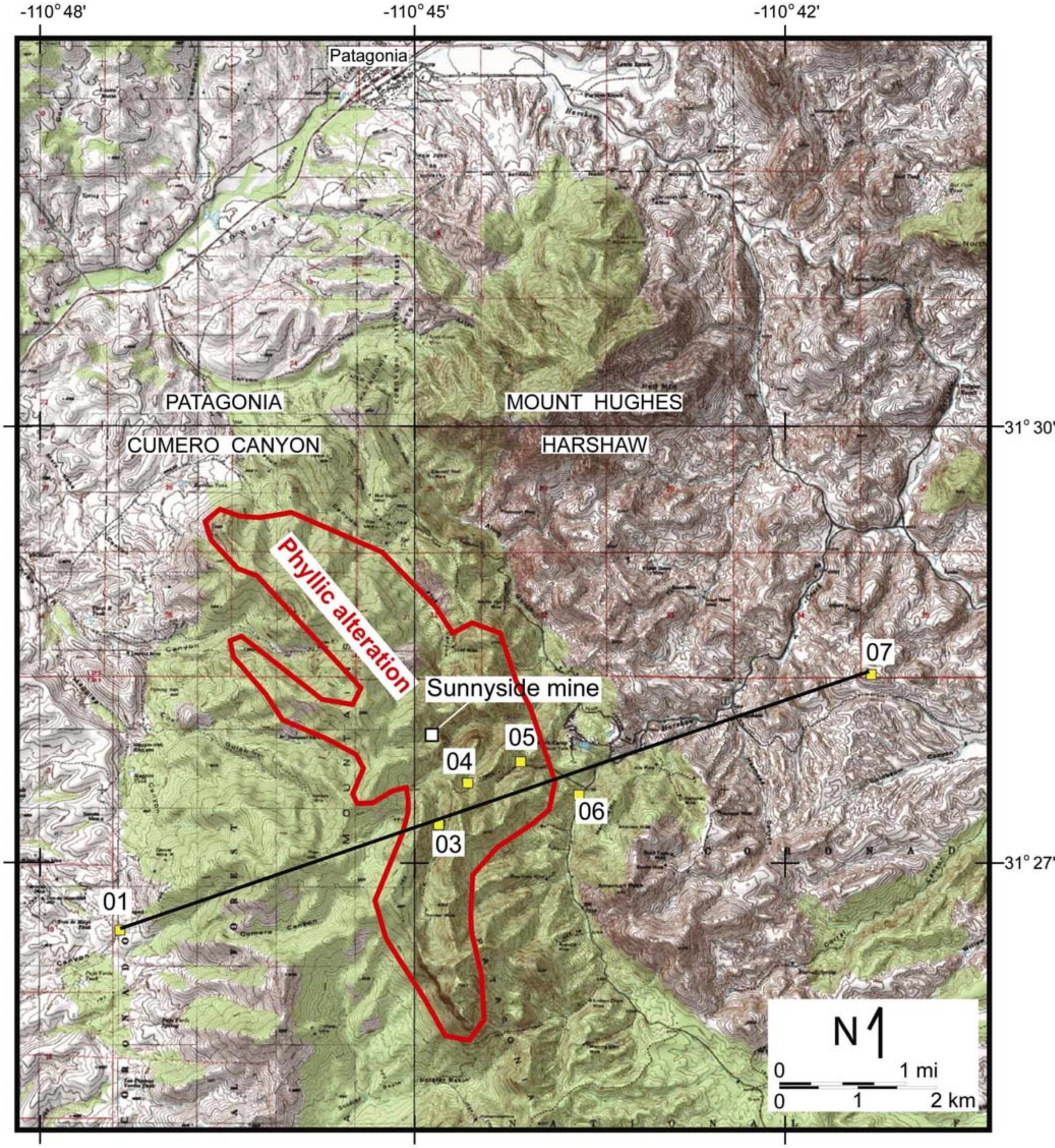

Figure 1. Magnetotelluric profile across the Sunnyside porphyry in the Patagonia Mountains, Arizona. Magnetotelluric stations acquired in May 2008 are numbered yellow squares (station 2 not acquired). Base map from Cumero Canyon, Harshaw, Patagonia, and Mount Hughes, Arizona, 1:24,000 topographic quadrangles.

Electrical Rock Properties

Electromagnetic geophysical investigation methods detect variations in the electrical properties of rock units, in particular electrical resistivity, which is measured in units of ohm-meters (Ωm), or its inverse, electrical conductivity in units of Siemens/meter (S/m). Electrical resistivity can be correlated with geologic units on the surface and at depth using lithologic logs to provide a three dimensional picture of subsurface geology. In the upper crust, the resistivities of geologic units are largely dependent upon their fluid content, pore volume porosity, interconnected fracture porosity, and conductive mineral content (Keller, 1987).

Although there is not a one-to-one relationship between lithology and resistivity, there are general correlations that can be made using typical values, even though values can be found at other geographic locations (Palacky, 1987) that may fall outside of the ranges presented below. Fluids within the pore spaces and fracture openings, especially if saline, can reduce resistivities in what would otherwise be a resistive rock matrix. Resistivity can also be lowered by the presence of electrically conductive clay minerals, graphitic carbon, and metallic mineralization. It is common, for example, for altered volcanic rocks to contain replacement minerals that have resistivities ten times lower than those of the surrounding rocks (Nelson and Anderson, 1992). Fine grained sediments, such as clay rich alluvium, marine shales, and other mudstones are normally conductive, with resistivities ranging from a few Ωm to tens of Ωm (Keller, 1987; Palacky, 1987). Metamorphic rocks (non graphitic) and unaltered, unfractured igneous rocks are normally moderately to highly resistive (a few hundred to thousands of Ωm). Carbonate rocks can have similarly high resistivities depending on their fluid content, porosity, and impurities (Keller, 1987; Palacky, 1987). Fault zones may be moderately conductive (tens of Ωm) when composed of rocks fractured enough to have hosted fluid transport and consequent mineralogical alteration (Eberhart Phillips and others, 1995). At greater depths, higher subsurface temperatures cause higher ionic mobility that reduces rock resistivities (Keller, 1987; Palacky, 1987). Tables of electrical resistivity for a variety of rocks, minerals, and geological environments may be found in Keller (1989) and Palacky (1987).

Magnetotelluric Method

The magnetotelluric method is a passive surface geophysical technique that uses the Earth's natural electromagnetic fields to investigate the electrical resistivity structure of the subsurface from depths of tens of meters to tens of kilometers (Vozoff, 1991). Natural variations of the Earth's magnetic and electric fields are measured and recorded at each magnetotelluric station. Worldwide lightning activity at frequencies of about 1 to 20,000 Hertz and geomagnetic micro-pulsations at frequencies of about 0.0001 to 1 Hertz provide the majority of the signal sensed by the magnetotelluric method.

The orthogonal horizontal electric and magnetic field components (Ex, Ey, Hx, and Hy) and the vertical magnetic field component (Hz) are recorded. For resistivity modeling, magnetotelluric data are normally rotated into directions that are parallel and perpendicular to the subsurface geologic strike. These are usually the principal directions that correspond to the direction of maximum and minimum apparent resistivity. For a two-dimensional (2-D) Earth, in which the Earth's resistivity structure varies with depth and in one lateral direction, the analysis is simplified. The magnetotelluric fields can be decoupled into transverse electric (TE) and transverse magnetic (TM) modes. In this case, 2-D resistivity modeling is generally computed to fit both modes. When the geology satisfies the 2-D assumption and the magnetotelluric profile is perpendicular to the geologic strike, the magnetotelluric data for the TE mode represents the electric field parallel to geologic strike, while the data for the TM mode represents the electric field across strike. The magnetotelluric method is well suited for studying complicated geological environments because the electric and magnetic field transfer functions are sensitive to vertical and horizontal variations in resistivity. The method is capable of establishing whether the electromagnetic fields are responding to subsurface rock bodies of effectively 1, 2, or 3 dimensions. An introduction to the magnetotelluric method and references for a more advanced understanding are in Kaufman and Keller (1981), Dobrin and Savit (1988), and Vozoff (1991).

Magnetotelluric Survey

Six magnetotelluric soundings were collected the first week in May 2008, along a 10 km long profile in southern Arizona (fig. 1). The profile starts along the western foothills of the Patagonia Mountains about 6 km northeast of Nogales International Airport then continues northeasterly, passing roughly halfway between the Sunnyside mine and Thunder mine and ends almost 2 km northeast of the town of Harshaw. The profile location was selected to disect the northwest-trending Sunnyside porphyry copper system whose location is based on the phyllic alteration zone mapped by Graybeal (1996).

Station locations were chosen for proximity to roads and in order to avoid electrical noise from powerlines. All data at the stations were collected with a portable Electromagnetic Instruments, Inc. (EMI) MT-1 system (EMI, Inc.,1996). Horizontal electric fields were recorded using copper-sulfate porous pots placed in an L-shaped, three-electrode array with dipole lengths of 30 m. The orthogonal, horizontal magnetic fields in the direction of the electric-field measurement array were sensed using high-magnetic-permeability, mu-metal-cored induction coils (EMI, Inc.,1996). Frequencies were sampled from about 0.009 to 70 Hertz using single-station recordings of the orthogonal, horizontal components of the electric and magnetic fields and the vertical magnetic field.

Table 1 lists the 6 magnetotelluric station locations. Station 2 was not acquired because of road access problems. Remote reference stations were not used because man-made noise sources were assumed to be minimal in this inactive mining area.

Table 1. Magnetotelluric station coordinates

[Coordinates are referenced to the 1866 Clarke spheroid and North American 1927 Western United States datum. Longitude and latitude format is degrees:minutes:seconds. Universal Transverse Mercator (UTM) units and station elevations are in meters. The accuracy of the north and east component is ±5 m and is ±10 m for the elevation. X direction (X Dir.) is in degrees clockwise from true north]

Station	X Dir.	Longitude	Latitude	North (m)	East (m)	Elevation (m)
01	19	-110:47:21	31:26:32	3,478,446	520,029	1,377
03	241	-110:44:48	31:27:15	3,479,792	524,068	1,737
04	0	-110:44:34	31:27:33	3,480,321	524,436	1,718
05	320	-110:44:08	31:27:41	3,480,590	525,131	1,622
06	45	-110:43:40	31:27:28	3,480,174	525,872	1,561
07	208	-110:41:19	31:28:17	3,481,710	529,577	1,551

Magnetotelluric Data

The recorded time-series data were converted to the frequency domain and processed to determine the impedance tensor, which is used to derive apparent resistivities and phases at each site. Rotation of the impedance tensor allows for decoupling into the TE and TM modes. The data provided here have not been rotated from the original acquisition orientation (X Dir.) listed in table 1 above.

During the analysis and interpretation process, each station should be rotated to a fixed angle determined by the given nominal profile orientation. Cross-power files were sorted to select optimal signal-to-noise time-series data sets (see appendix 1).

Cultural features, such as fences, pipelines, communication lines, moving vehicles and trains, and other manmade sources of electromagnetic noise can contaminate the responses of the magnetotelluric system. Care is taken to avoid these sources of noise when acquiring the data.

The figures in appendix 1 represent the field-processed magnetotelluric data for each station, after the time-series data were converted to the frequency domain and the tensor-transfer function was developed.

For each station, eight separate plots are given:

1. Apparent Resistivity (x and o symbols are xy and yx components)
2. Impedance Phase (x and o symbols are xy and yx components)
3. Impedance Skew
4. Multiple Coherency (x and o symbols are xy and yx components)
5. Impedance Polar Plots
6. Tipper Magnitude
7. Tipper Strike
8. HzHx (x symbol) and HzHy (o symbol) Coherency

Apparent resistivity is the ratio at a given frequency of the electric field strength magnitude to the magnetic field strength magnitude. The impedance phase is proportional to the slope of the apparent resistivity curve on a log-log plot, relative to a baseline at -45^{o} (Vozoff, 1991). A measure of the dimensionality for magnetotelluric data is provided by the impedance skew of the impedance tensor (Vozoff, 1972). If the effective, measured resistivity response to the geology beneath an magnetotelluric station is truly one- or two-dimensional, then the skew will be zero. Both instrumental and environmental sources of noise contribute to non zero skew values but are typically small (about 0.1) for relatively low-noise-level recordings. Higher skews (more than 0.2) indicate either the resistivity response to 3-D geology or higher levels of noise.

In the study area, noise from a number of small powerlines and small moving vehicles was negligible at distances of 0.25 km and farther from the noise source. Powerline amplitude levels were measured at each site and were typically less than 20 percent of the maximum recordable signals. Noise from larger power lines, power generators, pipelines, and trains was negligible at distances greater than 5 km. Local lightning, wind, and rainstorms also can degrade data quality, but these noise sources were avoided by not recording during active thunderstorm periods. Burying the magnetic induction coils and keeping the electric dipole wires flat on the ground helped to minimize wind noise.

Predicted values of the electric field can be computed from the measured values of the magnetic field (Vozoff, 1991). The coherence of the predicted electric field with the measured electric field is a measure of the signal-to-noise ratio provided in the multiple coherency plots. Values are normalized between 0 and 1, where values at 0.5 signify signal levels equal to noise levels. For this data set, coherencies generally were at an acceptable level, except at times in the frequency “dead band” (0.01 to 5 Hertz) (Dobrin and Savit, 1988) and also at times at frequencies below 0.01 Hertz.

The figures in appendix 1 represent the field-processed magnetotelluric data at each station and include some data scatter and poor signal-to-noise ratios. The only effort aimed at removing noisy data points was to visually inspect and digitally select the best signal to noise field data to combine into the final data plots.

The impedance polar plots provide a measure of the magnetotelluric data dimensionality (Reddy and others, 1977). For 1-D resistivity structures, the principal impedance (off diagonal elements) polar diagram (dashed line) is a circle. For 2-D or 3-D resistivity structures, the principal impedance polar diagram (dashed line) elongates either parallel to or perpendicular to strike direction. Over resistors, the principal impedance polar diagram elongates perpendicular-to-strike direction, while over conductors, the principal impedance polar diagram elongates parallel-to-strike direction. For 2-D resistivity structures, the additional impedance polar diagram (solid line) attains the shape of a symmetric clover leaf. For 3-D resistivity structures, the additional impedance polar diagram (solid line) elongates in one direction, and its amplitude is comparable to that of the principal impedance polar diagram (dashed line), although high noise levels can produce the same effect on the polar diagram. A 3-D analysis of polar plots at each frequency should also take into account the corresponding coherence and skew values along with their associated error levels. The polar plots computed for our data show the electromagnetic response for station 1 was 3-D below 20 Hertz. Stations 3, 4, 5, 6, and 7 were 3-D over all frequencies measured.

The tipper can be calculated from the vertical component of the magnetic field. The tipper magnitude is a measure of the tipping of the magnetic field out of the horizontal plane (Vozoff, 1991). The magnitude is 0 for the 1-D case, typically increases between 0.1 to 0.5, and rarely is as large as 1 as it responds to vertical and subvertical structures. The tipper strike typically is used to help resolve the 90^{o} ambiguity in the impedance rotation angle. The tipper magnitude of these stations typically ranges between 0.1 and 0.6 over the lower frequencies, indicating some vertical structure at depth.

The HzHx and HzHy coherency is a measure of the signal-to-noise ratio of the vertical magnetic field with respect to each of the orthogonal, horizontal magnetic field directions. Values are normalized between 0 and 1, where values of 0.5 signify signal levels equal to noise levels. These three components of magnetic-field coherence provide a check on the quality of the measured values in the tipper magnitude and tipper strike plots.

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Appendix 1. Magnetotelluric Data Plots

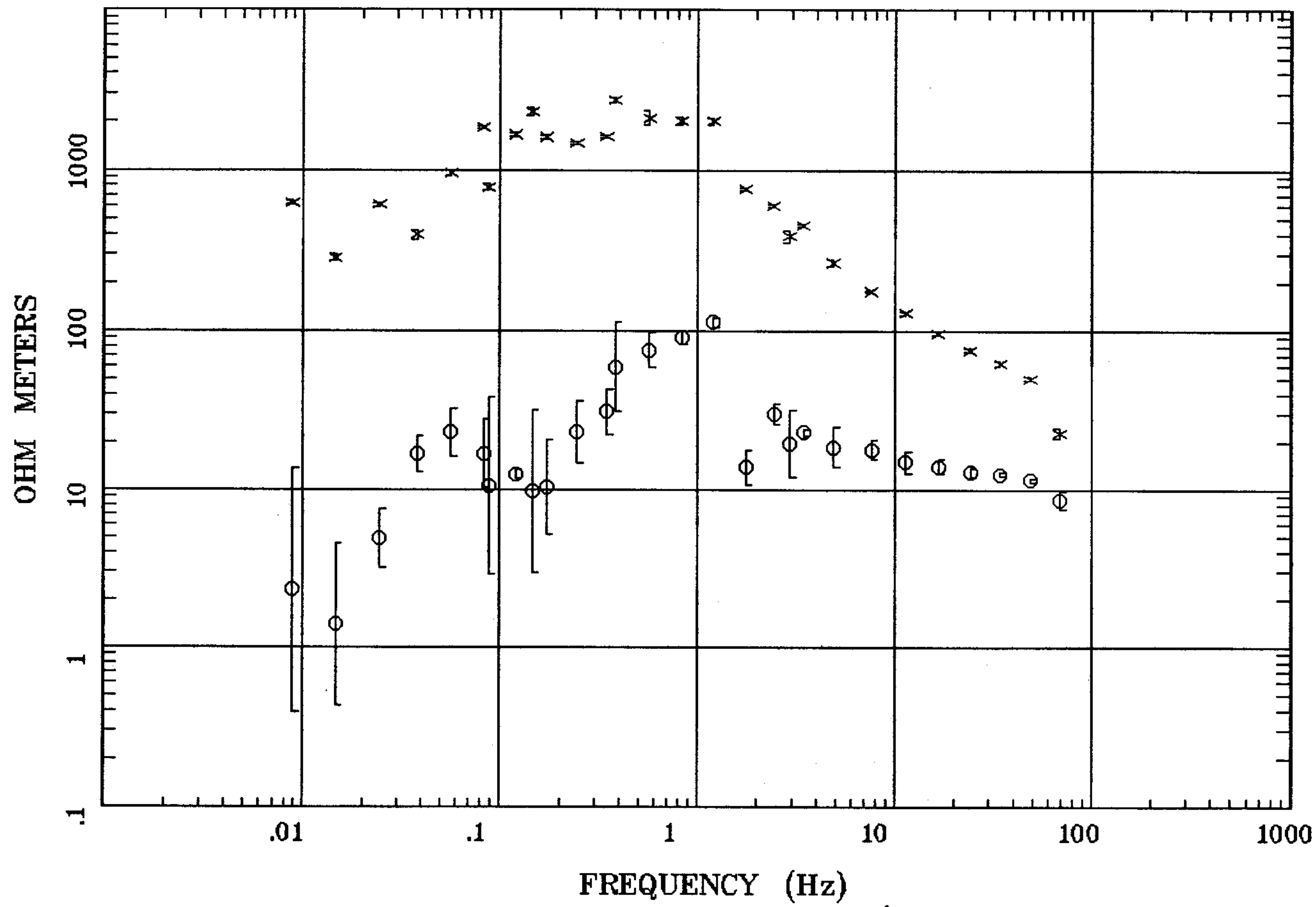
There are eight separate plots for each station:

1. Apparent Resistivity for the unrotated xy (x symbol) and yx (o symbol) modes
2. Impedance Phase for the unrotated xy (x symbol) and yx (o symbol) modes
3. Impedance Skew for the impedance tensor
4. Multiple Coherency for the xy (x symbol) and minimum (o symbol) modes of the electric field
5. Impedance Polar Plots (at 12 selected frequencies)
6. Tipper Magnitude for the vertical magnetic field
7. Tipper Strike for the vertical magnetic field
8. HzHx (x symbol) and HzHy (o symbol) Coherency

Error bars (],[) on the apparent resistivity, impedance phase, skew, tipper magnitude, and tipper strike plots represent probable errors within one standard deviation of the sample variance (Gamble and others, 1979). Refer to the “Magnetotelluric Data” section in this report for an explanation of these plots.

Station 01

APPARENT RESISTIVITY Patagonia Mtns, Arizona



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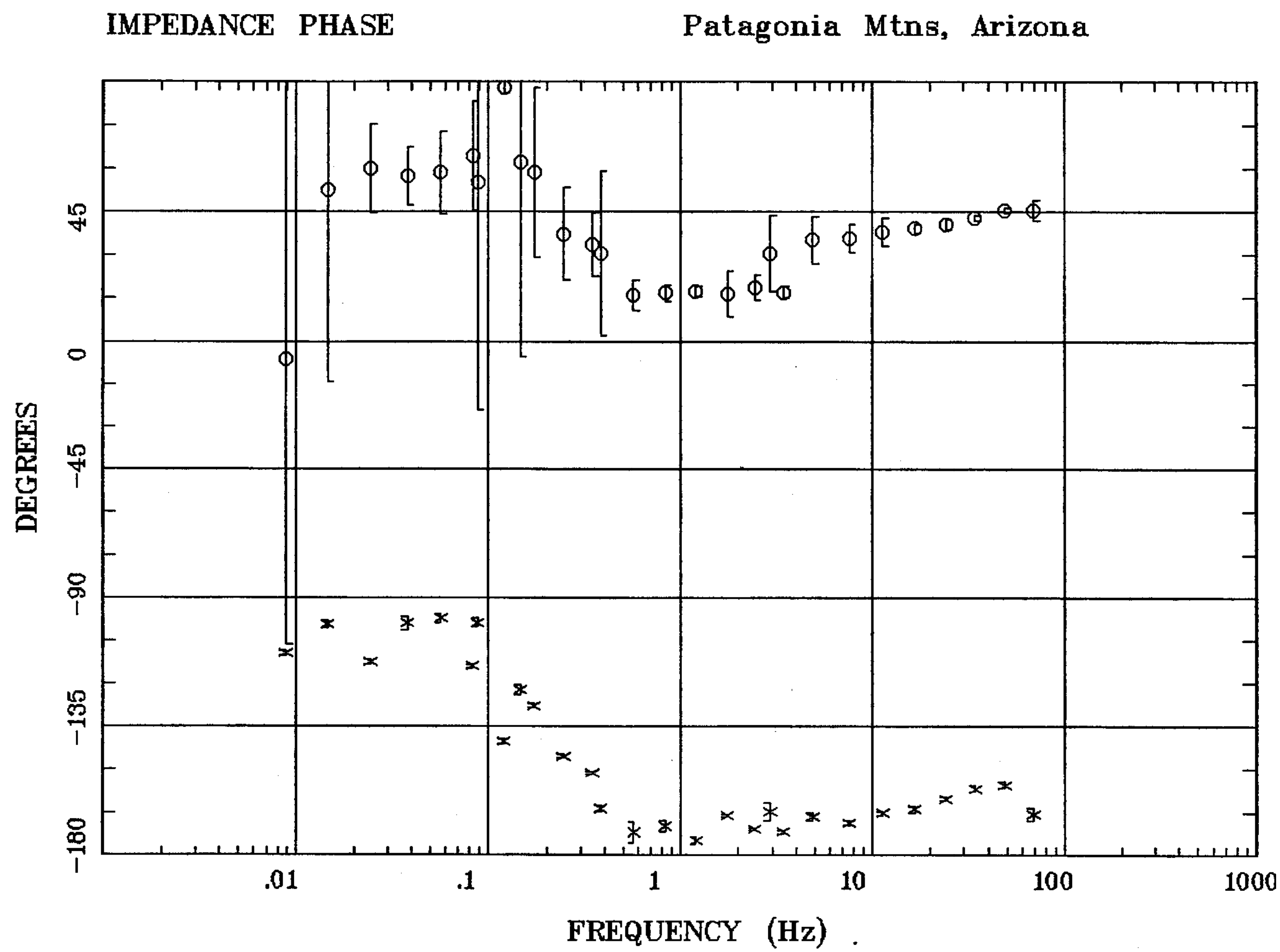

