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Electrical conductivity mechanism of sericite schist from Gold Lake area of the Yellowknife mining district, Northwest Territories[1]

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Abstract: The electrical conductivity mechanisms have been determined for six mineralized sericite schist specimens cut from a large sample collected from the Gold Lake area of the Yellowknife mining district, Northwest Territories. This work consists of analysis and interpretation of 3-D electrical resistivity measurements. The sample was selected to characterize the resistivity of the alteration zone and determine the effect of crosscutting veins and the sections of fine-grained sulphides oriented parallel to foliation. The purpose of this paper is to document results of the electrical resistivity determinations obtained to assist interpretation of electromagnetic surveys currently being conducted in the area. The bulk electrical resistivities (ρ_r) of the six specimens investigated in this study are in the range of 5.9–140 Ω·m with anisotropy values ranging from 3:1 to 7:1. The arsenopyrite-filled fractures showed the lowest ρ_r values (5.9–17 Ω·m).

Résumé : On a déterminé les mécanismes de la conductivité électrique dans six spécimens de schiste à séricite minéralisé extraits d'un gros échantillon recueilli dans la région du lac Gold, dans le district minier de Yellowknife (Territoires du Nord-Ouest). Le travail consistait à analyser et à interpréter les mesures de la résistivité électrique en trois dimensions. L'échantillon a été choisi de manière à pouvoir représenter la résistivité de la zone d'altération ainsi qu'à permettre de déterminer les effets sur la résistivité de veines discordantes et d'intervalles de sulfures à grain fin parallèles à la foliation. Ce document présente les résultats des analyses de résistivité électrique obtenus dans le but de faciliter l'interprétation des levés électromagnétiques que l'on effectue présentement dans la région. Les six spécimens analysés dans le cadre de cette étude présentent tous une valeur de la résistivité électrique apparente (ρ_r) comprise entre 5,9 et 140 Ω·m et des valeurs d'anisotropie s'échelonnant entre 3/1 et 7/1. Les fractures à remplissage d'arsénopyrite présentaient les plus basses valeurs de ρ_r (de 5,9 à 17 Ω·m).

[1] Contribution to the 2000-2001 Yellowknife Mining District, Northwest Territories Exploration Science and Technology (EXTECH-III) Initiative.

INTRODUCTION

The electrical conductivity mechanisms have been determined for six mineralized sericite schist specimens cut from a single sample collected from the Gold Lake area of the Yellowknife mining district, Northwest Territories. This work consists of analysis and interpretation of data obtained by 3-D electrical resistivity measurements and follows similar work previously performed on mineralized and nonmineralized sericitic schist samples (Connell et al., 2000). The sample was selected to characterize the resistivity of the alteration zone and determine the effect of crosscutting veins and of fine-grained sulphide minerals oriented parallel to foliation. The purpose of this paper is to document, within the framework of the Yellowknife EXTECH-III, results of the electrical resistivity determinations for use in interpreting ground electromagnetic surveys that are currently being conducted in the area.

METHOD OF INVESTIGATION

Six specimens and subspecimens (MWA-4AA, MWA-4AB, MWA-4BB, MWA-4BC, MWA-4CA, and MWA-4CB) were cut from a single slab of highly deformed and/or altered sericite schist rock, sample MWA-4 (Fig. 1). The sample was collected by John Kerswill (Geological Survey of Canada, Ottawa) to obtain a better understanding of the electrical resistivity anisotropic characteristics of this rock type for application to exploration by electromagnetic methods in the Yellowknife mining district. Further information on the specimens are listed in Table 1.

Each specimen was cut with surfaces parallel and perpendicular to foliation. Detailed visual examinations were performed on these specimens and the key structural features recorded as shown in the block diagrams of Figures 2–4. Detailed description of the laboratory 3-D electrical measurements and procedures can be found elsewhere (Scromeda et al., 2000).