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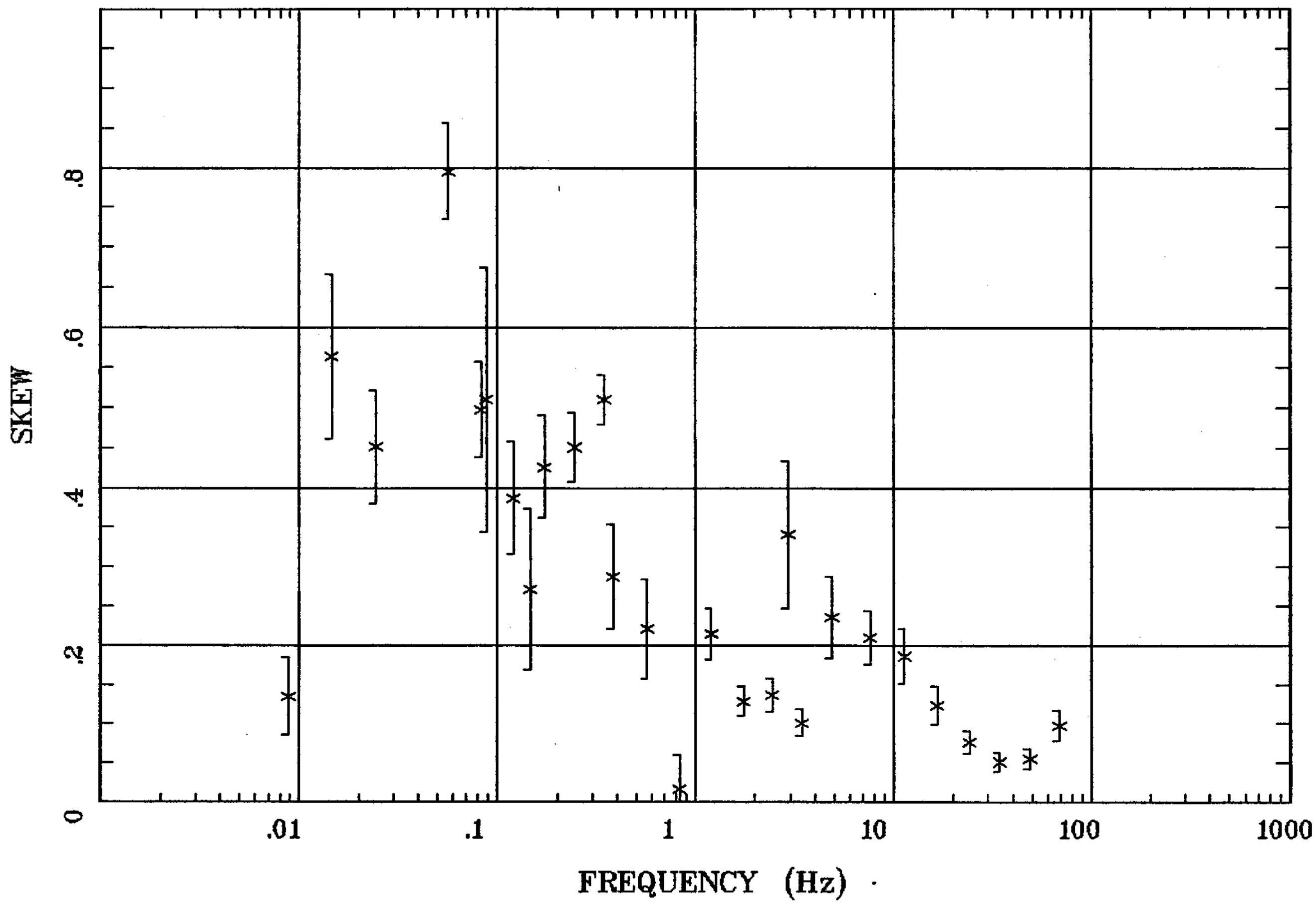
Station 01

IMPEDANCE SKEW | Patagonia Mtns, Arizona



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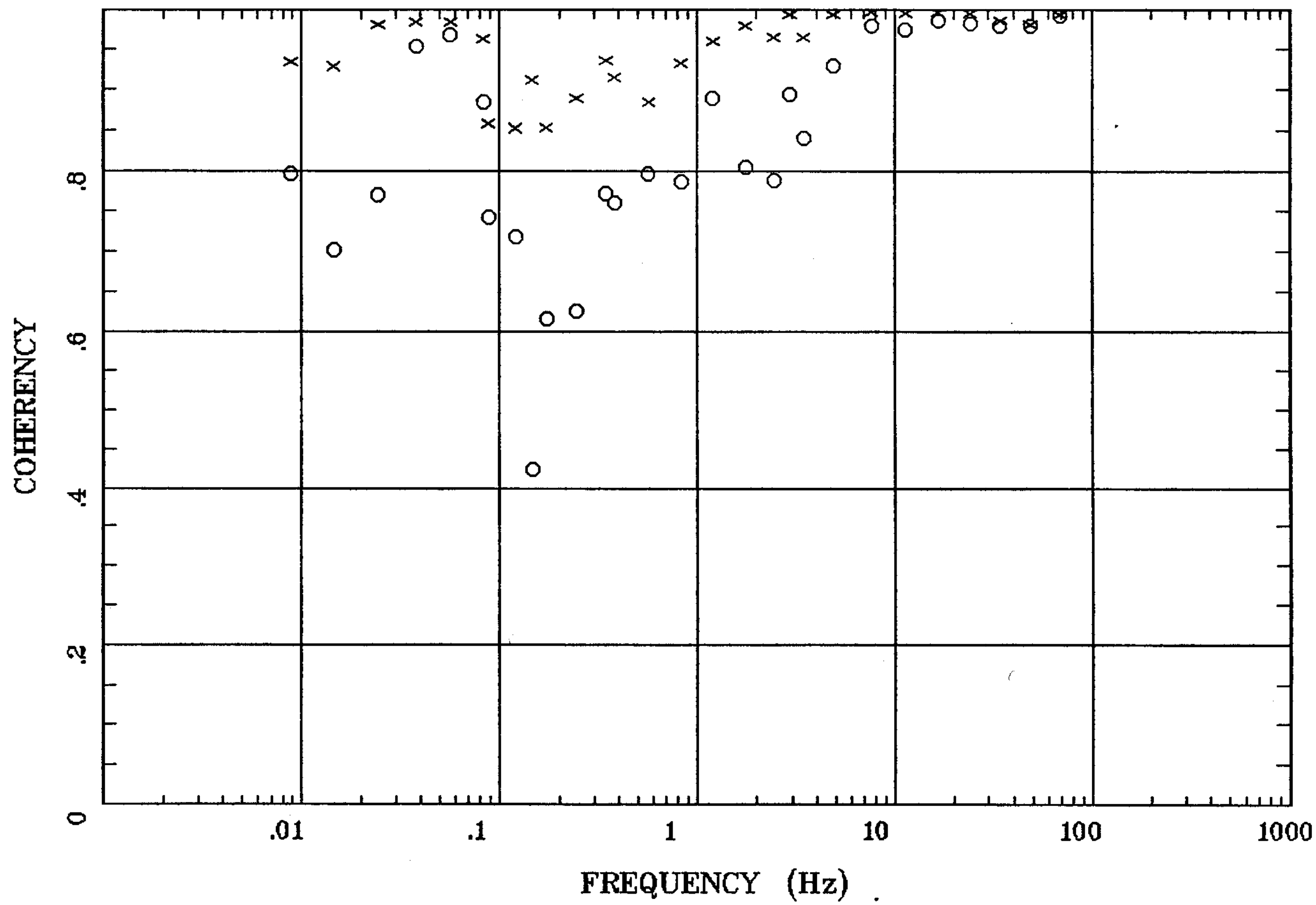
E MULT Coh. Patagonia Mtns, Arizona



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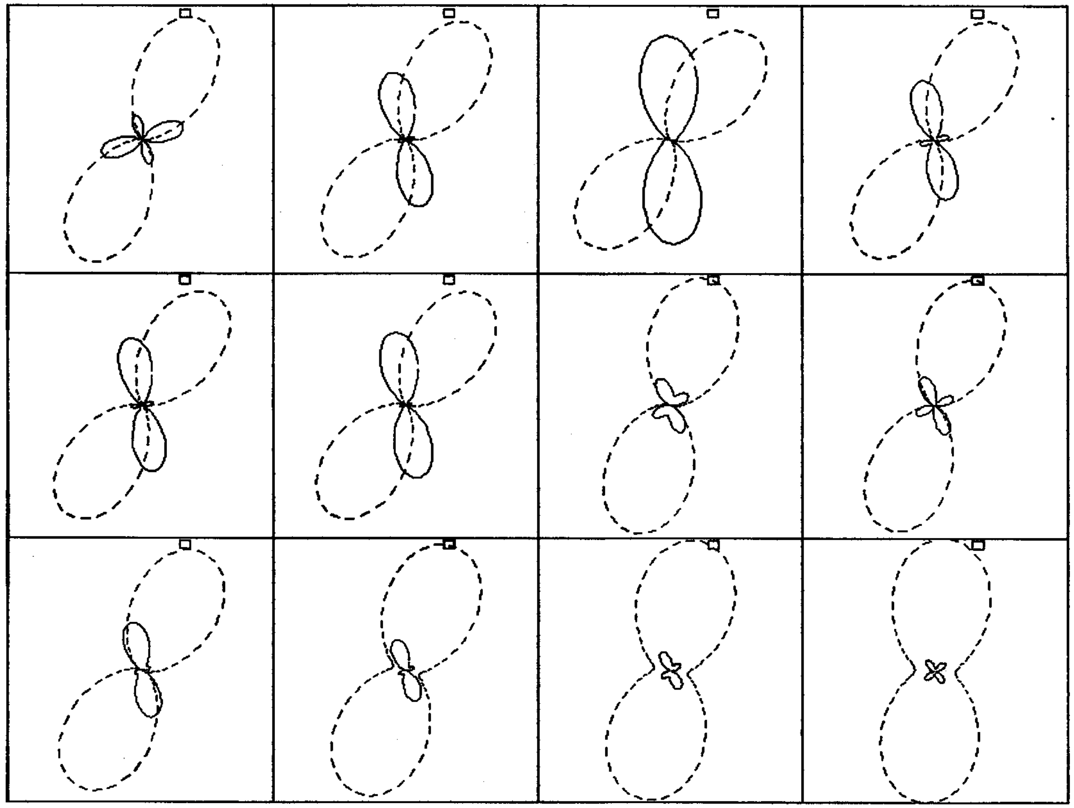
Station 01

POLAR PLOTS Patagonia Mtns, Arizona



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.172 Hz	.345 Hz	.566 Hz	1.758 Hz
2.930 Hz	7.617 Hz	16.602 Hz	34.375 Hz

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Survey Co:USGS

Rotation:
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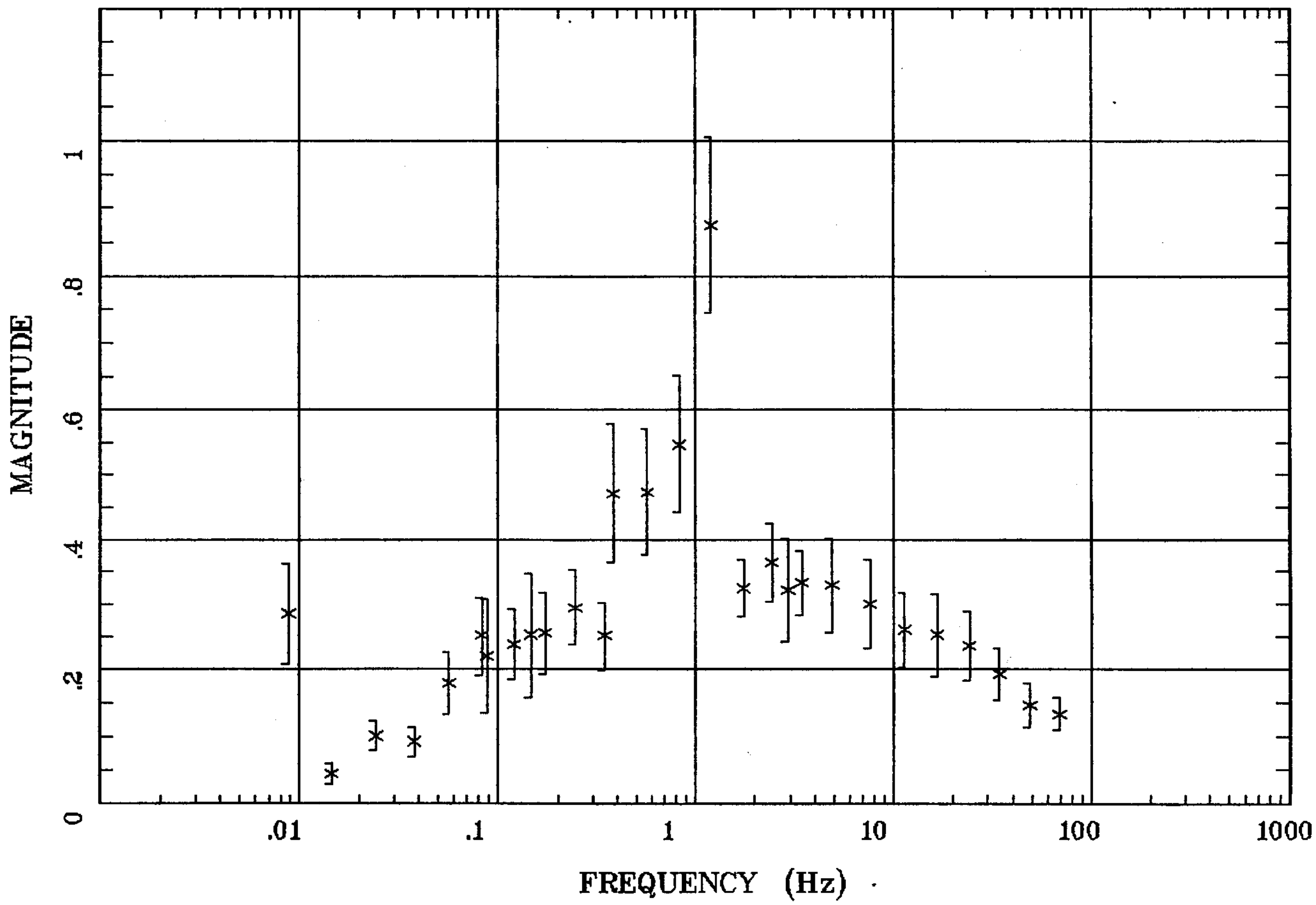
Station 01

TIPPER MAGNITUDE Patagonia Mtns, Arizona



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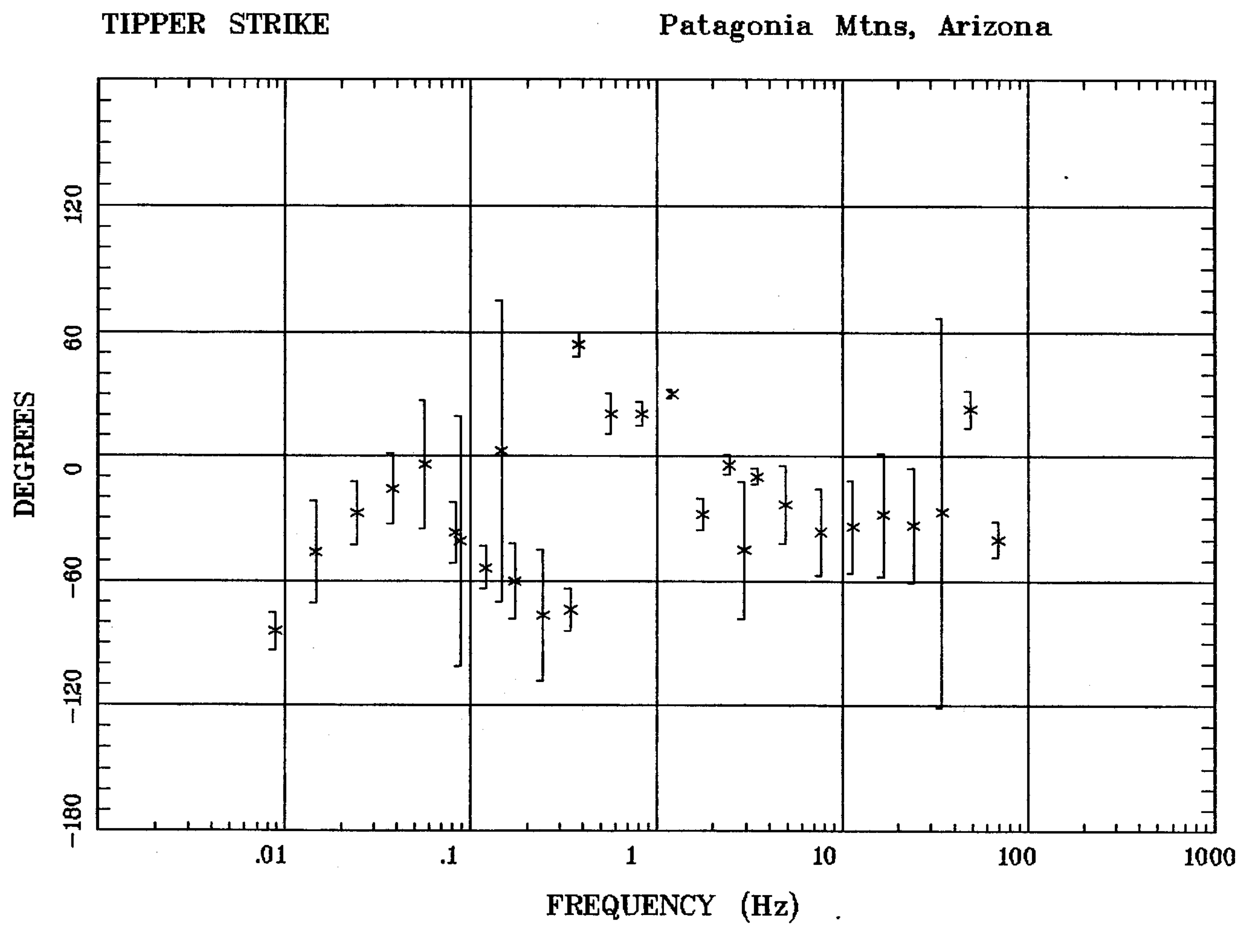

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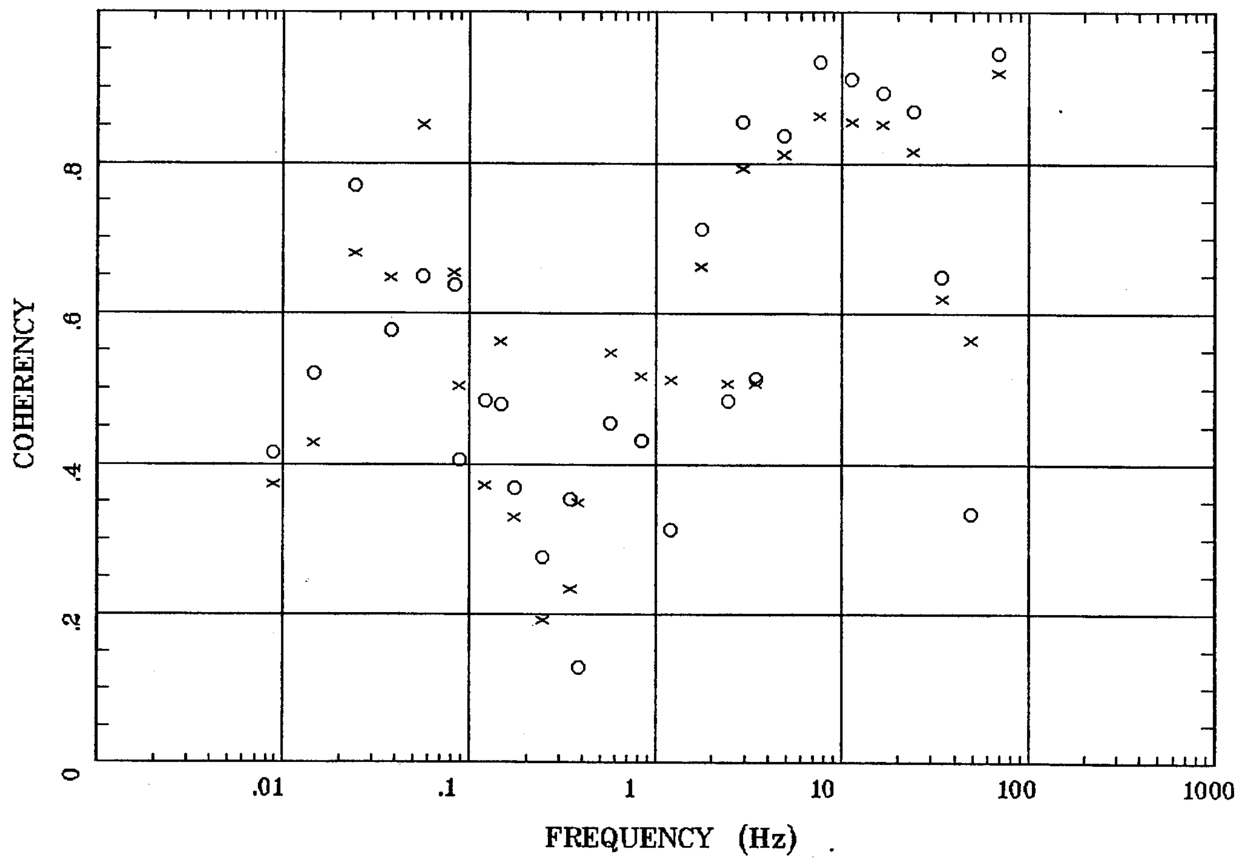
Station 01

HzHx.x Coh HzHy.o　　　　Patagonia Mtns, Arizona



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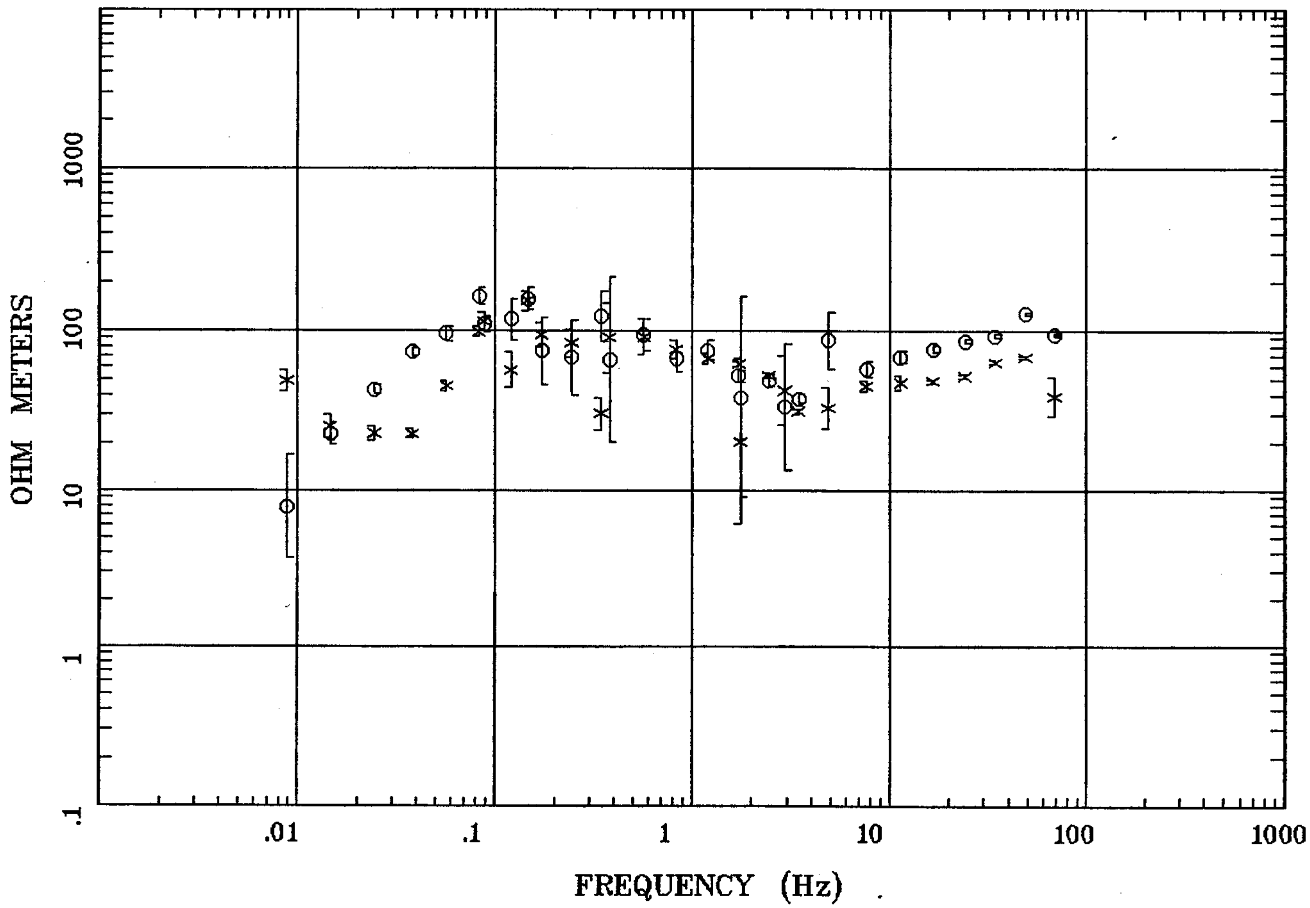
Station 03