ANALYTICAL RESULTS AND INTERPRETATION

Results of the visual examinations for the six rectangular specimens and subspecimens representing the rock slab are shown as block diagrams in Figures 2–4, with the complex resistivity plots shown for each of the directions measured. The results of the 3-D electrical resistivity measurements are compiled in Tables 2, 3, 4, and 5. The electrical resistivities (ρ_r) are in the ranges of 5.92–140.5 Ω·m (Table 1). Electrical anisotropy (λ) values range from 3:1 to 7:1, with the larger values generally in the direction perpendicular to foliation and the smaller values parallel to foliation. Each of the specimens and subspecimens measured are strongly foliated, having been sampled from an area of high deformation. Each specimen and subspecimen was selected to isolate a particular vein or foliation to help characterize the various features of the alteration zone.

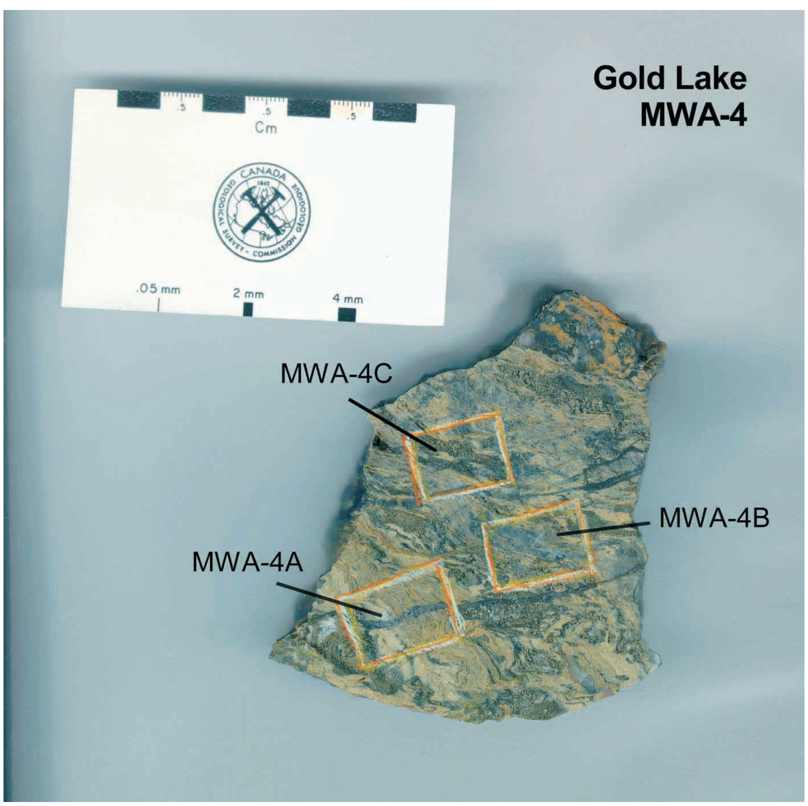

Figure 1.

Photograph of sericite schist sample MWA-4, collected from the Gold Lake area. The locations of the specimens cut from the slab are indicated as MWA-4A, MWA-4B, and MWA-4C.

Each of the specimens and subspecimens have somewhat similar descriptions and mineralogy, having been cut from the same rock slab. The overall mineralogy includes quartz, sericite, pyrite, and arsenopyrite with minor carbonate, apatite, rutile, and possible sulphosalt minerals. The sulphide content is high (10–20%) with patches of fine-grained pyrite oriented parallel to foliation. Some veins of quartz and arsenopyrite crosscut the dominant foliation. The only variation between specimens are the sulphide content and abundance of vein or other special features which were selected for characterization by the measurements (Fig. 1).

Specimen MWA-4A (Fig. 2) was selected to isolate a vein of arsenopyrite which crosscuts the dominant foliation. Subspecimen MWA-4AA isolates this vein and was measured in three directions. The low resistivity values in the direction parallel to the vein (β- and γ-directions) indicates a

Table 1. Rock descriptions and mean bulk electrical resistivity values for sericite schist samples collected from the Gold Lake area, Yellowknife, Northwest Territories.

Specimen number	Special features and comments	Mean ρ_r, (Ω.m)			Anisotropy (λ)
		α	β	γ	
MWA-4AA MWA-4AB	Arsenopyrite vein crosscutting dominant foliation	39.75 ± 6.05 9.8 ± 2.2	5.92 ± 1.36	16.5 ± 0.6	7:1
MWA-4BB MWA-4BC	Siliceous vein parallel to dominant foliation	59.4 ± 6.1	 140.5 ± 16.5		
MWA-4CA MWA-4CB	Sulphide vein parallel to foliation	30.05 ± 8.75	10.55 ± 0.55 23.25 ± 1.55	19.65 ± 5.75	3:1

ρ_r, λ = electrical resistivity and anisotropy values obtained from previously published work (Scromeda et al., 2000).
α-direction = direction measured perpendicular to vein or foliation.
β- and γ-direction = direction measured parallel to foliation.

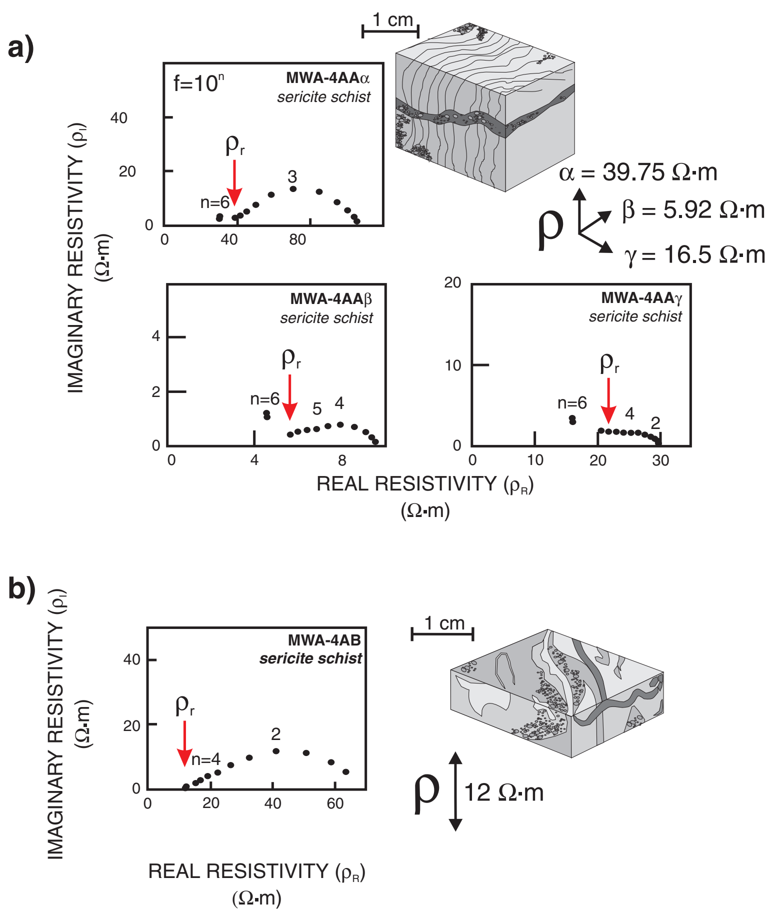

Figure 2.