APPARENT RESISTIVITY   Patagonia Mtns, Arizona



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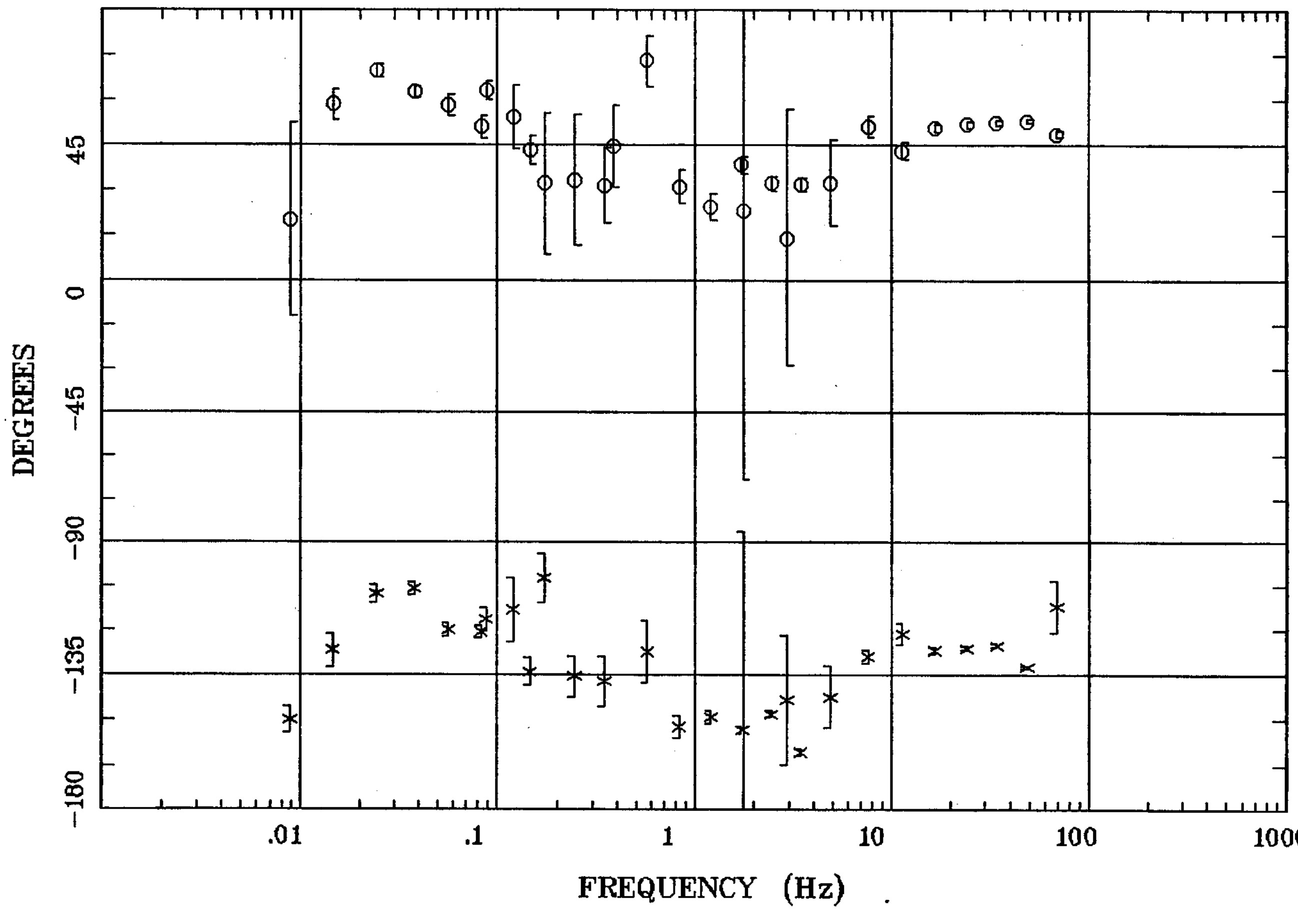
Station 03

IMPEDANCE PHASE Patagonia Mtns, Arizona



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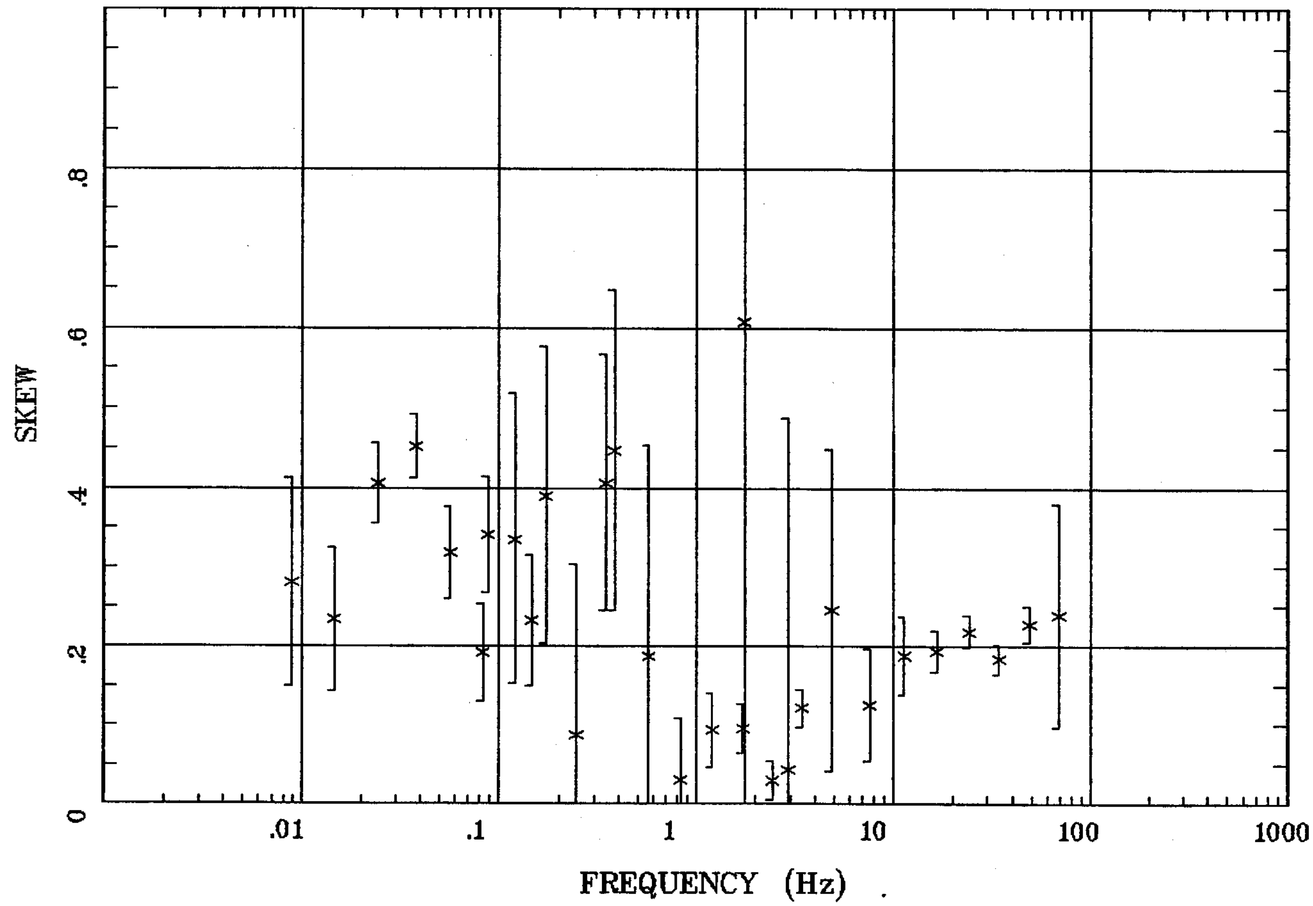
Station 03

IMPEDANCE SKEW

Patagonia Mtns, Arizona



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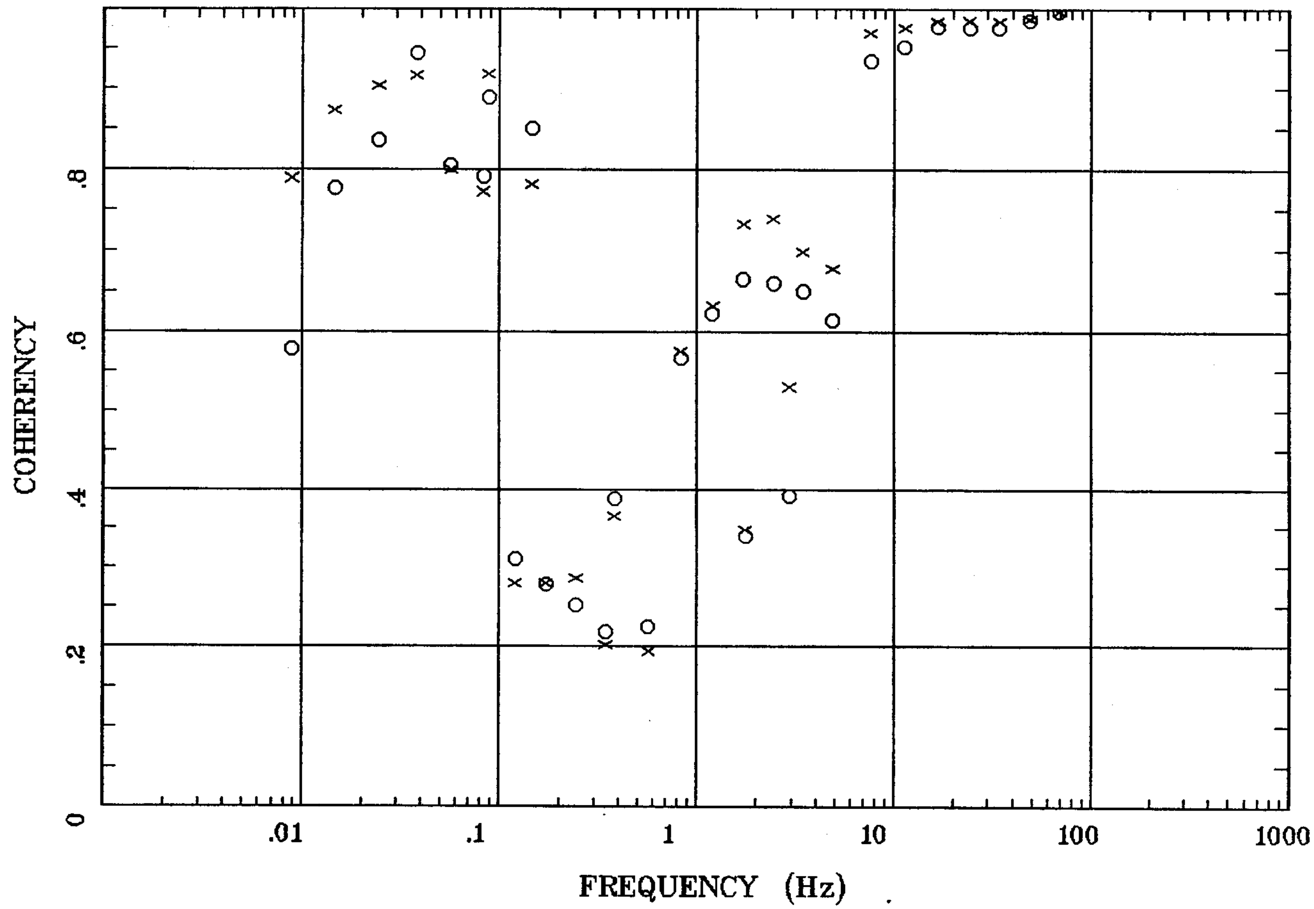
Station 03

E MULT Coh. Patagonia Mtns, Arizona



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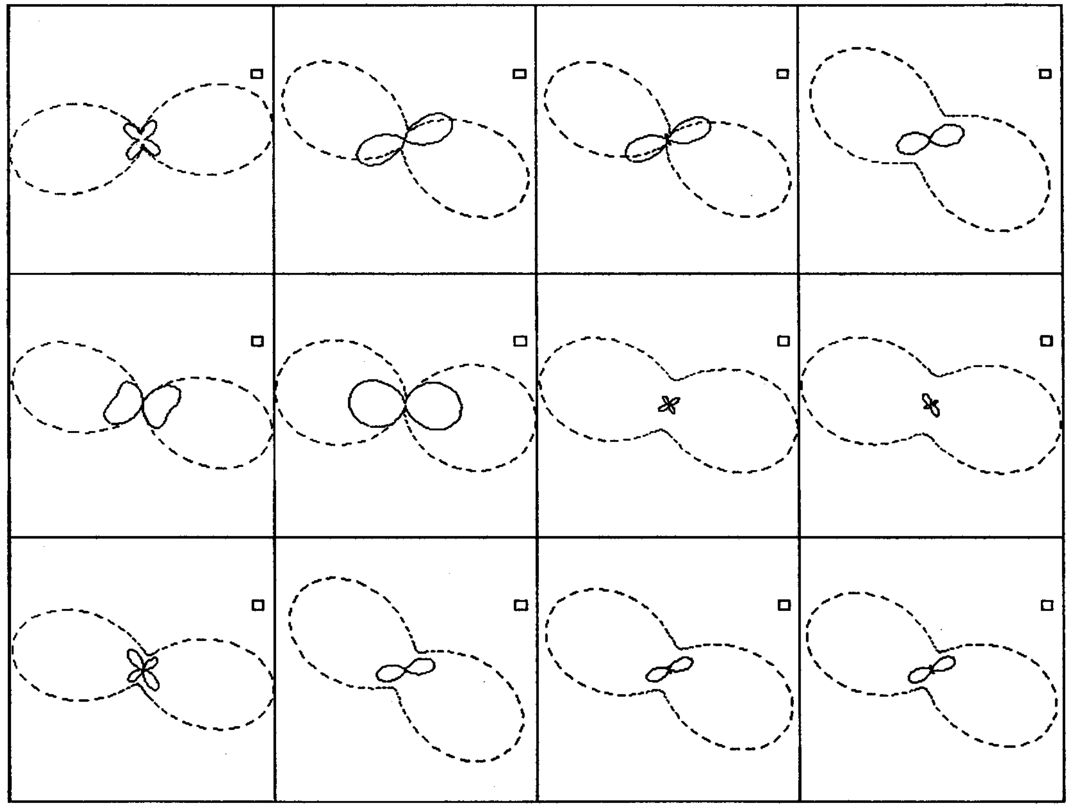
Station 03

POLAR PLOTS Patagonia Mtns, Arizona



.0088 Hz	.0244 Hz	.0566 Hz	.120 Hz
.172 Hz	.381 Hz	.830 Hz	1.719 Hz
2.930 Hz	4.883 Hz	16.602 Hz	34.375 Hz

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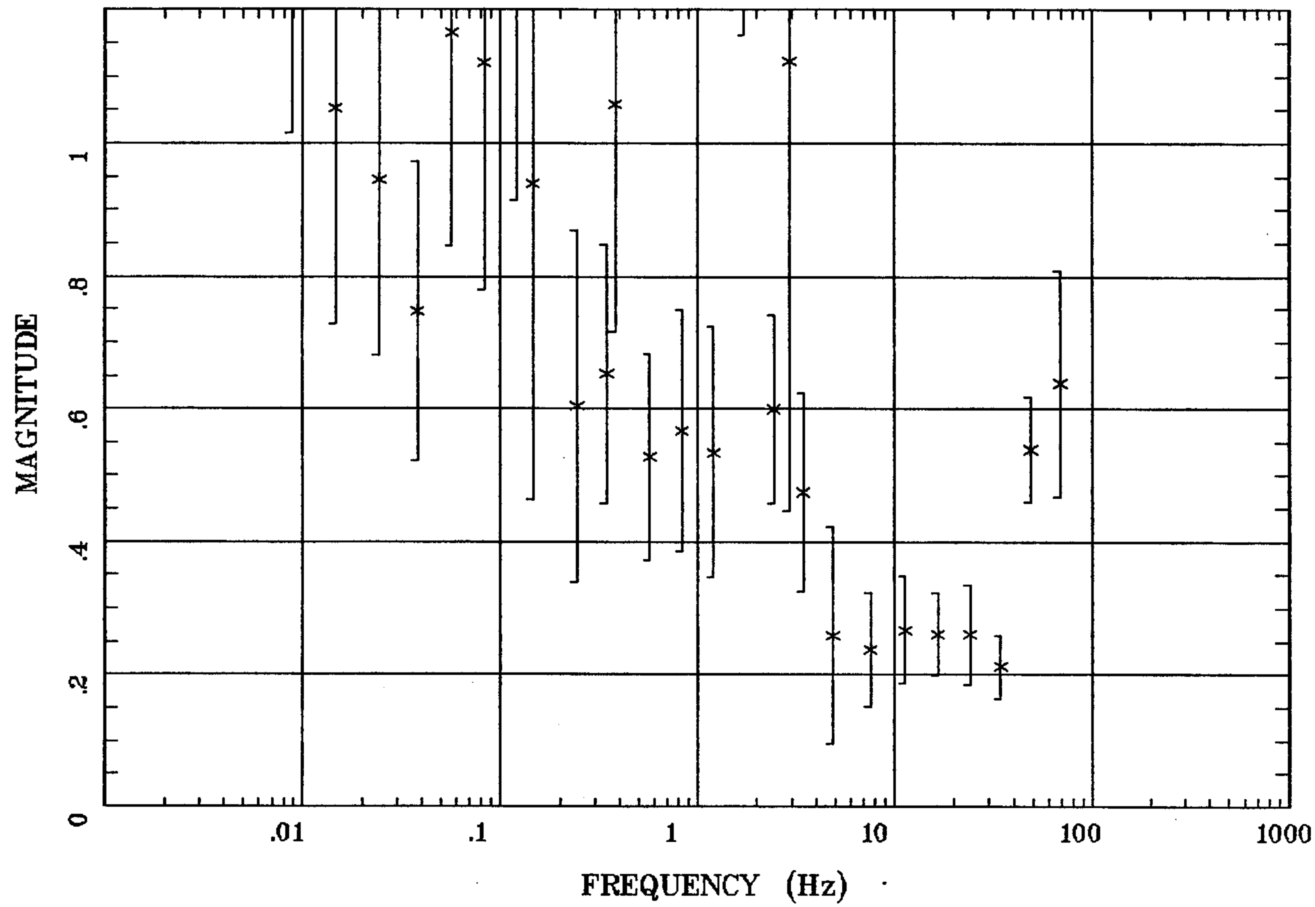
Plotted: 21:37 Sep 27, 2008
Survey Co:USGS
< EMI – ElectroMagnetic Instruments >

Station 03

TIPPER MAGNITUDE Patagonia Mtns, Arizona

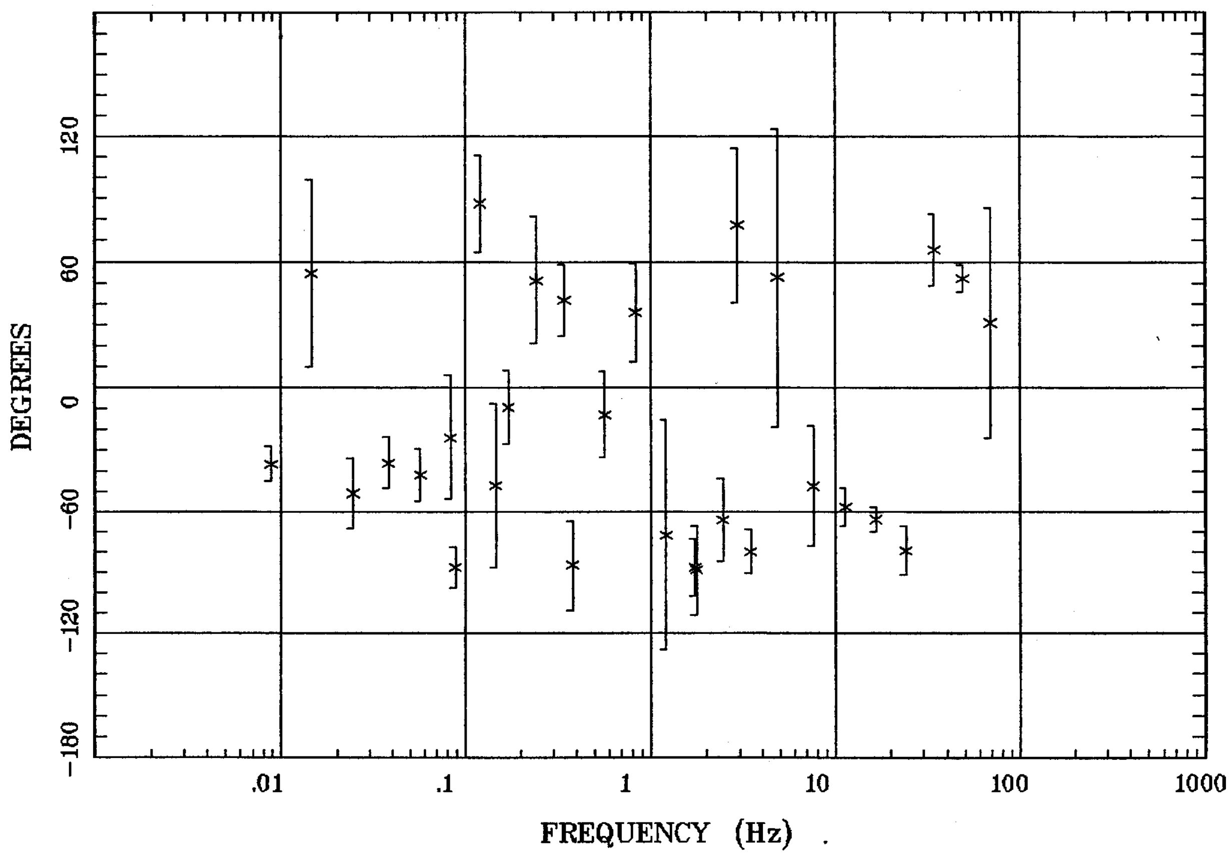


Client: Mineral Resources Program
Remote: none
Acquired: 12:3 May 01, 2008
Survey Co:USGS

Rotation:
Filename: sp03mall.avg
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Plotted: 21:37 Sep 27, 2008
< EMI – ElectroMagnetic Instruments >

Station 03

TIPPER STRIKE Patagonia Mtns, Arizona



Rotation:

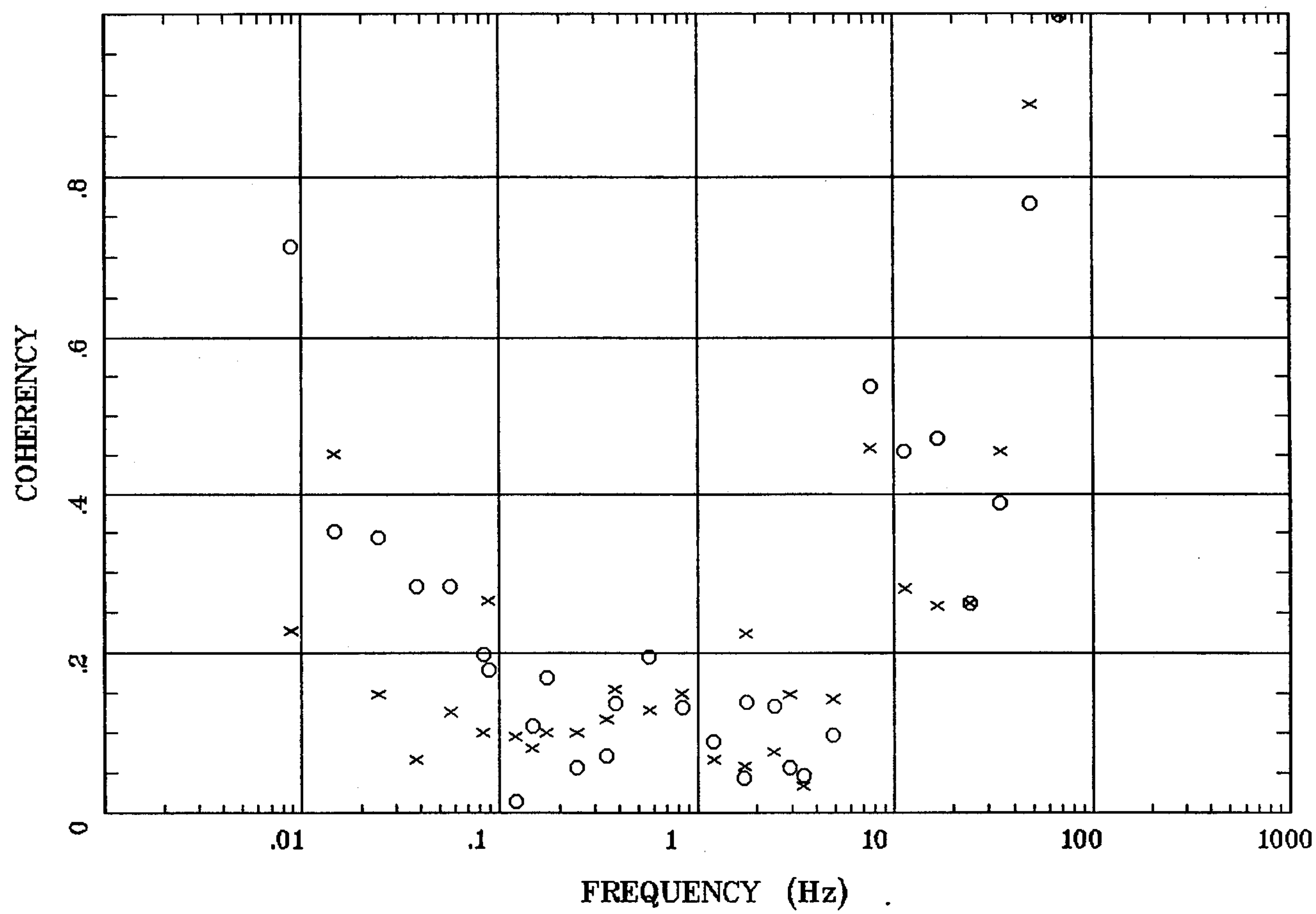
Client: Mineral Resources Program
Remote: none
Acquired: 12:3 May 01, 2008
Survey Co:USGS

Filename: sp03mall.avg
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Plotted: 21:37 Sep 27, 2008
< EMI – ElectroMagnetic Instruments >