Schematic presentation of a sericite schist specimen MWA-4A represented by ***a)*** *a block diagram of subspecimen MWA-4AA with sketches of the rock texture and 3-D electrical resistivity (ρ_r) values shown below (argon plots are displayed for surfaces perpendicular to the α-, β-, and γ-directions). Schematic presentation of subspecimen MWA-4AB represented by* ***b)*** *a block diagram and ρ_r value is shown below with an argon plot displayed of the direction measured.*

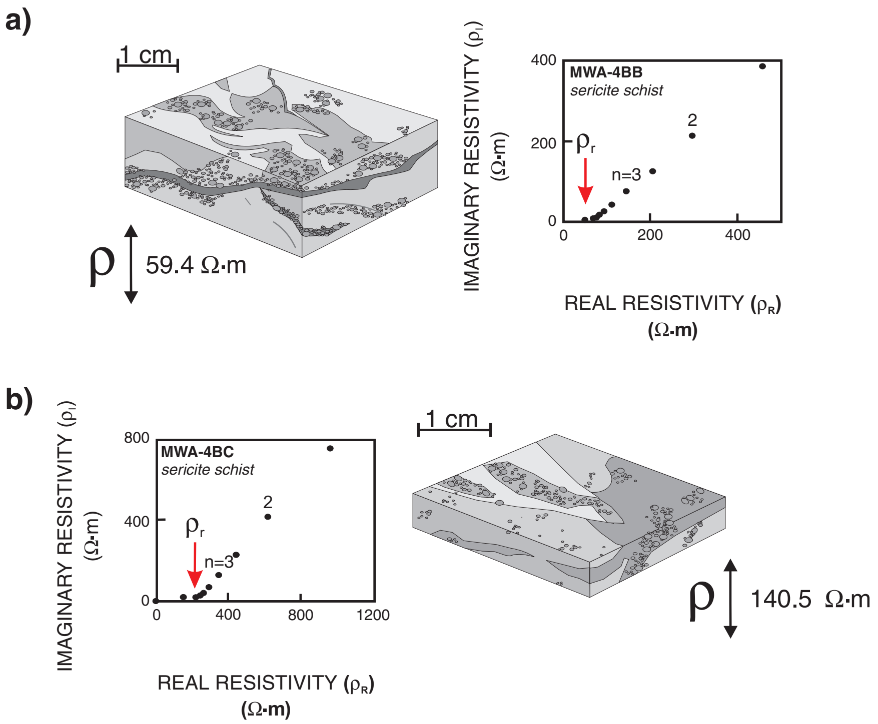

Figure 3.

*Schematic presentation of a sericite schist specimen MWA-4B represented by **a)** a block diagram of subspecimen MWA-4BB with sketches of the rock texture and electrical resistivity (ρ_r) value shown below, and an argon plot displayed for the surfaces measured. Schematic presentation of subspecimen MWA-4BC represented by **b)** a block diagram and a ρ_r value is shown below with an argon plot displayed of the direction measured.*

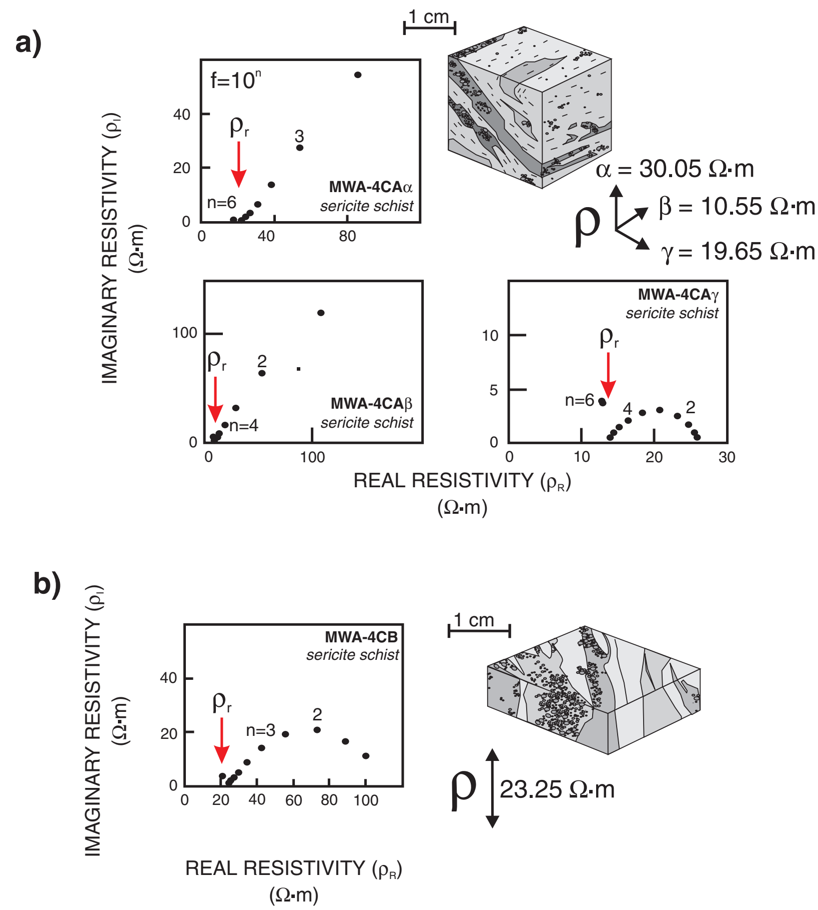

Figure 4.

*Schematic presentation of a sericite schist specimen MWA-4C (Gold Lake) represented by **a)** a block diagram of subspecimen MWA-4CA with sketches of the rock texture and 3-D electrical resistivity (ρ_r) values shown below (argon plots are displayed for surfaces perpendicular to the α-, β-, and γ-directions). Schematic presentation of subspecimen MWA-4CB represented by **b)** a block diagram and $_r$ value is shown below with an argon plot displayed for the direction measured.*

good connection between the arsenopyrite grains. The ρ_r values are not as high as expected for the direction perpendicular to the vein as a result of the dominant foliation extending in that direction. The smaller ρ_r value (5.92 Ω·m) in the β-direction could be because it is parallel to the vein as well as the foliation. The 24 hour saturation argon plots have produced complete arcs for each of the directions measured. Subspecimen MWA-4AB was selected to represent the adjacent area without the vein.

Specimen MWA-4B (Fig. 3) was selected to isolate a siliceous vein. Subspecimen MWA-4BA, which does isolate the vein, has not yet been measured. Subspecimen MWA-4BB has isolated an arsenopyrite vein similar to that of MWA-4AA; however, this vein does not appear to be as continuous as the vein in subspecimen MWA-4AA. This could explain the slightly larger ρ_r value (59.4 Ω·m). Subspecimen MWA-4BC (Fig. 3b) is more siliceous and lacks a sulphide vein. The large ρ_r value (140.5 Ω·m) is likely a result of the high quartz content. Whereas the sulphide content is still high, there may be poor connection between the grains. Further investigation is necessary to determine if this is the case. The argon plots (Fig. 3a, b) have produced larger partial arcs for both the subspecimens measured.

Specimen MWA-4C (Fig. 4) was selected to isolate a more pyritic vein which runs parallel with the dominant foliation. Subspecimen MWA-4CA was measured in three directions, with the largest ρ_r value in the direction perpendicular to the vein and foliation, as would be expected. The sulphide grains in this vein do not appear to be as well interconnected as those of the arsenopyrite vein in subspecimen MWA-4AA, since the ρ_r values parallel to the vein are slightly larger. The

Table 2. Results of the 3-D (α-, β-, and γ- directions) electrical resistivity measurements (24 hour saturation) for mineralized rock specimens. Note: the ρ_r (bulk electrical resistivity) values in bold text are those taken as the representative ρ_r value.