Station 03

HzHx.x Coh HzHy.o

Patagonia Mtns, Arizona

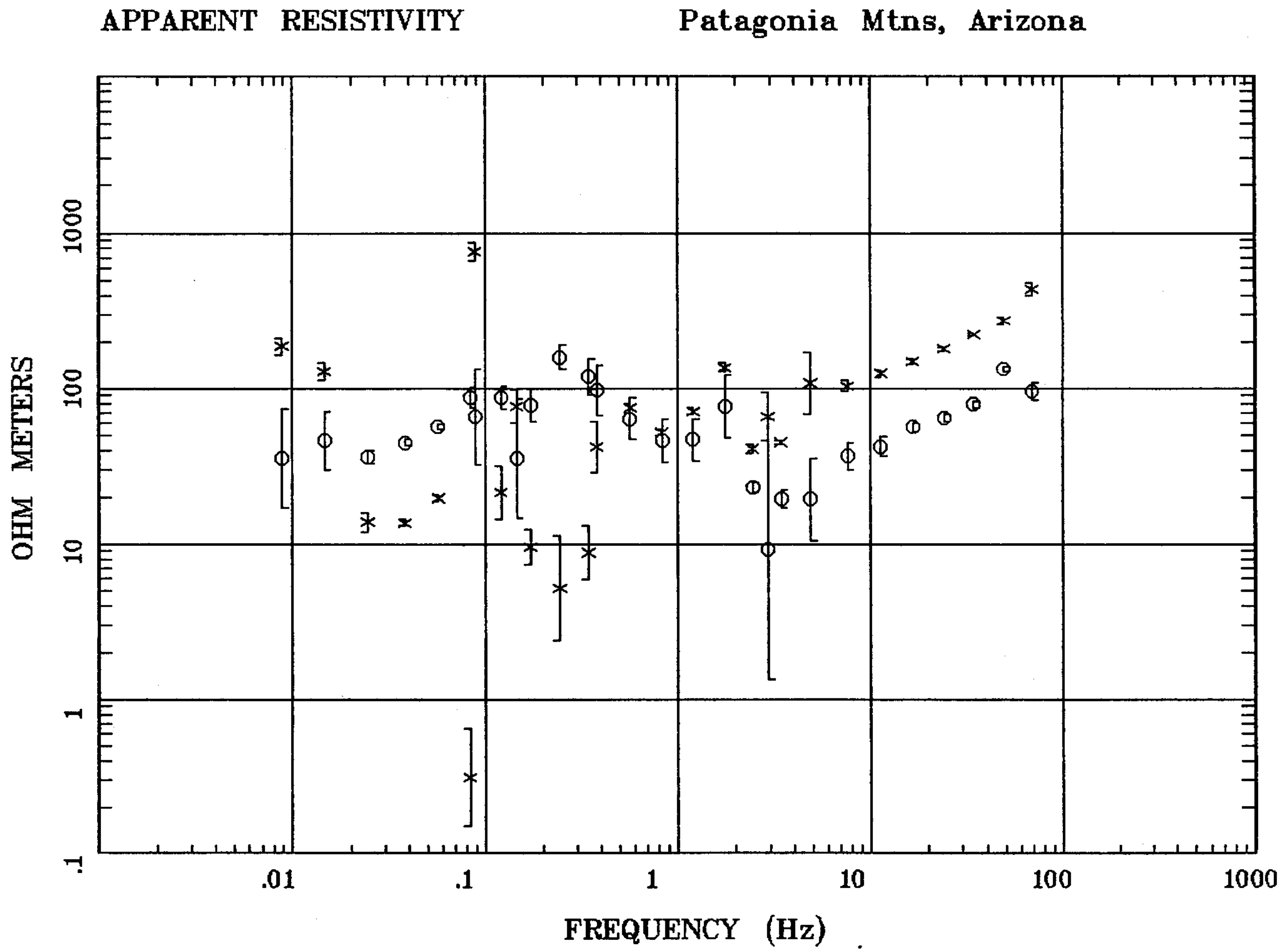


Rotation:

Client: Mineral Resources Program
Remote: none
Acquired: 12:3 May 01, 2008
Survey Co:USGS

Filename: sp03mall.avg
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Plotted: 21:37 Sep 27, 2008
< EMI – ElectroMagnetic Instruments >

Station 04

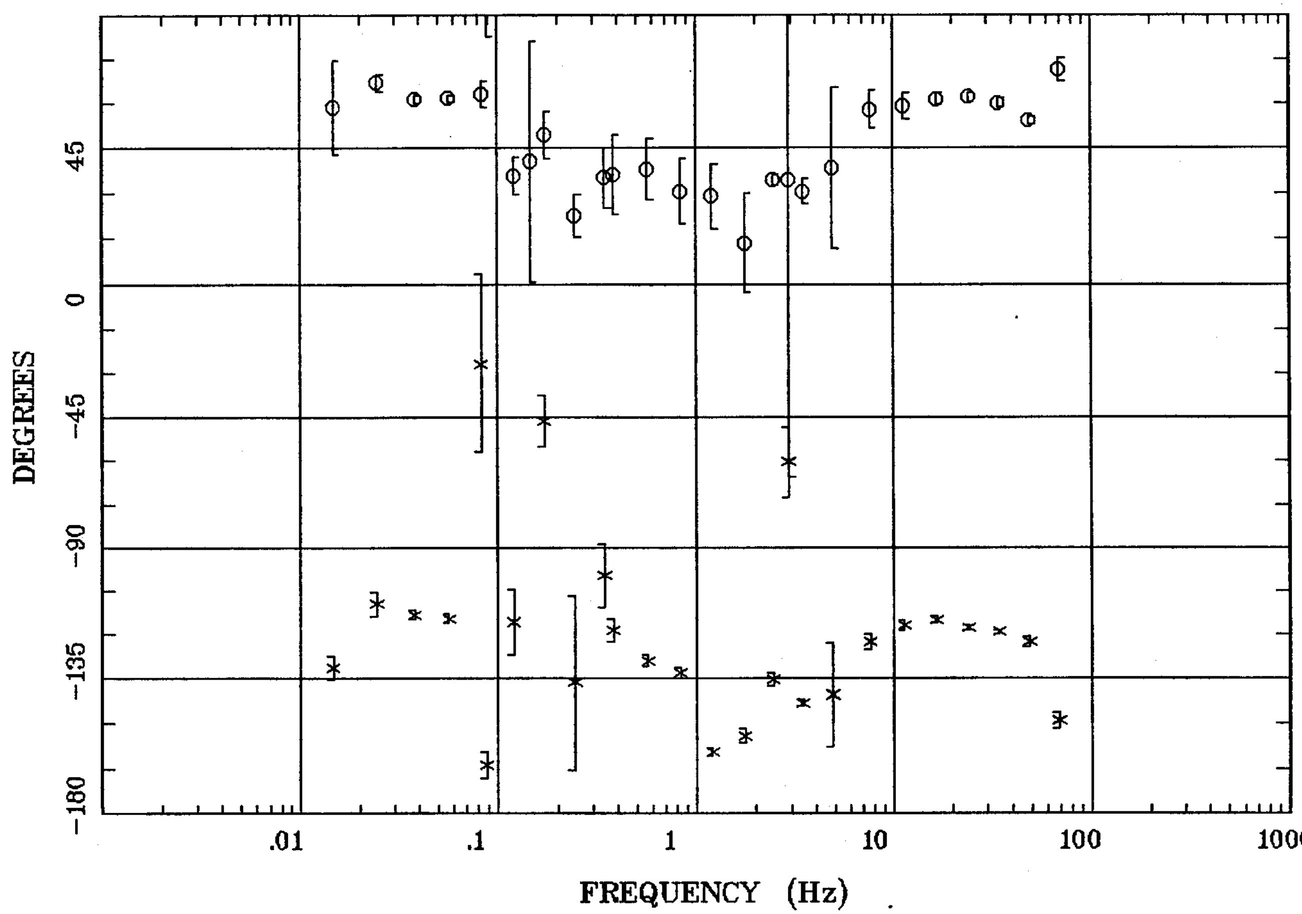


Client: Mineral Resources Program
Remote: none
Acquired: 13:4 Apr 30, 2008
Survey Co:USGS

Rotation:
Filename: sp04m2.avg
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Plotted: 21:39 Sep 27, 2008
< EMI – ElectroMagnetic Instruments >

Station 04

IMPEDANCE PHASE   Patagonia Mtns, Arizona

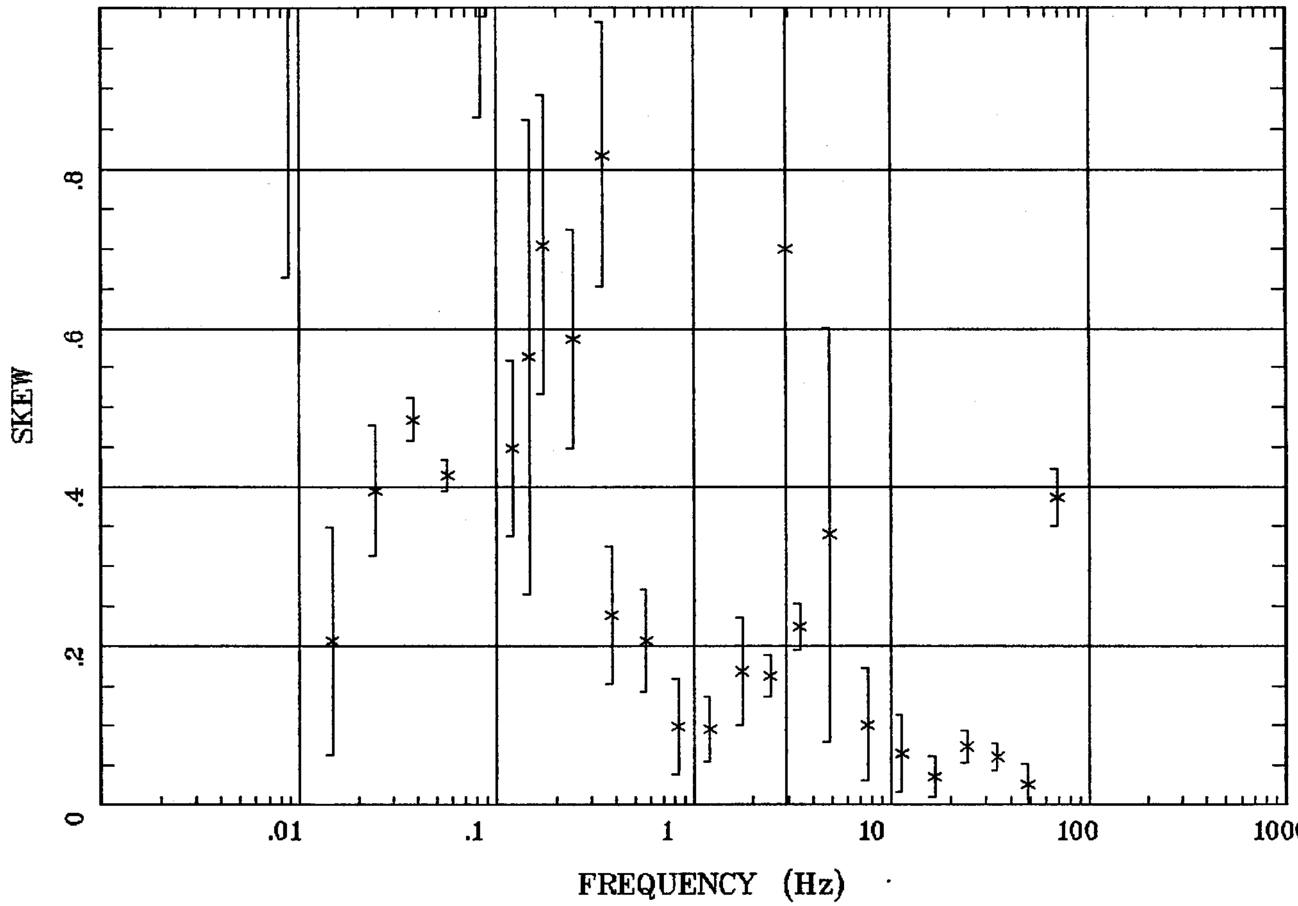


Client: Mineral Resources Program
Remote: none
Acquired: 13:4 Apr 30, 2008
Survey Co:USGS

Rotation:
Filename: sp04m2.avg
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Plotted: 21:39 Sep 27, 2008
< EMI – ElectroMagnetic Instruments >

Station 04

IMPEDANCE SKEW   Patagonia Mtns, Arizona

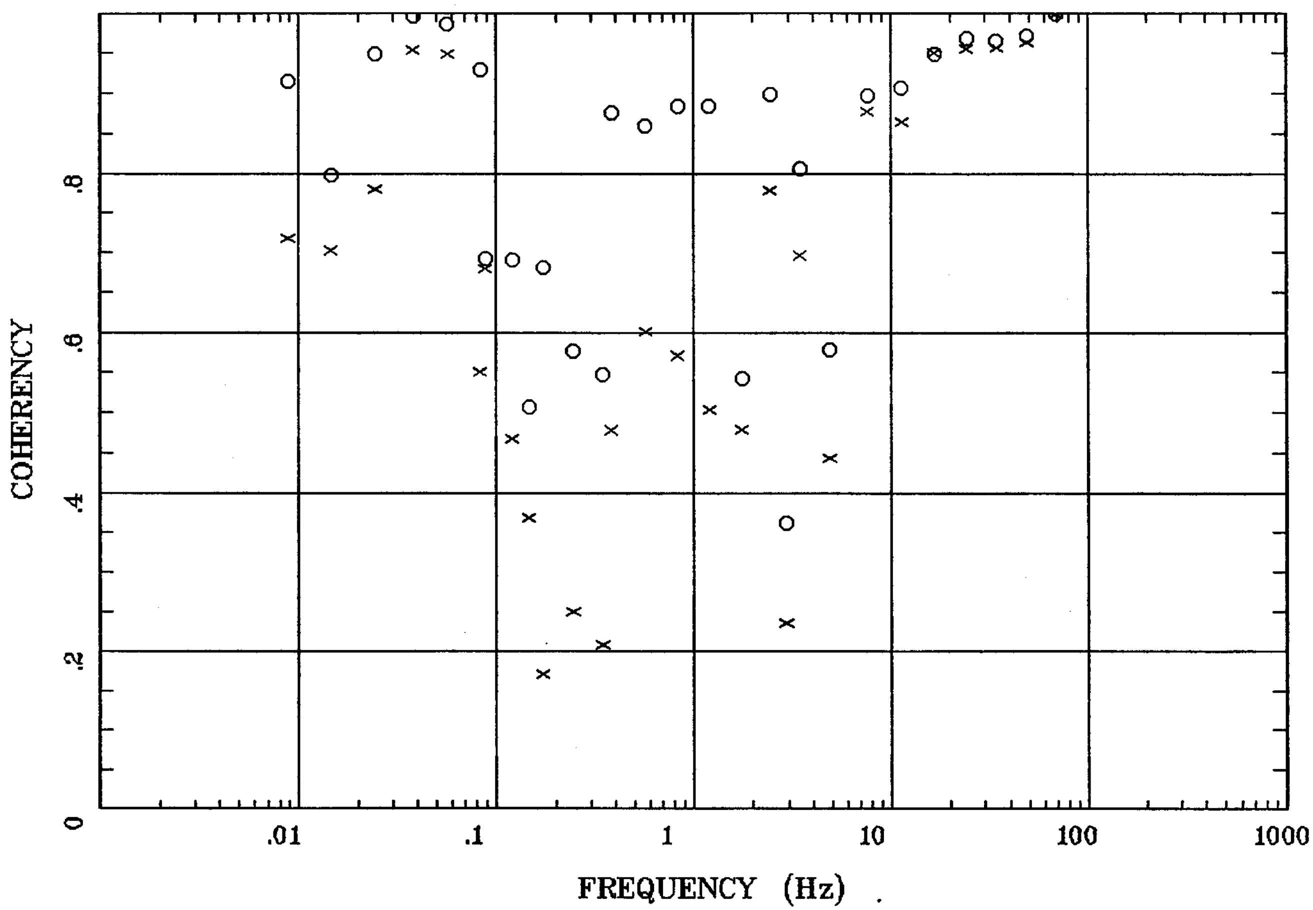


Client: Mineral Resources Program
Remote: none
Acquired: 13:4 Apr 30, 2008
Survey Co:USGS

Rotation:
Filename: sp04m2.avg
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Plotted: 21:39 Sep 27, 2008
< EMI – ElectroMagnetic Instruments >

Station 04

E MULT Coh. Patagonia Mtns, Arizona



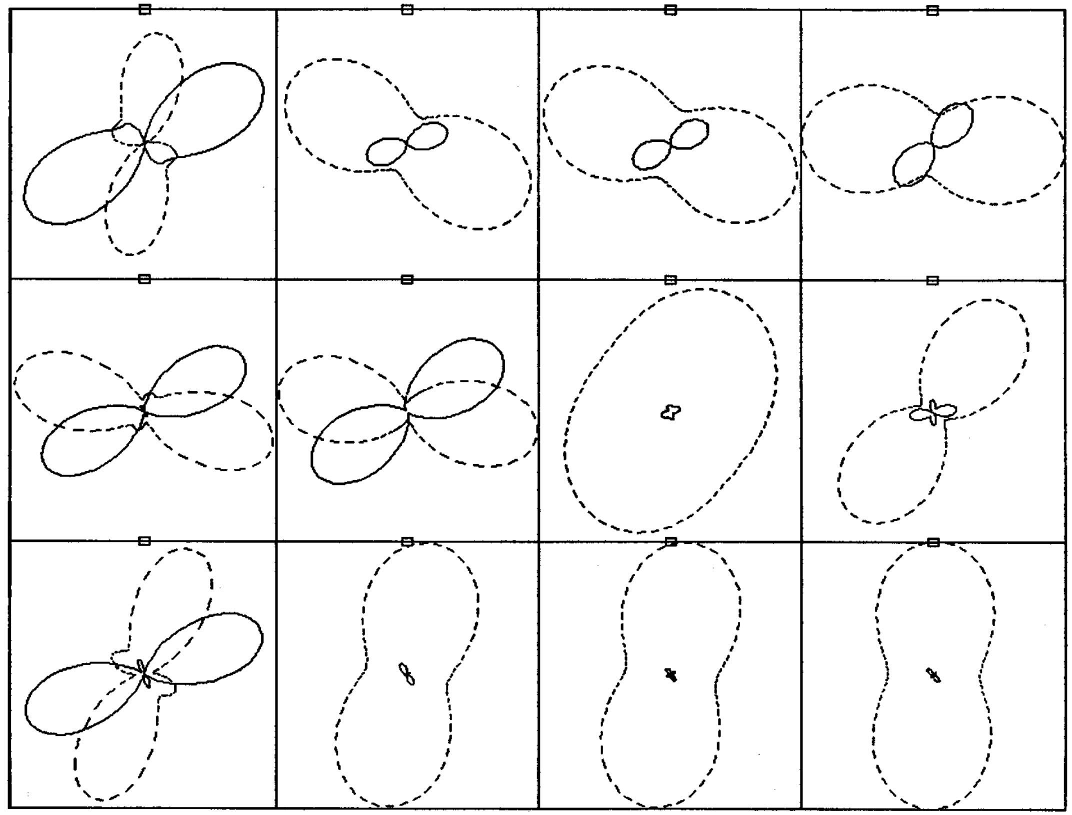
Rotation:

Client: Mineral Resources Program
Remote: none
Acquired: 13:4 Apr 30, 2008
Survey Co:USGS

Filename: sp04m2.avg
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Plotted: 21:39 Sep 27, 2008
< EMI – ElectroMagnetic Instruments >

Station 04

POLAR PLOTS Patagonia Mtns, Arizona



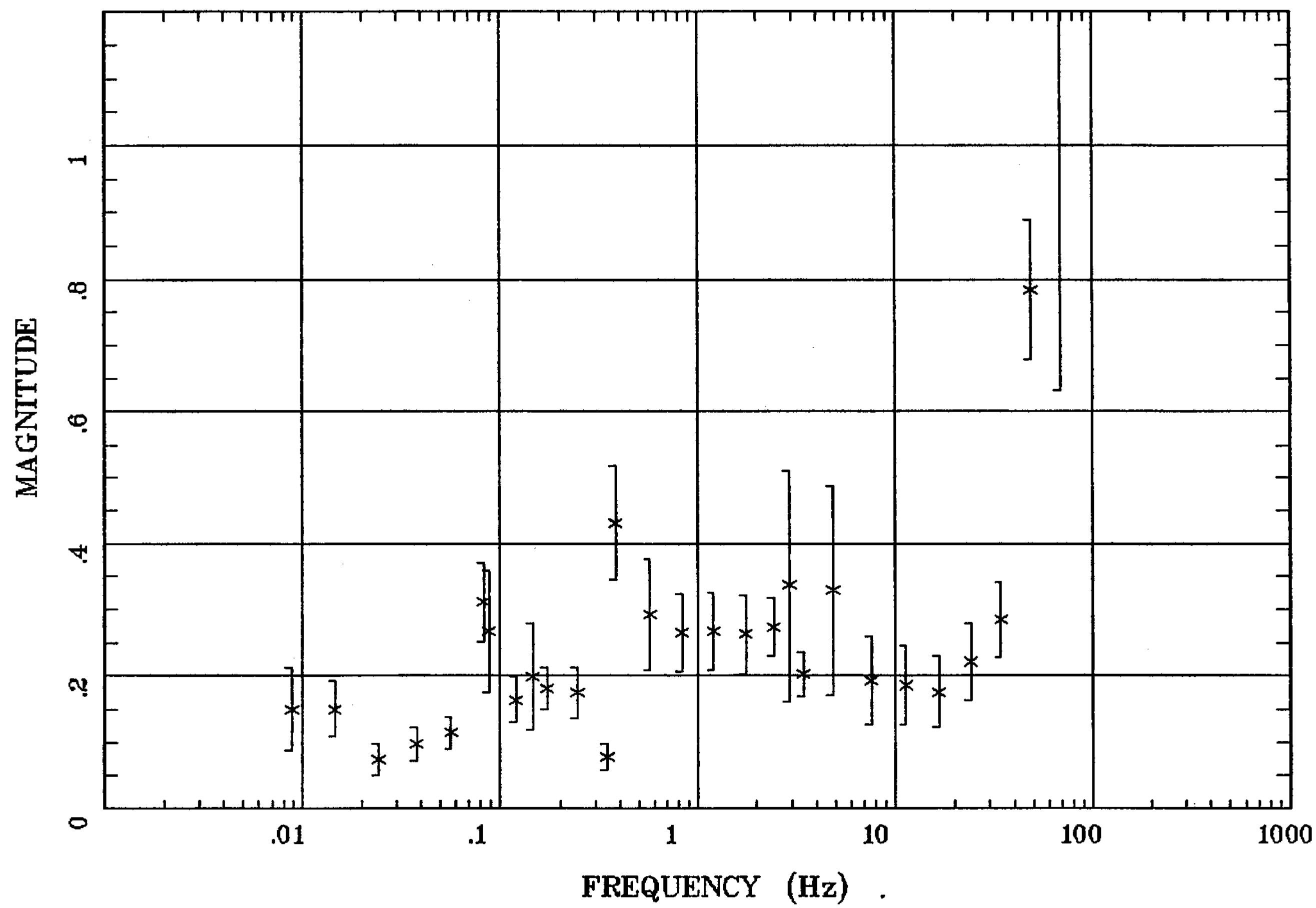
.0088 Hz	.0244 Hz	.0566 Hz	.120 Hz
.172 Hz	.345 Hz	.566 Hz	1.758 Hz
2.930 Hz	7.617 Hz	16.602 Hz	34.375 Hz

Client: Mineral Resources Program
Remote: none
Acquired: 13:4 Apr 30, 2008
Survey Co:USGS

Rotation:
Filename: sp04m2.avg
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Plotted: 21:39 Sep 27, 2008
< EMI – ElectroMagnetic Instruments >

Station 04

TIPPER MAGNITUDE　　Patagonia Mtns, Arizona

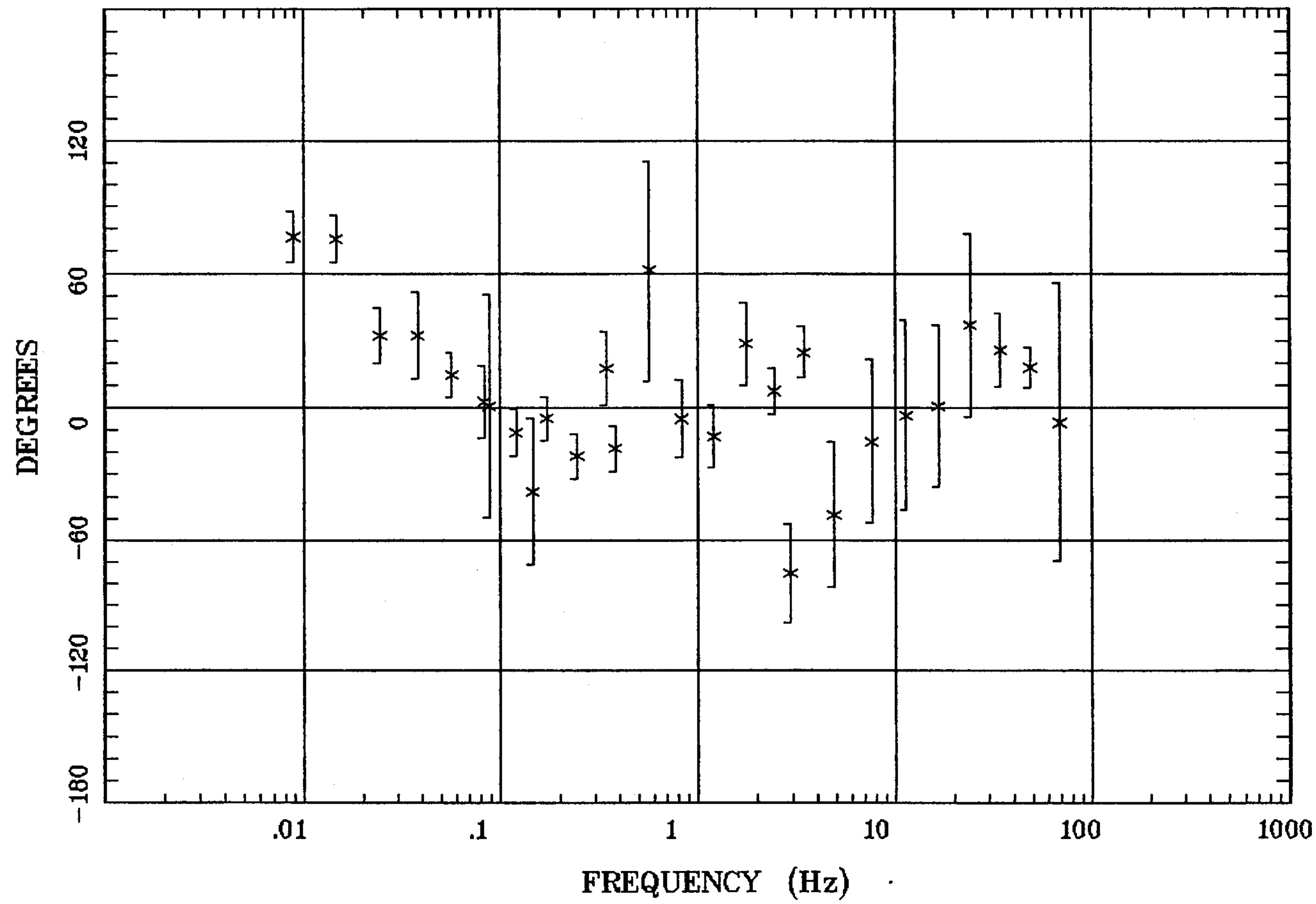


Client: Mineral Resources Program
Remote: none
Acquired: 13:4 Apr 30, 2008
Survey Co:USGS