Sample Identification	Frequency (Hz)	Real resistivity ρ_r (Ω.m)	Imaginary resistivity ρ_I (Ω.m)
MWA-4AAα	1	84.7	3.40
K_G: 1.98x10^{-2}	3.16	84.8	5.52
	10	79.9	8.94
	3.16x10^1	71.4	12.6
	10^2	60.0	13.7
	3.16x10^2	49.6	11.2
	10^3	42.8	7.77
	3.16x10^3	38.5	5.15
	10^4	35.8	3.62
	3.16x10^4	**33.7**	2.95
	10^5	26.4	3.32
	3.16x10^5	26.3	3.13
	10^6	26.2	3.01
MWA-4AAβ	1	9.51	0.17
K_G: 2.03x10^{-2}	3.16	9.37	0.31
	10	9.08	0.52
	3.16x10^1	8.59	0.72
	10^2	7.96	0.80
	3.16x10^2	7.36	0.73
	10^3	6.86	0.65
	3.16x10^3	6.40	0.60
	10^4	5.98	0.51
	3.16x10^4	5.64	0.41
	10^5	4.56	1.16
	3.16x10^5	**4.56**	1.14
	10^6	4.57	1.18
MWA-4AAγ	1	29.6	0.50
K_G: 1.09x10^{-2}	3.16	29.1	0.75
	10	28.5	1.04
	3.16x10^1	27.5	1.31
	10^2	26.5	1.50
	3.16x10^2	25.3	1.55
	10^3	24.1	1.57
	3.16x10^3	23.0	1.62
	10^4	21.8	1.69
	3.16x10^4	20.5	1.74
	10^5	15.9	3.04
	3.16x10^5	**15.9**	2.95
	10^6	16.0	3.00

Table 3. Results of the electrical resistivity measurements (24 hour saturation) for mineralized rock specimens. Note: the ρ_r values in bold text are those taken as the representative ρ_r value.

Sample Identification	Frequency (Hz)	Real resistivity ρ_r (Ω·m)	Imaginary resistivity ρ_I (Ω·m)
MWA-4AB	1	63.7	5.28
K_G: 4.18x10^{-2}	3.16	58.9	8.52
	10	50.9	11.4
	3.16x10^1	41.1	11.7
	10^2	32.7	9.71
	3.16x10^2	26.5	7.24
	10^3	22.3	5.29
	3.16x10^3	19.2	3.93
	10^4	16.8	2.82
	3.16x10^4	15.2	1.91
	10^5	12.2	0.72
	3.16x10^5	12.2	0.58
	10^6	**12.0**	0.35
MWA-4BB	1	459	386
K_G: 5.91x10^{-2}	3.16	298	212
	10	206	124
	3.16x10^1	147	73.6
	10^2	113	41.9
	3.16x10^2	95.2	23.6
	10^3	84.8	14.1
	3.16x10^3	78.1	9.13
	10^4	73.4	6.52
	3.16x10^4	69.9	5.58
	10^5	**53.3**	1.58
	3.16x10^5	53.0	2.22
	10^6	51.2	2.33
MWA-4BC	1	-	-
K_G: 1.49x10^{-1}	3.16	961	750
	10	623	415
	3.16x10^1	446	229
	10^2	348	126
	3.16x10^2	296	69.1
	10^3	267	40.2
	3.16x10^3	249	26.7
	10^4	235	20.5
	3.16x10^4	223	19.3
	10^5	**157**	13.0
	3.16x10^5	156	14.3
	10^6	151	16.0

anisotropy in this subspecimen is 3:1. The argon plots produced two larger partial arcs for the α- and β-directions and a smaller complete arc for the γ-direction. Subspecimen MWA-4CB was measured in only one direction parallel to foliation. The ρ_r value is larger than would be expected (23.3 Ω·m) when compared to the other specimens measured. This could be a result of poorly interconnected sulphide grains and a high quartz content.

DISCUSSION AND CONCLUSIONS

The bulk electrical resistivities (ρ_r) of the six specimens and subspecimens investigated in this study are in the range of 5.92–140.5 Ω·m (Table 1). Three of the specimens measured have isolated a vein with the ρ_r values in the direction perpendicular to the feature ranging from 30.05 Ω·m to 59.4 Ω·m. The ρ_r value measured in the direction parallel to the vein ranges from 5.92 Ω·m to 19.65 Ω·m. The arsenopyrite filled fractures showed the lowest ρ_r values (5.9–17 Ω·m). The anisotropy values range from 3:1 to 7:1. Overall, the ρ_r range for these specimens and subspecimens is very low probably due to high sulphide content and good connectivity between sulphide grains. This is in contrast to other similar rock types. For example the ρ_r is 360–4450 Ω·m and 2400–7510 Ω·m, in the directions parallel and perpendicular to foliation, respectively, for sericitic schist samples from the Giant and Con mine areas (Connell et al., 2000).

Table 4. Results of the 3-D (α-, β-, and γ- directions) electrical resistivity measurements (24 hour saturation) for mineralized rock specimens. Note: the ρ_r (bulk electrical resistivity) values in bold text are those taken as the representative ρ_r value.

Sample Identification	Frequency (Hz)	Real resistivity ρ_r (Ω·m)	Imaginary resistivity ρ_I (Ω·m)
MWA-4CAα	1	-	-
K_G: 1.82x10^{-2}	3.16	-	-
	10	144	135
	3.16x10^{1}	91.5	69.4
	10^{2}	65.8	35.2
	3.16x10^{2}	53.0	18.0
	10^{3}	46.2	9.52
	3.16x10^{3}	42.4	5.26
	10^{4}	40.2	3.10
	3.16x10^{4}	**38.8**	2.14
	10^{5}	31.5	2.38
	3.16x10^{5}	31.3	2.12
	10^{6}	30.7	2.11
MWA-4CAβ	1	108	118
K_G: 1.74x10^{-2}	3.16	54.0	62.7
	10	30.5	30.9
	3.16x10^{1}	20.0	14.9
	10^{2}	15.1	7.16
	3.16x10^{2}	12.7	3.51
	10^{3}	11.5	1.81
	3.16x10^{3}	10.8	1.01
	10^{4}	10.3	0.57
	3.16x10^{4}	**10.0**	0.28
	10^{5}	9.35	3.27
	3.16x10^{5}	9.39	3.22
	10^{6}	9.53	3.32
MWA-4CAγ	1	25.9	0.49
K_G: 1.35x10^{-2}	3.16	25.5	0.92
	10	24.7	1.63
	3.16x10^{1}	23.1	2.50
	10^{2}	20.8	3.04
	3.16x10^{2}	18.3	2.79
	10^{3}	16.5	2.09
	3.16x10^{3}	15.2	1.45
	10^{4}	14.4	0.95
	3.16x10^{4}	**13.9**	0.54
	10^{5}	12.8	3.84
	3.16x10^{5}	12.8	3.75
	10^{6}	13.0	3.74

Table 5. Results of the electrical resistivity measurements (24 hour saturation) for mineralized rock specimen. Note: the ρ_r values in bold text are those taken as the representative ρ_r value.

Sample Identification	Frequency (Hz)	Real resistivity ρ_r (Ω·m)	Imaginary resistivity ρ_I (Ω·m)
MWA-4CB	1	100.0	11.1
K_G: 4.72x10^{-2}	3.16	89.0	16.8
	10	73.4	21.0
	3.16x10^{1}	55.9	19.5
	10^{2}	42.6	14.0
	3.16x10^{2}	34.8	8.85
	10^{3}	30.4	5.38
	3.16x10^{3}	27.7	3.44
	10^{4}	25.9	2.25
	3.16x10^{4}	**24.8**	1.53
	10^{5}	21.2	4.14
	3.16x10^{5}	21.3	3.97
	10^{6}	21.3	3.74

The electrical measurements produced two types of argon plots. Specimens and subspecimens MWA-4AA, MWA-AB, and MWA-CB produced small arcs; MWA-4BB and MWA-BC produced larger partial arcs; and MWA-4CA produced both types of arcs depending on the direction measured.

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