Rotation:
Filename: sp04m2.avg
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Plotted: 21:39 Sep 27, 2008
< EMI – ElectroMagnetic Instruments >

Station 04

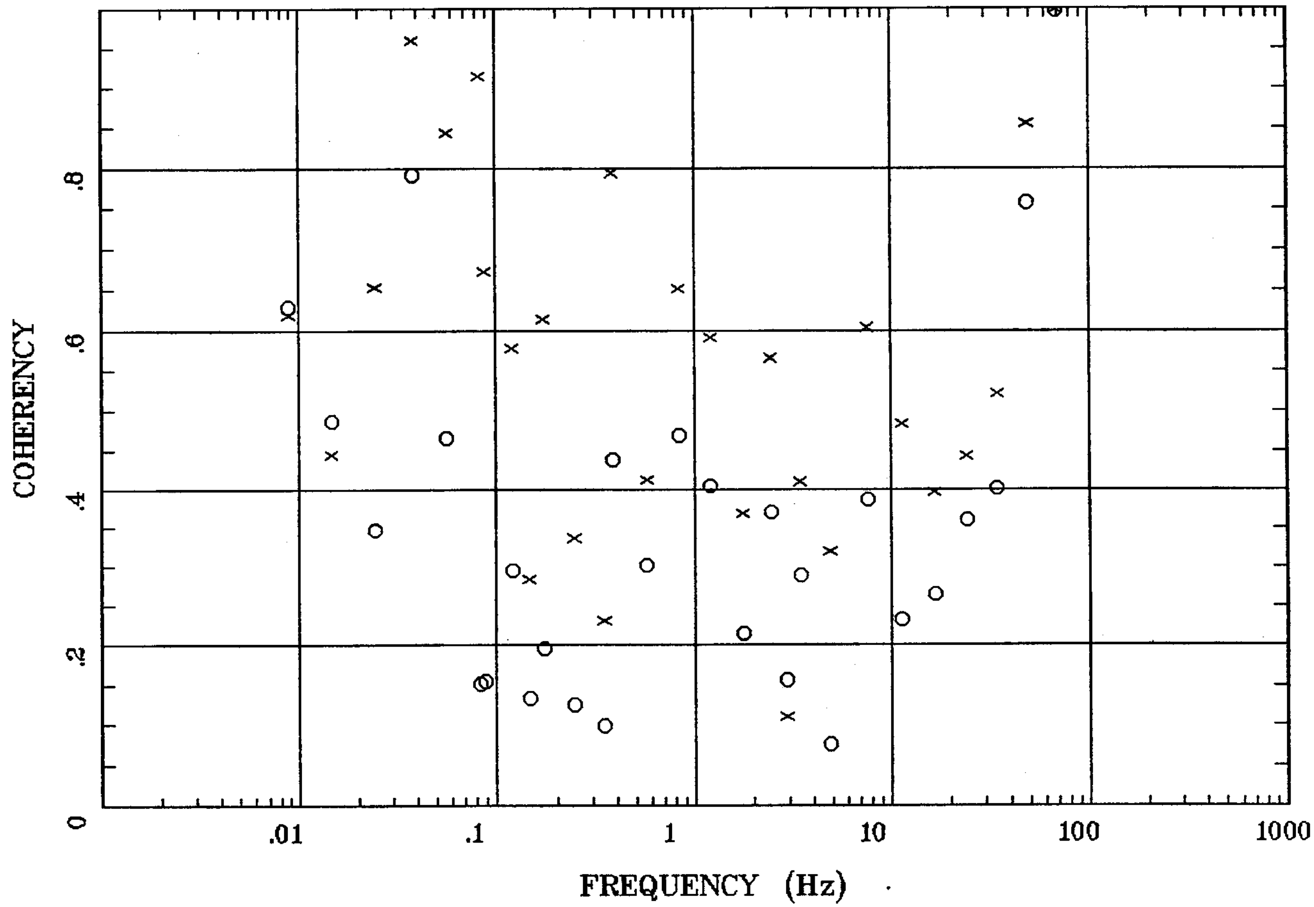
TIPPER STRIKE Patagonia Mtns, Arizona



Rotation:
Client: Mineral Resources Program
Filename: sp04m2.avg
Remote: none
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Acquired: 13:4 Apr 30, 2008
Plotted: 21:39 Sep 27, 2008
Survey Co:USGS
< EMI – ElectroMagnetic Instruments >

Station 04

HzHx.x Coh HzHy.o Patagonia Mtns, Arizona

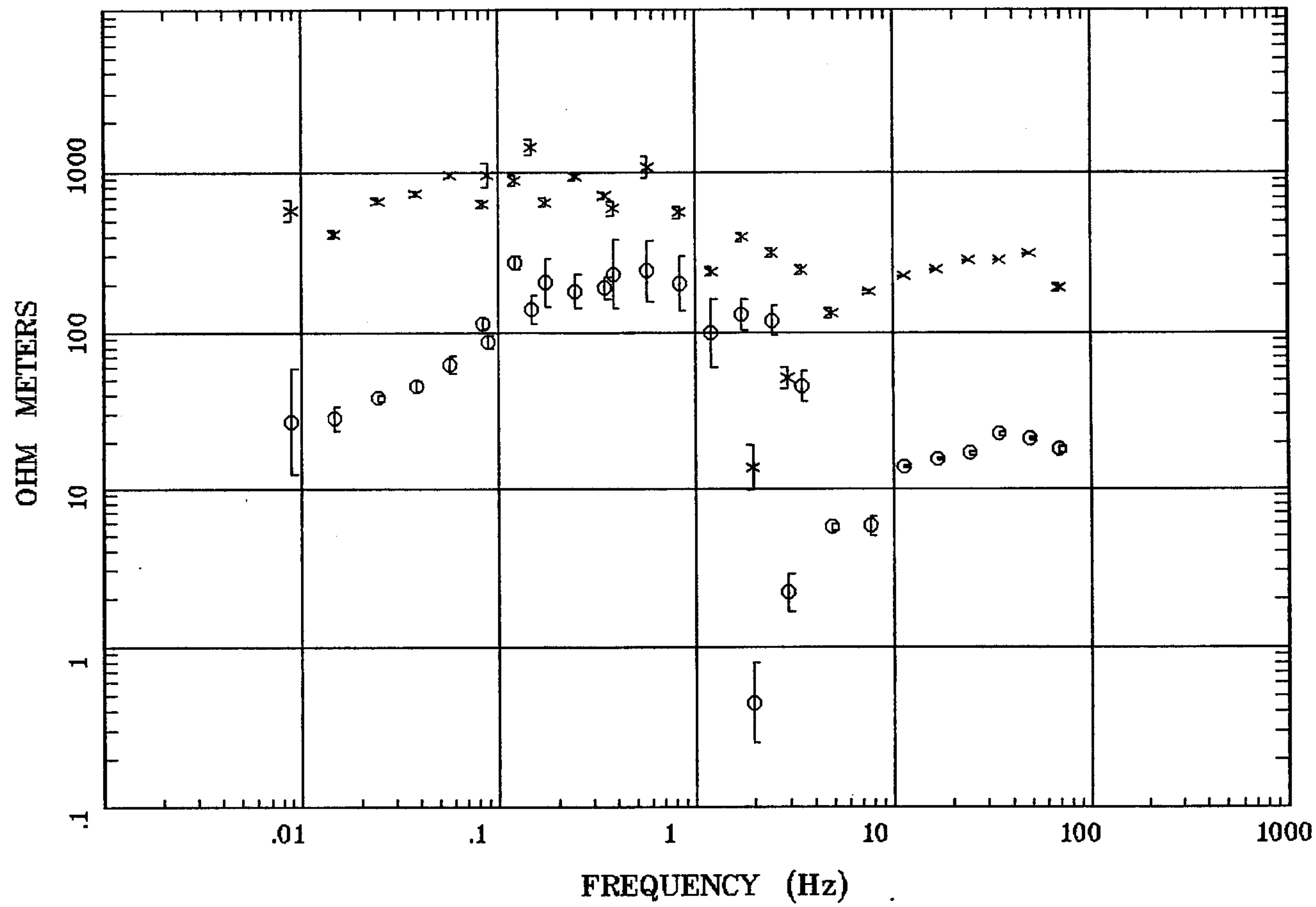


Client: Mineral Resources Program
Remote: none
Acquired: 13:4 Apr 30, 2008
Survey Co:USGS

Rotation:
Filename: sp04m2.avg
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Plotted: 21:39 Sep 27, 2008
< EMI – ElectroMagnetic Instruments >

Station 05

APPARENT RESISTIVITY — Patagonia Mtns, Arizona



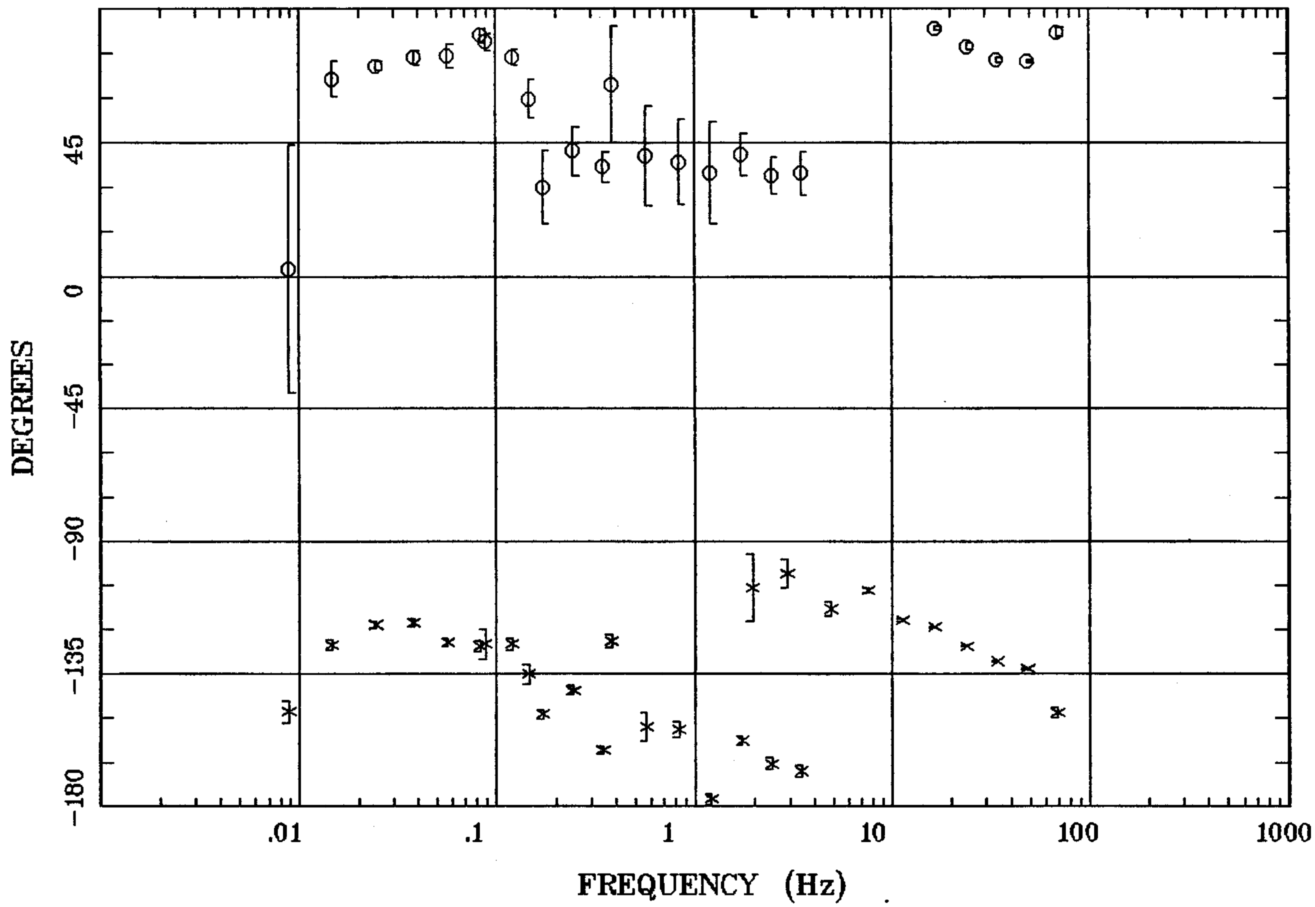
Client: Mineral Resources Program
Remote: none
Acquired: 11:2 May 02, 2008
Survey Co:USGS

Rotation:
Filename: sp05m1b.avg
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Plotted: 21:43 Sep 27, 2008
< EMI – ElectroMagnetic Instruments >

Station 05

IMPEDANCE PHASE

Patagonia Mtns, Arizona

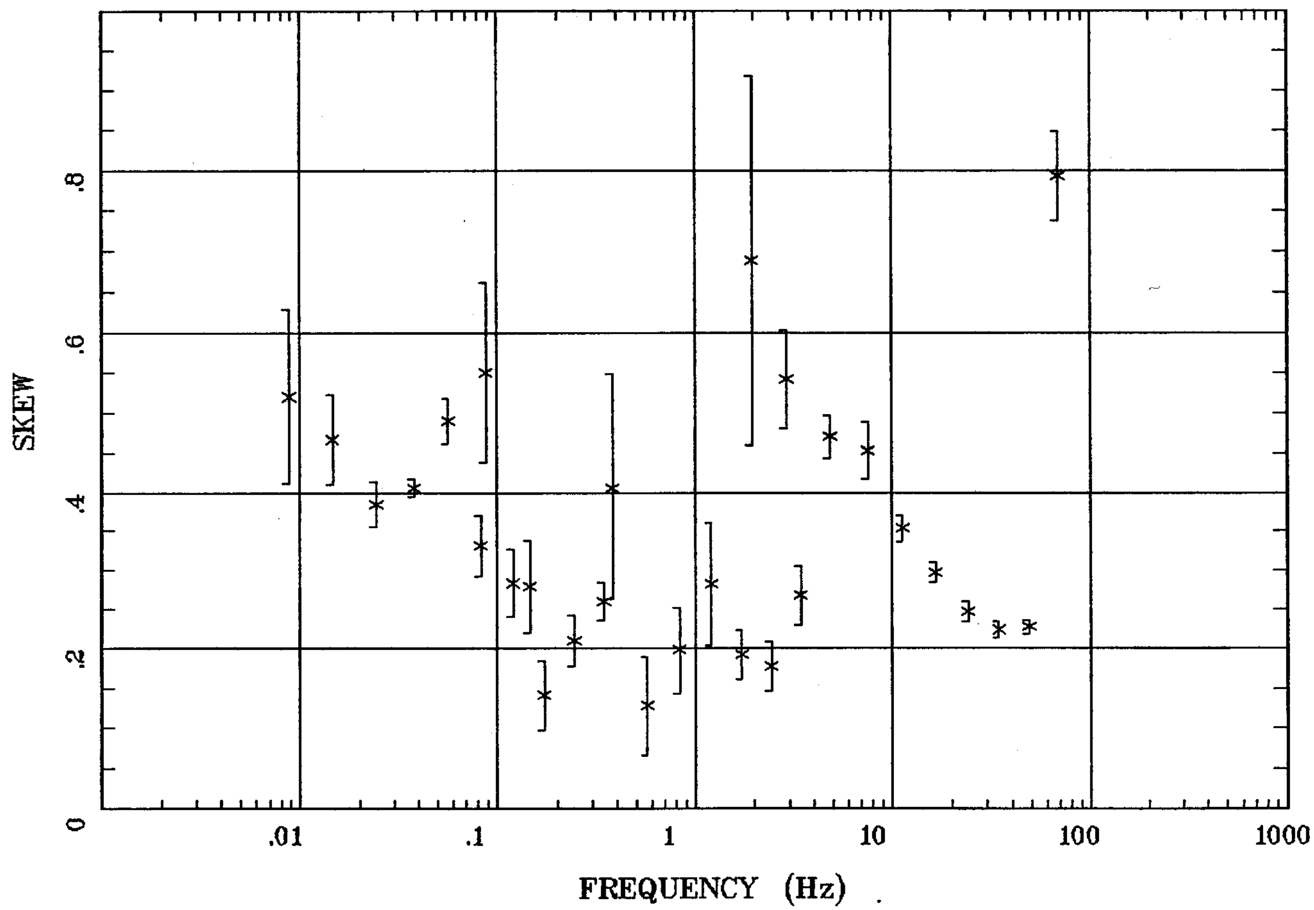


Client: Mineral Resources Program
Remote: none
Acquired: 11:2 May 02, 2008
Survey Co:USGS

Rotation:
Filename: sp05m1b.avg
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Plotted: 21:43 Sep 27, 2008
< EMI – ElectroMagnetic Instruments >

Station 05

IMPEDANCE SKEW Patagonia Mtns, Arizona



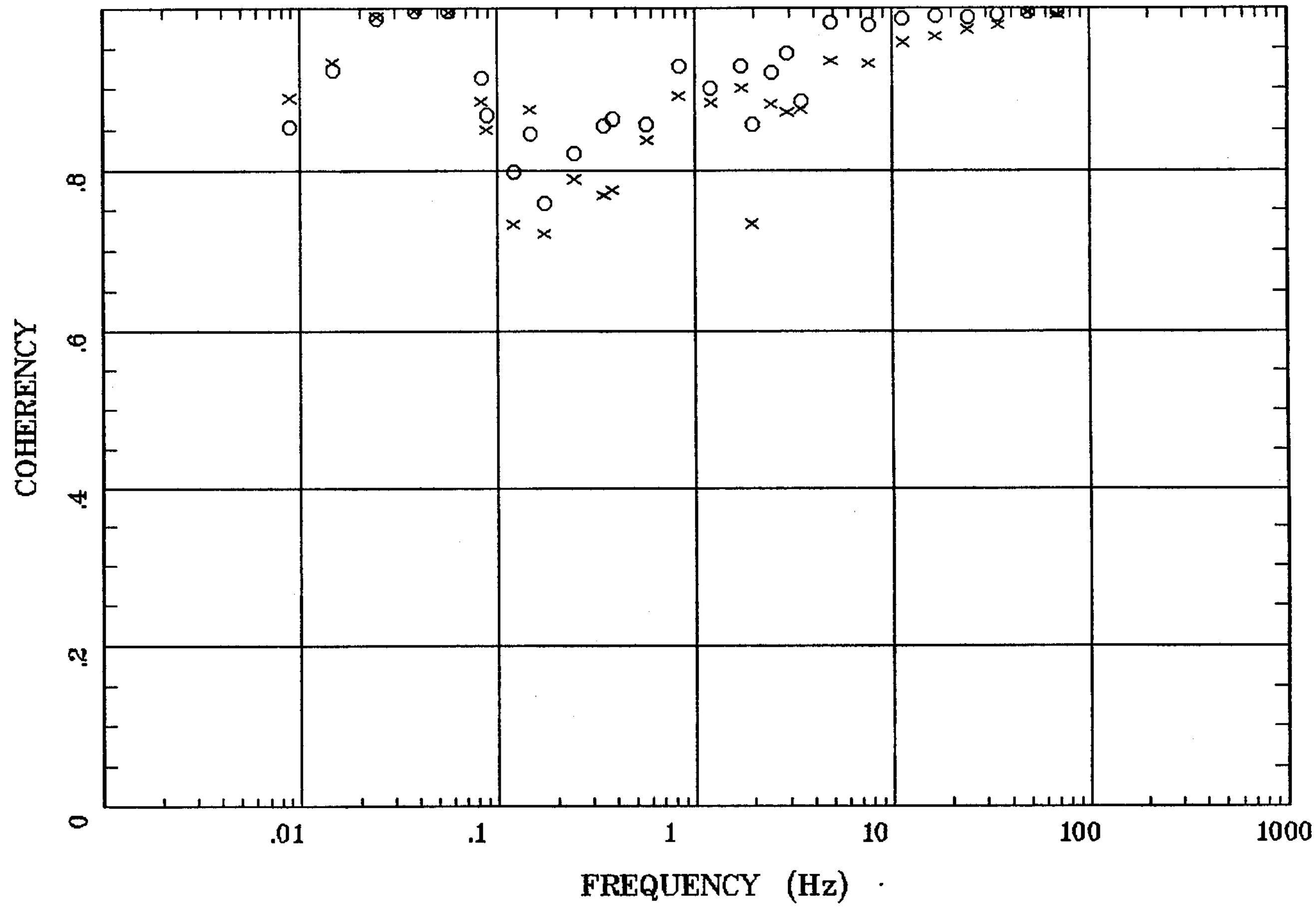
Rotation:

Client: Mineral Resources Program
Remote: none
Acquired: 11:2 May 02, 2008
Survey Co:USGS

Filename: sp05m1b.avg
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Plotted: 21:43 Sep 27, 2008
< EMI – ElectroMagnetic Instruments >

Station 05

E MULT Coh. Patagonia Mtns, Arizona

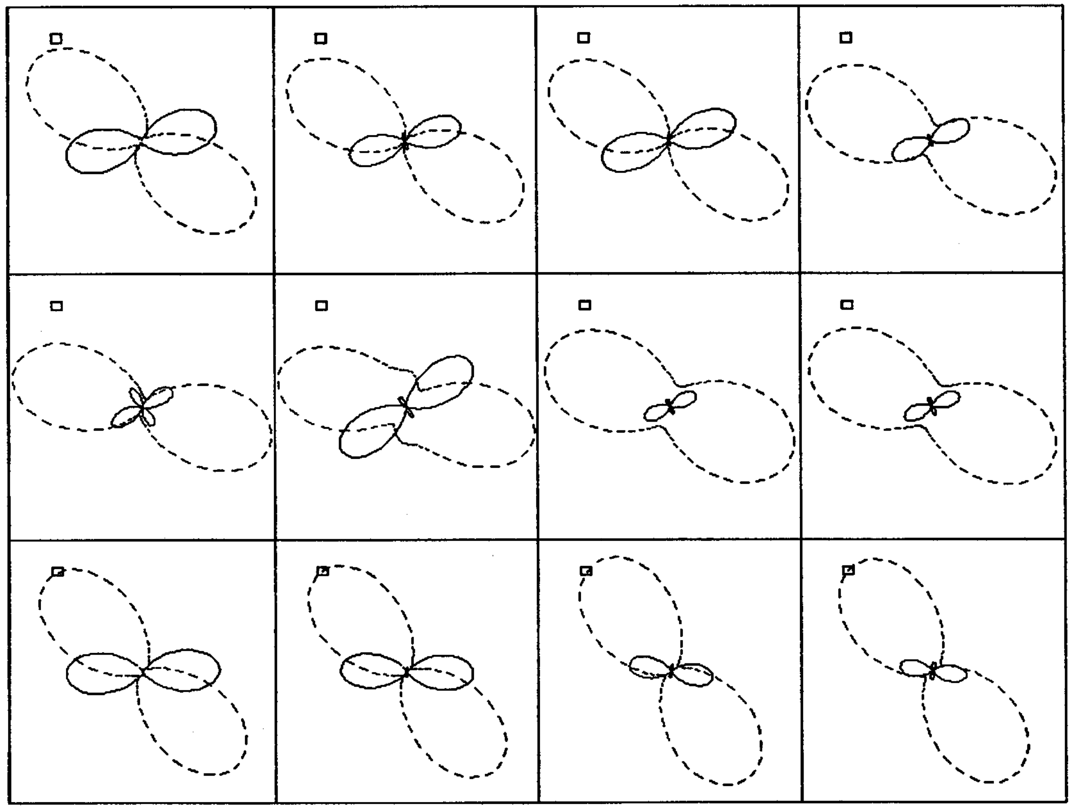


Client: Mineral Resources Program
Remote: none
Acquired: 11:2 May 02, 2008
Survey Co:USGS

Rotation:
Filename: sp05m1b.avg
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Plotted: 21:43 Sep 27, 2008
< EMI – ElectroMagnetic Instruments >

Station 05

POLAR PLOTS Patagonia Mtns, Arizona



.0088 Hz	.0244 Hz	.0566 Hz	.120 Hz
.172 Hz	.381 Hz	.830 Hz	1.719 Hz
2.930 Hz	4.883 Hz	16.602 Hz	34.375 Hz

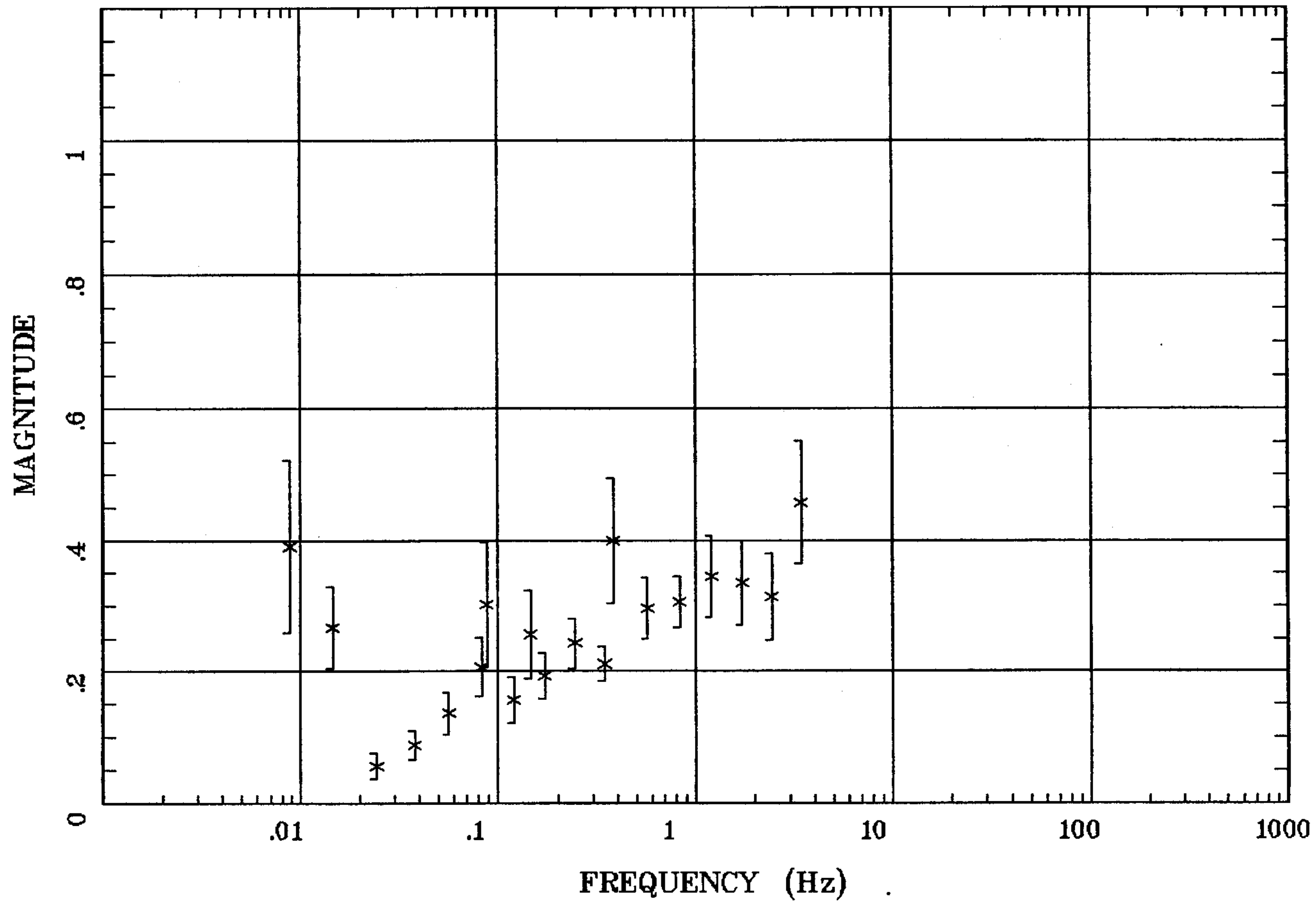
Client: Mineral Resources Program
Remote: none
Acquired: 11:2 May 02, 2008
Survey Co:USGS

Rotation:
Filename: sp05m1b.avg
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Plotted: 21:43 Sep 27, 2008
< EMI – ElectroMagnetic Instruments >

Station 05

TIPPER MAGNITUDE

Patagonia Mtns, Arizona

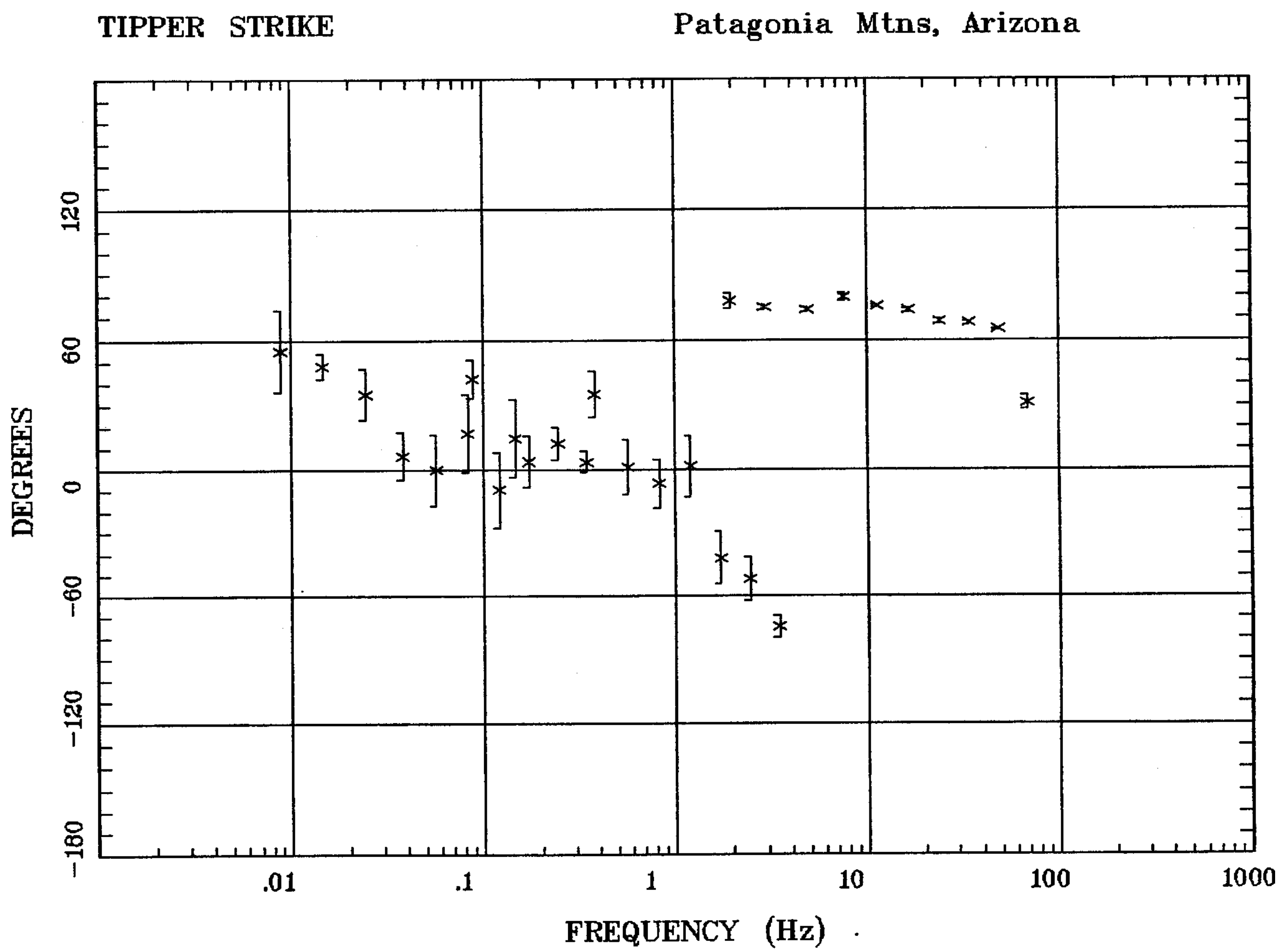


Rotation:

Client: Mineral Resources Program
Remote: none
Acquired: 11:2 May 02, 2008
Survey Co:USGS

Filename: sp05m1b.avg
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Plotted: 21:43 Sep 27, 2008
< EMI – ElectroMagnetic Instruments >

Station 05



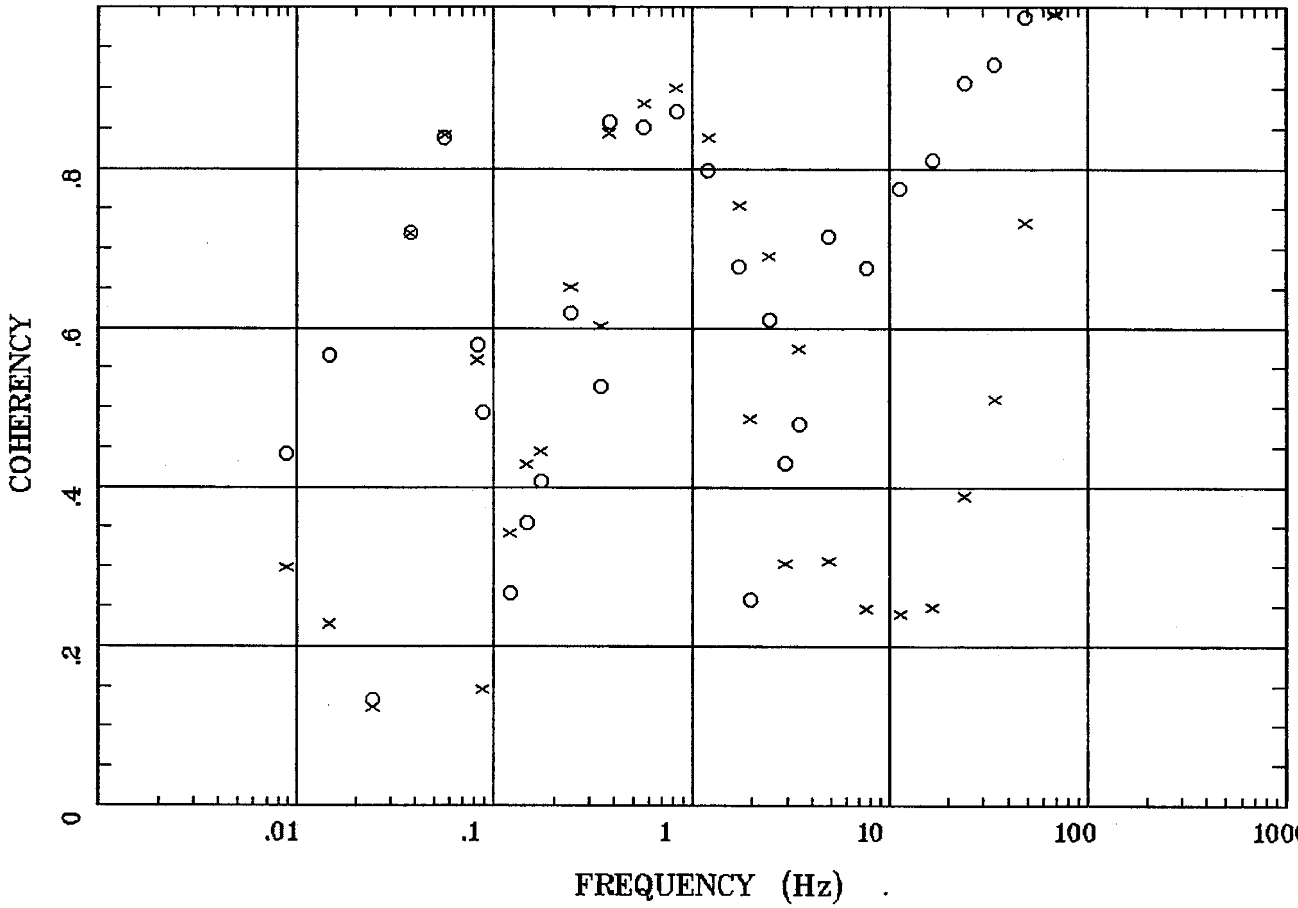
Client: Mineral Resources Program
Remote: none
Acquired: 11:2 May 02, 2008
Survey Co:USGS

Rotation:
Filename: sp05m1b.avg
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Plotted: 21:43 Sep 27, 2008
< EMI – ElectroMagnetic Instruments >

Station 05

HzHx.x Coh HzHy.o

Patagonia Mtns, Arizona



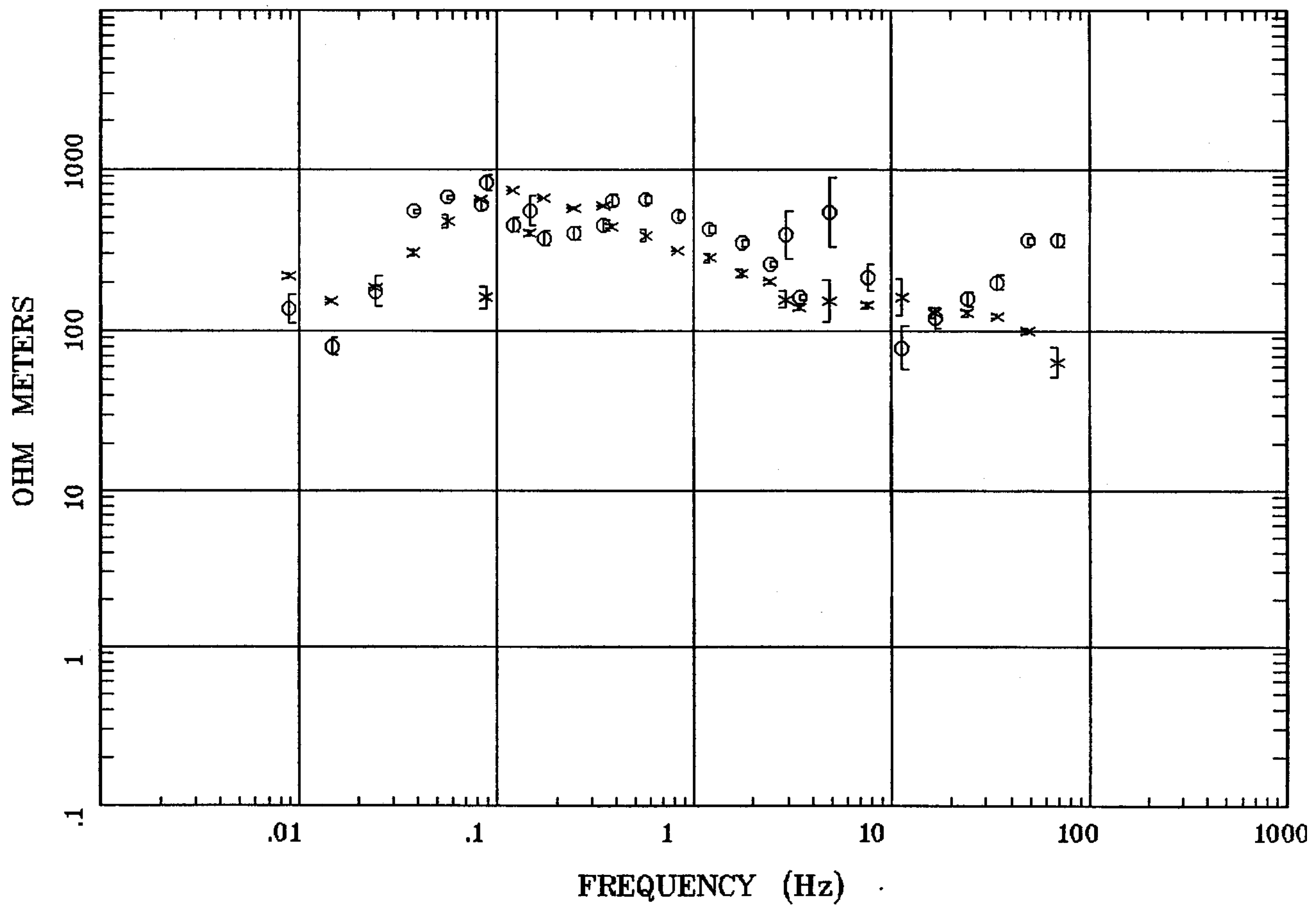
Rotation:

Client: Mineral Resources Program
Remote: none
Acquired: 11:2 May 02, 2008
Survey Co:USGS

Filename: sp05m1b.avg
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Plotted: 21:43 Sep 27, 2008
< EMI – ElectroMagnetic Instruments >

Station 06

APPARENT RESISTIVITY Patagonia Mtns, Arizona

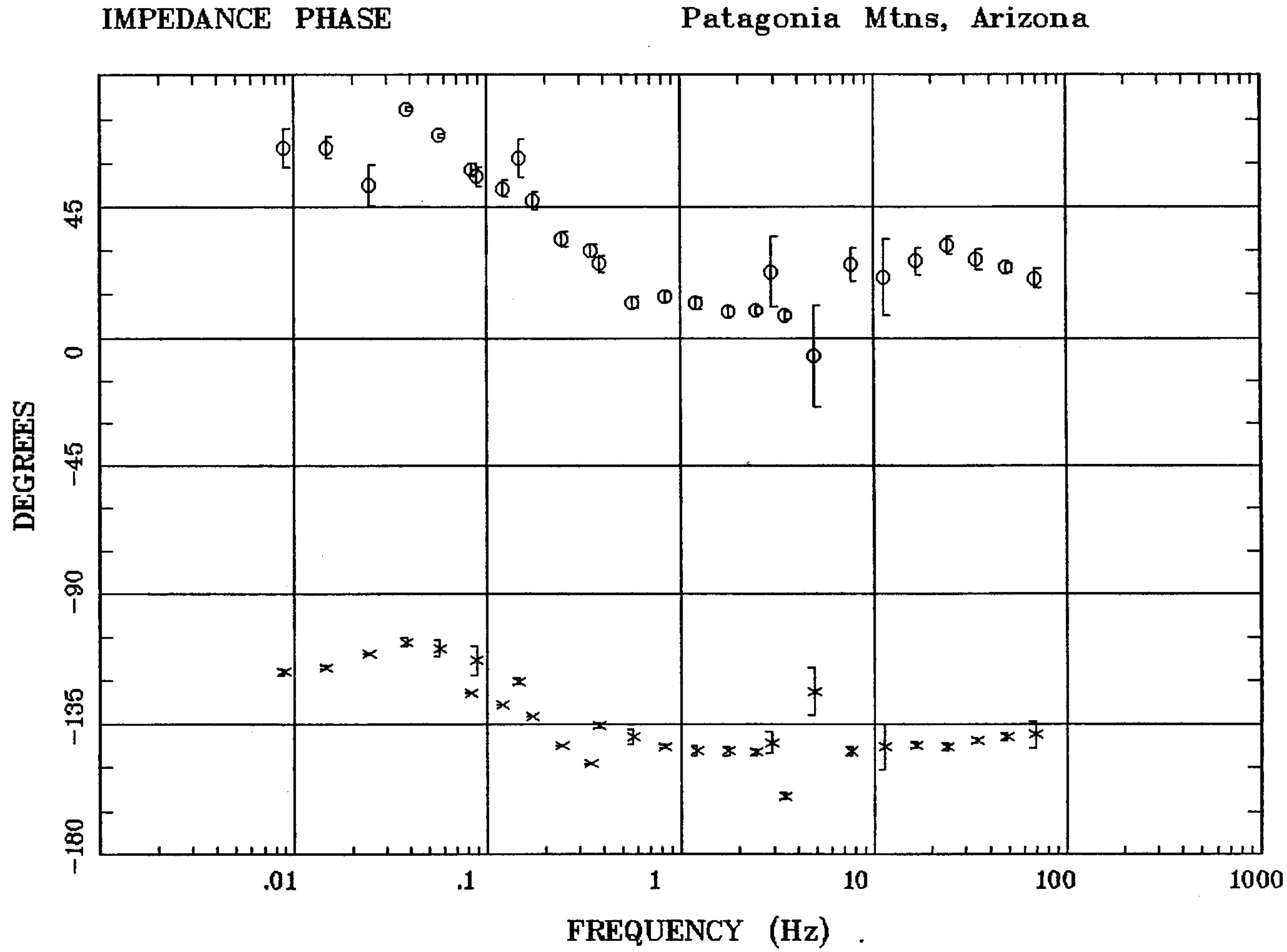


Rotation:

Client: Mineral Resources Program
Remote: none
Acquired: 15:1 May 02, 2008
Survey Co:USGS

Filename: sp06m2.avg
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Plotted: 21:34 Sep 27, 2008
< EMI – ElectroMagnetic Instruments >

Station 06



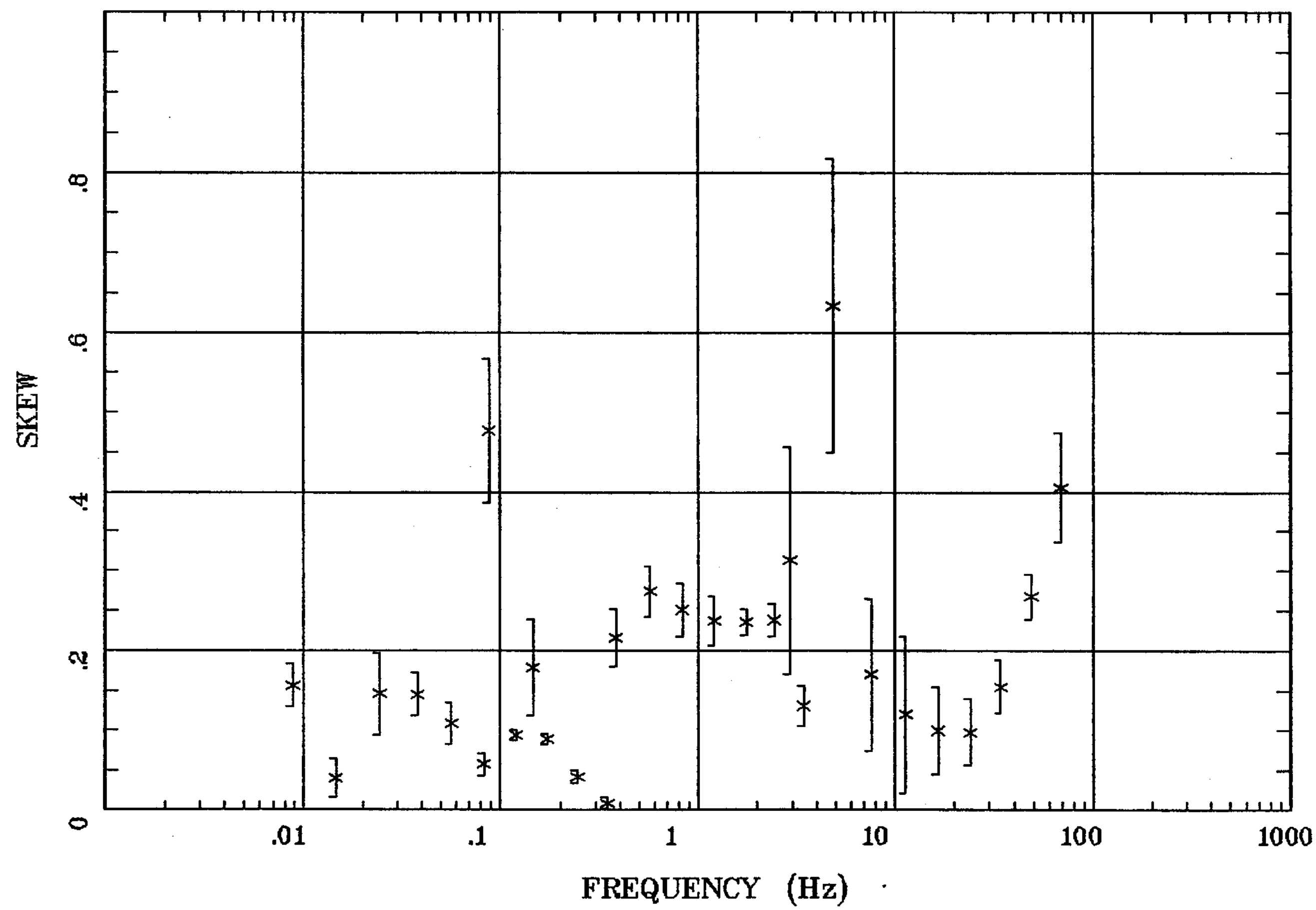
Client: Mineral Resources Program
Remote: none
Acquired: 15:1 May 02, 2008
Survey Co:USGS

Rotation:
Filename: sp06m2.avg
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Plotted: 21:34 Sep 27, 2008
< EMI – ElectroMagnetic Instruments >

Station 06

IMPEDANCE SKEW

Patagonia Mtns, Arizona



Rotation:

Client: Mineral Resources Program

Filename: sp06m2.avg

Remote: none

Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4

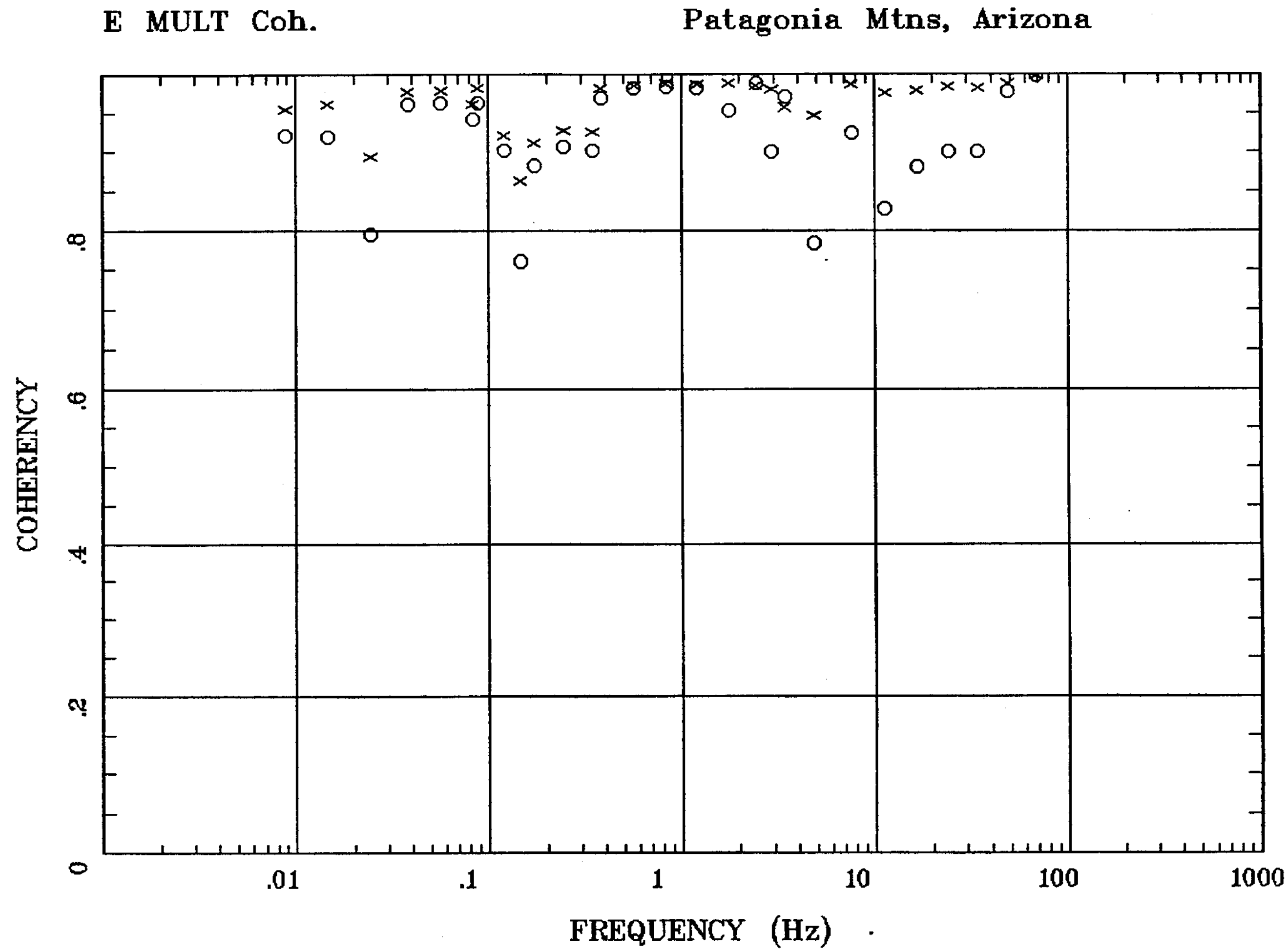
Acquired: 15:1 May 02, 2008

Plotted: 21:34 Sep 27, 2008

Survey Co:USGS

< EMI – ElectroMagnetic Instruments >

Station 06

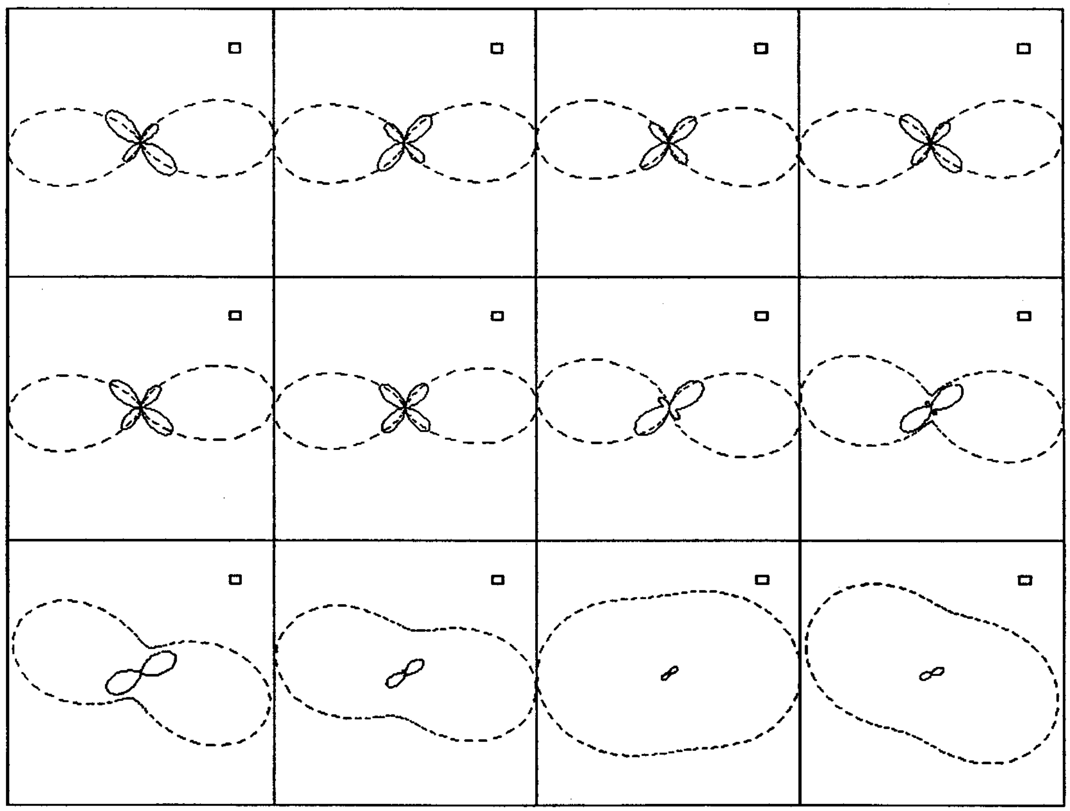


Client: Mineral Resources Program
Remote: none
Acquired: 15:1 May 02, 2008
Survey Co:USGS

Rotation:
Filename: sp06m2.avg
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Plotted: 21:34 Sep 27, 2008
< EMI – ElectroMagnetic Instruments >

Station 06

POLAR PLOTS — Patagonia Mtns, Arizona



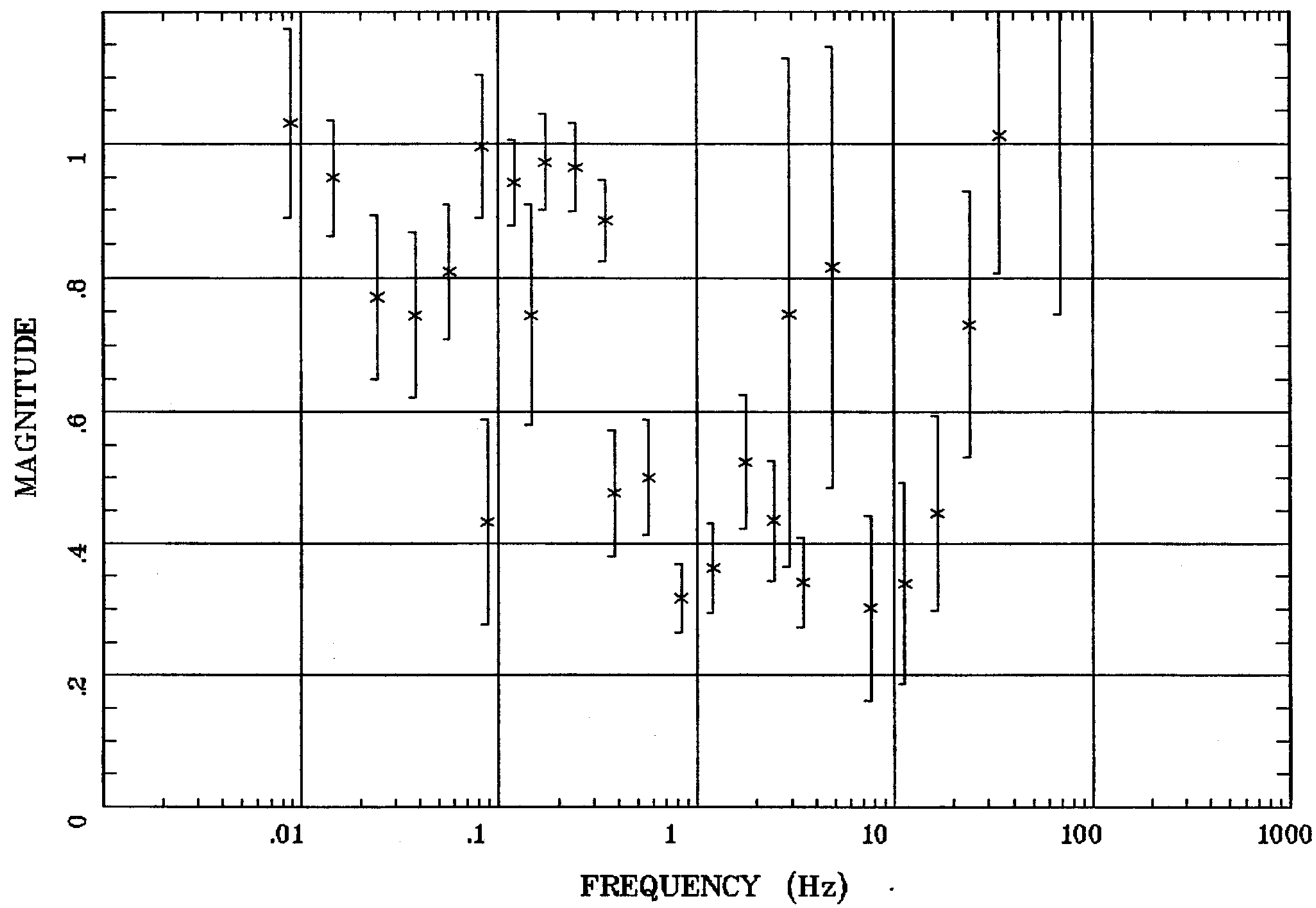
.0088 Hz	.0244 Hz	.0566 Hz	.120 Hz
.172 Hz	.345 Hz	.566 Hz	1.758 Hz
2.930 Hz	7.617 Hz	16.602 Hz	34.375 Hz

Client: Mineral Resources Program
Remote: none
Acquired: 15:1 May 02, 2008
Survey Co:USGS

Rotation:
Filename: sp06m2.avg
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Plotted: 21:35 Sep 27, 2008
< EMI – ElectroMagnetic Instruments >

Station 06

TIPPER MAGNITUDE Patagonia Mtns, Arizona

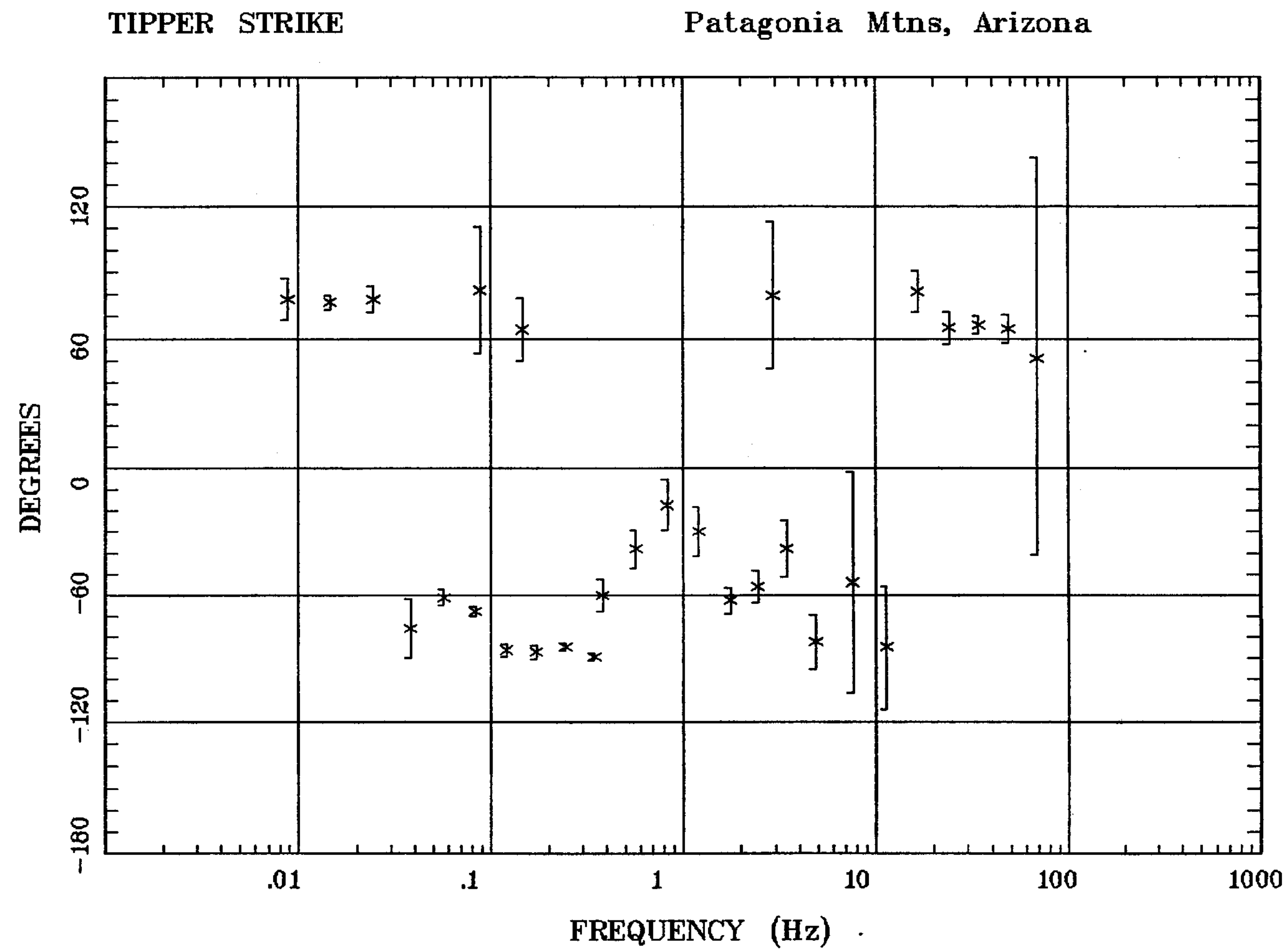


Rotation:

Client: Mineral Resources Program
Remote: none
Acquired: 15:1 May 02, 2008
Survey Co:USGS

Filename: sp06m2.avg
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Plotted: 21:35 Sep 27, 2008
< EMI – ElectroMagnetic Instruments >

Station 06

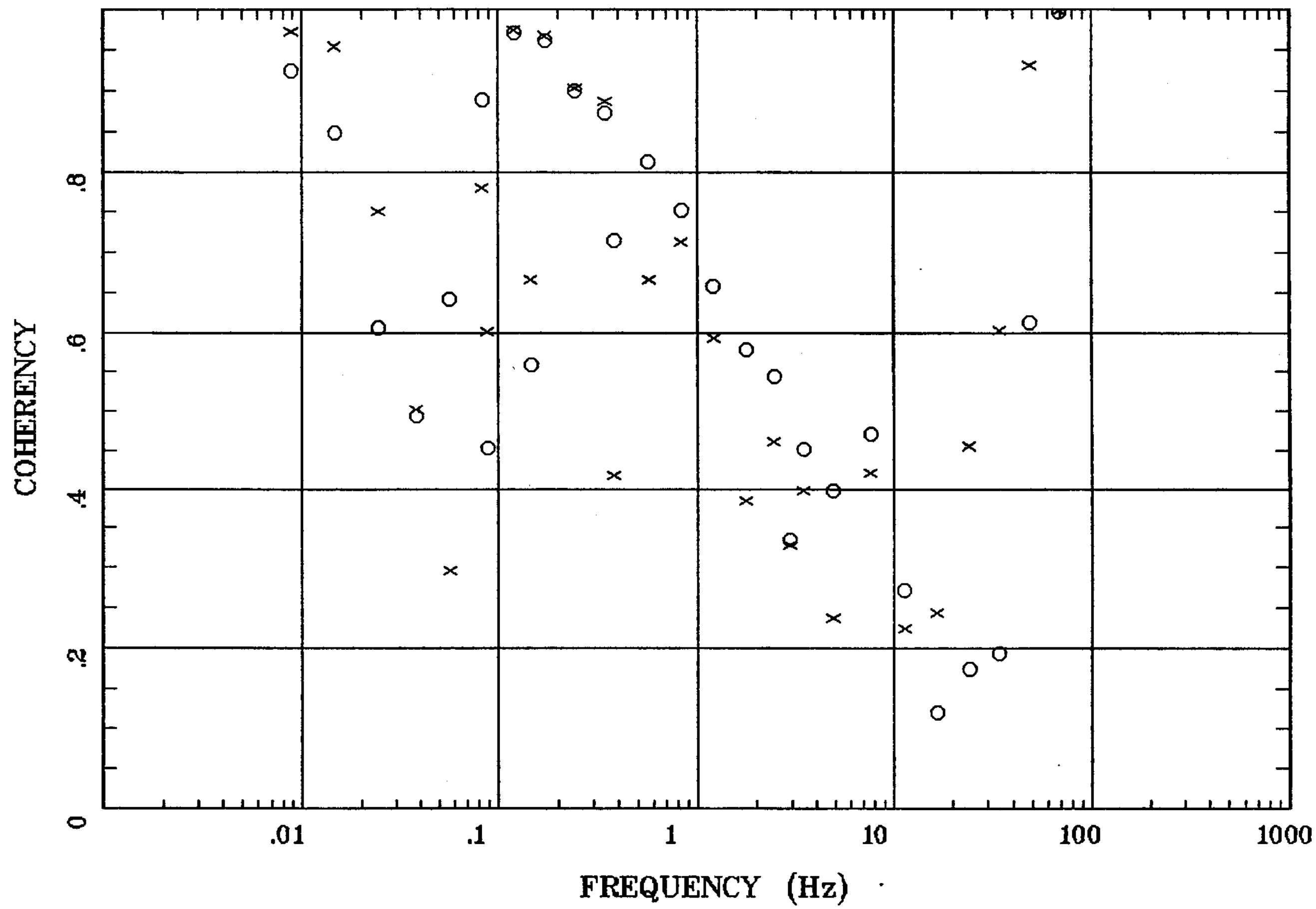


Client: Mineral Resources Program
Remote: none
Acquired: 15:1 May 02, 2008
Survey Co:USGS

Rotation:
Filename: sp06m2.avg
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Plotted: 21:35 Sep 27, 2008
< EMI – ElectroMagnetic Instruments >

Station 06

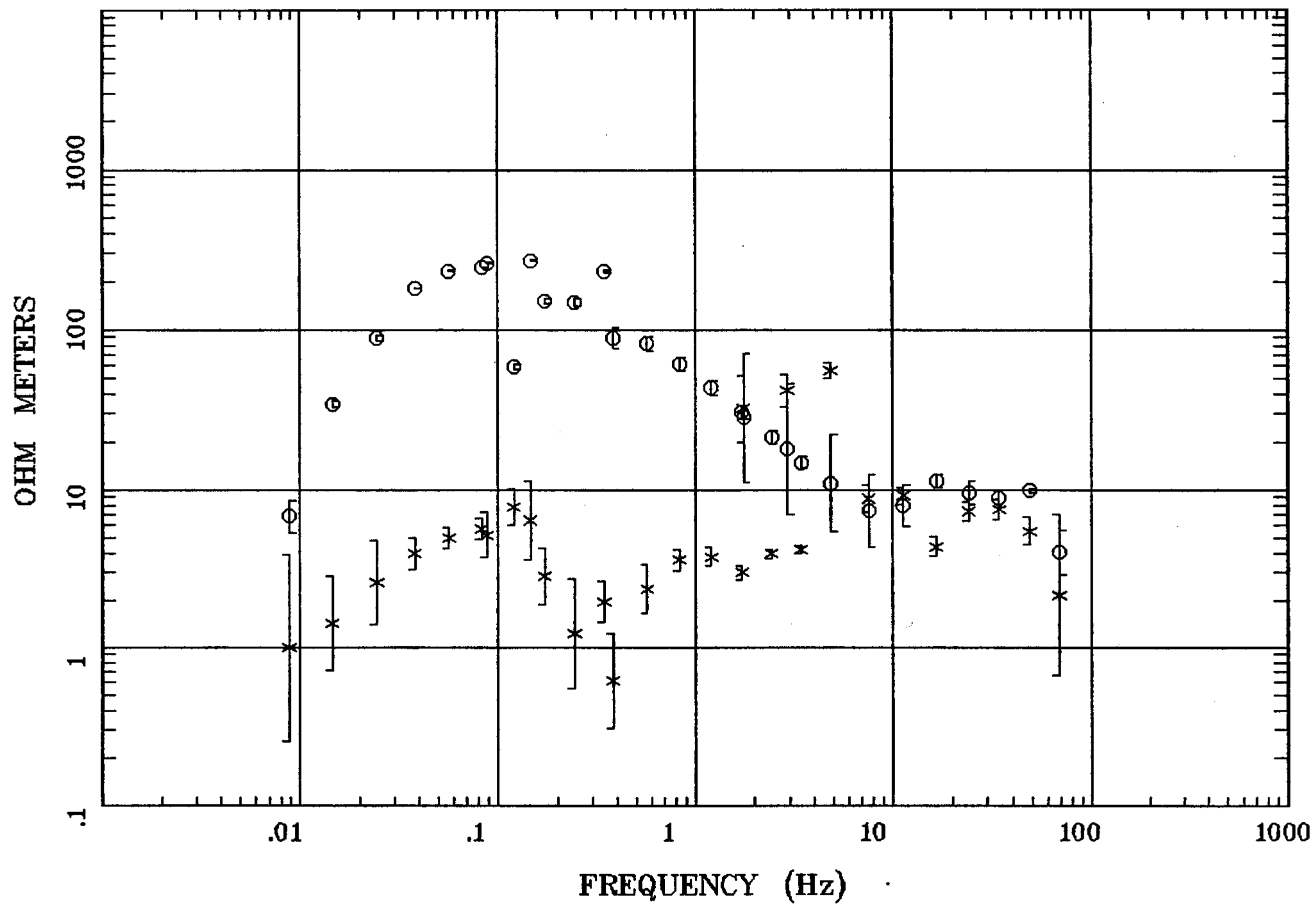
HzHx.x Coh HzHy.o Patagonia Mtns, Arizona



Rotation:
Client: Mineral Resources Program
Filename: sp06m2.avg
Remote: none
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Acquired: 15:1 May 02, 2008
Plotted: 21:35 Sep 27, 2008
Survey Co:USGS
< EMI – ElectroMagnetic Instruments >

Station 07

APPARENT RESISTIVITY Patagonia Mtns, Arizona

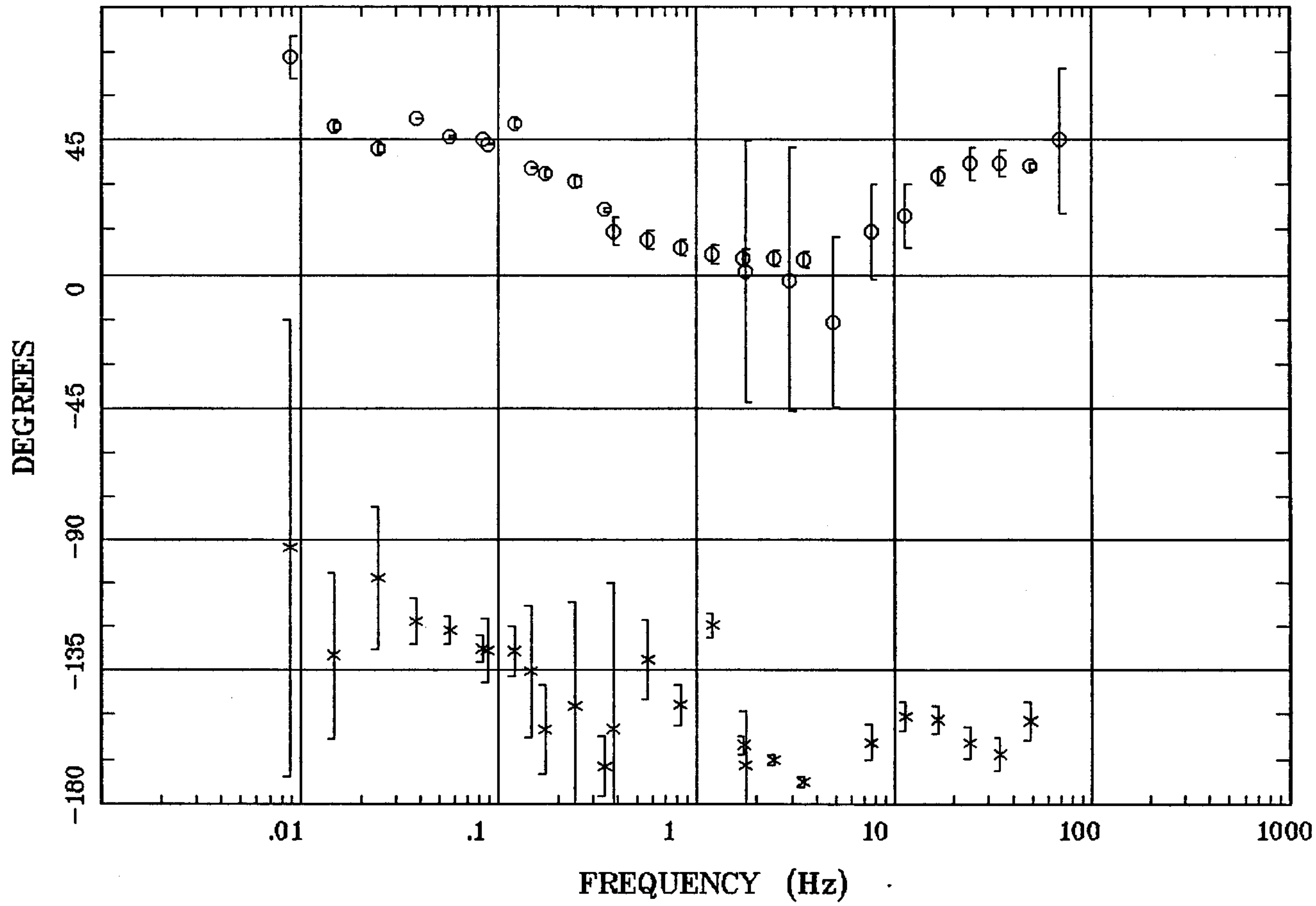


Client: Mineral Resources Program
Remote: none
Acquired: 10:3 May 03, 2008
Survey Co:USGS

Rotation:
Filename: sp07mall.avg
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Plotted: 21:42 Sep 27, 2008
< EMI – ElectroMagnetic Instruments >

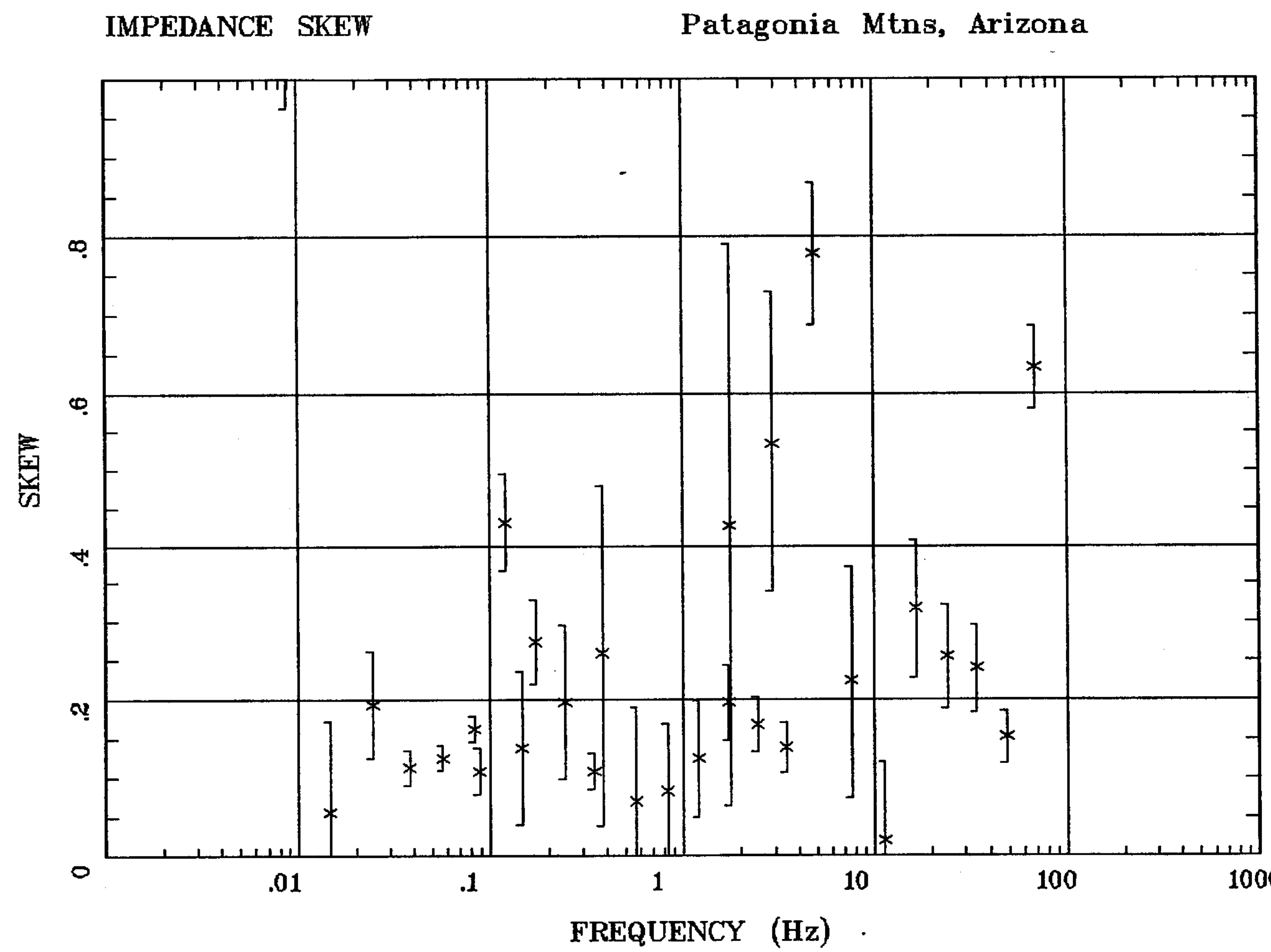
Station 07

IMPEDANCE PHASE Patagonia Mtns, Arizona



Rotation:
Client: Mineral Resources Program
Filename: sp07mall.avg
Remote: none
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Acquired: 10:3 May 03, 2008
Plotted: 21:42 Sep 27, 2008
Survey Co:USGS
< EMI – ElectroMagnetic Instruments >

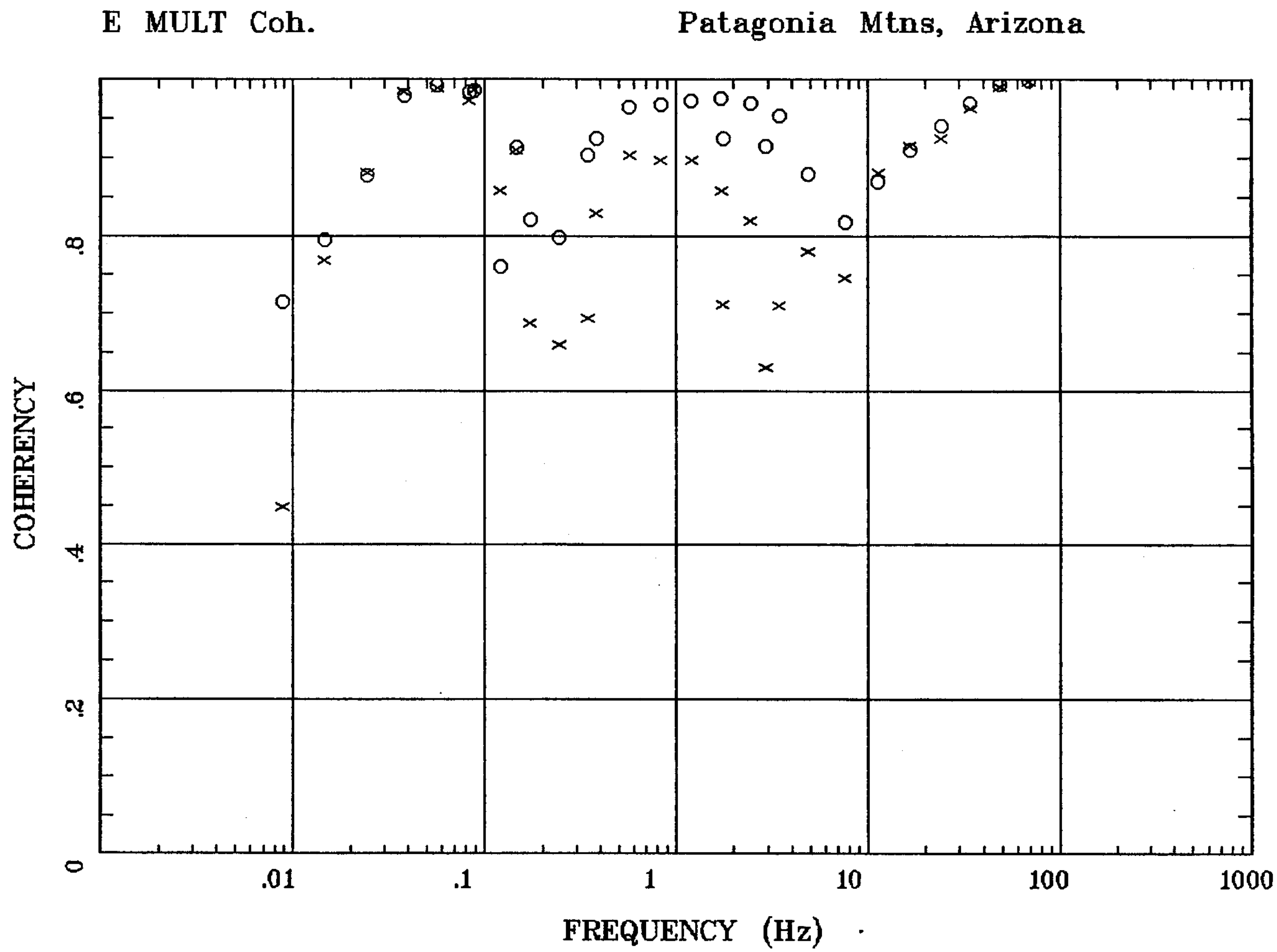
Station 07



Client: Mineral Resources Program
Remote: none
Acquired: 10:3 May 03, 2008
Survey Co:USGS

Rotation:
Filename: sp07mall.avg
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Plotted: 21:42 Sep 27, 2008
< EMI – ElectroMagnetic Instruments >

Station 07

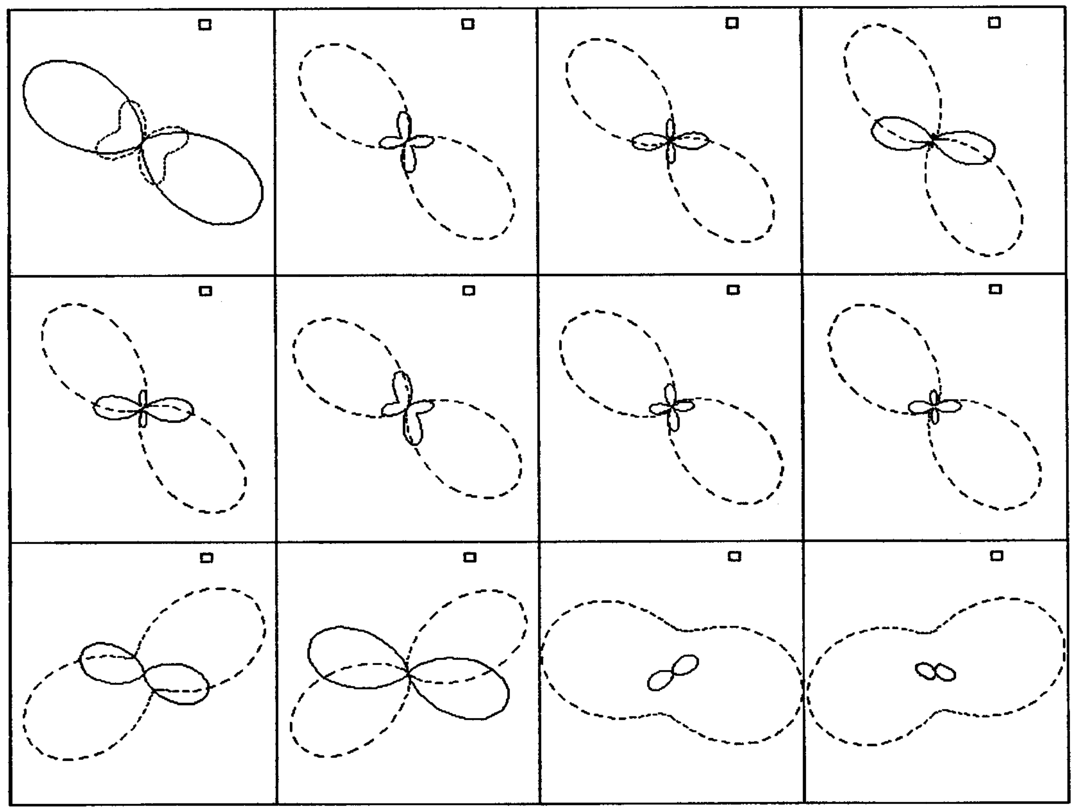


Client: Mineral Resources Program
Remote: none
Acquired: 10:3 May 03, 2008
Survey Co:USGS

Rotation:
Filename: sp07mall.avg
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Plotted: 21:42 Sep 27, 2008
< EMI – ElectroMagnetic Instruments >

Station 07

POLAR PLOTS Patagonia Mtns, Arizona



.0088 Hz	.0244 Hz	.0566 Hz	.120 Hz
.172 Hz	.381 Hz	.830 Hz	1.719 Hz
2.930 Hz	4.883 Hz	16.602 Hz	34.375 Hz

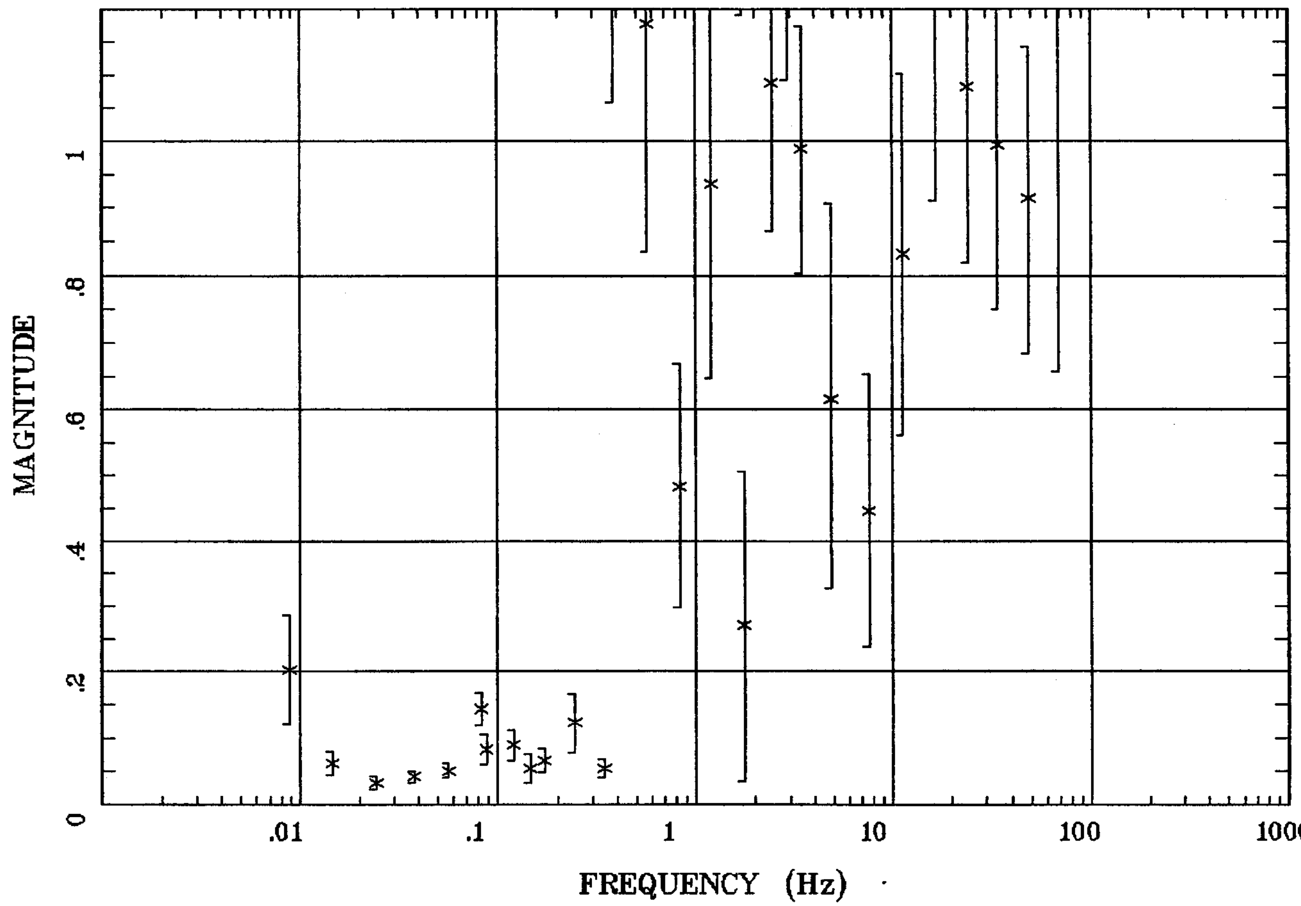
Rotation:

Client: Mineral Resources Program
Remote: none
Acquired: 10:3 May 03, 2008
Survey Co:USGS

Filename: sp07mall.avg
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Plotted: 21:42 Sep 27, 2008
< EMI – ElectroMagnetic Instruments >

Station 07

TIPPER MAGNITUDE Patagonia Mtns, Arizona



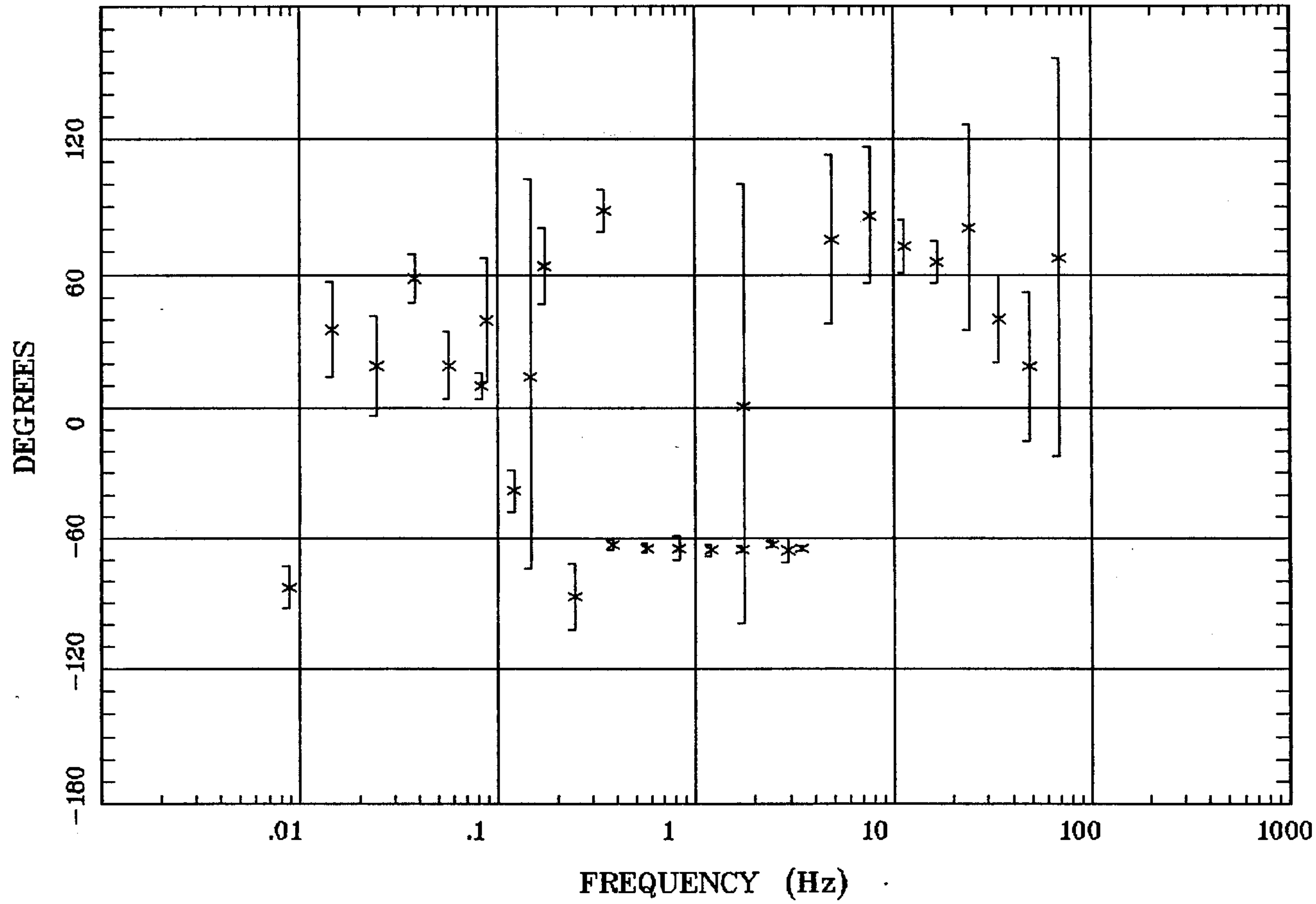
Client: Mineral Resources Program
Remote: none
Acquired: 10:3 May 03, 2008
Survey Co:USGS

Rotation:
Filename: sp07mall.avg
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Plotted: 21:42 Sep 27, 2008
< EMI – ElectroMagnetic Instruments >

Station 07

TIPPER STRIKE

Patagonia Mtns, Arizona

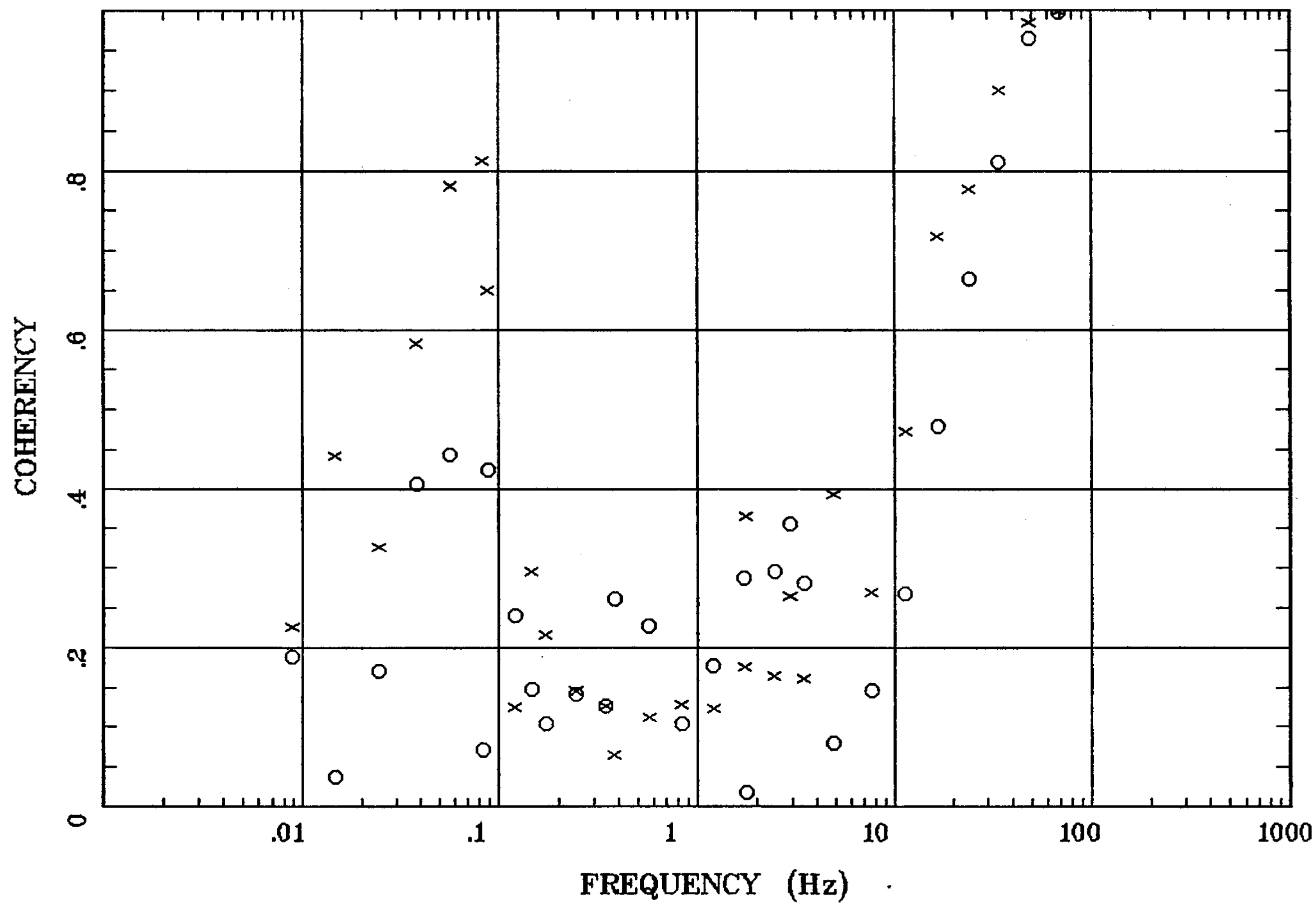


Client: Mineral Resources Program
Remote: none
Acquired: 10:3 May 03, 2008
Survey Co:USGS

Rotation:
Filename: sp07mall.avg
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Plotted: 21:42 Sep 27, 2008
< EMI - ElectroMagnetic Instruments >

Station 07

HzHx.x Coh HzHy.o Patagonia Mtns, Arizona



Rotation:
Client: Mineral Resources Program
Filename: sp07mall.avg
Remote: none
Channels: Ch1 Ch2 Ch3 Ch4 Ch5 Ch3 Ch4
Acquired: 10:3 May 03, 2008
Plotted: 21:42 Sep 27, 2008
Survey Co:USGS
< EMI - ElectroMagnetic Instruments >